RESEARCH DEVELOPMENT AND DEMONSTRATION NEEDS OF THE OIL AND GAS INDUSTRY

VOLUME I

Summary and Discussion

A REPORT OF THE NATIONAL PETROLEUM COUNCIL • AUGUST 1995

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A REPORT OF THE NATIONAL PETROLEUM COUNCIL • AUGUST 1995

W. W. Allen, Chair, Committee on Research and Development Needs

NATIONAL PETROLEUM COUNCIL

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U.S. DEPARTMENT OF ENERGY

Hazel R. O'Leary, *Secretary*

The National Petroleum Council is a federal advisory committee to the Secretary of Energy.

The sole purpose of the National Petroleum Council is to advise, inform, and make recommendations to the Secretary of Energy on any matter requested by the Secretary relating to oil and natural gas or to the oil and gas industries.

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PREFACE

On July 27, 1994, Energy Secretary Hazel R. O'Leary asked the National Petroleum Council (NPC) to conduct a new study of research, development, and demonstration (RD&D) needs of the U.S. oil and gas industry. Specifically, she requested:

> that the National Petroleum Council conduct a study of research, development, and demonstration needs of the natural gas and oil industry. This study should analyze the needs of all components of the industry, considering the near- and long-term needs of both the upstream and downstream sectors.

(See Appendix A for the complete text of the Secretary's request letter and a description of the National Petroleum Council.)

The NPC established the Committee on Research and Development Needs to prepare a proposed response to the Secretary's request. The Committee was chaired by W. W. Allen, Chairman of the Board and Chief Executive Officer, Phillips Petroleum Company. Patricia Fry Godley, Assistant Secretary, Fossil Energy, served as the Committee's Government Cochair. The Committee was assisted by a Coordinating Subcommittee and two Task Groups. (See Appendix B for rosters of the Committee, Coordinating Subcommittee, and Task Groups.)

The study analyzes the needs of the industry, considering the near- and long-term needs of both the upstream and downstream sectors. The scope encompasses natural resource identification through the output of the refinery and the gas processing facilities. In addition, the study examines the relevant capabilities and role the nine national laboratories and the National Institute for Petroleum and Energy Research (NIPER)[1] could play in providing technical and scientific support to the industry.[2] The role of other public and private labs also is discussed.

In addition to presenting information on the technology needs of the industry, the study presents information on the importance of oil and gas to the vitality of the

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[1]Argonne, Brookhaven, Idaho National Engineering Laboratory, Lawrence Berkeley, Lawrence Livermore, Los Alamos, Oak Ridge, Pacific Northwest, Sandia, and NIPER are collectively referred to as The Labs in this report.

[2]The scope distinguishes this study from the Galvin task force on *Alternative Futures for the Department of Energy National Laboratories*, the Yergin Task Force on *Strategic Energy R&D*, and the NPC Committee on the *Issues and Policies Affecting the Future of the Oil and Gas Industries.*

American economy and insights into new approaches for conducting oil and gas RD&D in the coming years. The study describes the mechanisms that could be used to effectively match unique technical capabilities with the technology needs identified by industry. Importantly, the perceived barriers to collaboration that must be addressed to foster a better climate and receptivity to joint activities are also addressed in this report.

This study is presented in three volumes. Volume I contains the body of the report, including the Council's recommendations and the analyses supporting them. Volume II presents the NPC's 1995 Survey of Research and Development Needs, which provides the data describing the research and development needs of the oil and gas industry. Volume III contains detailed data on the capabilities of the nine DOE national laboratories and NIPER.

Executive Summary and Recommendations

THE U.S. OIL AND GAS INDUSTRY—CURRENT AND FUTURE

For nearly one hundred years the oil and gas industry has been essential to the economic growth, high standard of living, and national security of the United States. There remain large known reserves and undiscovered resources of oil and gas in the U.S. and worldwide. Even with progress in the development and use of alternative energy sources, the reality is that oil and gas will continue to be essential. Statistical data on the oil and gas industry may be found in Appendix C.

Oil and gas supplied nearly 65 percent of the total U.S. energy demand in 1993. In addition, although the overall Consumer Price Index has increased by 75 percent between 1980 and 1993, the indexes for fuel oil and motor fuel are at 1980 levels. These and other data in this report illustrate the importance of oil and gas to a strong U.S. economy.

In our vision of the future, the competitive edge of the industry will increasingly depend on the ability to manage and apply technology effectively and rapidly. This will include leadership in technology for environmentally sound operations and environmentally acceptable hydrocarbon fuels.

The industry faces significant challenges to effectively and efficiently finding, producing, and processing new reserves of oil and gas, and converting these reserves into products while complying with regulations at acceptable costs. Advancing technologies are expected to play an important role in meeting these challenges. *The NPC believes that achievement of the necessary technological advancements is a strategic imperative for both the industry and the nation.*

In a companion report to the Secretary of Energy, entitled *Future Issues—A View of U.S. Oil & Natural Gas to 2020*, the Council explores more deeply the value of the oil and gas industry to the economy and the full spectrum of issues the industry will face over the next 25 years.

KEY TECHNOLOGY NEEDS

The assessment of the current RD&D needs of the industry is a primary focus of this study. The oil and gas industry's technology needs were determined by the combination of a comprehensive survey sent to a large cross-section of the industry (primary data) and an analysis of other pertinent studies completed in the last several years (secondary data).

The survey was developed to determine the desired technology advances, their impact, and their likelihood of commercial availability both in the short term (by 1999) and the long term (between 1999 and 2010). The survey was sent to 130 members of the National Petroleum Council. The responses included information on 250 technologies in 11 technology areas:

- Exploration
- Development
- Drilling and Completion
- Production
- Deepwater Offshore
- Arctic Region Activities
- Oil Processing and Refining
- Gas Processing
- Gas Gathering
- Gas Storage
- Environment and Regulatory.

The 89 companies who responded to the survey reported U.S. reserves of 11.8 billion barrels of oil and 74.6 trillion cubic feet of gas—*or about 50 percent of total U.S. reserves.* The companies also reported worldwide oil reserves of 24 billion barrels and worldwide gas reserves of 128 trillion cubic feet. The respondents' U.S. refining capacity is 9 million barrels per day, which is about 60 percent of U.S. capacity. The blank survey form and the results of the survey are in Appendix D (Volume II of this report).

The survey was designed to identify specific advances needed in each technology area, the expected level of impact and timing of technology advances, and the degree of willingness to collaborate to advance these technologies. A further purpose was to identify issues that are barriers to technical collaborations with other oil and natural gas companies, DOE, the national laboratories, universities, and other public and private laboratories.

An analysis of the survey responses identified 36 technologies that are highest priority based on their impact on business and their likelihood of not being met under a business-as-usual scenario. These technologies are shown in Figure 1. Although the figure is a composite, the detailed survey results shown in the appendices indicate that majors, other integrated oil and gas companies, independents, and service companies have distinct technology needs. The following examples illustrate some of the highest priority distinct technology needs from the survey.

In the upstream,

- High priority needs for majors and independents were:
  - High-resolution depth imaging
  - Improved well productivity
  - Hydrate control and prevention.
- High priority need for service companies was horizontal well technology.
- Paraffin control was rated to have high impact for independents, but not for majors.

In the downstream for majors and independents, high priority needs were:

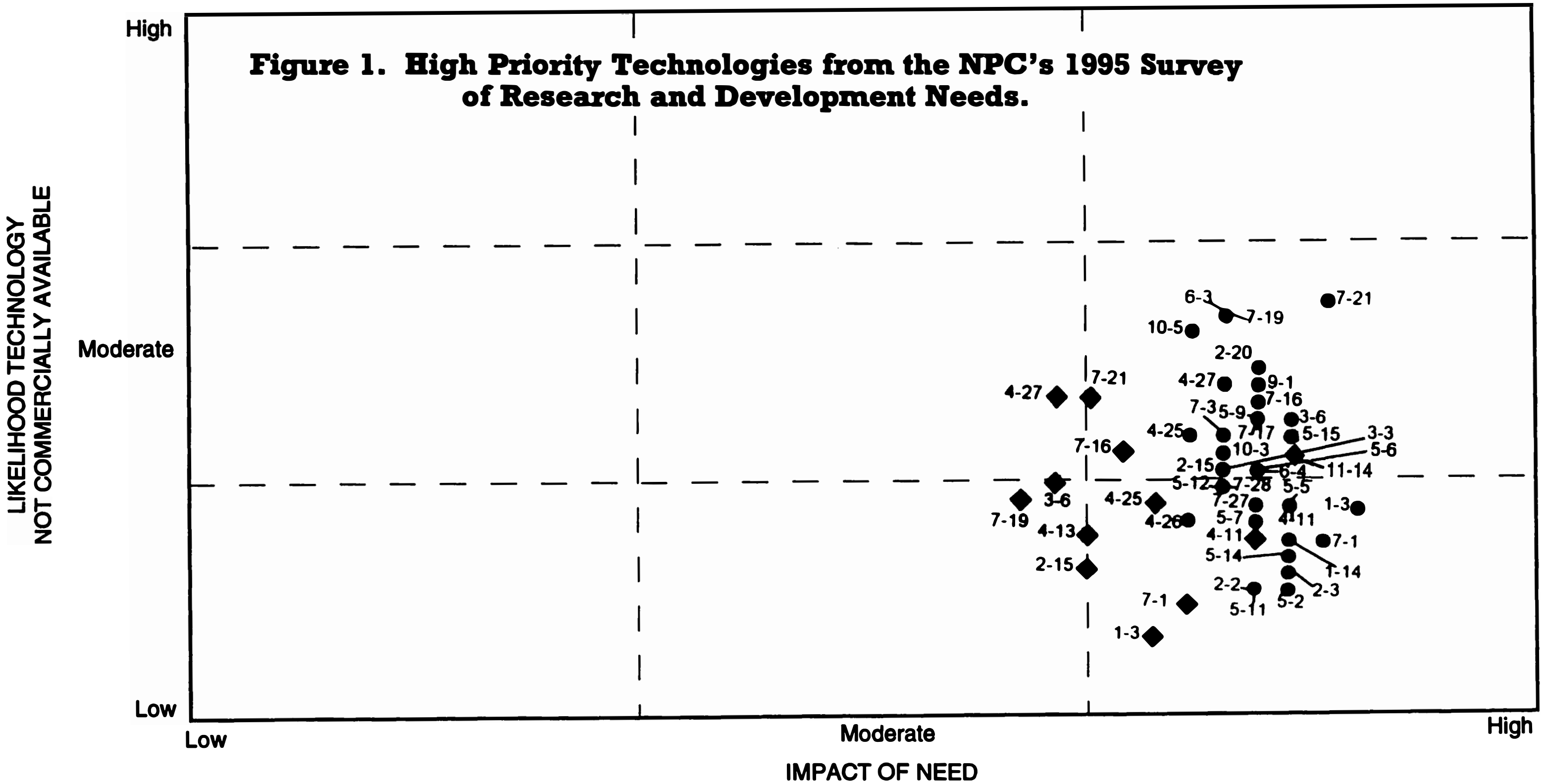
- Catalysts with improved selectivities, yields, and lifetimes
- New approaches to refining heavy feeds
- Improved energy efficiency of processes and equipment
- Improved plant and process reliability.

In the environmental area, a high priority industry need was a scientific basis for risk-based environmental regulation.

CAPABILITIES OF THE LABS

The development of technology for the oil and gas industry is accomplished through a variety of sources well known to the industry including in-house oil and gas company RD&D programs, universities, research institutes, and service companies. Recently the government laboratories have become increasingly involved in RD&D; however, the capabilities of these labs are less well known to the industry. In order to completely respond to the request of the

Figure 1. High Priority Technologies from the NPC's 1995 Survey of Research and Development Needs.



● ***SHORT TERM*****

Q.1 Exploration
- 1-3 (51) High-resolution seismic depth imaging
- 1-14 (46) Advanced seismic acquisition

Q.2 Development
- 2-2 (45) Computer-based 3D geological modeling
- 2-3 (43) Development-scale seismic applications
- 2-15 (50) Through casing logging
- 2-20 (46) Permeability logging techniques

Q.3 Drilling And Completion
- 3-3 (49) Advanced fracture techniques
- 3-6 (47) Well productivity

Q.4 Production
- 4-11 (53) Stimulation techniques
- 4-25 (49) Near well bore stimulation
- 4-26 (43) New directional drilling
- 4-27 (39) Advanced recovery of natural gas

Q.5 Deep Water Offshore
- 5-2 (20) Extended reach drilling or production
- 5-5 (12) Flowlines
- 5-6 (13) Flow metering
- 5-7 (15) Subsea equipment
- 5-9 (14) Risers

Deep Water Offshore (continued)
- 5-11 (20) Drilling
- 5-12 (11) Workover
- 5-14 (11) Hydrate prevention
- 5-15 (11) Multi-phase pumps

Q.6 Arctic Region Activities
- 6-3 (7) Development
- 6-4 (10) Drilling

Q.7 Oil Processing and Refining
- 7-1 (22) Catalysts with improved selectivities yields, lifetimes
- 7-3 (19) Plant and process reliability
- 7-16 (21) Energy efficiency of processes
- 7-17 (19) Energy efficiency of equipment
- 7-19 (14) Separations technologies
- 7-21 (10) New approaches to refining heavy feeds
- 7-27 (10) Performance characteristics of new hydrocarbon fuel compositions
- 7-28 (14) Environmental characteristics of new hydrocarbon fuel compositions

Q.9 Gas Gathering
- 9-1 (30) Compression

Q.10 Gas Storage
- 10-3 (11) Reservoir management
- 10-5 (9) Base gas minimization techniques

Q-11 Environmental and Regulatory
- 11-14 (41) Provide scientific basis for risk-based regulation

◆ ***LONG TERM*****

Q.1 Exploration
- 1-3 (27) High-resolution seismic depth imaging

Q.2 Development
- 2-15 (22) Through casing logging

Q-3 Drilling and Completion
- 3-6 (28) Well productivity

Q-4 Production
- 4-11 (21) Stimulation techniques
- 4-13 (18) Recompletion techniques
- 4-25 (19) Near well bore stimulation
- 4-27 (28) Advanced recovery of natural gas

Q-7 Oil Processing and Refining
- 7-1 (14) Catalysts with improved selectivities yields, lifetimes
- 7-16 (15) Energy efficiency of processes
- 7-19 (21) Separations technologies
- 7-21 (21) New approaches to refining heavy feed

* Numbers in parentheses indicate number of responses.

Secretary, specific information was compiled on the RD&D projects and capabilities in The Labs[1] directed at the needs of the oil and gas industry.

The comprehensive data compiled on The Labs are contained in Appendix E (Volume III of this report), which includes:

- *Project Summaries*: These provide quantitative information in the form of one-page summaries of projects that reflect current capabilities being applied in areas of direct interest to the petroleum industry. In preparing these summaries, The Labs used the 11 technical categories listed in the survey. The major purpose of the project summaries is to relate the capabilities of The Labs to the technology needs as identified by industry.
- *Enabling Capabilities*: Descriptions of enabling capabilities or technical strengths of The Labs that have potential value to, but that are not necessarily now being applied to, the petroleum industry, and thus may not be captured in the project summaries.
- *Historical Legacy*: Each of The Labs was given the opportunity to describe its "legacy" that led to its current technology position vis-a-vis the oil and gas industry.

The cumulative industry-related RD&D project expenditures for The Labs during the period FY91-FY95 were almost $600 million. The Labs have significant efforts in the technology needs categories of Environmental and Regulatory, Oil Processing and Refining, and Development technologies. Together, these represent 75 percent of the funding and 73 percent of the projects identified by The Labs. Total funding during the last five years for these three technical categories is nearly $450 million. The Labs participate at a modest level in the technology needs categories of Exploration, Drilling and Completion, and Production. Total funding during the last five years for these three technical categories is about $106 million and represents nearly 18 percent of the funding and 18 percent of the projects identified by The Labs.

The $600 million cumulative industry-related RD&D project expenditures for The Labs are equivalent to 5 percent of the annual expenditures of the respondents. The Labs have doubled their active projects with industry, with expenditures increasing from $70 million per year in 1991 to $190 million per year in 1995.

The data show that The Labs have impressive research and development capabilities in many energy related technologies. However, in order for the RD&D to be effective, these capabilities should be aligned with the long-term missions of The Labs and the users' needs. It is therefore very important to increase user input into the selection and conduct of The Lab RD&D programs. The NPC industry needs survey indicated considerable interest within the industry to collaborate on RD&D projects to develop oil and gas technology. This forms a basis for cooperation with The Labs in selected areas of RD&D.

Research efforts at universities and other public and private research organizations are a central component of the RD&D activities of the industry. The impact of DOE expenditures and/or increased oil and gas research at The Labs must be carefully considered in establishing DOE funding priorities.

The industry currently benefits from some RD&D projects that utilize the unique facilities that are available at The Labs, such as high-intensity photon sources. These joint projects with the oil and gas industry enable leading edge research to be conducted in a variety of areas that would be difficult otherwise. The Labs should continue to cooperate with industry by making these special facilities available for

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[1]Argonne, Brookhaven, Idaho National Engineering Laboratory, Lawrence Berkeley, Lawrence Livermore, Los Alamos, Oak Ridge, Pacific Northwest, Sandia, and NIPER are collectively referred to as The Labs in this report.

collaborative RD&D on a priority basis consistent with the primary mission of The Labs.

The Labs have strong capabilities in fundamental science and engineering, which could be very effective in the conduct of basic research needed by the oil and gas industry. The relevance and impact of this research can be maximized by review and guidance by direct industry participants. The results of this RD&D should be made available to all components of the U.S. oil and gas industry.

The Labs should emphasize technology development efforts in the areas of environmental technology that impact the oil and gas industry. The Labs, in close cooperation with industry, should work to develop a scientific basis for emission, effluent, and cleanup standards that balance the need to minimize risk to human health and ecosystems with the costs and benefits of control and cleanup technologies.

The Labs can play an effective role in applied RD&D provided there is strong direction from industry in the definition of goals and funding levels for these projects. Direct industry involvement is a critical success factor for applied RD&D.

DEVELOPERS AND SUPPLIERS OF ADVANCED TECHNOLOGY

A "new paradigm" for oil and gas RD&D is evolving because intense competition that contributes to low oil and gas prices, and the need to reallocate scarce funds for large investments related to environmental compliance, have forced the industry to re-evaluate every aspect of its business, including their RD&D investments. This re-evaluation brought better efficiency and cost-effectiveness to private sector RD&D activities. In many companies, in-house programs have moved toward projects that are likely to provide a competitive advantage and a nearer term payout. Industry also compensated for smaller in-house programs by making greater use of collaborations for technology development with many different entities. The new RD&D paradigm evolved from the business, regulatory, and technological needs of the industry. One of the outcomes is a user-driven, strategic, and collaborative RD&D effort that culminates in application. The new paradigm in oil and gas RD&D meets the demands of the marketplace and encompasses leveraging, cost-effectiveness, and an increased focus on user-driven RD&D.

The willingness to collaborate and form technology alliances with all types of other organizations, including other oil and gas companies, research consortiums, universities, DOE, the national laboratories, and other consortia has increased with the emergence of the new paradigm (see Table 1). However, in order to be successful, these collaborations must be focused on user-driven technology development.

The survey showed a relatively high overall willingness to collaborate. Sixty-three percent of all responses to the survey question for each technology indicated a willingness to collaborate. The willingness varied both by technology area and industry sector. There was a

Paradigms for Meeting RD&D Needs

	OLD PARADIGM		NEW PARADIGM
Source of Technology:	In-House	——>	Leverage & Collaborate
Project Prioritization:	Technology Push	——>	User Needs
Motive:	Own It	——>	Use It

TABLE 1

WILLINGNESS TO COLLABORATE ON A SPECIFIC TECHNOLOGY
(Percent of Responses)

	Vendors/ Service Com- panies	Oil & Gas Com- panies	Univer -sities	Research Institutes	Trade Assoc.	National* Labs.	DOE†	USGS/ State Survey
All Respondents	*53*	*51*	*48*	*46*	*43*	*42*	*41*	*36*
Majors	66	57	59	56	49	49	44	41
Other Integrated	55	53	43	43	45	35	35	35
Independents	49	48	44	43	43	41	42	35
Service	33	46	39	29	21	34	34	27

*The National Laboratories are Argonne, Brookhaven, Idaho National Engineering Laboratory, Lawrence Berkeley, Lawrence Livermore, Los Alamos, Oak Ridge, Pacific Northwest, and Sandia.

†Collaboration with DOE refers to cost-sharing arrangements with Morgantown Energy Technology Center, Pittsburgh Energy Technology Center, National Institute for Petroleum and Energy Research, Metairie Site Office, and Rocky Mountain Oilfield Testing Center.

higher interest in collaboration for meeting shorter term needs than longer term needs. When asked the question in general, with no specific technology, there was a greater willingness to collaborate than is presently occurring. This indicates that increased collaboration is likely to occur if perceived barriers are addressed.

The barriers to collaboration with DOE and national laboratories identified by the respondents included excessive paperwork, hold harmless agreements, uncertainty of ongoing funding, red tape, confidentiality issues, intellectual property issues, limited resources, and alignment issues such as differing business objectives, goal orientation, and timelines. These issues/perceptions need to be addressed if DOE and The Labs desire a customer orientation that will result in an increase in collaboration.

CONCLUSIONS AND RECOMMENDATIONS

This study on RD&D needs could be the starting point for establishing an improved process of focused oil and gas RD&D unprecedented by previous efforts. The current need to improve efficiencies and control costs makes such an effort timely and imperative. The theme of these recommendations is for the Secretary to establish a process that embodies the "new paradigm" in oil and gas RD&D *user-driven technology development*. Regardless of the final spending levels, this approach will improve efficiencies and cost-effectiveness.

Many Council members believe there is a place for industry-government collaboration in the development of oil and gas technology. However, there is a wide range of opinions among NPC members concerning both the value and the desirability of a government role. At one end of the spectrum is the belief that government should leave the significant components and expenditures for energy RD&D to the private sector, and that RD&D tax incentives for industry are preferred over government funding of opportunities for collaboration. Those at the opposite end of the spectrum hold that energy RD&D is so important to our national and economic security that it should not be entirely the responsibility of the private sector.

Council members who see value in collaboration with government stress that their position does not represent a blank check. The level of government RD&D funding was not addressed in this study. Any oil- and gas-related research undertaken by government should be focused on areas of user-identified technology needs, and must be timely and cost-effective.

The NPC recognizes that public debate is continuing and policy decisions are continuously being reviewed regarding government's role. In addition, there is congressional and administrative review of DOE's budget, as well as other government expenditures. Realignment efforts presently underway at DOE offer an opportunity to develop new and improved processes to prioritize government spending in the area of energy RD&D expenditures and programs.

The interest within the industry, indicated by our survey, to expand collaborative RD&D to develop oil and gas technology presents a positive opportunity for both the Department of Energy and the industry. The Council and its members are interested in working with DOE on programs that focus on user needs and to develop new programs and policies that meet the changing dynamics of the RD&D needs of the oil and gas industry. The following recommendations are presented in the same spirit of cooperation and improvement that led the Secretary of Energy to request this report on the RD&D needs of the oil and gas industry.

The Secretary of Energy should immediately utilize and fully incorporate this study's analysis into the Department of Energy's current realignment activities, program development, spending prioritization, and budgeting activities at all levels of DOE's strategic planning activities.

The Department of Energy should focus its sponsorship of research on areas of technology needs that cannot be effectively conducted in the private sector.

Current and newly proposed expenditures should be analyzed in order to match the high impact needs identified by the analysis in this report with the unique capabilities of The Labs. The focus in this activity should be on the highest priority needs which benefit all industry participants without competing with the private sector developers of technology.

Continuity should be provided for logical (cost-effective) completions of all short-term projects, no matter how the industry-Lab RD&D collaborations change over the next few years. Long-term projects should be judged individually and be provided transitional funding as necessary.

The Department of Energy should place greater emphasis on prioritizing RD&D programs based on the industry's needs and participation. Current efforts by DOE and the government laboratories, such as the *Natural Gas and Oil Technology Partnership* and the *Refinery of the Future* initiative, have improved processes and identified initiatives through which the oil and gas industry can leverage its resources. Improved processes or mechanisms are needed to accommodate industry input.

The Department of Energy should develop a project definition system that utilizes broadly based industry input to prioritize and recommend all DOE funding that is directly related to oil and gas research, development, and demonstration needs. This process should ensure a user-driven, strategic, and collaborative RD&D effort that eliminates duplication.

DOE and the government laboratories should remove barriers to collaboration. To implement this recommendation, DOE should initiate simplified administrative procedures that minimize paperwork and the turnaround time for bringing technology to practical application.

The government laboratories should not become a technical services organization competing with industry resources. The NPC concurs with the Galvin task force recommendation that the activities at the national laboratories should be privatized as appropriate.

The NPC believes that the implementation of the above recommendations will result in more effective and efficient oil and gas research, development, and demonstration.

CHAPTER ONE

THE U.S. OIL AND GAS INDUSTRY—CURRENT ROLE AND VISION OF FUTURE

The oil and gas industry is vital to a strong U.S. economy. To introduce this report on the research, development, and demonstration needs of the oil and gas industry, NPC members believe it is important to discuss the current role of the industry, the industry's vision of the future, and the challenges to attaining that vision. Because the oil and gas industry is vital to a strong U.S. economy, any challenges to maintaining a strong domestic oil and gas industry can and must be overcome.

For nearly one hundred years, the U.S. oil and gas industry has been essential to the economic growth, high standard of living, and national security of the United States. Large known and undiscovered reserves of oil and gas remain in the U.S. and worldwide. Even with progress in the development and use of alternative energy sources, the reality is that oil and gas will continue to be essential.

Before outlining the industry vision of the future and the challenges that can be overcome with technological advancements, the current role of the industry in the U.S. economy is discussed and an array of information is presented that illustrates the importance of the oil and gas industry to a strong U.S. economy.

CURRENT ROLE OF OIL AND GAS

U.S. Energy Consumption and Supply

Energy consumption increases as oil and gas supply nearly 65 percent of U.S. energy demand. In 1993, U.S. energy consumption was about 84 Quads (quadrillion BTUs), about 26 percent more than in 1970 (Figure 1-1). Oil and gas supplied nearly 65 percent of the total demand in 1993. Although the share of energy supplied by oil and gas decreased from 77 percent in 1970, the total energy supplied from oil and gas actually increased from 51 to 55 Quads in this time period.

