MEETING U.S. ENERGY RESOURCE NEEDS

THE ENERGY RESOURCES PROGRAM OF THE U.S. GEOLOGICAL SURVEY

Panel to Review the U.S. Geological Survey's Energy Resources Program

Committee on Earth Resources

Board on Earth Sciences and Resources

Commission on Geosciences, Environment, and Resources

National Research Council

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PANEL TO REVIEW THE U.S. GEOLOGICAL SURVEY'S ENERGY RESOURCES PROGRAM

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This report has been reviewed by individuals chosen for their diverse perspectives and technical expertise in accordance with procedures approved by the NRC's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the authors and the NRC in making their published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The content of the review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their participation in the review of this report:

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Although the individuals listed above have provided many constructive comments and suggestions, responsibility for the final content of this report rests solely with the authoring committee and the NRC.

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Preface

A decade ago, the United States Geological Survey (USGS) *Budget Justifications FY 1989* (DOI, 1988a) stated that the USGS energy program "is conducted to improve the understanding of the nature, distribution, and size of the national endowment of energy-related resources as a prerequisite to the formulation of an effective national energy policy and optimum development of energy resources" (p. GP-160). At the same time, a National Research Council (NRC) committee reviewed the USGS energy programs and commented that "effective and timely scientific information from these programs is needed to help the nation determine its energy options through the year 2000 and beyond" (NRC, 1988, p. 17). Ten years later, as the year 2000 approaches, many of the issues addressed in that report are still timely, and the need for accurate information about energy resource options is every bit as great. The fact that the 1988 review considered many issues that are still relevant today is an indication that the time scales for changes in the energy mix are long, and the products of the USGS Energy Resources Program are important to the economic, environmental, and security future of the United States.

This report examines the current state of the Energy Resources Program (ERP) in the USGS and offers suggestions for the future of the program. It was assembled based on the thoughtful evaluations and comments of the members of the panel, who shared their expertise, invested many hours in program review meetings, and reviewed carefully a succession of drafts of the report. It was a pleasure to work with them. The panel is also grateful to Dave Houseknecht and many members of the staff of the Energy Resources Program, who prepared cogent briefings about ERP activities and responded rapidly to every request for

information from the panel. Finally, we are especially indebted to Tony de Souza, NRC staff director for the study, and his able assistant Judy Estep. Their efforts kept us organized and on track, and they contributed substantially to the final product. The talented group of people who contributed to this review made my job as chairman a pleasure to fulfill.

Lynn Orr
Chairman

Contents

Executive Summary

This study was undertaken in recognition of the critical role played by the Energy Resources Program (ERP) of the U.S. Geological Survey (USGS) in the energy future of the United States. The ERP performs fundamental research to understand the origin and recoverability of fossil energy resources and conducts assessments of their future availability. The ERP also provides information and expertise on environmental effects.

In 1997 the Geologic Division (GD) of the USGS invited the National Research Council (NRC) to conduct an independent review of the ERP. Subsequently, an NRC panel was formed and asked to consider the mission (see Chapter 2), role (see Chapter 2), balance (see Chapter 3), effectiveness (see Chapter 4), and future directions (see Chapter 4) of the ERP. The charge to the NRC panel included five questions:

1. Is the scientific mission of the ERP appropriate for a federal earth-science agency?
2. Is the role of the program clearly defined in relation to other federal agencies and are the program's responsibilities consistent with its mission?
3. Is the program appropriately balanced between resource and environmental issues? Is it appropriately balanced between research and assessment activities?
4. Has the program proven effective in addressing energy resource issues of national importance?
5. How should the program's activities, scientific and technical expertise, and infrastructure evolve to meet future needs?

Accordingly, the aim of this report is to provide guidance to the USGS about the present and future directions of its ERP. Specifically, the report reviews and recommends improvements to the program in relation to the energy challenges of the next century.

A concise description of the panel's answers to these questions (with major conclusions and suggestions printed in italics and recommendations in bold type) follows:

Mission. ***Is the scientific mission of the USGS Energy Resources Program appropriate for a federal earth-science agency?***

The ERP does not have a formal mission statement, but *the panel concludes that the mission of the ERP—to provide up-to-date and impartial assessments of geologically based energy resources of the nation and the world—is fully appropriate for a federal earth-science agency.* The information and data are essential to the management of federal lands, to the understanding of the environmental impacts of the extraction and use of energy resources, and to the planning of national energy policy. The panel believes that the ERP fulfills a mission essential to the federal government, and therefore, **it recommends that the ERP develop a formal mission statement and a strategic plan that fits within and contributes to the mission statements and strategic plans adopted recently for the GD and for the USGS as a whole.**

Role. ***Is the role of the program clearly defined relative to other federal energy agencies and are the program's responsibilities consistent with its mission?***

The panel also concludes that the role of the ERP is clearly defined. The ERP focuses primarily on onshore United States energy resources and the geologic factors that control the abundance of the resource, its quality, and its location. In contrast, the Minerals Management Service (MMS) manages energy and mineral resources of federal offshore areas and conducts lease sales. The ERP and MMS have similar assessment objectives but cover mutually exclusive geographic areas. *The panel urges the ERP and the MMS to continue to work closely together.* The objective of a close collaboration is the provision of consistent and complementary onshore and offshore resource assessments. The Bureau of Land Management (BLM), Bureau of Indian Affairs (BIA) on Indian reservations, and U.S. Forest Service (USFS) are responsible for managing energy and mineral resources of federal onshore lands but do not undertake assessments of undiscovered resources. The Department of Energy (DOE) and particularly its Energy Information Administration (EIA) collect information about energy reserves (known and identified quantities of resources that can be profitably exploited now), energy production, and energy use. ERP data are used by EIA, BLM, BIA, and USFS to perform their functions. A significant duplication of effort would

be the result if agencies were to develop internally the information provided to them by the ERP. Nonetheless, the ERP must take every step to ensure that its data are readily available to federal agencies, both inside and outside the Department of the Interior (DOI).

Balance. ***Is the program appropriately balanced between resource and environmental issues? Is it appropriately balanced between research and assessment activities?***

In the panel's view, the test of a balanced program should extend beyond the sets of issues and activities raised by the two questions posed above. Specifically, the panel urges more balanced consideration of the diversity of energy sources of potential significance in the nation's future.

The level of effort on the environmental side has been lower than that on resource assessment. Environmental activities in the ERP have been undertaken in selected areas: oil and gas chemistry, chemistry and disposal of produced waters, and coal chemistry and acid-mine drainage. The objective, an appropriate one in the panel's view, has been to provide information and expertise related to the potential impact