In 1993, industrial and residential/commercial sectors accounted for about 37 and 36 percent, respectively, of end-use energy consumption.[1] Industrial sector consumption includes oil- and gas-derived feedstocks for production of high-value "petrochemicals." Transportation accounted for the remaining 27 percent of 1993 end-use consumption, with about 80 percent used to fuel cars, trucks, and buses.[2] Sixty-two percent of total oil consumption is used for

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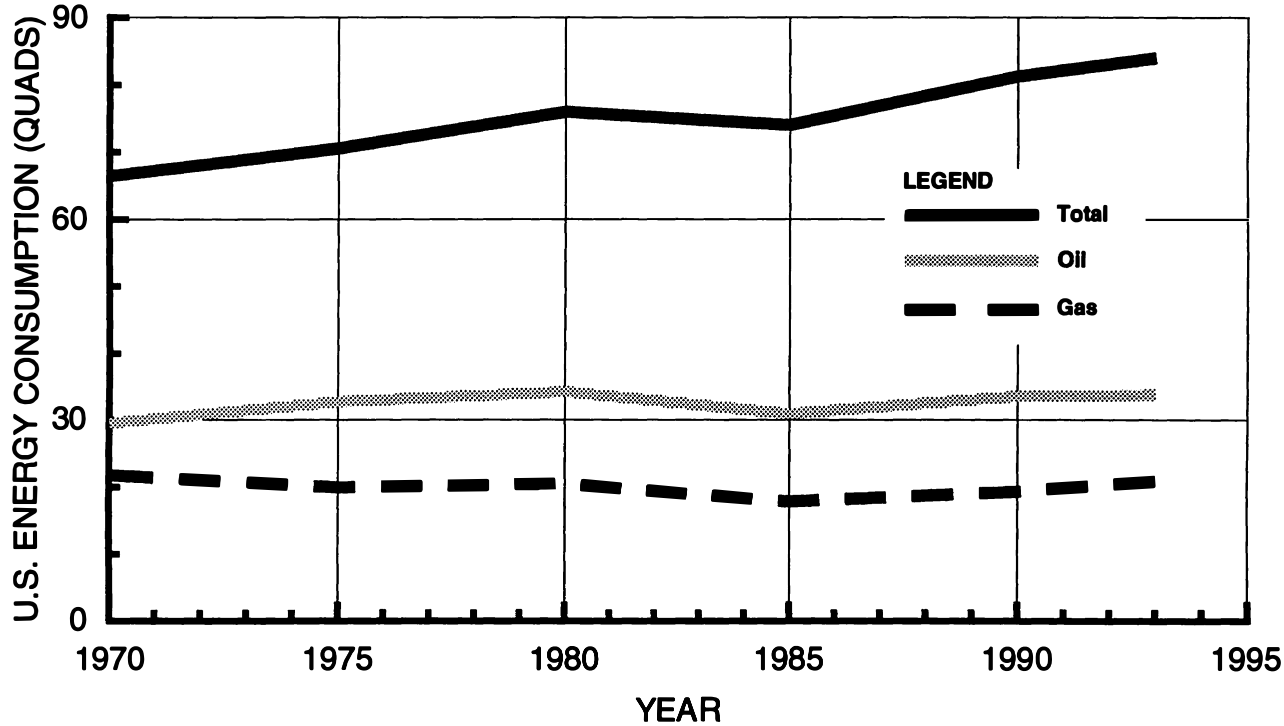
[1] Energy Information Administration, *Annual Energy Review*, 1993, p. 39.

[2] Source for fuel consumption data: Statistical Abstract of the United States, 1994, Table No. 1024.



Source: Energy Information Administration, *Annual Energy Review*, 1993, page 5.

Figure 1-1. U.S. Energy Consumption Summary: 1970-1993.

transportation. This sector is 90 percent dependent on oil and will remain so well into the 21st century.

Electricity, though a major form in which energy is consumed, is generated from primary energy sources of which coal, oil, and gas are the major foundations. In 1993, 25 percent of total U.S. energy consumption—including 3 percent of the oil and 13 percent of the gas consumed—was used to generate electricity.[3]

U.S. energy and oil & gas consumption will increase despite energy efficiency improvements. In recent testimony to Congress, Secretary O'Leary forecasted that by the year 2010 U.S. energy consumption will increase by 24 percent, and that the relative contributions of oil, gas, and other energy sources will be the same.[4]

Annual energy consumption on a per capita basis remained unchanged at about 325 million BTU during the 1970-1993 period.[5] This is despite dramatic improvements in energy efficiency, which are exhibited by a nearly 30 percent decrease in energy consumption (BTU) per dollar GDP.[6] For example, between 1970 and 1992, total fuel consumption by vehicles increased by about 44 percent while average fuel economy improved by 60 percent for cars and by 38 percent for trucks.

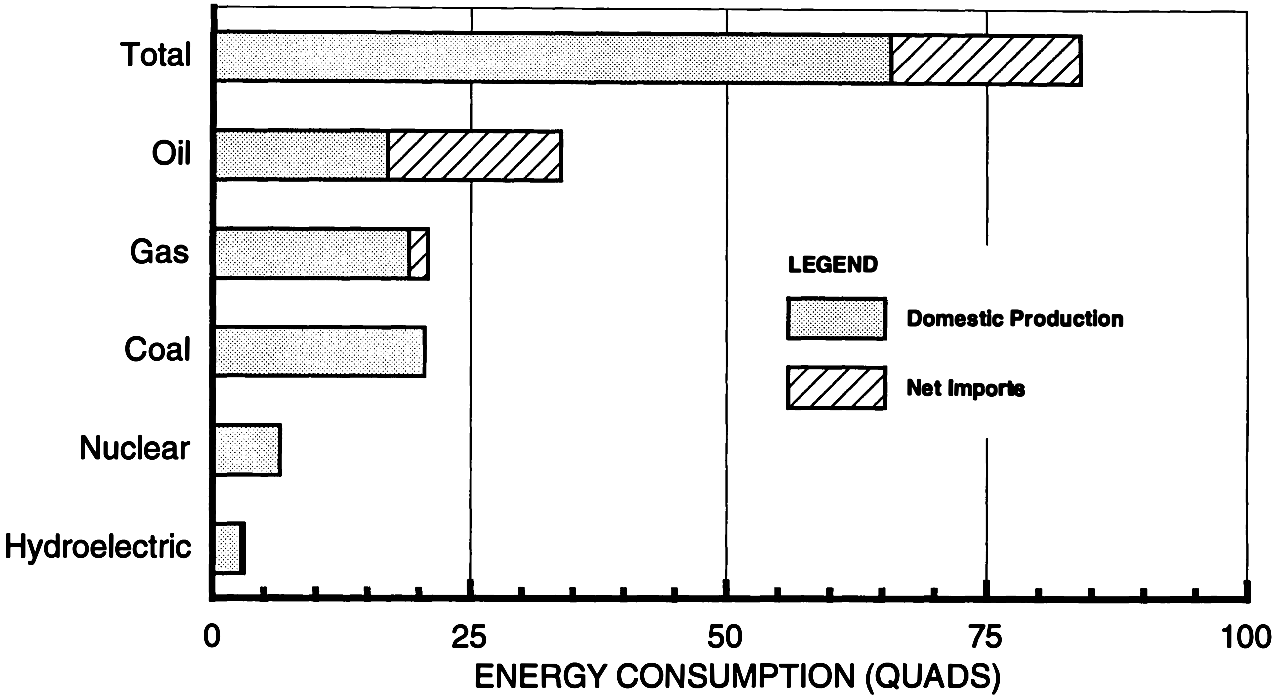
Domestic production provided nearly 80 percent of domestic energy demand. In 1993, domestic energy production was 66 Quads, or about 80 percent of total energy consumption (Figure 1-2). About 50 percent of the oil consumed and 91 percent of the gas were produced domestically.

[3] Energy Information Administration, *Annual Energy Review*, 1993, pp. 5 and 237.

[4] Statement of Hazel R. O'Leary before the Committee on Appropriations, Subcommittee on Interior and Related Agencies, January 19, 1995.

[5] Statistical Abstract of the United States, 1994, Table No. 922.

[6] Statistical Abstract of the United States, 1994, Table No. 922.



Note: Net imports equal consumption minus domestic production.
Source: Energy Information Administration, *Annual Energy Review*, 1993, page 5.

Figure 1-2. 1993 U.S. Energy Consumption.

Gas imports, which came primarily from Canada, account for about 11 percent of the total gas consumption and are expected to increase to 14 percent in the year 2000. Oil imports came from a number of countries, but three-fourths of imports came from six countries (in order of volume imported): Saudi Arabia, Venezuela, Canada, Mexico, Nigeria, and the United Kingdom. (See details in Table 1-3.)

U.S. reserves of oil and gas represent a 9-year supply of U.S. production. U.S. oil and gas reserves recoverable *with current technology and at current oil and gas prices* totaled 23.7 billion barrels and 165 trillion cubic feet, respectively, in 1993.[7] At current rates of production—and with no accounting for further reserve additions—these domestic reserves represent a 9-year supply. In fact, during the 1983-1992 period, additions to U.S. reserves occurred at a rate of about 80 percent as great as production.[8]

Known worldwide recoverable reserves represent a 50-year supply. Worldwide recoverable reserves are believed to be about one trillion barrels of oil and five quadrillion cubic feet of gas (Table 1-1). At the 1993 worldwide production level of 22 billion barrels,[9] these crude oil reserves represent a 45-year supply. In 1992, 75 trillion cubic feet of dry gas was produced.[10]

[7] Reserves data from *Oil and Gas Journal*, as reported in EIA *Annual Energy Review*, 1993, p. 287. Current production data from EIA *Annual Energy Review*, 1993, pp. 141 and 189. Reserves do not include natural gas liquids. See EIA *Annual Energy Review*, 1993, p. 129.

[8] U.S. domestic oil reserves at year-end 1983 and 1992 were 27.7 and 23.7 billion barrels, respectively. Gas reserves were 200.2 and 165.0 trillion cubic feet, respectively. In the 1983-1992 period, cumulative production of domestic oil and gas were 29.7 billion barrels and 170 trillion cubic feet, respectively. Source: Energy Information Administration, *Annual Energy Review*, 1993, pp. 129, 141, and 189.

[9] Energy Information Administration, *Annual Energy Review*, 1993, p. 291.

[10] Energy Information Administration, *Annual Energy Review*, 1993, p. 305.

TABLE 1-1

WORLDWIDE OIL AND GAS RESERVES, JANUARY 1, 1993
(Recoverable With Current Technology and Prices Except as Noted)

Country or Region	Crude Oil (Billion Barrels)	Natural Gas (Trillion Cubic Feet)
United States	23.7	165.0
Canada	5.3	95.7
Mexico	51.3	70.9
Central and South America	72.5	188.6
Western Europe	16.1	194.7
Eastern Europe and FSU	59.0	1960.4
Saudi Arabia	260.3	183.1
Other Middle East	401.5	1337.0
Africa	61.9	346.9
Far East and Oceania	44.6	341.0
World	996.1	4883.3

Note: Oil reserves for FSU (Former Sovier Union) are "explored reserves" and "gas reserves" for Canada are "proved or possible" reserves.

Source: *Oil and Gas Journal*, as reported in Energy Information Administration, *Annual Energy Review*, 1993, p. 287.

At this level, worldwide natural gas reserves represent a 65-year supply to the world.

Worldwide reserves shown in Table 1-1 represent a 50 percent increase over reserves at the end of 1982.[11] With allowance for the cumulative worldwide consumption of oil and gas during the 1983-1992 period, new reserves of oil were found at a rate 2.5 times consumption, and gas reserves were added at a rate 3.5 times consumption.[12]

The impact of technology has changed the view of the U.S. resource base over the last two decades—greatly increasing the estimates of oil and gas resources and at the same time decreasing the cost of converting the resource base to producible reserves.

There are vast U.S. oil and gas resources remaining to be discovered. Recently updated estimates of U.S. reserve extensions and "undiscovered recoverable" resources are equivalent to a 35-year supply of oil and a 59-year supply of gas at current production rates (Table 1-2).

Additional oil and gas could be recovered at a higher price or with better technology. For example, it has been estimated that advanced technology could increase domestic gas supplies in the year 2010 by about one-third over current levels, and nearly double supplies compared to those projected based on existing technology[13] (Figure 1-3).

[11] As of December 31, 1983, worldwide crude oil and natural gas reserves were 669.3 billion barrels and 3,200 trillion cubic feet, respectively. Source: *Oil and Gas Journal*, as reported in Energy Information Administration, *Annual Energy Review*, 1983, p. 73.

[12] For the 1983-1992 period, cumulative worldwide oil production was 209 billion barrels, and gas production was 671 trillion cubic feet. Source: Energy Information Administration, *Annual Energy Review*, 1993, pp. 291 and 305.

[13] Gas Research Institute (GRI) statistics.

TABLE 1-2

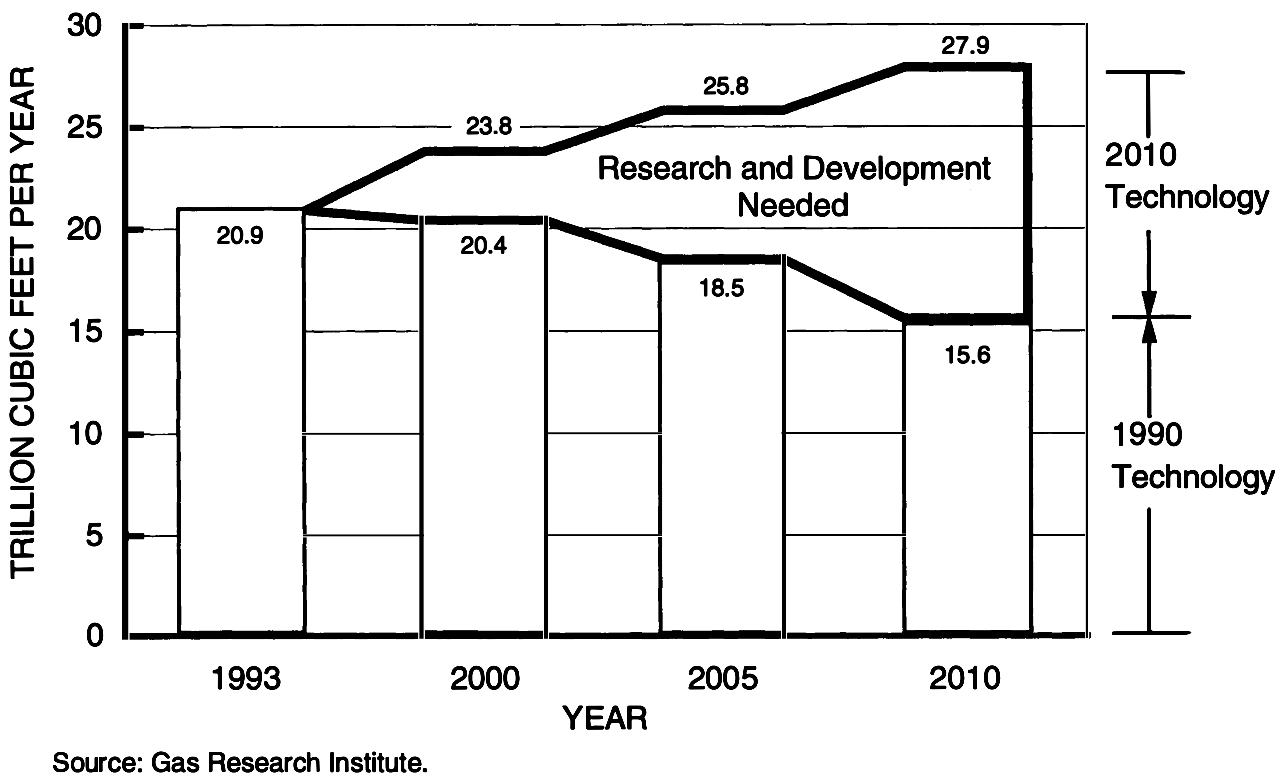
POTENTIAL ADDITIONAL U.S. CRUDE OIL AND NATURAL GAS RESOURCES
(Mean Estimates)

Region	Crude Oil (Billion Barrels)	Natural Gas (Trillion Cubic Feet)
Reserve Growth in Conventional Fields	60.0	322.0
Undiscovered Conventional Resources Onshore and State Waters	30.3	258.7
Other Accumulations	2.1	358.0
Undiscovered Federal Offshore	16.1	145.1
U.S. Total	**108.5**	**1083.8**
Years Supply at Current Rates of Production	34.7	58.9

Sources: "1995 Assessment of Oil and Gas Reserves," U.S. Geological Survey; and 1989 report of Minerals Management Service.

In addition to the above "conventional" reserves, the United States has proved reserves of oil shale and tar sand resources that are estimated to be equivalent to 560 to 720 billion and 63 billion barrels of oil, respectively.[14] It will be an economic

[14] "Fuels to Drive Our Future, " Committee on Production Technologies for Liquid Transportation Fuels, National Research Council, Washington, D.C., 1990, p. 16.



Source: Gas Research Institute.

Figure 1-3. Domestic U.S. Gas Supply with and without Advancing Technology.

advantage to U.S. consumers if the U.S. oil and gas industry assures and extends the existing worldwide conventional oil and gas resource base.

Economic Impacts of Oil and Gas

Oil imports are rising, but international trade provides an important offset. In 1993, the net cost of imported crude oil and petroleum products was about $46 billion.[15] However, the concerns that this generates should be tempered by considering the broader facts and implications. For example, the *net trade deficit* with the six largest suppliers—who account for about 75 percent of crude oil and petroleum products imports—was about $13 billion (Table 1-3).

Furthermore, in 1993 exports of organic chemicals and plastics derived from oil and gas were worth $21.8 billion, and net exports of these products were $8.3 billion.[16]

Oil and gas play a key role in the U.S. economy. A study prepared for the NPC indicates that the oil and gas industry provides the following to the U.S. economy.[17]

- 4.7 percent of U.S. gross output ($380 billion in 1987)
- 3 percent of private, nonresidential U.S. domestic investment ($22.5 billion in 1987)
- 2.9 percent of all private U.S. research and development ($2.2 billion in 1991)
- 4.3 percent of all federal, state, and local taxes ($91.9 billion in 1991)
- 84.4 percent of federal mineral lease royalties ($3.1 billion in 1993)
- 1.4 percent of U.S. employment (1.5 million jobs in 1993)
- 20.8 percent of U.S. spending on pollution abatement in manufacturing ($5.3 billion in 1992)
- Wages 14.2 percent higher than U.S. average ($30,117 vs. $26,361 in 1993)

Consumer price index data show that the U.S. economy continues to grow on the back of the oil and gas industry. In real terms, prices of crude oil and gasoline are near those that preceded the market upset of the mid-1980s (Figures 1-4 and 1-5).[18]

[15] Energy Information Administration, *Annual Energy Review*, 1993, p. 177.

[16] U.S. Chemical Industry Statistical Handbook, 1994, Chemical Manufacturers Association, Table 3.1.

[17] National Petroleum Council, *Future Issues—A View of U.S. Oil & Natural Gas to 2020*, Appendix C, August 1995.

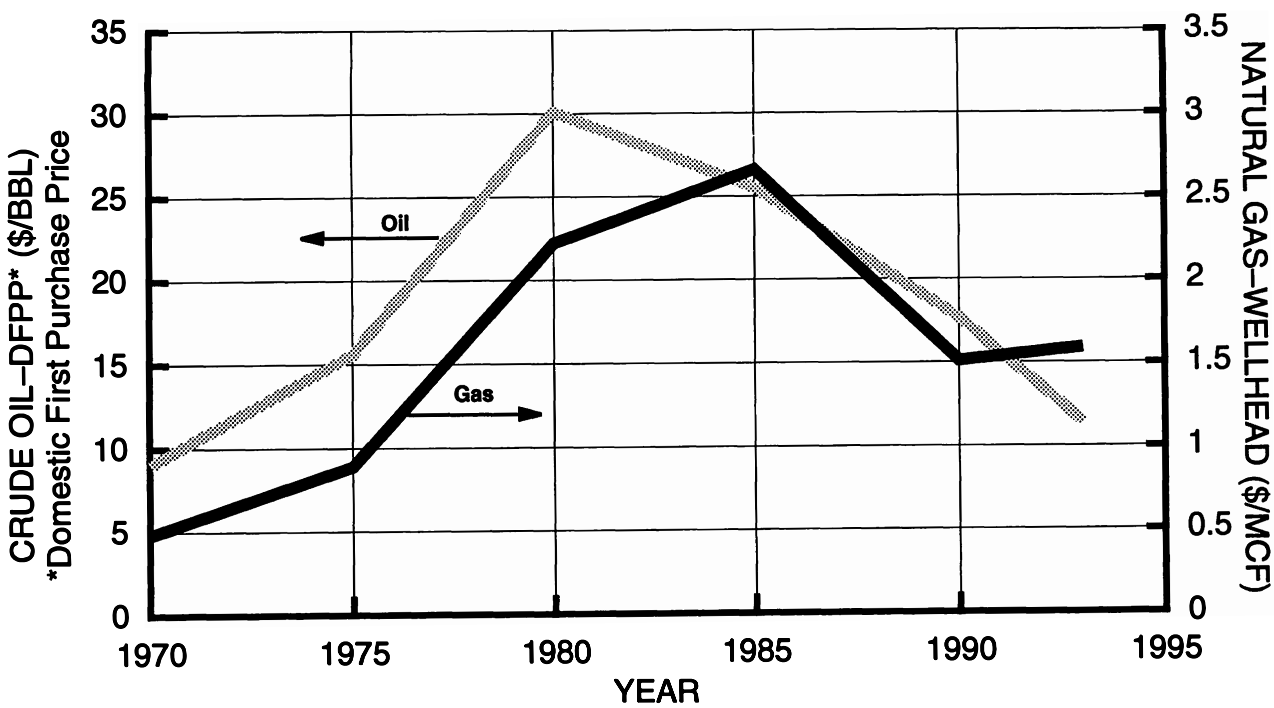
[18] Energy Information Administration, *Annual Energy Review*, 1993, pp. 173, 183, 203.

TABLE 1-3

SIX LARGEST SOURCES OF U.S. OIL IMPORTS, 1993

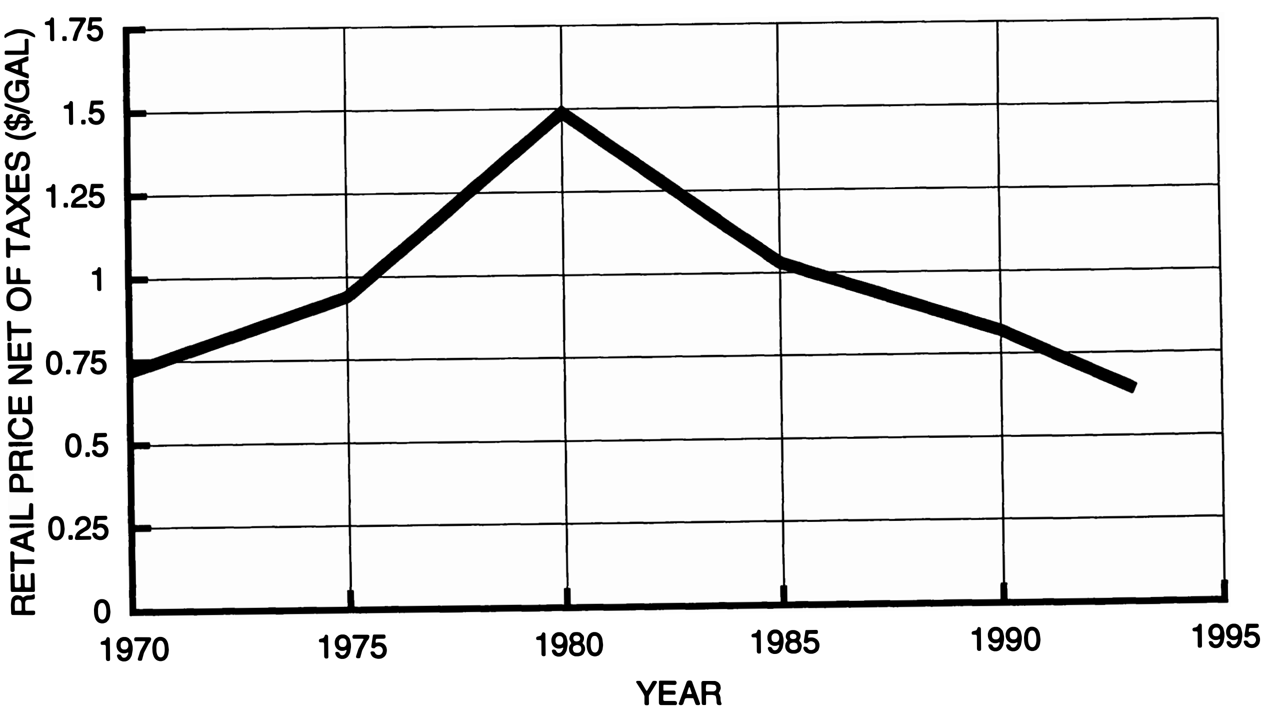
Country	Net Oil Imports (MB/D)	Balance All Trade ($Billion)
Saudi Arabia	1,408	($1.0)
Venezuela	1,281	($3.5)
Canada	1,103	($10.7)
Mexico	810	$1.7
Nigeria	734	($4.4)
United Kingdom	330	$4.6
Total	**5,666**	**($13.4)**

Sources: Net Oil Imports from Energy Information Administration, *Annual Energy Review*, 1993, p. 153. Balance of trade data from Statistical Abstract of the United States, 1994, Table No. 1329.



Source: Energy Information Administration, *Annual Energy Review*, 1993, pp. 173 and 203.

Figure 1-4. Oil and Natural Gas Prices—Summary: 1970-1993 (1987 Dollars).



Source: American Petroleum Institute, "The Cost of Motor Gasoline to Consumers", *Annual Energy Review*, 1993, Table 4.

Figure 1-5. Retail Gasoline Price—Summary: 1970-1993 (1987 Dollars).

In fact, the price of gasoline has actually declined over the past 20 years.

Although the overall Consumer Price Index (CPI) has increased by 75 percent between 1980 and 1993, the CPIs for fuel oil and motor fuel are at 1980 levels. The next lowest growth area—household furnishing and operation—grew 38 percent over the period.[19] These data illustrate that the growth of the U.S. economy owes a great deal to the "strong back" of the oil and gas industry.

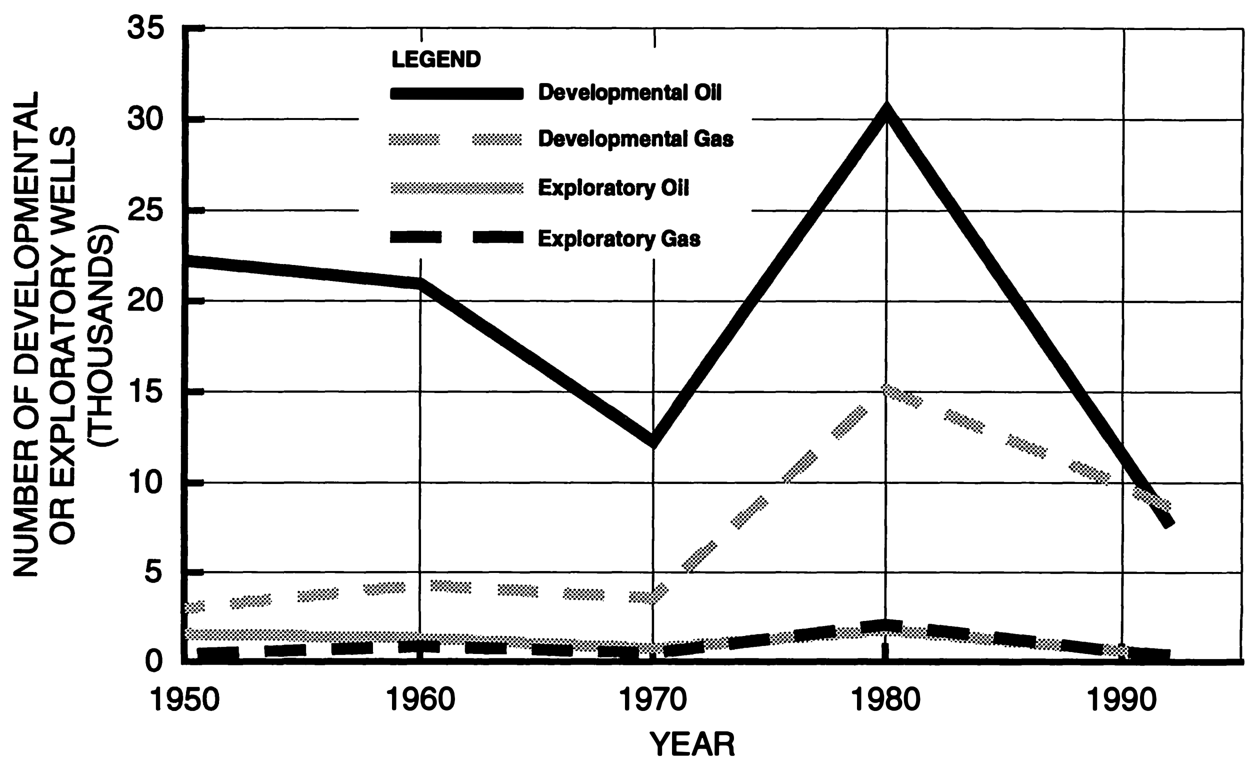
The Domestic Oil and Gas Industry

Many of the most promising areas for oil and gas development in the United States are closed to exploration. Exploration and development activity in the United States is well down from the peak of the early 1980s (Figure 1-6). This is a result of lower oil and gas prices, but also because many of the most promising areas are closed to exploration. It is in these frontier areas that the largest discoveries are most likely. It is significant that a steadily increasing fraction of oil, gas, and coal production is on "federally administered lands" (Figure 1-7).

U.S. refining operations are technically advanced and energy-efficient. U.S. refiners have increased the technical complexity of their operations in order to achieve improved conversion of each barrel of crude oil—even as the crude oil slate has become heavier and higher in sulfur content—and as environmental restrictions have become more severe.

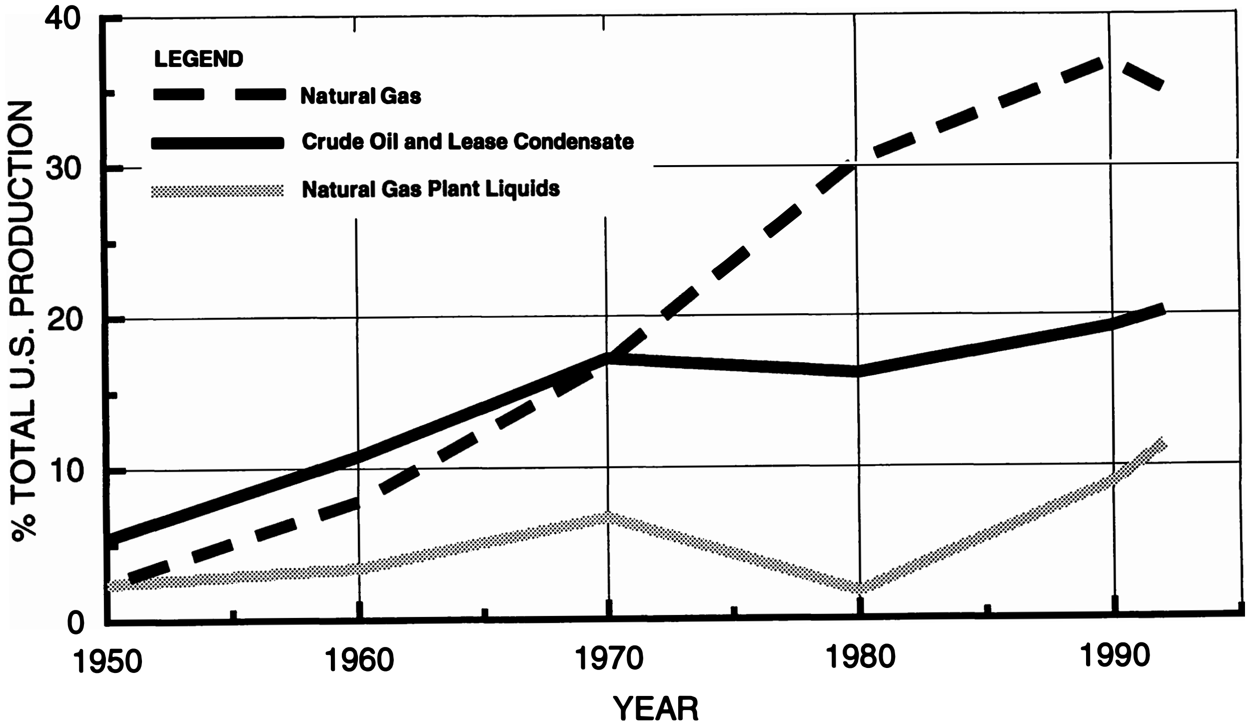
One gauge of this complexity is the "downstream capacity," or the capacity to process crude oil using fluid catalytic cracking, hydrocracking, hydrotreating, alkylation, reforming, and coking. Figure 1-8 shows that the ratio of downstream capacity to crude oil capacity has steadily increased. In spite of the greater complexity, between 1973 and 1990 total

[19] Statistical Abstract of the United States, 1994, Table No. 748.



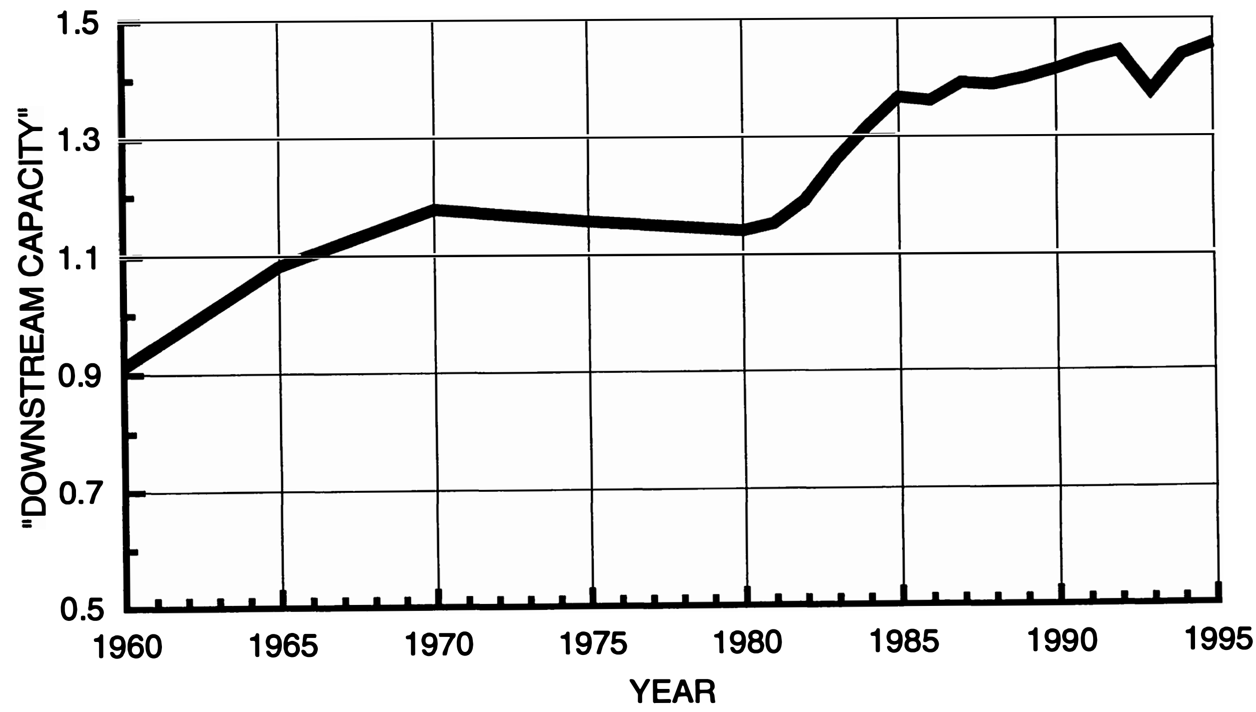
Source: Energy Information Administration, *Annual Energy Review*, 1993, pp. 121 and 123.

Figure 1-6. U.S. Drilling Activity: 1950-1992.



Source: Energy Information Administration, *Annual Energy Review*, 1993, p. 31.

Figure 1-7. Oil & Gas Production on Federally Administered Lands.



Source: Oil & Gas Journal Annual Surveys.

Figure 1-8. Technical Complexity of U.S. Refineries.

energy consumption per barrel of crude oil processed has been reduced by 15 percent.[20]

However, *weak margins continue to undermine profitability.* Between 1970 and 1993, the number of U.S. refineries decreased by 33 percent (Table 1-4). And the refining business has become so difficult that it is generally accepted by the industry that *no new refineries will be built in the United States.* Increased demand will be met at first through more complete utilization of existing refineries, then by de-bottlenecking and expansion of existing refineries, and ultimately by importing refined products.[21]

Refiner margins—the difference between the acquisition price of crude oil and the sale price of finished products—are below 1980 levels except in the case of fuel oil (Table 1-5). During the 1980s, refiners had an average profit of only 2.5 cents per gallon of finished product.[22] Many had operating losses. Those losses and the end of the small refiner entitlement program resulted in the closure of 132 refineries between 1980 and 1993. More efficient operations have been key to survival.

[20] "Technology Partnerships," U.S. DOE Office of Energy Efficiency and Renewable Energy, p. 54.

[21] National Petroleum Council, *U.S. Petroleum Refining—Meeting Requirements for Cleaner Fuels and Refineries*, August 1993, cover letter.

[22] National Petroleum Council, *U.S. Petroleum Refining—Meeting Requirements for Cleaner Fuels and Refineries*, August 1993, cover letter.

TABLE 1-4

U.S. REFINERY CAPACITY AND UTILIZATION, 1950-1993

	1950	1960	1970	1980	1990	1993
Number	320	309	276	319	205	187
Capacity (million barrels per day)	6.22	9.84	12.02	17.99	15.57	15.12
Average Capacity (thousand barrels per day)	19.4	31.8	43.6	56.4	76.9	80.9
Utilization (percent)	92.5	85.1	92.6	75.4	87.1	91.4

Source: Energy Information Administration, *Annual Energy Review*, 1993, p. 157.

TABLE 1-5

REFINER MARGINS: 1978 TO 1993
Cents per Gallon (Current Dollars), Excluding Taxes

	1980	1985	1990	1993
Motor Gasoline	27.3	19.8	25.7	23.4
Jet Fuel, Kerosene-Type	20.0	15.8	24.4	18.6
No. 2 Distillate Fuel Oil	13.4	13.8	16.6	16.8
Residual Fuel Oil	-14.0	-6.0	-11.6	-9.8
Composite	22.4	17.0	22.1	20.6

Source: Energy Information Administration, Annual Energy Review, 1993, p. 181.

Regulation is dramatically increasing product costs. The NPC study on U.S. petroleum refining published in August 1993 concluded that investments in the 1990s to comply with environmental requirements on refineries and products would be $37 billion. *This exceeds the $31 billion (1993) book value of these refineries.* To recover 10 percent return on capital employed, by the year 2000 the costs to consumers of light products will have to increase by 10 cents per gallon.[23]

VISION FOR ENERGY CONSUMPTION AND SUPPLY IN 2020

Oil and Gas Consumption

Oil, gas, and coal will continue to fuel U.S. and world economies. Between now and 2020, U.S. consumption of oil and gas will increase. New technology will continue to improve the efficiency of energy utilization, but efficiency improvements will be more than offset by population growth and changes in the standard of living.

In the industrial sector, de-regulation of utilities will allow the industrial plants (including refineries) to be producers of electric power. This will result in improvement in the overall efficiency of oil and gas utilization.

Use of gas for commercial space cooling will increase because of improvements in energy efficiency and cost reductions of gas-fueled units, and because of phase-out of CFCs. Residential uses will also increase because growth in the number of customers will offset improvement in equipment efficiency and building thermal integrity.

In the transportation sector, petroleum-based fuels will continue to dominate the market, and these fuels will continue to change to meet new demands.

[23] National Petroleum Council, *U.S. Petroleum Refining—Meeting Requirements for Cleaner Fuels and Refineries*, August 1993, cover letter.

Advances in engine and transmission technologies, and continued vehicle weight reduction will improve fuel economy of automobiles by as much as 50 percent. However, increases in vehicle miles travelled will more than offset these improvements.

Advances made in alternatively fueled vehicles may improve uses in niche-situations. However, even if the economics and convenience of alternatively fueled vehicles (including electric vehicles) prove acceptable to consumers, inertia in fleet turnover and required investment in fuel distribution infrastructure will limit the extent of fuel substitution.

Oil and Gas Supply

Technology will be a critical component to discovery and utilization of new oil and gas resources. Major new reserves of oil and gas will be found.

Gas resources will be used to fuel local and regional economies (thereby substituting for oil), converted to liquid fuels, or marketed globally as liquefied natural gas (LNG).

Deepwater exploration and production in the Gulf of Mexico will progress rapidly during the next 10 to 20 years, primarily due to the advancements in technology and the high per-well producing rates recently confirmed. It is highly probable that the deepwater Gulf will become the primary supplier of domestic oil and gas in the very near future.

The Arctic regions of the United States will continue to be an attractive alternative to the other sources of supply of oil and gas. However, the advancements in deepwater technology will push Arctic development further back due to the high cost of development and lingering environmental concerns. The Arctic region will once again have to wait for its turn.

Oil and gas prices will remain under pressure due to continued high investment in abundant global opportunities.

Refining

Refining operations will be even more technically sophisticated. Refineries will require the flexibility to accommodate changes in crude oil slates and in compositional requirements for finished products. To accomplish this, refineries will utilize "agile manufacturing" concepts. This will result in greater flexibility and improved utilization of facilities, and also will affect the size and required skill level of the refinery workforce.

New families of catalytic materials will provide the basis for major improvements in existing refining processes and will lead to the use of new chemistry and new process concepts in refining. These processes will be more efficient, more reliable, and have a much lower impact on the environment than do current processes.

The environmental impact requirements of refining products throughout the world will be similar to those in the U.S. markets. There will be minimal demand for products that do not conform to standards equivalent to U.S. standards.

New structural materials will be available that will allow operational improvements in existing processes and facilitate implementation of new processes. Nondestructive on-line testing of equipment will become widespread. Use of these techniques will dramatically reduce incident rates and maintenance costs, and will extend the useful life of plants.

Environmental remediation of refineries related to past operations should be largely completed. The new driving force for environmental performance will be "zero emissions" processes.

Response of the U.S. Industry

The U.S. oil and gas industry will be a vigorous competitor domestically and internationally. The U.S. oil and gas industry will continue to focus on its core businesses of oil and gas exploration, production, transportation, refining/processing, and marketing.

The industry will conduct business globally—exploring and developing the best prospects available—and will make investments in business sectors and geographical regions where it is possible to produce a fair return to its stockholders. In this capacity, the industry will be a strong contributor to the economic development and standard of living of nations throughout the world.

The competitive edge of the industry will increasingly depend on the ability to manage and apply technology effectively and rapidly. This will include leadership in technology for efficient investment of capital for environmentally sound operations and environmentally acceptable hydrocarbon fuels.

BARRIERS TO ENERGY SUPPLY VISION

NPC members identified a set of barriers to the vision; overcoming some will require new and improved technology. Recipients of the survey used to identify RD&D needs (see Chapter Two) were asked to describe "in broad general terms" the barriers and problems that might prevent them from accomplishing their corporate business needs and for which there might be emerging technological solutions. Sixty-seven companies responded to the question, and the responses provided separate barrier statements that were grouped and analyzed under the following four themes:

- Cost Control
- Economics and Capital Availability
- Environmental Compliance and Regulatory Issues
- Technology Transfer.

Cost Control

Twenty-five statements related to needs to reduce costs. In some cases, the statements included specific technology solutions. The barrier statements related to costs by the business activity headings used in the survey are included in Appendix D on survey results (Appendix D is Volume II of this report). The overriding emphasis and theme that was consistent throughout these statements was the desire for technology to reduce costs in the respective area.

Economics and Capital Availability

Sixteen percent of the responses relating to barriers to achieving their broad business needs related to economics and availability of capital. In general, these statements raised the concern regarding availability of capital for investment. Although it is difficult to relate this to a technological solution, since this dilemma is driven by industry profitability and a number of broad trends within the industry, the general inference is for the need of new technology to help improve success rates or lower costs that will make new investments more attractive.

Environmental Compliance and Regulatory Issues

Not unexpectedly, many of the statements related to compliance issues such as waste disposal and short lead times. There were also a group of statements about "property issues." These relate to lack of access to promising but "sensitive" exploration areas, such as offshore and Alaska, that low-impact exploration technology could affect. Statements related to downstream barriers noted that regulations had reduced the expected useful economic life of refineries, and that remediation requirements hindered alternative development of sites.

Technology Transfer

In the category of technology transfer, three areas were identified as problems or barriers to achieving broad business needs. The three primary areas noted in the statements were (1) identification of technology needs, (2) evaluation of available technologies, and (3) demonstration or application of available technologies. It is important to note that these areas were raised by a significant number of survey respondents as a barrier or problem to achieving their business needs.

SUMMARY

As the discussions of the role of the U.S. oil and gas industry and the vision of the future have indicated, this industry is vital to a strong U.S. economy. This chapter also has outlined the broad business challenges facing the industry that were identified by our survey and that could be overcome with advanced technologies. These challenges were identified and discussed in order to better understand the basis and broad parameters of the technology needs.

NPC members believe that improvements in technology are the key to overcoming many of these barriers. Therefore, identifying the specific RD&D needs of the industry is the central component of this study. Chapter Two focuses on identifying these industry needs.

CHAPTER TWO

TECHNOLOGY NEEDS OF THE INDUSTRY AND IMPACT OF TECHNOLOGY SOLUTIONS

The RD&D needs of the U.S. oil and gas industry have been assessed by the Council with the assistance of an Industry Needs Task Group consisting of representatives from industry, government, and RD&D consortia. The oil and gas industry's technology needs were determined based on a comprehensive survey distributed to a large cross-section of the industry (primary data), an analysis of other pertinent studies completed in the last several years (secondary data), and the best judgment of the Task Group to interpret the data from the first two sources. The scope of this study began with identification of the resource and ended with the output of the oil refinery and the gas processing plant.

INDUSTRY NEEDS SURVEY

A 31-page survey (see Appendix D, Volume II of this report) was developed to query the members of the National Petroleum Council about needed technology advances, the impact of these advances, and the likelihood that such advances would be commercially available in the short term (by 1999) and in the long term (between 2000 and 2010). A further purpose was to determine the degree of willingness to collaborate to advance these technologies, and to identify issues that are barriers to technical collaborations with other oil and natural gas companies, DOE, the national laboratories, and other public and private laboratories.

The survey identified and addressed nearly 250 individual technologies. Respondents also had an opportunity to write in technologies that they did not find listed and believed would have a high impact on their business performance. The survey grouped the technologies in eleven categories:

- Exploration
- Development
- Drilling and Completion
- Production
- Deepwater Offshore
- Arctic Region Activities
- Oil Processing and Refining
- Gas Processing
- Gas Gathering
- Gas Storage
- Environmental and Regulatory.

SECONDARY SOURCES

The NPC reviewed published summaries of recent petroleum RD&D priority recommendations and trends in petroleum

RD&D expenditures. They designed these reviews to provide a context in which to interpret the results of the survey and both supplement and corroborate the survey results.

First, the study participants reviewed a representative sample of more than 30 recently published oil and gas technology needs assessments and documentation of current federal RD&D programs. A detailed review of the most representative of these revealed that research priorities vary considerably among types of company and by types of technology. The diverse way these assessments characterize technology needs made a direct comparison difficult. However, the major themes of technology needs were improved resource characterization (for both exploration and development), reduced drilling costs, and improved understanding of complex reservoirs. This apparent bias toward extraction technologies is partly due to the dominance of upstream technology assessments in the literature. The reviews provided insights into how technology priorities have changed over time and differ between majors and independents.

SURVEY RESPONDENTS

The survey was distributed to NPC member companies and 89 responses were received. The response rate was approximately 75 percent, which is very high for a survey of this type. For purposes of analysis of the survey results, the respondents were categorized as majors, other integrated oil and gas companies, independents, or service companies. Statistics for these categories are given in Table 2-1. The respondents are listed by segment in Appendix D.

The 89 companies reported U.S. reserves of 11.8 billion barrels of oil and 74.6 trillion cubic feet of gas—*or about 50 percent of total U.S. reserves.* The companies also reported worldwide oil reserves of 24 billion barrels and worldwide gas reserves of 128 trillion cubic feet. The respondent companies reported sales greater than $425 billion. The respondents have 9 million barrels per day of refining capacity, which is about 60 percent of total U.S. capacity. The 20 service company respondents represent most of the upstream service companies.

METHODOLOGY FOR ANALYSIS OF SURVEY TECHNOLOGY NEEDS RESULTS

Responses to survey questions about impact of a particular technology and likelihood that it would *not* be commercially available were scored 1, 3, and 5 for "low," "medium," and "high," respectively. Then, for each technology a mean score was computed for each of the different groupings based on the short term (1995-1999) and long term (2000-2010) needs for each of the four categories of respondents listed in Table 2-1.

For each of the 11 technology areas, the technology needs were plotted using the scores for numerical impact and likelihood of commercial availability. Of most relevance to this chapter are those needs that have both a high impact and a higher likelihood of not being met (see Figure 2-1). In the figures in this chapter, these points appear in the upper right. Selected plots are included in following section on

TABLE 2-1

SURVEY RESPONDENT STATISTICS

Category	No. of Respondents
Majors	17
Other Integrated Oil and Gas Companies	12
Independents	40
Service Companies	20
Total	**89**

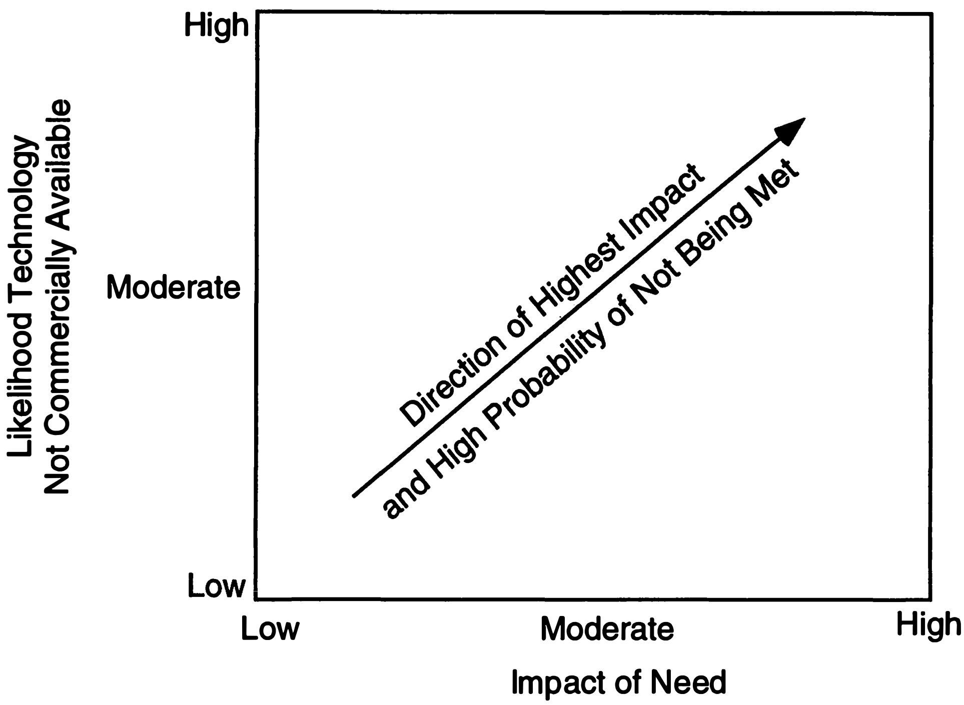


Figure 2-1. Plotting Needs and Availability.

Key Technology Needs. Appendix D contains the additional plots for each technology area by each respondent grouping (major, independent, etc.).

KEY TECHNOLOGY NEEDS

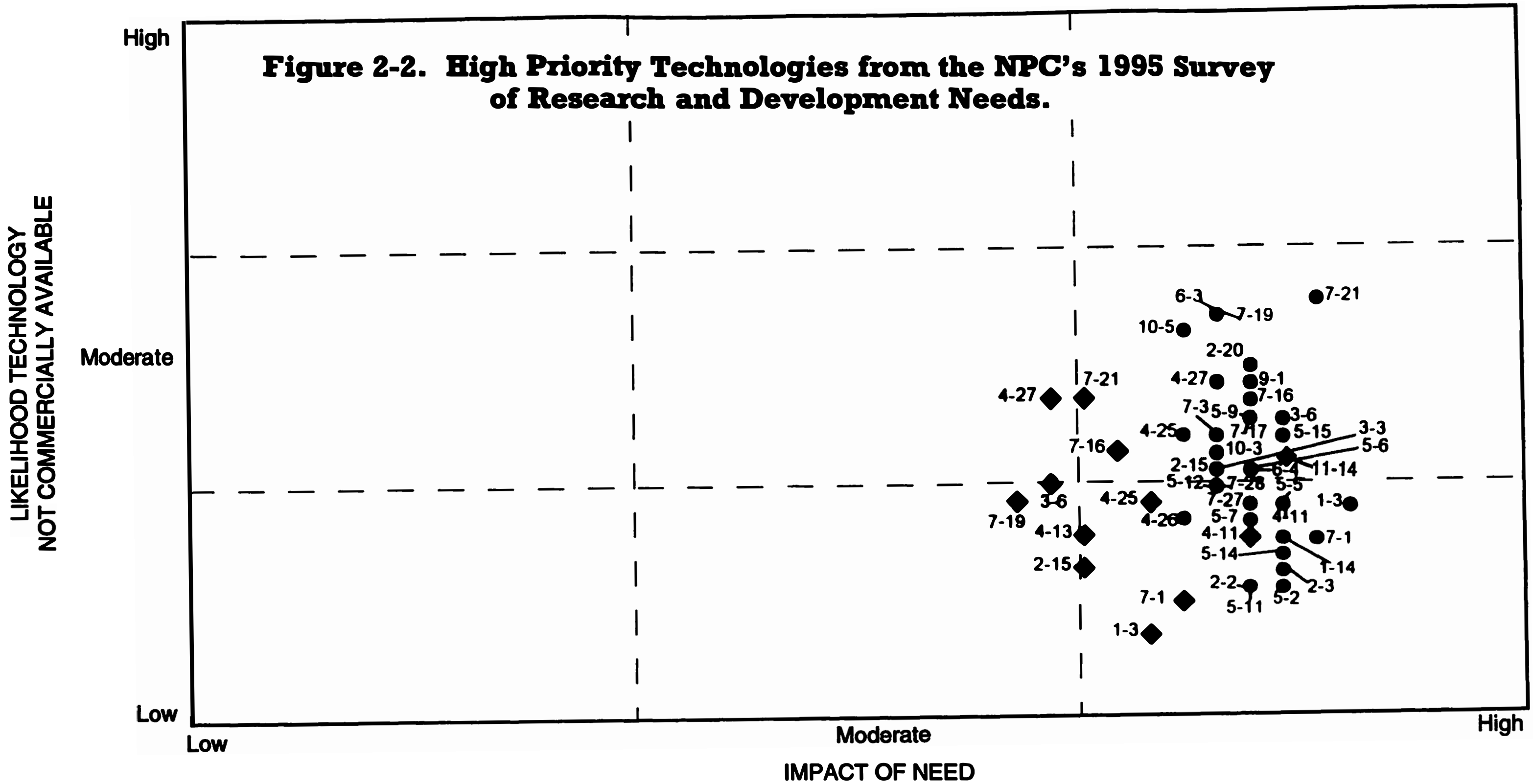
Overall

From the nearly 250 technology needs (including write-ins) across all 11 technology areas, the study participants identified 36 technology needs in which advances should have the broadest application, highest impact, and the highest likelihood of not being commercially available.

The Task Group believed that the respondents had greater confidence in judging the impact of a technology on their business than the likelihood that a technology would not be commercially available. Therefore, the impact of a technology advance on a company's business was the primary factor in ranking the need for that technology. The likelihood that it might *not* be commercially available was a secondary factor. Those needs with impact scores of 4.0 or more in the short term and 3.5 in the long term were further screened using the index: (impact x 2) + (likelihood of *not* being commercially available). There were one long-term and 35 short-term technology needs that had index scores of ten or more and were voted on by at least five respondents. These high-scoring needs were distributed across virtually all of the 11 technology areas. Figure 2-2 lists the 36 technologies and shows the plot of availability vs. impact. The needs that meet the above screening criteria, as well as needs that were written in by three or more respondents, are discussed more fully below.

Across the 11 technology areas, the highest areas of impact identified by majors, other integrated companies, and independents in the upstream are high-resolution depth imaging and improved well productivity. Hydrate control and removal also is important. Advanced seismic acquisition is a high need for independents, and horizontal well technology is the highest ranking need for service companies. In

Figure 2-2. High Priority Technologies from the NPC's 1995 Survey of Research and Development Needs.



● ***SHORT TERM****

Q.1		**Exploration**
1-3	(51)	High-resolution seismic depth imaging
1-14	(46)	Advanced seismic acquisition
Q.2		**Development**
2-2	(45)	Computer-based 3D geological modeling
2-3	(43)	Development-scale seismic applications
2-15	(50)	Through casing logging
2-20	(46)	Permeability logging techniques
Q.3		**Drilling And Completion**
3-3	(49)	Advanced fracture techniques
3-6	(47)	Well productivity
Q.4		**Production**
4-11	(53)	Stimulation techniques
4-25	(49)	Near well bore stimulation
4-26	(43)	New directional drilling
4-27	(39)	Advanced recovery of natural gas
Q.5		**Deep Water Offshore**
5-2	(20)	Extended reach drilling or production
5-5	(12)	Flowlines
5-6	(13)	Flow metering
5-7	(15)	Subsea equipment
5-9	(14)	Risers
		Deep Water Offshore (continued)
5-11	(20)	Drilling
5-12	(11)	Workover
5-14	(11)	Hydrate prevention
5-15	(11)	Multi-phase pumps
Q.6		**Arctic Region Activities**
6-3	(7)	Development
6-4	(10)	Drilling
Q.7		**Oil Processing and Refining**
7-1	(22)	Catalysts with improved selectivities yields, lifetimes
7-3	(19)	Plant and process reliability
7-16	(21)	Energy efficiency of processes
7-17	(19)	Energy efficiency of equipment
7-19	(14)	Separations technologies
7-21	(10)	New approaches to refining heavy feeds
7-27	(10)	Performance characteristics of new hydrocarbon fuel compositions
7-28	(14)	Environmental characteristics of new hydrocarbon fuel compositions
Q.9		**Gas Gathering**
9-1	(30)	Compression
Q.10		**Gas Storage**
10-3	(11)	Reservoir management
10-5	(9)	Base gas minimization techniques
Q-11		**Environmental and Regulatory**
11-14	(41)	Provide scientific basis for risk-based regulation

◆ ***LONG TERM****

Q.1		**Exploration**
1-3	(27)	High-resolution seismic depth imaging
Q.2		**Development**
2-15	(22)	Through casing logging
Q-3		**Drilling and Completion**
3-6	(28)	Well productivity
Q-4		**Production**
4-11	(21)	Stimulation techniques
4-13	(18)	Recompletion techniques
4-25	(19)	Near well bore stimulation
4-27	(28)	Advanced recoveryof natural gas
Q-7		**Oil Processing and Refining**
7-1	(14)	Catalysts with improved selectivities yields, lifetimes
7-16	(15)	Energy efficiency of processes
7-19	(21)	Separations technologies
7-21	(21)	New approaches to refining heavy feed

* Numbers in parentheses indicate number of responses.

the downstream, the highest needs are for improvements in catalysts, heavy feed processing, reliability, and efficiency. The environmental compliance issue also is an important crosscutting need.

Exploration

More precise characterization of the resource would have the greatest impact on exploration success. Specifically, in the short term, advances in high-resolution seismic depth imaging and advanced seismic acquisition are identified as having high impact (Figure 2-3). In the longer term, advances in high-resolution seismic depth imaging continues to be a technology need. The majors also see more impact in the long term from 3-D visualization tools and feel these needs will probably be met.

Development

The highest priority need for the development area in the short term is in better characterizing the reservoir. Improved borehole logging techniques to either estimate permeability or operate through-casing are part of this need. Away from the borehole, improved characterization of the reservoir results from improved development-scale 3-D geologic computer modeling and seismic techniques. Logging through-casing will not be adequately met in the short term and will require continued development in the long term (Figure 2-4).

Advances in characterizing fractured reservoirs was written in by a large number of respondents as a critical need. This technology need was listed in the exploration area and highly rated there, as well.

The four different groups of respondents all had the preceding needs. The greatest divergence of opinion exists between the majors and the other three groups in the long term. The majors need ongoing development of all of the technical areas identified for the short term. They may also need development of wellbore tools that have a greater depth of investigation (>1 foot) from the wellbore. The other three groups felt that their needs would be met in the short term in all areas except in the through-casing logging area.

Drilling and Completion

In the Drilling and Completion category, the two areas in which the survey participants ranked the highest RD&D needs are well productivity and advanced fracturing techniques. This is consistent with the outcome of the Production category, in which well stimulation techniques and new directional drilling are most important (Figure 2-5).

The majors also considered advances in unconventional, slimhole, and multilateral drilling to be needed. The other integrated companies added coiled tubing to their priority list. The independents also consider perforating and wellbore applications to be an important need, in addition to well productivity and advanced fracturing.

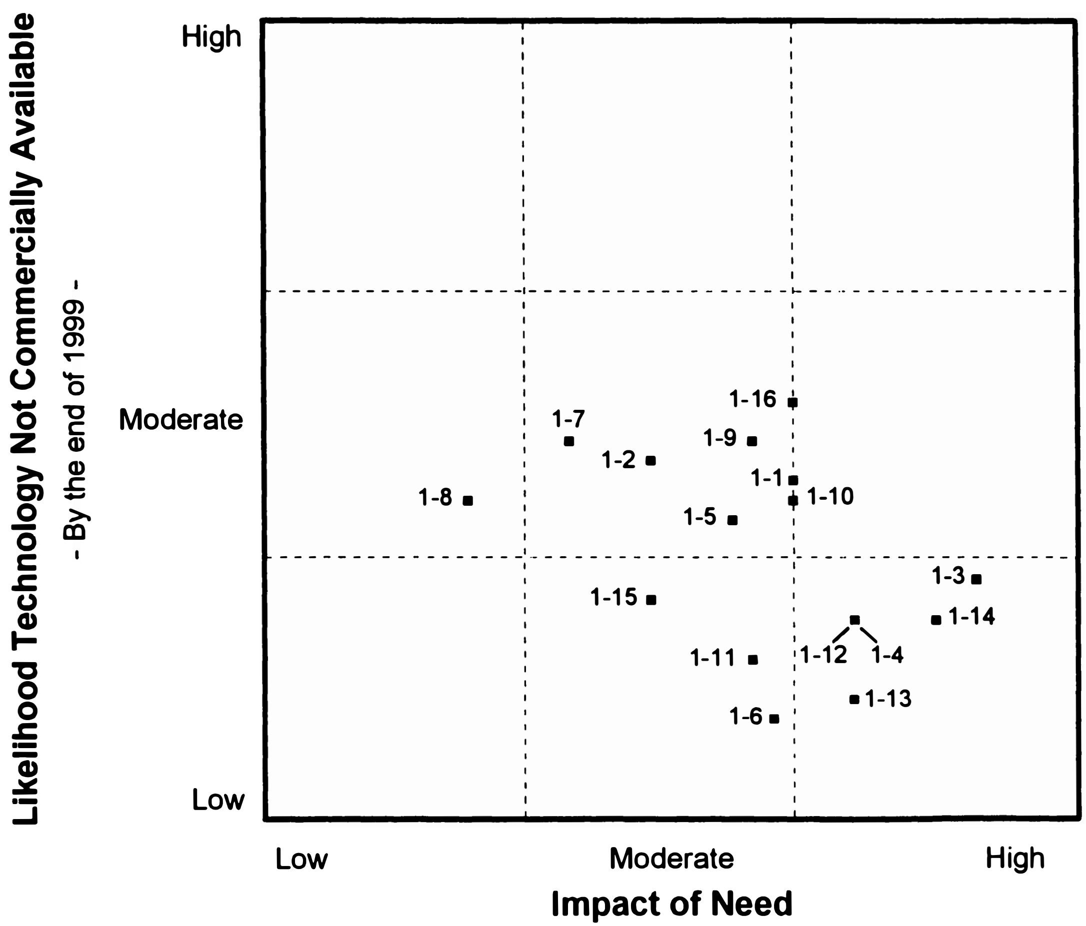
The results for the service companies were quite different from the other groups. The only technologies with significant needs are multilateral drilling, measurement-while-drilling (MWD), and horizontal wellbore applications. Fracturing and gravel pack technologies were added as a write-in by all segments except the service companies.

In the long term, well productivity is the most important technology in the category for total respondents. For independent firms and service companies, perforating and wellbore cleanup rank as the highest priority that is not considered likely to be developed.

Production

Based on the survey, the production development that will have the highest future impact is stimulation technology (Figure 2-6). This need is shared by all sectors of the industry: majors, other integrated companies, and independents. There is a moderate expectation that these needs will be met in the near term and increasing

Figure 2-3. Exploration Technologies, Short Term, from the 1995 NPC Survey of Research and Development Needs.

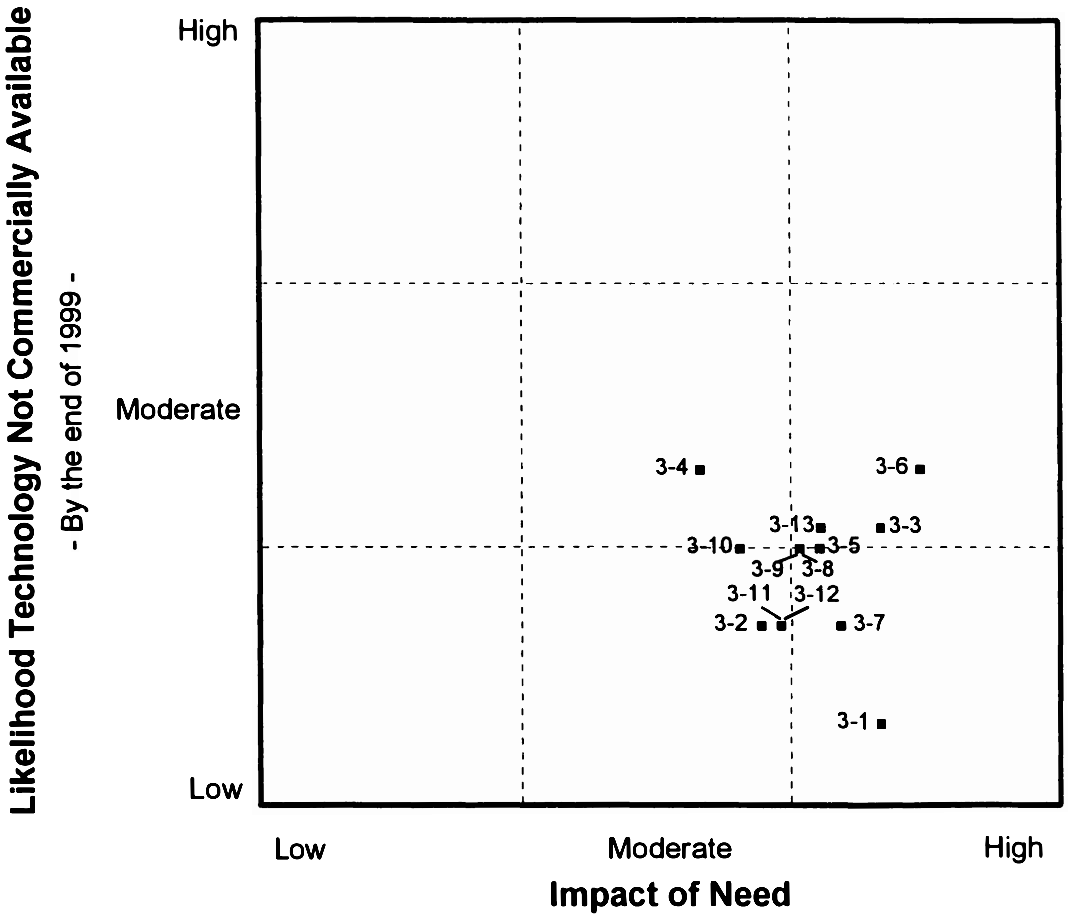


Technology		*No. of Resp.*
1-1	3D Basin modeling	30
1-2	Risk assessment methods	34
1-3	High-resolution seismic depth imaging	51
1-4	Specialized seismic processing	47
1-5	Sequence stratigraphy techniques	42
1-6	Workstation seismic modeling	51
1-7	Geochemical analysis	30
1-8	Airborne/satellite remote sensing	21
1-9	Fault seal analysis	37
1-10	Multi-component seismic techniques	32
1-11	3D Paleostructural restoration	33
1-12	Amplitude versus offset (AVO) in 3D	52
1-13	3D Visualization tools	45
1-14	Advanced seismic acquisition	46
1-15	Geographic information systems	29
1-16	Geophysical fracture-detection methods	37

Figure 2-4. Development Technologies, Short Term, from the 1995 NPC Survey of Research and Development Needs.

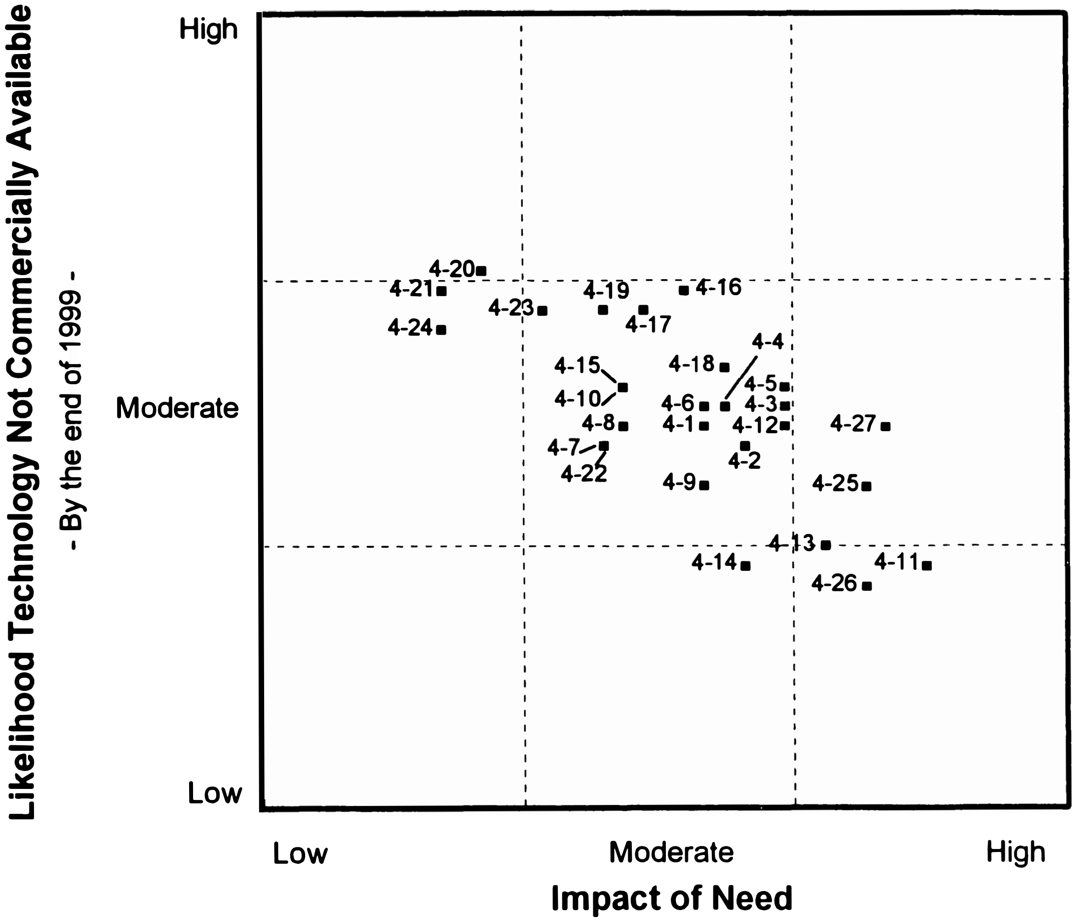
Technology		*No. of Resp.*
2-1	Advanced reservoir analog models	32
2-2	Computer-based 3-D geological modeling	45
2-3	Development-scale seismic applications	43
2-4	Tracers (biologic/chemical/radioactive)	24
2-5	Core analysis/imaging	35
2-6	Geostatistical reservoir descriptions	36
2-7	Outcrop analog studies	24
2-8	Fluid-rock interaction	39
2-9	Rock physics	30
2-10	Cross-well geophysical imaging	32
2-11	Advanced attribute processing	34
2-12	Seismic/log/core calibration	48
2-13	Cuttings analysis	28
2-14	Reservoir property identification	44
2-15	Through-casing logging	50
2-16	Deep investigation techniques	42
2-17	High resolution borehole imaging logs	41
2-18	Specialized core analysis	29
2-19	Characterization of rock wettability	26
2-20	Permeability logging techniques	46
2-21	Tracer techniques	23
2-22	CT scanning and NMR imaging	24
2-23	Formation water chemistry	25
2-24	Fluid sampling and analysis	31
2-25	Advanced reservoir simulation modeling	43
2-26	Workstation single well simulations	37
2-27	Procedures for data scale-up	28
2-28	Expert systems applications	20
2-29	Time lapse seismic imaging	22
2-30	Advanced monitoring of EOR processes	24
2-31	Advanced well testing and interpretation	38
2-32	Material balance applications	28
2-33	Decision and risk analysis	31
2-34	Expendable well bore instrumentation	20

Figure 2-5. Drilling and Completion Technologies, Short Term, from the 1995 NPC Survey of Research and Development Needs.



Technology		*No. of Resp.*
3-1	Horizontal well bore applications	56
3-2	Drilling fluid design	45
3-3	Advanced fracture techniques	49
3-4	Cementing	42
3-5	Perforating and well bore cleanup	48
3-6	Well productivity	47
3-7	Multilateral technology	36
3-8	Innovative bit and tubular technology	42
3-9	Slim hole drilling	39
3-10	Under balanced drilling	30
3-11	Measurements while drilling	46
3-12	Coiled tubing drilling	39
3-13	Unconventional drilling technology	25

Figure 2-6. Production Technologies, Short Term, from the 1995 NPC Survey of Research and Development Needs.



Technology		No. of Resp.
4-1	Injection water treatment	37
4-2	Produced water treatment	43
4-3	Corrosion control	48
4-4	Scaling inhibitors	51
4-5	Paraffin control/removal	48
4-6	Oil/water/gas/separation	37
4-7	Beam pump analysis	35
4-8	Gas lift analysis	33
4-9	Submersible pump analysis	35
4-10	Rod/tubing wear evaluation	38
4-11	Stimulation techniques	53
4-12	Gas compression techniques	39
4-13	Recompletion techniques	50
4-14	Remote control and data analysis	39
4-15	Compact processing on offshore platforms	25
4-16	Modification of reservoir fluid mobilities	30
4-17	Miscible contact/displacement	25
4-18	Viscosity reduction of heavy oils	24
4-19	In situ generation of foams/emulsions	20
4-20	Thickeners for CO_2 floods	18
4-21	Microbial EOR processes	14
4-22	High-velocity gas flow modeling	23
4-23	Thermal processes	22
4-24	Combustion processes	18
4-25	Near well bore stimulation	49
4-26	New directional drilling	43
4-27	Advanced recovery of natural gas	39

likelihood that the needs will be met in the long term. Advanced recovery methods for natural gas is an important need for other integrated companies and independents. New directional drilling methods will be needed in the future, but there is a general expectation that this technology will be available.

Deepwater Offshore

Deepwater offshore needs for technology advancement were prioritized in the following order in the short term (Figure 2-7):

1. Multiphase pumps
2. Risers
3. Flow lines
4. Flow metering
5. Workover
6. Hydrate prevention
7. Subsea equipment
8. Extended reach wells
9. Drilling.

Only the majors identified higher impact needs in the long term: multiphase pumps and workovers.

The write-in areas of concern concentrated on mooring systems, paraffin buildup prevention, and pipeline laying, repairing, and pigging. Remote power distribution systems and remote controls were also suggested as areas of high technology need.

Arctic Region Activities

The Arctic region activities area received responses primarily from the majors, with one or two responses from the independents and the service companies. There were no responses from the other integrated oil and gas companies. Two areas received a medium to high impact rating. They are development and drilling (Figure 2-8). These categories are very general and do not define specific areas to focus research and development. There was skepticism that the technology would be commercially available in all categories, but Arctic drilling seemed to be of less concern in the near term than the other areas.

More people responded to the long-term time frame than the short term. This could indicate that the industry believes the Arctic is a long-range frontier to be addressed after the year 1999. The impact of Arctic technology is less than the deepwater area.

Refining

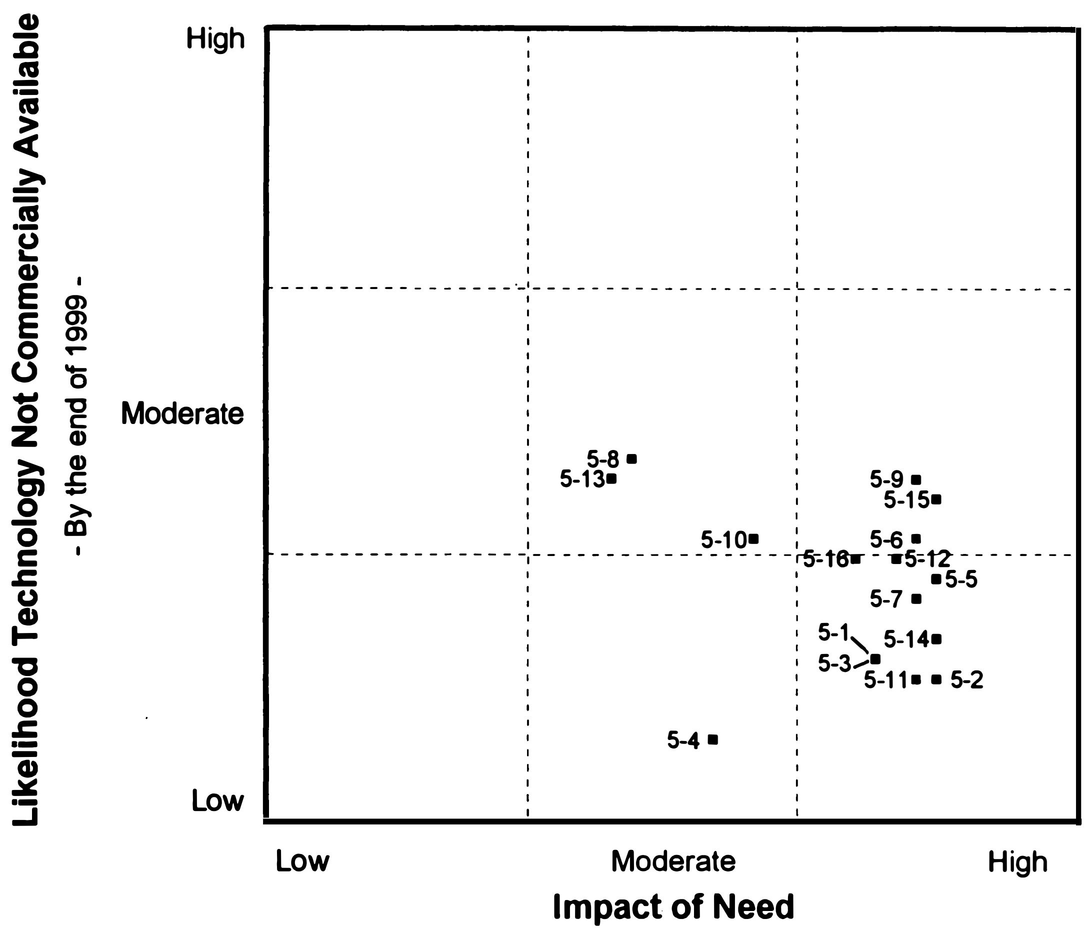
The impact of advances in technologies on the performance of the refining area is governed largely by the business environment. The majors, other integrated companies, and independents perceive that advances in the following technology areas will have major impacts on the performance of their operations in both the short term (Figure 2-9) and the long term:

- Catalysts with improved selectivities
- Plant and process reliability
- Energy efficiency of operations
- New approaches for refining heavy feedstocks
- Relating chemical composition to performance of processes and products
- Performance (including environmental) characteristics of new hydrocarbon fuels (such as future reformulated gasolines)
- Separations.

The majors tend to place greater importance on the need for advances in plant and process reliability and on the need for new processes for heavy feeds, while the independents emphasize separations technologies to a greater extent than do the majors.

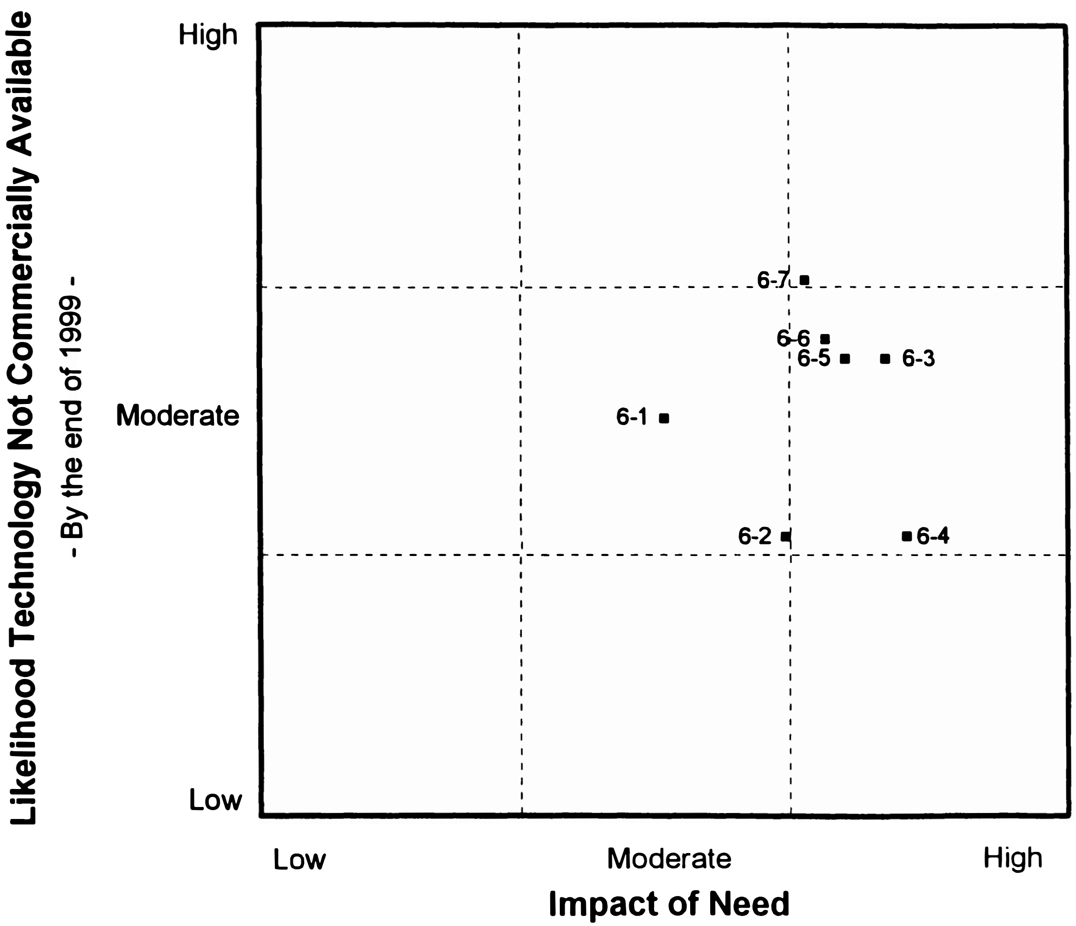
Catalysts, which have been a mainstay for refining technology, are viewed as an area that will have one of the greatest impacts but is one in which the industry is confident that successful advances will occur. On the other hand, the industry as a whole is less confident that advances in technology for energy efficiency or processing heavy

Figure 2-7. Deepwater Offshore Technologies, Short Term, from the 1995 NPC Survey of Research and Development Needs.



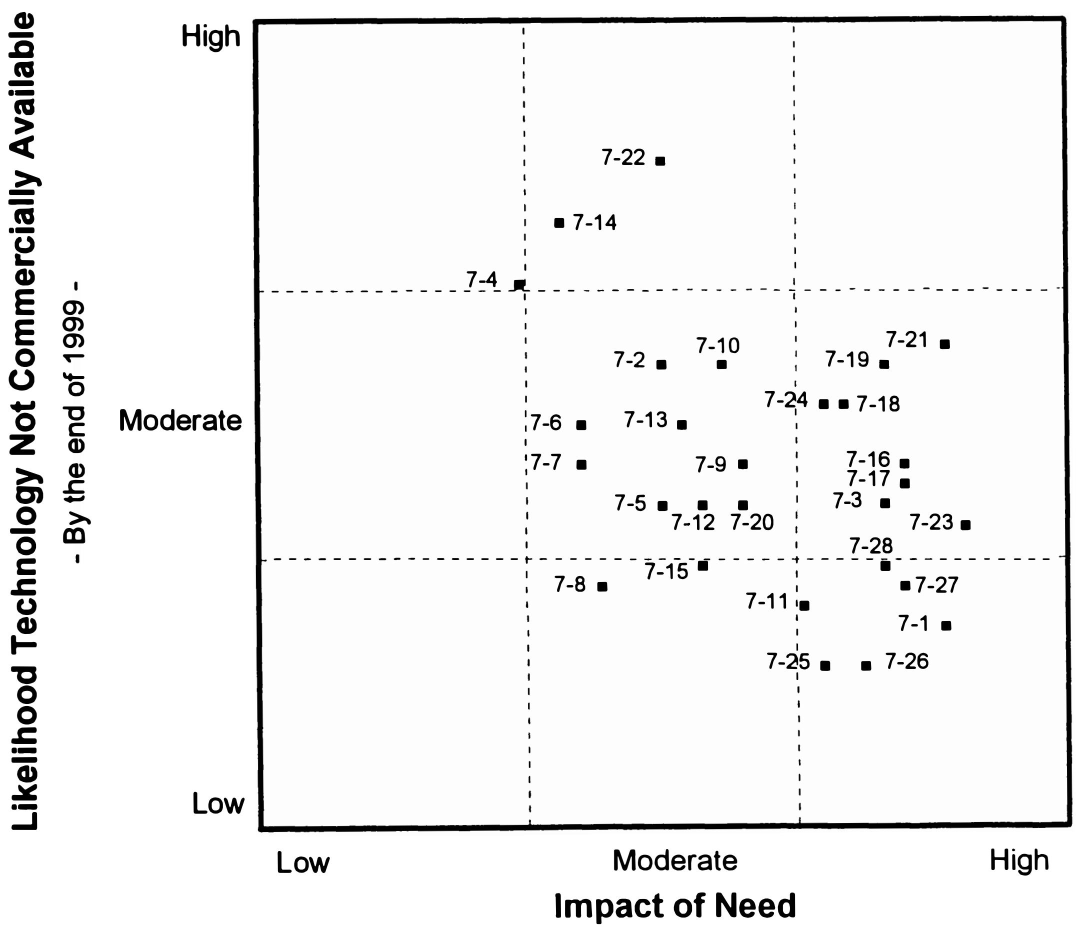
Technology		No. of Resp.
5-1	Produced fluid disposal	10
5-2	Extended reach drilling or production	20
5-3	Extended reach control systems	12
5-4	High pressure systems	9
5-5	Flowlines	12
5-6	Flow metering	13
5-7	Subsea equipment	15
5-8	External corrosion protection	10
5-9	Risers	14
5-10	ROV systems	10
5-11	Drilling	20
5-12	Workover	11
5-13	Water/gas injection	6
5-14	Hydrate prevention	11
5-15	Multi-phase pumps	11
5-16	Structures	11

Figure 2-8. Arctic Region Activities, Short Term, from the 1995 NPC Survey of Research and Development Needs.



Technology		*No. of Resp.*
6-1	Transportation	7
6-2	Exploration	7
6-3	Development	7
6-4	Drilling	10
6-5	Production	7
6-6	Deepwater offshore activities	5
6-7	Mobile ice	6

Figure 2-9. Oil Processing and Refining Technologies, Short Term, from the 1995 NPC Survey of Research and Development Needs.



Technology		No. of Resp.
7-1	Catalysts with improved selectivities, yields, lifetimes	22
7-2	Hydrogen production and recovery	16
7-3	Plant and process reliability	19
7-4	Unconventional process technology	3
7-5	New materials of construction	5
7-6	Reactor engineering and modeling	10
7-7	Catalyst manufacturing technology	10
7-8	Risk assessment methodology	21
7-9	Solid acid catalysts	9
7-10	Alternatives to olefin alkylation process	8
7-11	Techniques for integration of environmental solutions into process and plant design	17
7-12	Improved on-line NDE inspection technology	17
7-13	Predicting useful remaining lifetimes of aging equipment	16
7-14	Robotics for safety applications	4
7-15	Worker safety systems	21
7-16	Energy efficiency of processes	21
7-17	Energy efficiency of equipment	19
7-18	Energy efficiency of separations	18
7-19	Separations technologies	14
7-20	Determining chemical composition of crudes, refinery intermediates, and products	14
7-21	New approaches to refining heavy feeds	10
7-22	Processing synthetic fuels	3
7-23	Conversion of methane to liquid fuels	4
7-24	Relating chemical compositions to process and product performance	15
7-25	Advanced computational modeling of processes/reactions	15
7-26	Advanced control and information systems	20
7-27	Performance characteristics of new hydrocarbon fuel compositions	10
7-28	Environmental characteristics of new hydrocarbon fuel compositions	14

feeds will be commercialized in the short or long term. Reliability is a major current issue for the majors, but they believe their technology needs will probably be met in the near term.

Gas Processing

No technology from this area made the overall key technology need area. However, several are very important to the independents. The respondents ranked separation of high impurities and trace constituent areas as highest impact followed by acid gas removal and gas dehydration. This may reflect the belief that new gas sources will be higher in impurities, thus requiring more processing. A number of respondents expressed concern about hydrate control and removal. There was perceived to be a significantly higher short-term impact from advances in these technologies (Figure 2-10).

Gas Gathering

Compression improvements and multiphase metering are deemed to have the highest short-term impact and have the highest likelihood of not being commercially available (Figure 2-11). New compression improvement will have the greatest impact in the long term, reflecting the respondents' view that the needs will not be met in the short term.

Gas Storage

Well gas deliverability restoration and reservoir management ranked as high-impact technologies in both the short and long term. These are expected to be achieved by the long term. In the short term, base gas minimization techniques ranked very high reflecting the large dollar commitment required (Figure 2-12).

Environmental

Environmental requirements cut across all sectors of the industry, and compliance with regulatory requirements is a major expenditure for all participants in the industry. The one area that the industry respondents consistently ranked as having a high impact in the short term is the need for advances in improving the scientific basis for risk-based environmental assessments (Figure 2-13). The need is for environmental cleanup standards that balance the need to minimize risks to human health and ecosystems with costs and benefits of the cleanup.

SUMMARY

The survey results indicate that there are several technology needs that the industry feels may not be met. The survey also indicates that majors, other integrated oil and gas companies, independents, and service companies have distinct technology needs. As indicated in the composite of key technology needs of the 11 technology areas, high areas of impact identified were:

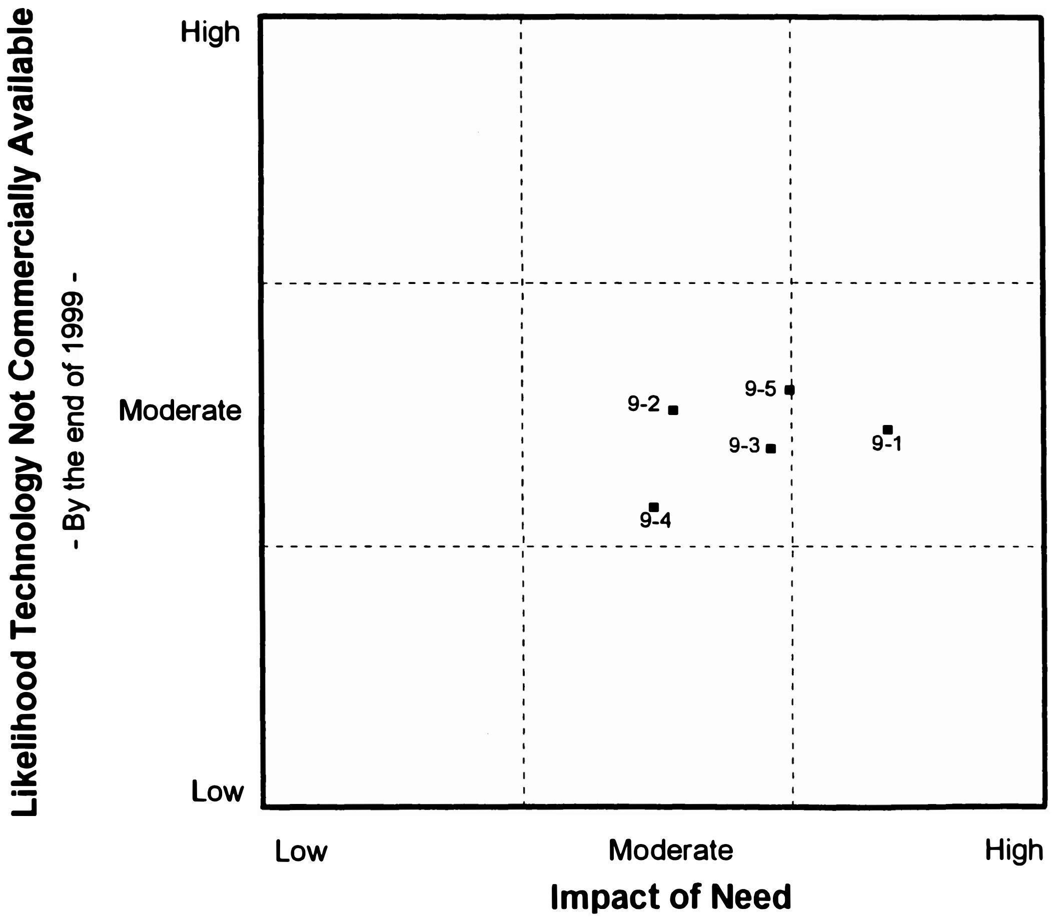
- In the upstream:
  - High-resolution depth imaging
  - Improved well productivity
  - Hydrate control and prevention
  - Paraffin control (for independents)
  - Horizontal well technology (for service companies).
- In the downstream:
  - Catalysts with improved selectivities, yields, and lifetimes
  - New approaches to refining heavy feeds
  - Improved energy efficiency of processes and equipment
  - Improved plant and process reliability
  - Separations technologies.

The above examples illustrate some of the highest priority distinct technology needs from the survey. Although some of the needs overlap, the priorities change with the size and type of company and with the level of research budget. The willingness to collaborate also changes by specific technology need. This chapter has needs plots for the composite of key technology needs and each of the key technology areas. Appendix D contains additional plots for the research and development needs of the industry by specific groups of survey respondents.

Figure 2-10. Gas Processing Technologies, Short Term, from the 1995 NPC Survey of Research and Development Needs.

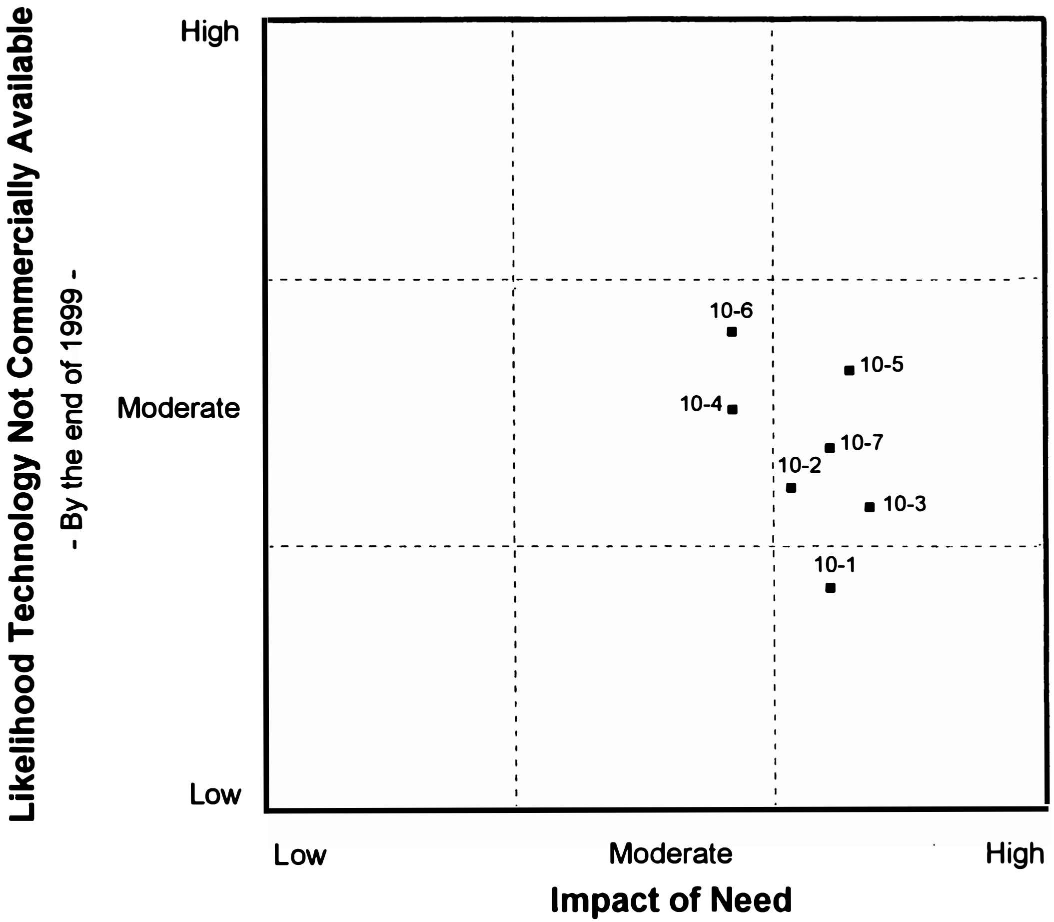
Technology		*No. of Resp.*
8-1	Gas dehydration	21
8-2	Acid gas removal	25
8-3	H_2S scavenger technology	23
8-4	Natural gas liquid separation	18
8-5	Nitrogen separation	17
8-6	Trace constituent (arsenic, Hg, etc.) removal	10
8-7	Sulfur recovery	13
8-8	Separation of high concentrations of impurities (nitrogen, CO_2, H_2S . . .)	23

Figure 2-11. Gas Gathering Technologies, Short Term, from the 1995 NPC Survey of Research and Development Needs.



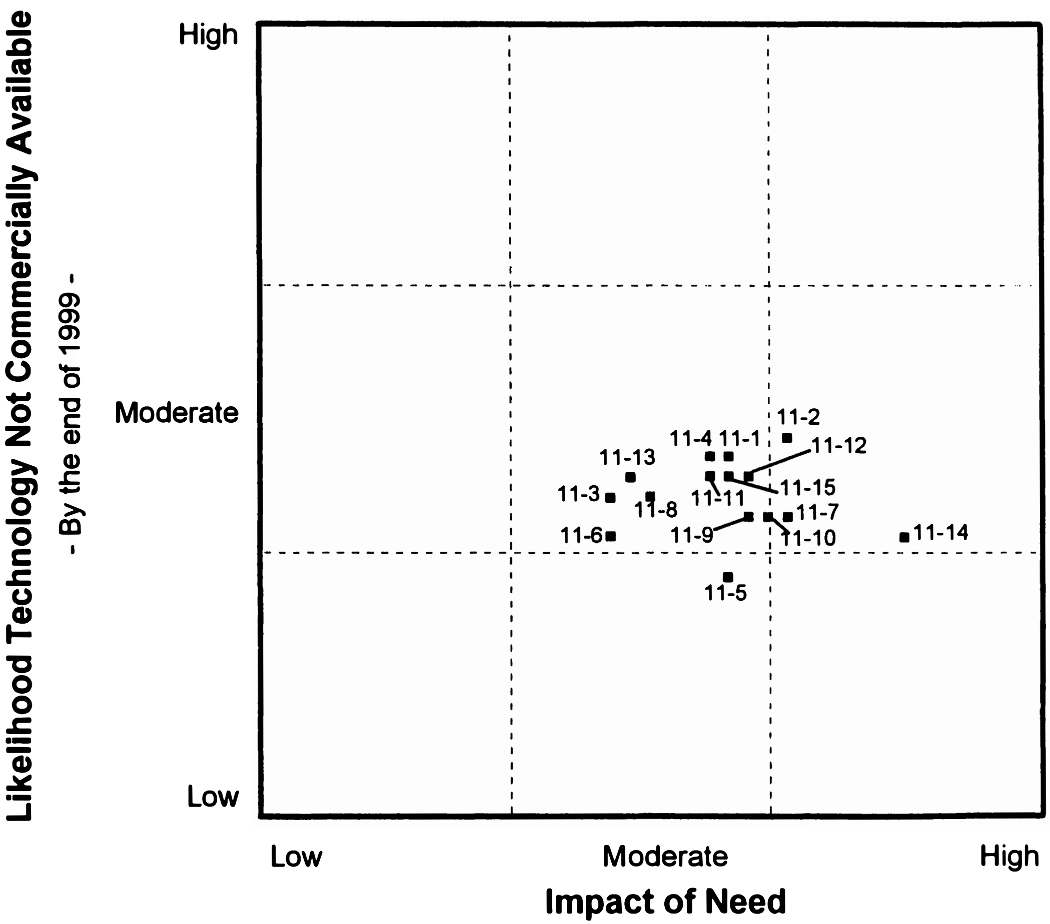
	Technology	*No. of Resp.*
9-1	Compression	30
9-2	Leak detection	23
9-3	Plastic pipe (higher pressure rating)	20
9-4	High pressure measurement	13
9-5	Multi-phase metering	19

Figure 2-12. Gas Storage Technologies, Short Term, from the 1995 NPC Survey of Research and Development Needs.



Technology		*No. of Resp.*
10-1	Well deliverability restoration	13
10-2	Leak detection and mitigation	9
10-3	Reservoir management	11
10-4	Gas migration control	9
10-5	Base gas minimization techniques	9
10-6	Inert base gas research	5
10-7	Unconventional development techniques	9

Figure 2-13. Environmental and Regulatory Technologies, Short Term, from the 1995 NPC Survey of Research and Development Needs.



Technology		*No. of Resp.*
11-1	Disposal methods for drilling fluids	46
11-2	Treatment and disposal of produced fluids	43
11-3	Screening procedures for injection wells	27
11-4	Risk and reclamation analysis of disposal methods	41
11-5	Leak detection	40
11-6	Hydrological modeling	19
11-7	Compliance with CAAA stationary source issue	48
11-8	Advanced computation models to predict dispersion, transformation, and fate of air pollutants	28
11-9	Model transport and remediation of contaminants in ground water and soils	31
11-10	Effluent and emission monitoring, minimization, and control	43
11-11	Recycling of waste and byproduct streams	29
11-12	Remediation technology	39
11-13	Catalyst recycling	19
11-14	Provide scientific basis for risk-based regulation	49
11-15	NORM disposal	44

CHAPTER THREE

HOW LABORATORY CAPABILITIES RELATE TO INDUSTRY NEEDS

This chapter contains four sections. First is a description of the survey of the capabilities of the nine DOE national laboratories and the National Institute for Petroleum and Energy Research (NIPER) related to oil and gas industry areas of technology, followed by a discussion of the findings. Next is a section on how the laboratory capabilities align with industry needs. Finally, there are observations concerning areas for collaboration.

SURVEY OF CAPABILITIES

The oil and gas industry has traditionally worked with universities, research institutes, and service companies to develop technology, and their capabilities are well known. The capabilities of the government laboratories are less well-known to the industry and a need was felt to obtain specific information on the RD&D that the national laboratories were performing in support of the industry.

As indicated in Secretary O'Leary's original request letter to the Council, one of the key components of the programs in the *Domestic Natural Gas and Oil Initiative* is to "stimulate, facilitate, and coordinate the development and transfer of technology to the U.S. petroleum industry through technical interactions and collaborations with DOE's National Laboratories." Since analyzing the capabilities of all national laboratories was an undertaking the Council did not have the time or the resources to develop, the NPC focused its laboratory capability examination on NIPER and the following nine DOE national laboratories:

- Argonne National Laboratory
- Brookhaven National Laboratory
- Idaho National Engineering Laboratory
- Lawrence Berkeley Laboratory
- Lawrence Livermore National Laboratory
- Los Alamos National Laboratory
- Oak Ridge National Laboratory
- Pacific Northwest Laboratory
- Sandia National Laboratory.

These nine national laboratories and NIPER are hereafter collectively referred to as The Labs. These data do not include information on the approximately $26 million of RD&D at DOE technology centers not included in the above list.

The NPC was fortunate to obtain the assistance of the Partnership Office of the Natural Gas and Oil Technology Partnership (Partnership) in coordinating and collecting the information for The Labs. The Partnership is a part of the national laboratory system that was developed to promote interactions between the national laboratories and the oil and natural gas industry.

Data Collection Methodology

The NPC formally requested that the Partnership coordinate the collection of data relevant to laboratories' capabilities and provide their perspective on those capabilities. The NPC and the Partnership worked closely to define the types of information required to assess the capabilities of The Labs.

This information serves two purposes:

- Identifies The Labs' capabilities that relate to identified industry technology needs.
- Provides a versatile, useful catalog of The Labs' projects and capabilities.

The input from the Partnership draws upon a wealth of data submitted by The Labs. The data were compiled into the following categories, each of which appears as a separate appendix:

- *Project Summaries*: This section provides the most quantitative input in the form of one-page summaries of projects, which reflect current capabilities being applied in areas of direct interest to the petroleum industry. "Current" is defined as ongoing or active within the past five years. Total funding over the past five years (even though a project may have begun or been completed earlier) was taken as a measure of level-of-effort and capability. Each summary is tied to one or more of the 11 technology needs categories and 176 individual technologies defined by the NPC in its survey of industry needs. A standard input template and set of instructions were provided to facilitate data collection, and summary data were entered into a relational data base. The indexing of The Labs' capabilities by industry needs category represents the best judgment of the author of the project summary. A limit of approximately 50 summaries per lab was suggested to maintain a manageable size. Often The Labs combined individual projects in a way to reflect an overall capability. The data are contained in Appendix E (Volume III of this report), Part I. This appendix also contains a cross reference of the individual project summaries by technology needs category and capability index number. The table is divided into two parts. Part A is an index by primary technology needs category, and Part B is an index by individual technology needs.
- *Enabling Capabilities*: This section describes enabling capabilities or technical strengths of The Labs which have potential value, but which are not now necessarily being applied to the oil and gas industry, and thus may not be captured in the project summaries. The Labs were each given the opportunity to describe up to 20 such capabilities, but limited to six pages. Again, each capability is tied to one or more of the technology needs categories and individual technologies. The data are contained in Appendix E, Part II.
- *Historical Legacy*: The Labs were each given the opportunity to describe its "legacy" (i.e., activities predating 1991) that led to its current technology position relative to the oil and gas industry. This background information is valuable in setting the stage for the current activities described in the project summaries. This input was limited to one page. The data are contained in Appendix E, Part III.

DISCUSSION OF FINDINGS

The major purpose of the project summaries is to relate the capabilities of The Labs to the technology needs identified by industry. The Labs selected, for each project summary, a primary technology needs category. All funding for the project was assigned to this primary listing; other secondary categories could be listed if desired.

Two measures of The Labs' capabilities are the number of projects and the cumulative funding over the past five years. Table 3-1 presents the overall number of projects and total FY91-FY95 funding for the primary needs category listed for each of the 383 projects. The cumulative funding for the five-year period was about $600 million. This is equivalent to the cumulative five-year research expenditures of many individual majors. A significant portion of the $600 million represented broad capabilities rather than projects specifically directed toward oil and gas needs. We conclude that the existing effort is large enough that it deserves attention, to ensure that it is producing worthwhile results.

The Labs have significant funding and a large number of projects in the three technology needs categories of Environmental and Regulatory, Oil Processing and Refining, and Development. Together they represent 75 percent of the funding and 73 percent of the projects identified by The Labs. Total funding during the last five years for these three technical categories is nearly $450 million.

The Labs participate at a modest level in the technology needs categories of Exploration, Drilling and Completion, and Production. These three categories represent equal shares of about 18 percent of the funding of the projects identified by The Labs. Total funding during the last five years for these three technical needs categories is about $106 million.

The Labs participate at a low level in the technology needs categories of Gas Storage, Gas Processing, Deepwater Offshore, Gas Gathering, and Arctic Region Activities. These five categories represent 7 percent of the funding and 9 percent of the projects identified by The Labs. Total funding during the last five years for these five technical categories has been $42.5 million.

TABLE 3-1

NPC TECHNOLOGY NEED CATEGORY STATISTICS

	Technology Need	Number of Projects	FY91-FY95 Funding ($Million)	Funding (Percent)
1	Exploration	25	38	6.3
2	Development	68	123	20.6
3	Drilling and Completion	22	36	5.9
4	Production	23	33	5.5
5	Deepwater Offshore	7	4	0.7
6	Arctic Region Activities	2	1	0.2
7	Oil Processing and Refining	95	156	26.0
8	Gas Processing	14	12	2.1
9	Gas Gathering	6	4	0.6
10	Gas Storage	4	21	3.5
11	Environmental and Regulatory	117	171	28.5
	Totals	**383**	**599**	**100**

Individual Technologies

The data were sorted by total FY91-FY95 funding for individual technologies as a way of examining the level of oil and gas industry related activity at The Labs. Those that stand out well above the average are shown in Table 3-2. The three technology needs of Environmental and Regulatory ($53 million), Development ($42 million), and Oil Processing and Refining ($28 million) account for over 60 percent of funding for individual technologies.

Laboratory Oil and Gas Project Activity for the Past Five Years

Figures 3-1 and 3-2 show the trend of The Labs' activity in oil and gas projects over the past five years. The FY91-FY95 funding information was analyzed assuming a linear distribution of funding over a stated multi-year period and then summed by year. A strong trend of increased number of projects (>100 percent) and funding (>250 percent) between 1991 and 1995 is clearly evident. This reflects the strong push by DOE and The Labs for increased participation with industry, and the oil and gas industry in particular.

Maturity Statistics by Category

A maturity index was provided for each project summary, ranging from Basic Research (1) through Applied Research (3) and Development (5) to Ready-to-Use (7). The latter typically means demonstration, but sometimes means deployment. The Labs were allowed to respond with a single index or a range of numbers. In the analysis, both the number of projects and funding is distributed over the specified maturity index or range for each of the 11 technology needs categories (i.e., if a range of 2 to 5 was given, a quarter of the project and of the funding was assigned to each index value of 2, 3, 4, and 5). The results are presented in Tables 3-3 and 3-4. Figures 3-3 and 3-4 show the overall distribution. While interpretation of the data is subjective, we conclude that the majority of The Labs' focus is on applied research rather than basic research or technology deployment.

HOW LAB CAPABILITIES MATCH INDUSTRY NEEDS

It is clear that The Labs have outstanding RD&D capabilities in many energy-related technologies. The key issue to address is what are the best roles for The Labs in partnership with the oil and gas industry. There are a number of factors to consider including the current activities. The roles need to be consistent with the long-term missions of The Labs and the needs of the industry. Also, the impact on research efforts at universities or private research organizations should be carefully considered.

An area of mutual benefit between The Labs and the oil and gas industry is the area of "dual use." The Labs have developed very extensive capabilities in conjunction with their missions in national security. These resources are used infrequently by the oil and gas industry, but are unique and therefore invaluable when needed. A good example is the technical capability in the area of high explosive/shaped charge design that exists at Sandia, Livermore, and Los Alamos. Livermore's High Explosive Research Facility is a unique capability in this field. Joint projects using technology developed at the laboratories have made the oil and gas industry both more efficient and safer. The numerical methods developed for efficient use of parallel computers to solve national security problems have direct application to the oil and gas industry and this is another example of "dual use."

The role of The Labs in more applied projects is quite varied and not so well-defined. We agree with and quote from the Galvin task force report: "Alliances with the industrial users of the technology will be critical. RD&D produces knowledge, but the implementation of that knowledge

TABLE 3-2

INDIVIDUAL TECHNOLOGY FUNDING IN THE LABS

Technology	Needs Reference*	Funding FY91-FY95 ($Million)
Exploration		
Geographic Information Systems	1 - 15	$10.4
Specialized Seismic Processing	1 - 4	$ 9.9
Development		
Cross Well Geophysical Imaging	2 - 10	$22.8
Advanced Reservoir Simulation Modeling	2 - 25	$19.5
Drilling and Completion		
Slim Hole Drilling	3 - 9	$ 7.0
Cementing	3 - 4	$ 5.7
Production		
Corrosion Control	4 - 3	$ 8.7
Microbial EOR Processes	4 - 21	$ 5.6
Deepwater Offshore		
Structures	5 - 16	$ 2.7
Risers	5 - 9	$ 1.4
Arctic Region Activities		
Development	6 - 3	$ 1.1
Oil Processing and Refining		
Catalysts with Improved Selectivities, Yields, Lifetimes	7 - 1	$23.4
Process and Plant Design	7 - 3	$14.7
Gas Processing		
Acid Gas Removal	8 - 2	$ 7.4
Natural Gas Liquid Separation	8 - 4	$ 1.9
Gas Gathering		
Multi-phase Metering	9 - 5	$ 1.2
Compression	9 - 1	$ 0.9
Gas Storage		
Unconventional Development	10 - 7	$16.5
Leak Detection and Mitigation	10 - 2	$ 1.1
Environmental and Regulatory		
Remediation Technology	11 - 12	$30.4
Effluent and Emission Monitoring, Minimization, and Control	11 - 10	$22.3

* Refers to technology need designation in the NPC survey.

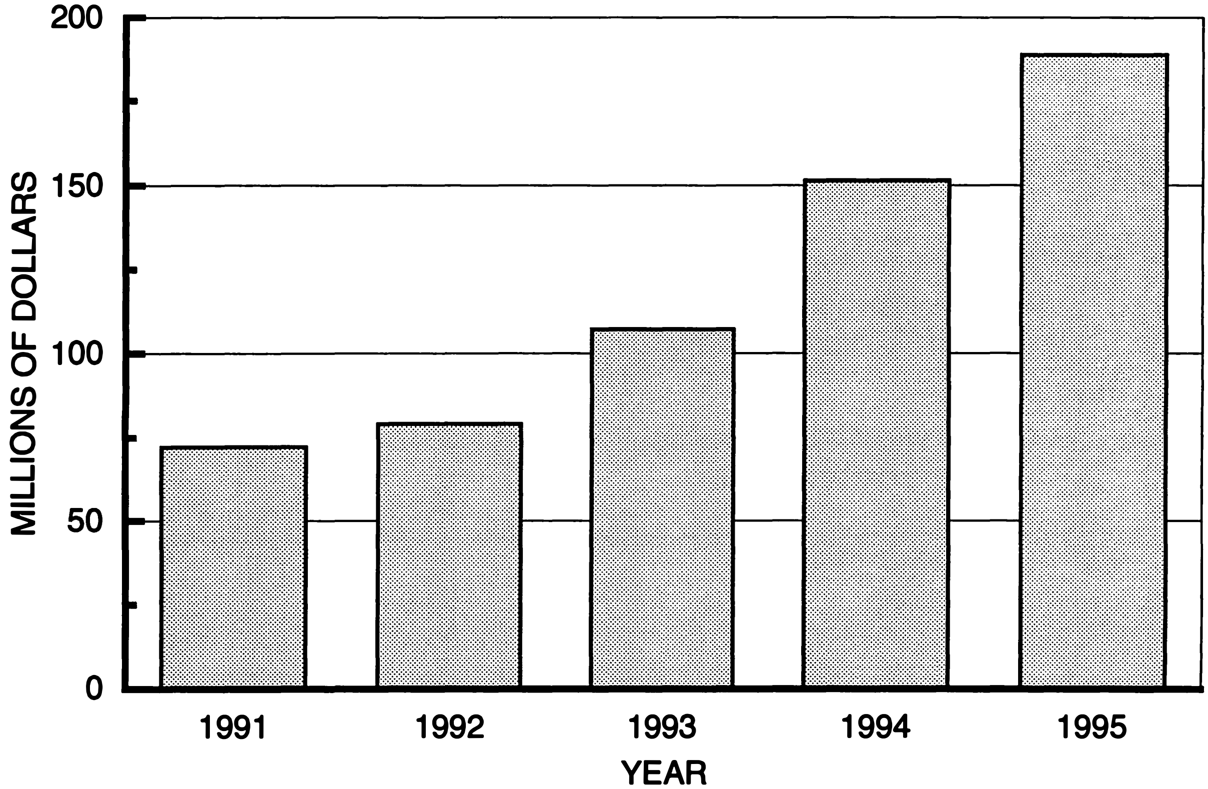


Figure 3-1. Total Funding by Year.

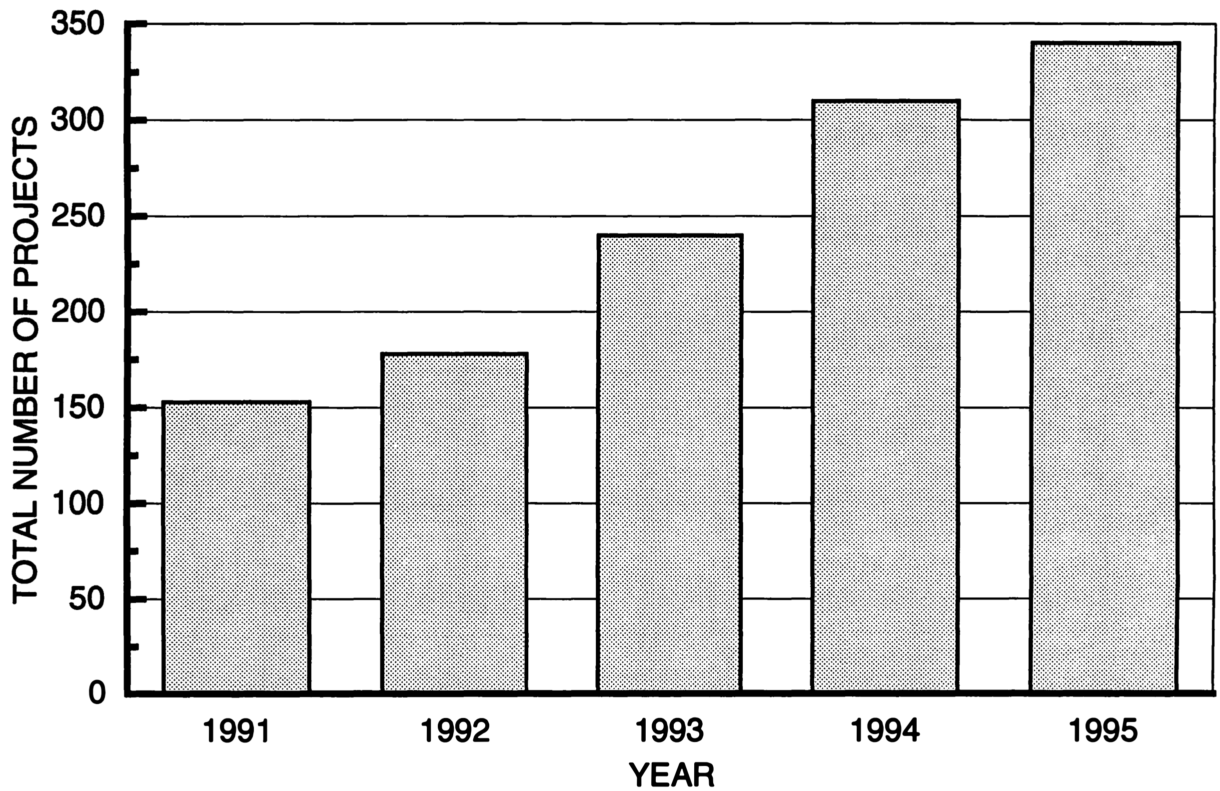


Figure 3-2. Number of Active Projects by Year.

TABLE 3-3*

MATURITY STATISTICS BY TECHNOLOGY NEED—PROJECT DISTRIBUTION
(Number of Projects)

Technology Need	One	Two	Three	Four	Five	Six	Seven	Total
Exploration	1.6	3.9	8.4	3.7	4.3	2.0	1.0	**25**
Development	4.2	3.9	15.0	12.2	17.4	7.6	7.7	**68**
Drilling and Completion	0.0	0.7	4.0	5.0	7.3	2.7	2.4	**22**
Production	0.5	1.4	7.7	4.9	3.9	2.5	2.2	**23**
Deepwater Offshore	0.0	0.0	0.9	1.4	1.9	1.7	1.2	**7**
Arctic Region Activities	0.0	0.0	0.0	0.0	1.0	0.0	1.0	**2**
Oil Processing and Refining	7.0	7.5	25.5	11.5	28.0	8.5	7.0	**95**
Gas Processing	2.0	1.3	1.3	3.8	3.4	2.3	0.0	**14**
Gas Gathering	0.0	0.0	0.0	0.5	3.5	0.5	1.5	**6**
Gas Storage	0.0	0.0	1.5	0.5	0.5	0.5	1.2	**4**
Environmental and Regulatory	1.7	4.7	19.7	10.9	39.0	24.9	16.1	**117**
Totals	**17**	**23**	**84**	**54**	**110**	**53**	**41**	**383**

*Maturity Index — One = Basic Research. Seven = Ready to Use.

TABLE 3-4*

MATURITY STATISTICS BY TECHNOLOGY NEED—FUNDING DISTRIBUTION
(Millions of Dollars)

Technology Need	One	Two	Three	Four	Five	Six	Seven	Total
Exploration	1.5	2.7	7.3	6.0	9.7	6.6	4.2	**38.0**
Development	2.7	5.8	23.0	21.3	31.4	18.0	21.3	**123.3**
Drilling and Completion	0	0.7	3.4	5.2	17.5	4.5	4.1	**35.5**
Production	1.4	2.3	7.7	5.1	5.8	5.8	5.0	**33.0**
Deepwater Offshore	0	0	0.9	1.2	1.3	0.4	0.4	**4.2**
Arctic Region Activities	0	0	0	0	1.1	0	0.1	**1.2**
Oil Processing and Refining	11.3	11.2	33.5	17.1	56.1	16.8	9.6	**155.7**
Gas Processing	3.8	0.6	1.0	1.7	4.3	0.9	0	**12.3**
Gas Gathering	0	0	0	0.4	2.4	0.4	0.7	**3.9**
Gas Storage	0	0	4.2	4.1	4.1	4.1	4.4	**21.0**
Environmental and Regulatory	1.2	3.6	25.6	10.9	55.6	45.8	28.0	**170.7**
Totals	**21.9**	**27.0**	**106.6**	**73.1**	**189.3**	**103.1**	**77.8**	**598.8**

*Maturity Index — One = Basic Research. Seven = Ready to Use.

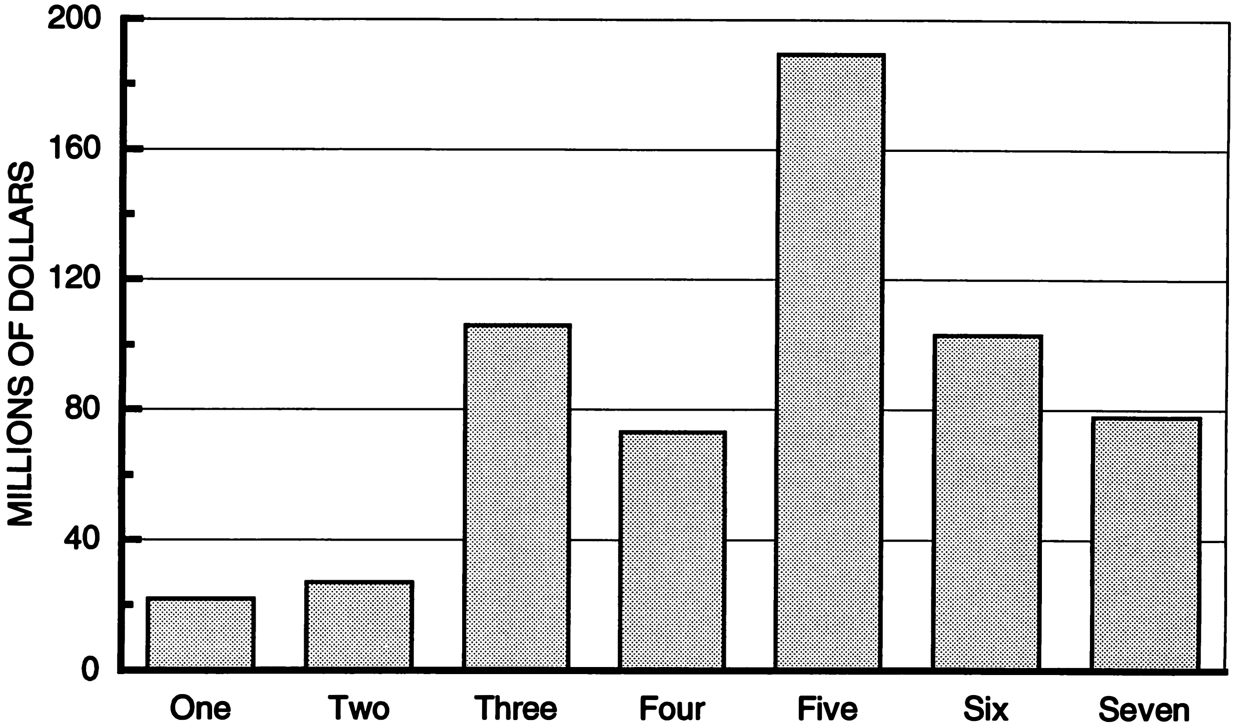


Figure 3-3. Project Funding by Maturity Index.

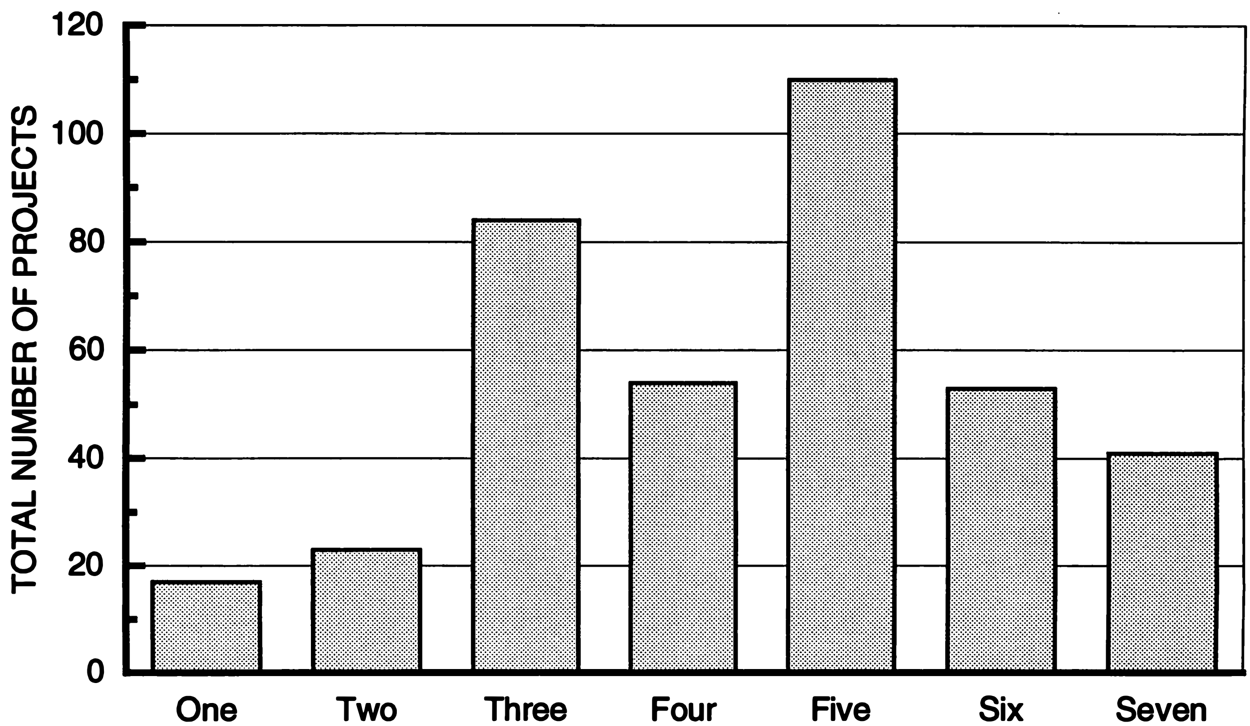


Figure 3-4. Number of Projects by Maturity Index.

in plants and products must be done by industry. If industry is not intimately involved in the planning and development of that knowledge, they will be slow to implement it if they do so at all."[1] The next section of this chapter will look at the combination of factors that must be considered to determine what are good program areas and projects for The Labs in conjunction with the oil and gas industry.

Methodology of Survey Analysis

To determine the alignment between the industry needs and the capabilities of The Labs, several criteria were developed to help understand the data. The most important factors are the industry assessment of the impact of technology, the willingness and ability of The Labs and industry to collaborate, the size and objectives of past and existing Lab projects, and the enabling capabilities of The Labs. The judgment and experience of the study participants are important factors in validating and interpreting the data.

These criteria were used in combinations to serve as screens to analyze the data. In one approach, a list of projects that would have highest impact on our business in the short and long term was identified. In this example, Lab funding levels and numbers of Lab projects were used to measure the level of effort in the laboratories. The project descriptions and enabling capabilities were used to help assess the quality and value of the work performed.

Another approach was to look for areas of high funding and compare the list with industry ranking of impact and willingness to collaborate with The Labs. It was assumed that the independents would collaborate in conjunction with the service companies. Again, the project description and enabling capabilities were used to assess the quality and value of the work.

Results of Survey Analysis

The analysis identifies several areas that are good fits for partnership, as well as highlights some areas where large expenditures by The Labs are not aligned with industry needs. It also revealed high-impact technology areas with very small project effort by The Labs. Several conclusions resulted and are contained in the following list.

1. *There is a good match between existing Lab projects and industry needs in several individual technology areas.* This is indicated by high-impact ratings coupled with a desire to collaborate with The Labs. The projects with highest impact and those with large funding are discussed below:
   - High-resolution seismic depth migration technology — Advances in this technology are highly valued by industry and take advantage of strong computational capabilities of The Labs.
   - Specialized seismic processing — The high level of industry interaction in most of these projects is somewhat surprising given the lower interest in collaboration shown in the needs survey. There are other industry sources for some of this technology; therefore, a continued high level of industry participation should be a key criterion for renewal of these projects.
   - Computer based 3-D geological modeling — Improvements to this technology take advantage of geotechnical and computational strengths of The Labs.
   - Development-scale seismic applications — Computational and theoretical capabilities of The Labs are important to the success of these projects, which have been reviewed and approved by industry through

[1] Secretary of Energy Advisory Board, Task Force on Alternative Futures for the Department of Energy Laboratories, *Alternative Futures for the Department of Energy National Laboratories*, February 1995.

the Advanced Computational Technology Initiative (ACTI). The service industry's participation will expedite the commercialization of results.

- Advanced fracture techniques — The Lab projects in this area are done as part of Gas Research Institute studies. Strong industry input validates both the value of the work and the technical fit of The Labs as partners.
- Well productivity — Significantly improved well productivity is extremely important if the industry is going to supply the hydrocarbon demand. These projects received industry review and approval as part of the Partnership program.
- Cross-well seismic imaging — The industry recently made a decision to move from a proprietary to a collective mode to develop technology in this area. The Labs responded to the industry need by participating as an active partner. Several projects received industry review and approval as part of the Borehole Seismic Forum, a technology area of the Partnership program.
- Plant and process reliability — Several of The Labs' projects take advantage of strengths in materials, corrosion, and a large project dealing with safety and reliability of the Advanced Neutron Source. The funding amount that is directly related to industry needs is probably overstated, but The Labs' work is valuable and has industry participation.
- Energy efficiency of equipment — This area takes advantage of Lab strengths in materials and corrosion and seeks to apply the technology to oil and gas industry needs.
- New approaches to refining heavy feeds — This is a very important area for refining, both today and in the future. Lab projects target industry needs and there is good industry participation. The projects take advantage of the wide variety of The Labs' capabilities including process engineering, computational modeling, and characterization methods of heavy feeds and syncrudes.

2. *The Labs had limited projects in production stimulation, and they were not seen to be addressing the kind of breakthrough that is needed.* Production stimulation has high-impact potential and industry indicates a willingness to collaborate with others including The Labs. There is one Lab project in this area that dealt with the use of very-high-power microwaves to change permeability characteristics of the reservoir. Projects that fit this category should be reviewed carefully.

3. *There were several technology areas that were identified by industry as having the potential for high impact for which there is little effort by The Labs.* Examples of where effort by The Labs is lacking are extended reach drilling, subsea systems, multi-phase equipment, performance and environmental characteristics of new hydrocarbons, and conversion of methane to liquid fuel. The lack of effort in these areas is consistent with the lack of relevant Lab enabling capabilities at The Labs and the ability of the industry to develop these technologies collectively outside of The Labs. The Labs should not be heavily involved in these areas, and they are to be commended for not duplicating industry efforts. Other technology areas include: through-casing logging, permeability logging techniques, near wellbore stimulation, new directional drilling techniques, advanced recovery of natural gas, deepwater drilling, deepwater workovers, hydrate prevention, Arctic drilling, gas compression, gas storage, reservoir management, and base gas minimization. In some of these, The Labs appear to have the relevant capabilities for RD&D.

4. *A few projects consume large resources in the laboratories and unnecessarily duplicate efforts in the private sector*. Examples are geographical information systems and catalysts with improved selectivities, yields, and lifetimes. Continued participation in these projects should be reviewed.

5. *The appropriateness of The Labs' involvement in alternative gas storage technology is questionable.* While there is a large project for geotechnical support to the Strategic Petroleum Reserve, it does not imply that The Labs should perform RD&D in the area of alternative gas storage.

6. *Careful review of the relevance of several energy efficiency programs to industry needs is required.* With the exception of the research on high performance, compact evaporators and condensers, projects in the energy efficiency category dealt principally with advanced bioreactor concepts and improved efficiency of equipment for the paper and pulp industry. The oil and gas industry is looking for more efficient processes, particularly in the area of light gas streams containing hydrogen.

7. *Better interaction between industry and The Labs will be required to tailor RD&D separation technologies research to fit the need.* The major portion of The Lab effort ascribed to this area comes in the form of strengths in analytical chemistry. Other projects look at magnetic and membrane separation technologies.

8. *There is a need is for a scientific basis for environmental cleanup standards that balance the need to minimize risks to human health and ecosystems benefits with the costs of cleanup.* Providing the scientific basis for risk-based regulation was identified as having high impact by the industry coupled with a strong interest in collaborative development of the technology. There were several Lab projects with large funding that were classified as belonging to this subtopic, which did not appear to address industry concerns but were directed towards improved analytical methods. The enabling capabilities of The Labs indicate that projects that much more closely meet industry needs should be possible.

9. *Projects dealing with fluid forces on risers and deepwater eddies take advantage of the theoretical and computational competencies of The Labs.*

10. *The Labs do not conduct large projects to develop new production systems or techniques for Arctic development.* The funding assigned to this area was two studies conducted for the state of Alaska addressing several industry issues, rather than for production system RD&D.

SUMMARY

There is considerable interest within the oil and gas industry to expand collaborative RD&D projects to develop oil and gas technology. Industry will work with the Department of Energy to ensure that government policy serves to enhance and enable this collaboration rather than impede or compete with industry efforts.

The Labs are not and should not become the national research and development organization for the oil and gas industry. They should not become engaged in assisting the oil and gas industry to develop technology in all of the areas that were designated as high-impact and amenable to collective technology development. A good example is The Lab decision not to become engaged in the development of subsea production and extended reach drilling systems. The Labs should become involved in an area only if the competence of the laboratory already exists and if there is clear industry consensus that private sector sources for the technology are not adequate.

To quote from the Galvin task force: "The Department of Energy should move to strengthen its efforts in fundamental science and engineering, both at the laboratories and in the universities."[2] We agree that this is a very appropriate role for The Labs. This can be accomplished by increasing industry input rather than increased funding. The relevance and impact of this research can be maximized by industry review and guidance as well as industry participation. The results of this effort should be made available to all U.S. industry. There are a number of areas where The Labs have made substantial accomplishments including areas of high-energy physics, atomic and nuclear physics, biomedical science, material science, fusion energy, and computational science. In many of these areas, the oil and gas industry has benefited either directly or indirectly.

There are ongoing programs that use the unique *facilities* that are available at The Labs. These joint projects with the oil and gas industry enable leading edge research to be conducted in a variety of areas. For example, Brookhaven's National Synchrotron Light Source and the High Flux Neutron Beam Reactor have been utilized in programs involving synthesis and characterization of molecular sieves. Similarly the pulsed neutron source at Argonne has been used in joint projects with the oil and gas industry for a number of material properties projects involving hydrocarbons and zeolites. Other unique facilities include Livermore's high-powered lasers, Sandia's combustion research facility, Los Alamos' LAMPF accelerator, and Berkeley's Advanced Light Source. Projects that utilize these facilities represent an excellent match between meeting the research needs of the oil and gas industry and the mission of The Labs. These types of projects should be continued with the strong endorsement by DOE and industry.

The Labs are a partner of choice in the collaboration to develop technology in areas that are computationally intensive. The ACTI program was established to take advantage of this capability and is a positive step toward becoming industry-driven as a result of beginning to change the project proposal and prioritization system. Participation in the computationally intensive multi-phase, multi-component flow modeling in the Deepstar Project is another good example.

The projects that were identified as "good matches between industry technology need and lab capabilities of The Labs" contained in the prior section should serve as examples of the oil and gas applied RD&D projects in which The Labs should be engaged.

The Labs played a constructive role in helping the industry respond to the decision that cross-well imaging technology would be developed collectively and shared rather than as proprietary technology by companies separately. This is an example of The Labs reacting to an industry request to become a focal point for industry collaboration. The evolution of this project should be considered as The Labs seek ways to become more industry needs driven.

In accordance with the recommendations of the Galvin task force, The Labs should maintain a technology development effort in the areas of environmental technology that impact the oil and gas industry. The enabling capabilities of The Labs are strong in the environmental area, and staff appear to be very interested in this technology.

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[2] Secretary of Energy Advisory Board, Task Force on Alternative Futures for the Department of Energy Laboratories, *Alternative Futures for the Department of Energy National Laboratories*, February 1995.

CHAPTER FOUR

DEVELOPERS AND SUPPLIERS OF ADVANCED TECHNOLOGY

As discussed in Chapter Two, there are high-impact technologies that the oil and gas industry believes will *not* likely be available when needed. This situation will be discussed in terms of the process by which technology becomes available to the oil and gas industry, the traditional and new roles of industry and others in this process, and the forces that have led to changing roles. Although the discussion of capabilities in Chapter Three focused on the capabilities of The Labs, the oil and gas industry has traditionally worked with universities, research institutes, service companies, and other national laboratories to achieve the research and development needs of the industry. The roles of these institutions and oil and gas company research facilities are an integral component of delivering the research and development needs of the industry. This chapter will focus on the changing roles of all these developers and suppliers of advanced technology.

For purposes of this discussion, the term "technology developers" will refer to organizations that are capable of oil- and gas-related research, development, and demonstration. There are numerous developers. Within the industry, the major oil and gas companies and the larger service companies operate their own research facilities. As described in this chapter, private research organizations, universities, and government laboratories also have relevant capabilities.

The term "supplier" will be used to describe organizations that participate in technology "deployment," the process by which new technology is put to use in an operating setting. Suppliers generally are in-house departments of an operating company, or service companies or vendors who provide services or materials for a fee.

CHANGES IN DEVELOPERS' ROLES

In-house technology developers—like the oil and gas industry itself—are in a state of transition that has been brought on by the collapse of oil prices in the 1980s and the expectation of constrained oil and gas prices in the foreseeable future. Besides the direct pressures on in-house developers created by oil prices and resulting requirements for cost reduction, there are other indirect pressures that have resulted in a greater proportion of short-term and technical service-type activities.

Pressures on In-House RD&D Organizations

Basic research has been under pressure because of the long-term investment it represents. In addition, RD&D aimed at regulatory compliance has displaced some potentially more productive efforts.

Even the majors recognize that they cannot justify large RD&D efforts unless they can effectively leverage their investments in technology. The largest gas producer in the U.S. accounts for only about 5 percent of domestic production, and the largest oil producer accounts for less that 10 percent. Therefore, there is increased effort to get economic return on proprietary technology through licensing or technology exchanges.

Service companies continue to support research and development to differentiate themselves from competitors and to gain market share. These companies have responded to the economic realities of the oil and gas industry by refocusing their efforts to the near term. Also, there have been several recent mergers of service companies.

The smaller producers (independents)—who account for about 60 percent of the natural gas production and over 40 percent of liquids production—have not invested in technology development in the past, and are not expected to do so in the future. Independents depend on majors and service companies to develop and on service companies to supply the advanced technology used in their operations.

Trends in Oil and Gas RD&D Expenditures

Table 4-1 presents survey data on oil and gas industry expenditures for RD&D. These data represent the aggregate industry response to Survey Question 13, which asked about levels of RD&D expenditures for years 1990, 1994, and 1998.

Table 4-1 shows that in nominal dollars, total expenditures reported were \$2.4 billion in 1994 vs. \$2.6 billion in 1990. This reduction of *only* \$200 million appears to be somewhat inconsistent with the many public and private reports of significant reductions in RD&D budgets and staff over this same time period. Even when expressed in constant dollars, the reduction is 19 percent. However, the R&D Needs Task Group believes that reductions in expenditures have been somewhat greater than these data suggest.

Table 4-2 shows trends in RD&D expenditures among the oil and gas industry sectors. The data indicate that the majors account for the largest fraction of the industry's RD&D expenditures, although their proportion has been reduced from 77 percent in 1990 to 67 percent in 1994. In contrast, service company expenditures are now 31 percent of the total in 1994, compared to 22 percent of the total in 1990. The data also confirm that the other integrated oil and gas companies and the independent producers provide limited funding of RD&D.

Respondents were asked to identify the percentage of total RD&D expenditures allocated to only oil, only gas, and both oil and gas. The distribution reported was virtually the same for 1990 and 1994: 70 percent of the investment in RD&D was directed at both oil and gas applications; 22 percent of expenditures were directed at primarily oil applications; with 8 percent of expenditures directed at primarily natural gas operations. The respondents reported that the projected distribution of expenditures in 1998 will be similar to those of 1990 and 1994.

Implications

The implications for technology development of the reduction in RD&D expenditures is not clear at this time. Industry leaders view the reduction as simply a reflection of achieving greater efficiency in

TABLE 4-1

RD&D EXPENDITURES OF THE OIL & GAS INDUSTRY*
Billions ($1990)

	1990	1994	1998
All Respondents	2.6	2.4	†
Respondents Submitting Expenditures for All Three Years	1.7	1.6	1.7

* Additional RD&D expenditures for oil and gas technology (not part of the survey)
GRI (private sector funds): $50 million/year directed at natural gas operations
DOE (public sector funds): $100 million/year directed at natural gas and oil operations.

† Some survey respondents did not submit a 1998 estimate.

TABLE 4-2

RD&D EXPENDITURES OF RESPONDENTS BY INDUSTRY SECTOR
($Millions)

	1990		1994	
	Expenditures	Percent (%)	Expenditures	Percent (%)
Majors	2004	76.6	1638	67.4
Service Companies	572	21.9	742	30.5
Other Integrated	35	1.3	42	1.7
Independents	4	0.2	7	0.3
Total	**2615**	**100.0**	**2429**	**100.0**

research programs. This argument points to the refocusing of in-house RD&D on the technology needs with highest impact, the effective use of computers and research instrumentation that was not available even a decade ago, and more effective leveraging of funds, including use of research consortia research.

In contrast, other industry leaders argue that the reduction in RD&D expenditures will constrain the long-term prospects of the oil and gas industry. The arguments here point to a reduction in basic research, an apparent focus on low-risk, short-term research, and significant reductions in research and engineering staffs. There is a

Paradigms for Industry RD&D

	OLD PARADIGM		NEW PARADIGM
Source of Technology:	In-House	———>	Leverage & Collaborate
Project Prioritization:	Technology Push	———>	User Needs
Motive:	Own It	———>	Use It

view that the underlying reduction in effectiveness is greater than the expenditures imply because a significant fraction of RD&D funds are actually being allocated to technical service demands. Furthermore, the technological challenges of the industry are growing at the same time RD&D expenditures are decreasing.

It is clear that the oil and gas industry will need to carefully manage the situation over the next several years in order to assure that it has access to the technology needed for its oil and gas operations.

THE NEW PARADIGM FOR INDUSTRY RD&D

The above-mentioned changes and pressures have led to a "new paradigm" for how the oil and gas industry conducts RD&D. The key characteristics of the new paradigm are leveraging through collaboration, and focus on customer-driven needs.

From a practical management of RD&D point of view, other characteristics are:

- In-house RD&D is focused on the "core technologies" that are critical to business competitiveness and marketplace differentiation.
- Industry is using consortia to minimize the cost of technology for regulatory compliance that provides no competitive advantage.
- The trend in the private sector is largely toward collaboration to develop the fundamental basis required for future technology advances in certain areas.
- RD&D funding is carefully managed to ensure focus on worthwhile targets and timely availability of needed technology.

There are other features and several implications to the new paradigm. *Using* advanced technology effectively and aggressively is considered a *core competency*. Owning the technology is less important except for service companies. However, the oil and gas industry *will* continue to selectively allocate funds to RD&D for proprietary technology.

Advances in oil and gas technologies traditionally enter the marketplace over a long period of time—on the order of a decade. Industry would like to see the cycle time for market introduction reduced through aggressive technology transfer and commercialization efforts. Some producer organizations have dedicated internal staff to accelerate the application of advanced technology within their organization.

All sectors of the oil and gas industry have reduced emphasis on longer term, basic research. However, companies that support RD&D will allocate resources *selectively* to longer term research that is considered vital to their business interests.

Although the private sector will continue to support selected university research, universities are increasingly being asked both to demonstrate that the research has practical application and to obtain higher levels of co-funding from industry or government sources.

Independent producers will continue to be dependent on others for the development, commercialization, and application of advanced technology used in their operations.

WILLINGNESS OF INDUSTRY TO COLLABORATE

Survey Results

The survey sent to NPC members (Appendix D) included a set of questions dealing with the issue of collaboration. The survey provided opportunities to respond either generally (survey questions 14 and 15) or specifically when dealing with specific technology collaboration.

Responses indicated a high overall willingness of industry to collaborate (see Table 4-3). On average, 63 percent of all

TABLE 4-3

WILLINGNESS TO COLLABORATE ON A SPECIFIC TECHNOLOGY
(Percent of Responses)

	Vendors/ Service Com-panies	Oil & Gas Com-panies	Univer-sities	Research Institutes	Trade Assoc.	National* Labs.	DOE†	USGS/ State Survey
All Respondents	*53*	*51*	*48*	*46*	*43*	*42*	*41*	*36*
Majors	66	57	59	56	49	49	44	41
Other Integrated	55	53	43	43	45	35	35	35
Independents	49	48	44	43	43	41	42	35
Service	33	46	39	29	21	34	34	27

*The National Laboratories are Argonne, Brookhaven, Idaho National Engineering Laboratory, Lawrence Berkeley, Lawrence Livermore, Los Alamos, Oak Ridge, Pacific Northwest, and Sandia.

†Collaboration with DOE refers to cost-sharing arrangements with Morgantown Energy Technology Center, Pittsburgh Energy Technology Center, National Institute for Petroleum and Energy Research, Metairie Site Office, and Rocky Mountain Oilfield Testing Center.

responses to the question for specific technologies indicated a willingness to collaborate *with one or more of the potential partners listed.* There was a higher interest in collaboration technologies needed in the shorter term (by 1999) than in the longer term (by 2010). However, the willingness varied both by technology area and industry sector.

Responses to the general question—that not tied to a specific technology—indicated that *there is a greater willingness to collaborate than is presently occurring.* This means that more collaboration will likely occur if perceived barriers are addressed. As with the responses tied to specific technologies, these data also indicated a higher willingness to collaborate with organizations that can either be users or providers of technology (i.e., oil and gas companies and vendors/service companies).

The data show a spread from 36 percent to 53 percent in willingness to collaborate when specific technologies were considered. When asked in general, the range jumped to 64–83 percent. This is interesting when one considers that approximately 40 percent of the respondents already collaborate with DOE or the national laboratories.

The survey also provided explanations as to why certain respondents were unwilling to collaborate with particular "partner" categories. In the responses tied to specific technologies, a set of pre-identified barriers could be identified. In rank order, the reasons most frequently selected were:

1. No benefit expected
2. Technology is perceived as too risky
3. Confidential proprietary concerns
4. Intellectual property concerns.

A write-in blank was provided for those who chose the "other reasons" category. Responses included: excessive paperwork and red tape, confidentiality issues, intellectual property issues, limited budgets and resources, and alignment issues such as business objectives, goal orientation, and timelines.

Some of the barriers deserve some exploration and/or clarification. For example:

- *Excessive Paperwork:* The paperwork requirements for working with the federal government are often excessive (even obsessive) and time-consuming for industry personnel. The delays caused by paperwork are exacerbated by lengthy approval chains that DOE and The Labs justify as good business practice.

Some examples of alignment issues that cause problems are:

- *Hold Harmless Agreements:* It is industry practice on collaborative projects to have all organizations execute a Hold Harmless Agreement that makes each organization responsible for the injury or death of only its own employees. However, such agreements are not acceptable to DOE.
- *Uncertainty of Ongoing Funding:* When industry invests in a collaborative project with The Labs, they expect that the project will be carried to completion. However—as is currently being demonstrated—even budget approval does not guarantee continuity of funding.

Finally, even the political environment can cause uncertainties that impede action.

- *Perception of Partnerships:* Recent changes in Congress are prompting a new look at the future role of DOE and the national laboratories, as well as the industry partnership arrangements with DOE and other agencies. The outcome of these decisions could have a profound impact on the magnitude and direction of future interactions between the petroleum industry and The Labs. A common need is providing supporting legislation for stability of funding.

The diversity of the responses written in seems to explain why "other reasons" was ranked high among predefined barriers. It is interesting to note that the ranking of reasons was different for short-term and long-term needs, showing a greater interest on the near term. It can be inferred from this that there is more focus on collaboration for the application of technology in the short term.

In summary, the primary barriers to formation of industry-Lab partnerships are primarily institutional and financial, not technical. To a significant degree, these barriers appear to be the result of redundant layers of management, and the extensive role that DOE maintains even in contractor-operated facilities.

Trends in Willingness to Collaborate

The survey results indicated a willingness to collaborate. The reality of this willingness is demonstrated by several trends:

- The oil and gas industry is establishing industry-funded alliances with other private sector organizations, universities, and the federal government to leverage funds and share in the development of advanced technology. The Petroleum Environmental Research Forum (PERF) is an example.
- Refiners are working closely with individual vendors to specify closely held specialty catalysts and chemicals.
- The oil and gas industry is more receptive to looking at non-industry sources of technology, such as the defense industry and The Labs, for advanced solutions to both traditional and non-traditional problems.
- Strategic alliances among oil companies in the refinery sectors are not common, but their number may be increasing. Most are with foreign entities, although some cooperative development agreements are being made among domestic refineries.

MECHANISMS FOR INDUSTRY-LAB COLLABORATION

As discussed in Chapter Three, there are a number of different and distinct reasons for the oil and gas industry to participate in technology development and transfer with The Labs:

- To address possible shortfalls in industrially sponsored basic research, and perhaps applied research also, including access to unique capabilities.
- To develop and apply technology existing in The Labs.
- To reduce time and cost to develop industry-shared technologies.
- To obtain technology that can enhance efficiency and competitiveness. A large number of industry companies—in particular the independents—don't have in-house RD&D capabilities.

Somewhat corresponding to these different reasons for technology transfer, there are a variety of mechanisms available.[1]

The Partnership Concept

The partnership concept is that the industry and The Labs can team for their mutual benefit. The most appropriate mechanism is determined by the role of the particular technology. The closer the technology is to playing a distinguishing competitive role, the more tightly these collaborations are held. In one extreme, a collaboration will consist of one company and an external research partner in which rights to intellectual property are clearly protected. At the other extreme, a sizable consortia of industry members and vendors will form to pool funding and resources for development of a technology that, by itself, will not impact the relative competitive positions of the companies.

An example of the partnership concept is the Advanced Computational Technology Initiative (ACTI) program, which is focused on strengthening the technology base of the oil and gas industry in exploration, production, and processing. Under ACTI, about $27 million has been allocated to fund 31 projects.

Another is the Natural Gas and Oil Technology Partnership (Partnership), which is an expansion of the Oil Recovery Technology Partnership that was initiated in 1988 by DOE at the Los Alamos and Sandia National Laboratories. This program is focused on transferring to the oil and gas industry technologies derived from DOE-funded weapons and energy, research and development programs.

Cooperative Research and Development Agreements (CRADAs)

The CRADA mechanism was authorized by Congress to facilitate the commercial application of technical capabilities already available in government laboratories. (This mechanism is NOT unique to DOE.) Key features of the CRADA are: (1) industry must cost-share; no transfer of cash is required; the DOE pays its costs, and industry pays its costs; (2) collaborations can be based on existing projects and programs at The Labs; and (3) confidentiality and intellectual property provisions can accommodate the need for project developments to be proprietary.

The cost-share provisions of the CRADA make it more favorable for industry members who already are funding RD&D, and who therefore can use "in-kind" contributions to satisfy the cost-sharing requirement. The CRADA mechanism can be used for a single company-single laboratory partnership, or for one that involves multiple companies and The Labs. A university or other non-profit organization also can be a CRADA participant.

The reviews on CRADAs are mixed. On one hand, as of January 19, 1995, the DOE had initiated 1,157 CRADAs with a total value of over $2 billion. Sixteen percent of these are energy-related (not necessarily oil and gas related). On the other hand, identifying the suitable expert in one of The Labs and agreeing to a statement of work

[1] CRADAs and other mechanisms of interaction with The Labs are described in detail in DOE publications including a DOE report entitled "Oil Technology Transfer: A Report to Congress," October 1993, which discusses these programs in some detail.

may be the *easiest* part of establishing a CRADA.

Other Mechanisms

There is a wide range of other mechanisms by which industry and government laboratories can participate in technical interactions.

Work for Others: Work performed by a laboratory for an industry sponsor that is fully funded by the industry. Results of such work may be proprietary and the sponsor owns rights to developed technology. The laboratories are not allowed, by law, to provide services that are in direct competition with the private sector.

DOE User Facilities: User facilities are unique, complex scientific facilities at The Labs that have been designated by DOE for use by the technical community including private industry. User facilities require only an informal agreement between the industry user and the laboratory, proprietary research is permitted, title to patents is granted to the user, and out-of-pocket cost recovery may be required by the laboratory.

Personnel Exchanges: A temporary transfer of personnel, either from a private industry to a government laboratory or from a government laboratory to a private industry, to exchange expertise and information. Costs are paid by the organization sending the personnel and generally no proprietary data are exchanged. Temporary personnel transfers have proven an extremely effective approach to technology transfer in industry.

Consulting Agreements: An industry party, under a specific written contract, provides advice or information to a laboratory; or a laboratory party, with the approval of the subject laboratory, provides advice or information to a private industry. Intellectual property conflicts must not exist.

Licensing Agreements: The transfer of intellectual property rights to permit industry to use a technology on either an exclusive or non-exclusive basis.

Laboratory Subcontracts with Industry: A formal contract originated by a laboratory to fund a project with private industry as a contractor through a prescribed "Statement of Work" prepared by the laboratory and specific deliverables. The work must be mission-driven and benefit the government. Patent rights belong to the laboratory and data protection and licenses can be negotiated. This can be an important mechanism for The Labs to gain cost-effective access to facilities such as pilot plants for process development (not available within the laboratory system.)

Laboratory Subcontracts with Universities: A formal contract originated by a laboratory to fund a university as a contractor through a prescribed "Statement of Work" and specific deliverables. Results are available to the entire scientific community.

Industry-Lab Visits: The informal and free exchange of information among industry and government laboratory colleagues during visits to one anothers' facilities includes the presentation of technical seminars. If proprietary information is to be disclosed, a Proprietary Information Agreement can be executed.

Technology Transfer Organizations

There are two technology transfer organizations that will assist industry in identifying technologies that might solve particular problems, and sources of that technology within The Labs or in other government facilities.

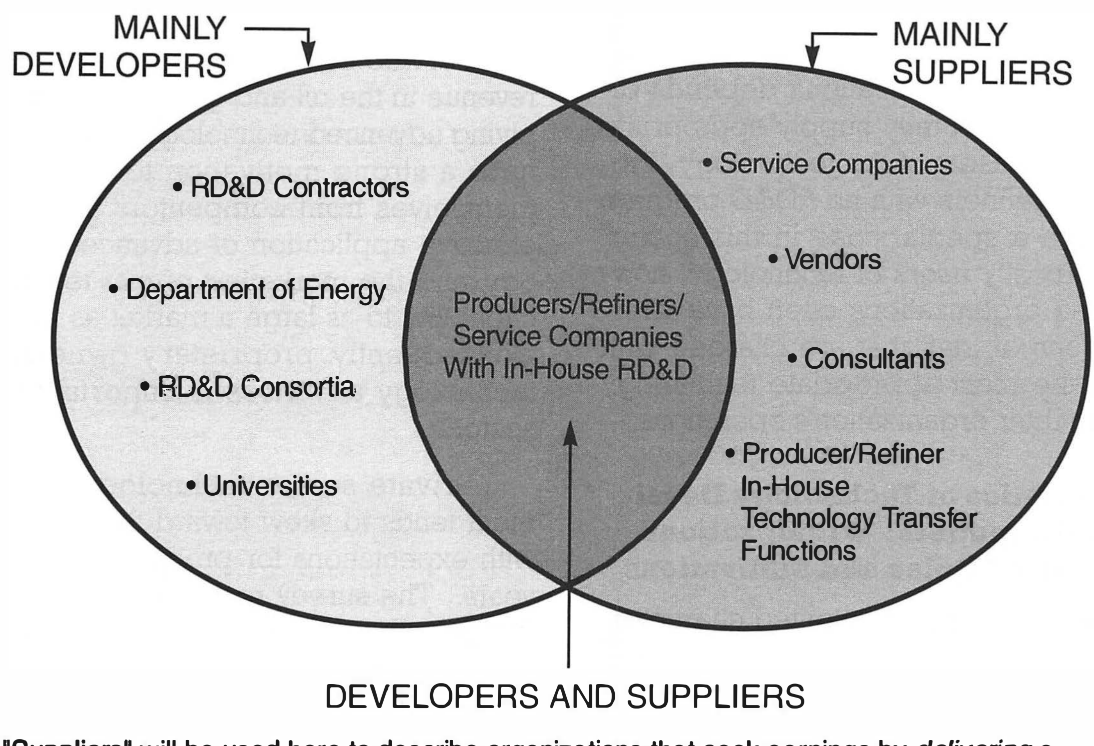
The Petroleum Technology Transfer Council (PTTC) was formed in 1993 by the independent sector of the oil and natural gas industry to improve the dissemination of exploration and production technology and technical information to domestic producers, primarily independents. The PTTC's initial five-year effort is being partially funded by DOE's oil and natural gas programs in the Office of Fossil Energy. Its mission is: (1) to identify priority technical problems of producers and communicate them back to the RD&D community, and (2) to transfer upstream oil and gas technologies that will help domestic producers reduce costs, improve operating efficiency, increase ultimate recovery, enhance environmental compliance, and add new oil and gas reserves. The PTTC serves as an integrated clearinghouse for upstream oil and gas technology information to U.S. petroleum producers.

The National Technology Transfer Center (NTTC) was created to help transfer the research performed in the federal laboratories to U.S. businesses, to put leading edge technologies to work, and create new technologies and jobs. The NTTC's mission is far broader in scope than just the petroleum industry. However, inquiries and responses can relate to virtually any area of technology. Typically about 6 percent relate to energy. NTTC is funded by NASA and other federal agencies.

ALTERNATIVE DEVELOPERS AND SUPPLIERS

Specifically, who are alternative developers and suppliers, what roles might they play under industry's new paradigm for RD&D, and why would they choose to participate?

As illustrated in Figure 4-1, one sector of the industry is mainly concerned with technology development. This sector includes universities, DOE, and RD&D consortia. These organizations recognize that their success is tied directly to the commercial deployment and marketplace impact of technologies they develop. However, they are not in the business of selling the technology (or technology service) for profit. Because their success is so closely tied to the commercialization of the technology



"Suppliers" will be used here to describe organizations that seek earnings by *delivering* a technology-based service to customers in other organizations, or within their own organization.

Figure 4-1. Developers and Suppliers of Technology.

developed, these organizations must pursue a strategy of technology transfer in collaboration with the private sector.

In contrast, there is a sector of the industry that both develops and supplies technology to the oil and gas industry (Figure 4-1). This sector is mainly involved with creating corporate earnings by either delivering a technology-based service to customers or by using the technology in their own business. This sector includes service companies, vendors, and producers/refiners with in-house RD&D programs. Technology development for these organizations provides a basis for increasing earnings and competitive advantage. They have the internal mechanisms and capability to identify, prioritize, and bring to the marketplace the technology they develop.

A third sector of the industry focuses on supplying technology (bringing the technology into practice), but they rely on others to develop the technology. Organizations in this sector include consultants, service companies, and vendors with no RD&D program funding. The financial health of these organizations depends directly on how well they supply appropriate technology to users of the technology. Producers and refiners with no RD&D program funding are a special case in this sector. They are mostly users of technology; however, these organizations often have internal functions or staff that are charged with bringing the most appropriate technology into use in their organization's operations.

Characteristics of Technology Developers and Suppliers: Organizations Exhibit Varied Roles and Motivations

Table 4-4 presents selected characteristics of major technology developers and suppliers for advanced oil and gas technology.

Private Sector

The first three oil and gas industry sectors shown in Table 4-4 have historically invested in development of advanced technology to increase their economic margins and marketplace competitiveness. Producers use technology to reduce the cost of operations. In-house research supported by major producers has been targeted mainly to reduce costs of their *individual* company operations. Their mainline business does *not* include supplying technology broadly to the industry-at-large. In fact, only about a dozen of the major producers, out of the more than 8,000 domestic oil and gas producers, support in-house technology development programs. More than 50 percent of total U.S. oil and gas is produced by organizations with essentially no in-house RD&D programs.

Refiners use technology to reduce the cost of operations or improve the product slate. Although some of the larger refiners have in-house research programs, their mainline business does *not* include providing a technology base to the industry at-large. In this respect, they are similar to producers.

Service companies and vendors earn revenue in the oil and gas industry by supplying advanced technology to users. They have a strong motivation to differentiate themselves from competitors through the effective application of advanced technology, and the marketing of that technology capability to as large a market as they can. Consequently, proprietary ownership of technology advances is important to this sector.

Private sector technology development tends to skew toward the short term, with expectations for products within three years. The survey responses also indicate that private sector in-house RD&D tends to focus on the latter stages of research: product development, product demonstration, and technical service. However, the private sector *will* support selected longer-term, higher-risk programs when the outcomes of those programs are vital to future business interests.

TABLE 4-4

SELECTED CHARACTERISTICS OF DEVELOPERS AND SUPPLIERS

Sector	Major Interest in Technology	Funding Source	Comments
Producers	Improve Economic Margins, Competitive Advantage	Sales Revenue	RD&D Funded Mainly by Majors, RD&D Funds Address Both International and Domestic Resources
Refiners	Improve Economic Margins, Increase Market Share	Sales of Refinery Products	Impacted by Environmental Regulations that Define Fuel Performance
Service Companies/ Vendors	Improve Economic Margins, Increase Market Share	Sales Revenue	Funds Address Both International and Domestic Resources
Federal Government	Energy Security, Competitiveness, Standard of Living	Taxes, Industry Cofunding	
- DOE	Energy Availability; National Security, Economic Stability	Taxes, Industry Cofunding	Increasing Pressure to Secure Industry Cofunding, Current Debate on Role
- MMS	Resource Management	Taxes, Industry Cofunding	Funds Mainly Not Research Oriented
- EPA	Environment	Taxes, Industry Cofunding	Funds Mainly Allocated to Support Setting Regulations
- NIST	Future Social Benefits	Taxes, Industry Cofunding	Focus is Not on Upstream O&G Industry; Crosscutting Research
State Government	Economic Health	Taxes (State & Federal), Industry Cofunding	Limited Budgets, Emphasis on Technology Transfer
- Geologic Survey	Support State Industry	State Funds, Industry Cofunding	New Information on Geological Aspects of O&G Resources
- RD&D Initiatives	Support State Industry	Federal/State Revenue	Some Producing States (e.g., Texas, Oklahoma, New Mexico) Support Limited RD&D Activity
Universities (State and Private)	Education, Support State Industry	State and Private Sector	Resource for Basic Research
Gas Research Institute	Natural Gas Availability and Deliverability; Economic Competitiveness of Natural Gas	Gas Industry Stakeholders: Producers, Pipelines, Distribution Companies and Consumers; Industry Cofunding	Technology Development and Technology Transfer; Mission Emphasizes Technology Transfer
Consultants	Competitive Advantage	Sales Revenue	Mainly Practitioners of Advanced Technology

Public Sector

Federal and state government organizations invest in the development of technology that has implications to oil and gas industry operations. The Department of Energy serves as the major federal organization that supports RD&D directed at the oil and gas industry (see Table 4-4). Federal and state programs must rely on other organizations to deploy the technology they develop.

Several other important federal and state government organizations that develop technology are identified in Table 4-4. In general, these other federal organizations develop technology that addresses many industries, with some elements of their portfolio having implications to oil and gas operations. However, their efforts are not directed at the industry. The RD&D deliverables that *are* applicable are so-called "dual-use" technologies that are complementary to the more general mission that they pursue.

Department of Energy

DOE efforts in advancing technologies are designed to use all domestic energy resources in ways that can promote economic growth while maintaining the nation's commitment to environmental quality. DOE's Office of Fossil Energy has an integral role in this effort by fostering advanced, more efficient, and cleaner oil and gas technologies through a comprehensive research, development, and demonstration program that addresses technological barriers from the reservoir through end use. The programs are coordinated through multiple sites.[2]

The natural gas RD&D program is comprised of the following four areas: Exploration and Production, Delivery and Storage, Gas Processing, and Environment/Regulatory Impact. The gas program complements the natural gas-related activities at other DOE offices such as the Office of Energy Efficiency and Renewable Energy, which is involved in end-use RD&D, and the Office of Energy Research, which is involved in fundamental geoscience and combustion RD&D. The oil RD&D program is comprised of activities that are grouped under the areas of Supporting Research, Field Demonstrations, Environmental Research, and Processing. Supporting Research includes Exploration and Drilling, Extraction, Reservoir Characterization, Technology Transfer, and the Natural Gas and Oil Technology Partnership which coordinates the *Advanced Computational Technology Initiative.*

Table 4-5 shows the FY95 budget for gas and petroleum technologies for DOE's Office of Fossil Energy (in millions of dollars and percentages) as an example of the breakdown of work by performer. This is equivalent to about 1.5 percent of the $7.4 billion of DOE RD&D spending.

State Government

State governments are not major players in the allocation of financial resources to developing advanced technology. An informal telephone survey of major oil and gas producing states suggested that states allocate less than $10 million nationally to independent oil and gas technology programs. The objective of their investment is to provide either educational support or to provide funds that can enhance the economic environment for increased oil and gas business activity in their state. In general, the products of their investment are limited in scope and targeted to issues that fall within their state borders.

Private Sector Consortia

The Gas Research Institute (GRI) supports a significant RD&D program (annual budget of approximately $50 million) di-

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[2] METC - Morgantown Energy Technology Center, Morgantown, West Virginia; PETC - Pittsburgh Energy Technology Center, Pittsburgh, Pennsylvania; BPO/NIPER - Bartlesville Project Office, Bartlesville, Oklahoma, National Institute for Petroleum and Energy Research; MSO - Metairie Site Office, Metairie, Louisiana.

TABLE 4-5

FY 1995 BUDGET FOR GAS AND PETROLEUM TECHNOLOGIES OFFICE OF FOSSIL ENERGY

	Oil	Gas	Total
In-House Research (METC, PETC, NIPER)	$18.3 (22.5%)	$2.1 (7.3%)	$20.4 (18.4%)
National Laboratories (Direct Funding and CRADAs)	$14.2 (17.4%)	$9.5 (33%)	$23.8 (21.5%)
Industry/States/Universities	$49.2 (60.2%)	$17.3 (59.7%)	$66.5 (60%)
Total	$81.7 (100%)	$29.0 (100%)	$110.7 (100%)

rected at *natural gas* exploration, production, processing, and storage operations. GRI is funded by gas industry stakeholders including producers, pipelines, gas distribution companies, and gas consumers. Producers and service companies actively participate in the formulation and evaluation of the GRI program through an extensive network of advisory bodies comprised of technology and policy leaders from the gas industry. Additionally, oil and gas industry organizations participate through cofunding of the development programs.

More than ever, industry considers consortium RD&D organizations as an important component of their business strategy. Industry-sponsored consortia can take a number of forms, including RD&D pools (CEA, DEA, PERF, Deepstar, POSC, university research centers, basic research cooperatives, and industry R&D institutes such as GRI).

- Industry-sponsored consortia are formed to provide members with several benefits, including sharing of costs and risks, improved technology transfer, and leveraging of scarce funds.
  - Because the consortia exist on behalf of their supporters, there is marketplace incentive to be productive. In short, in the new paradigm, consortia are treated as a business unit of the consortium supporters. Relevancy and value-added focus is driven by the participating members.
  - Industry-supported consortia are evaluated on their success in bringing high impact technology to the marketplace. The sponsor's investment in the consortia must show a measurable positive return based on the application of the advanced technology.
- Industry-sponsored consortia do not replace the industry's requirement for development of proprietary technology or technology that addresses the unique needs of a single company.
  - In general, technology developed by the consortia is shared by the funding members.
  - Individual company goals are relinquished in consortium RD&D in lieu of consensus goals.

SUMMARY

As discussed in this chapter, the nature of the technology programs supported by the different organizations varies considerably, in both focus and time horizon. In general, those organizations competing in the private sector limit their time horizon to the very near term (immediate to three years), and accordingly emphasize technical service and product development. In contrast, universities conduct very basic research that is targeted to provide the technology base for future products. Characteristic time horizons tend toward ten years or more. Federal and state funded technology development lies somewhere between these two end-points, with elements of their programs targeted toward basic research, technology development, and technology transfer. In general, programs supported by the federal or state governments will tend to emphasize the longer term, whereas partnerships and consortia supported by private funds will tend toward the shorter term.

APPENDICES

Appendix A

Request Letter and Description of the National Petroleum Council

The Secretary of Energy
Washington, DC 20585

July 27, 1994

Mr. Ray L. Hunt
Chairman
National Petroleum Council
1625 K Street, N.W.
Washington, DC 20006

Dear Mr. Hunt:

The Department of Energy (DOE) has recently forwarded to Congress and industry a draft program plan for the Advanced Computational Technology Initiative. This program is a key component of the Administration's Domestic Natural Gas and Oil Initiative, released last December, and is part of the existing Natural Gas and Oil Technology Partnership (Partnership) operated by the National Laboratories and the Department.

The Partnership is an expansion of the successful Oil Recovery Technology Partnership, a Department funded program initiated by the Los Alamos and Sandia National Laboratories in 1988. Two additional labs have since been incorporated in fiscal year 1994, and the Partnership will include the remaining five multi-program laboratories in fiscal year 1995.

The mission of the Partnership is to stimulate, facilitate, and coordinate the development and transfer of technology to the U.S. petroleum industry through technical interactions and collaborations with DOE's National Laboratories. The Partnership has four areas of focus or technology areas. The Advanced Computational Technology Initiative addresses one such technology area. Each focus area has an industry interface group, called a panel or forum, which is key to providing the industry-driven aspect of the Partnership.

The Advanced Computational Technology Initiative program is designed to enhance, apply, and transfer technologies developed within our National Laboratories to promote the competitiveness of domestic natural gas and oil companies. Specifically, the program will redirect the National Laboratories' computational capabilities to support the natural gas and oil industry and to accelerate the next revolution in exploration, production, and processing technologies. The underlying goals of the Advanced Computational Technology Initiative are to help producers find and recover natural gas and oil at lower costs and to enhance and apply technologies to increase domestic production.

To ensure the success of the Advanced Computational Technology Initiative and other technology programs in the Partnership, I am requesting that the National Petroleum Council (Council) conduct a study of research, development, and demonstration needs of the natural gas and oil industry. This study should analyze the needs of all components of the industry, considering the near- and long-term needs of both the upstream and downstream sectors. Significantly, your study will serve as the foundation for the Partnership's Industry Steering Committee, which provides program direction, and helps set funding allocations and other priorities.

This is an important study that, in my view, deserves expedient but thorough attention. As the initial funding for Advanced Computational Technology Initiative projects become available in fiscal year 1995 (beginning October 1, 1994), I would ask that the Council establish a schedule that would provide an interim report on the research, development, and demonstration needs study before the end of the year, with the final report as soon thereafter as possible.

Thank you for your continued assistance on issues important to the energy industry.

Sincerely,

Hazel R. O'Leary

Hazel R. O'Leary

DESCRIPTION OF THE NATIONAL PETROLEUM COUNCIL

In May 1946, the President stated in a letter to the Secretary of the Interior that he had been impressed by the contribution made through government/industry cooperation to the success of the World War II petroleum program. He felt that it would be beneficial if this close relationship were to be continued and suggested that the Secretary of the Interior establish an industry organization to advise the Secretary on oil and natural gas matters.

Pursuant to this request, Interior Secretary J. A. Krug established the National Petroleum Council on June 18, 1946. In October 1977, the Department of Energy was established and the Council was transferred to the new department.

The purpose of the NPC is solely to advise, inform, and make recommendations to the Secretary of Energy on any matter, requested by the Secretary, relating to oil and natural gas or the oil and gas industries. Matters that the Secretary of Energy would like to have considered by the Council are submitted in the form of a letter outlining the nature and scope of the study. This request is then referred to the NPC Agenda Committee, which makes a recommendation to the Council. The Council reserves the right to decide whether it will consider any matter referred to it.

Examples of recent major studies undertaken by the NPC at the request of the Secretary of Energy include:

- *U.S. Arctic Oil & Gas* (1981)
- *Environmental Conservation—The Oil & Gas Industries* (1982)
- *Third World Petroleum Development: A Statement of Principles* (1982)
- *Enhanced Oil Recovery* (1984)
- *The Strategic Petroleum Reserve* (1984)
- *U.S. Petroleum Refining* (1986)
- *Factors Affecting U.S. Oil & Gas Outlook* (1987)
- *Integrating R&D Efforts* (1988)
- *Petroleum Storage & Transportation* (1989)
- *Industry Assistance to Government* (1991)
- *Short-Term Petroleum Outlook* (1991)
- *The Potential for Natural Gas in the United States* (1992)
- *U.S. Petroleum Refining—Meeting Requirements for Cleaner Fuels and Refineries* (1993)
- *The Oil Pollution Act of 1990—Issues and Solutions* (1994)
- *Marginal Wells* (1994)
- *Future Issues—A View of U.S. Oil & Natural Gas to 2020* (1995).

The NPC does not concern itself with trade practices, nor does it engage in any of the usual trade association activities. The Council is subject to the provisions of the Federal Advisory Committee Act of 1972.

Members of the National Petroleum Council are appointed by the Secretary of Energy and represent all segments of the oil and gas industries and related interests. The NPC is headed by a Chair and a Vice Chair, who are elected by the Council. The Council is supported entirely by voluntary contributions from its members.

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Appendix C

Statistical Data on the Oil and Gas Industry

U.S. Energy Consumption Summary: 1970-1993

	1970	1975	1980	1985	1990	1993
U.S. Energy Consumption (Quads)	66.43	70.55	75.96	73.98	81.26	83.96
Petroleum	29.52	32.73	34.2	30.92	33.55	33.77
Natural Gas	21.79	19.95	20.39	17.83	19.3	20.79

Source: EIA Annual Energy Review, 1993, page 5.

1993 U.S. Energy Consumption by End-Use Sector

Quadrillion BTUs

	Total	Percent
Industrial	30.77	36.7
Residential and Commercial	30.34	36.1
Transportation	22.83	27.2
Total	83.96	100.0

Source: EIA Annual Energy Review, 1993, page 39.

1992 Consumption of Liquid Transportation Fuels

	Total	Cars	Buses	Trucks
Fuel Consumption (Billion Gallons)		73.9	0.9	58.0
Fuel Consumption (Quadrillion BTUs)*	22.83	9.24	0.12	8.04
Total	76.2	40.5	0.5	35.2

* Fuel consumption (gallons) data for cars was converted to BTUs using the heat content for gasoline: 5.253 million BTUs per barrel. Data for buses and trucks were converted using the heat content of distillate-fuel oil, 5.825 million BTUs per barrel. Source: EIA Annual Energy Review, 1993, page 341.

Source for fuel consumption data: Statistical Abstract of the United States, 1994, Table No. 1024.

1993 Electric Utility Consumption of Fossil Fuels to Generate Electricity

	Total	Oil	Gas	Coal
Consumption to Generate Electricity (Quads)	20.71	1.05	2.74	16.92
Total Consumption (Quads)	83.96	33.77	20.79	19.63
% of Total Consumption of Energy Source	24.67	3.10	13.18	86.19

Source: EIA Annual Energy Review, 1993, page 237.

U.S. Per Capita Energy Consumption: 1970-1993

	1970	1975	1980	1985	1990	1993
Per Capita Energy Consumption (million BTU)	327	351	327	311	326	326

Source: Statistical Abstract of the United States, 1994, Table No. 922.

Energy Consumption: 1970-1993

	1970	1975	1980	1985	1990	1993
Energy Consumption (thousand BTU) per $GDP	23.1	21.9	20.1	17.3	16.6	16.3

Source: Statistical Abstract of the United States, 1994, Table No. 922.

Motor Fuel Consumption and Motor Vehicle Efficiency

	Total Motor Fuel Consumption (Billion Gallons)	Average miles per gallon	
		Cars	Trucks
1970	92.3	13.52	7.85
1992	132.9	21.60	10.84
Percent change	+44.0	+59.8	+38.0

Source: Statistical Abstract of the United States, 1994, Table No. 1020.

1993 U.S. Domestic Energy Production

Quads

	Total	Oil	Gas	Coal	Nuclear	Hydro-electric	Other
Consumption	83.96	33.77	20.79	19.63	6.52	3.06	0.20 (a)
Domestic Production	65.81	16.88	18.98	20.49	6.52	2.76	0.18 (b)
Percent of Domestic Production	78.4	50.0	91.3	100	100	90.2	90.0

(a) Natural gas, petroleum products, electricity and coal coke.

(b) Electricity generated for distribution from wood, waste, geothermal, wind, photovoltaics, and solar thermal energy. Natural gas liquids included with oil.

Source: EIA Annual Energy Review, 1993, page 5.

U.S. Oil and Gas Reserves, January 1, 1993

Recoverable with current technology and prices

	Crude Oil (Billion Barrels)	Natural Gas (Trillion Cubic Feet)
Reserves	23.7	165.0
Current Rates of Production	2.5	18.4
Years Supply at Current Rates of Production	9.5	9.0

Sources: Reserves and current production data from EIA Annual Energy Review, 1993, pages 129, 141, 189, and 287. Reserves do not include natural gas liquids.

Oil and Gas Prices—Summary: 1970-1993
1987 Dollars

	1970	1975	1980	1985	1990	1993
Crude Oil Domestic First Purchase Price—U.S. Average ($/bbl)	9.03	15.59	30.11	25.52	17.68	11.47
Leaded Reg. Gasoline—Retail ($/gal)	1.014	1.152	1.662	1.181	1.014	—
Unleaded Reg. Gasoline—Retail ($/gal)	—	—	1.736	1.273	1.027	.892
Fuel Oil—Retail ($/gal)	0.526	0.766	1.358	1.115	0.938	0.733
Natural Gas—Wellhead ($/MCF)	0.48	0.89	2.22	2.66	1.51	1.59

Source: EIA Annual Energy Review, 1993, pp. 173, 183, 203.

Consumer Price Indexes for All Urban Consumers (CPI-U): 1980-1993
100 = 1982-1984 averages.

Item	1980	1985	1990	1993	Percent Change
All Items	**82.4**	**107.6**	**130.7**	**144.5**	**75**
Food and Beverages	86.7	105.6	132.1	141.6	63
Housing	81.1	107.7	128.5	141.2	74
Fuels and Other Utilities	75.4	106.5	111.6	121.3	61
Fuel Oil	**87.7**	**94.6**	**98.6**	**87.2**	**(1)**
Electricity	75.8	108.9	117.4	126.7	67
Utility (piped) gas	65.7	104.8	97.3	106.5	62
Household Furnishing and Operations	86.3	103.8	113,3	119.3	38
Apparel and Upkeep	90.9	105.0	124.1	133.7	47
Transportation	83.1	106.4	120.5	130.4	60
New Vehicles	88.4	106.1	121.0	131.5	49
Motor Fuel	**97.4**	**98.7**	**101.2**	**98.0**	**1**
Automobile Maintenance	81.5	106.8	130.1	145.9	79
Automobile Insurance	82.0	119.2	177.9	216.7	164
Medical Care	74.9	113.5	162.8	201.4	169
Entertainment	83.6	107.9	132.4	145.8	74
Tobacco and Smoking Products	72.0	116.7	181.5	228.4	217
Personal Care	81.9	108.3	130.4	141.5	73
Personal and Educational Expenses	70.9	119.1	170.2	210.7	197

Source: Statistical Abstract of the United States, 1994, Table No. 748.

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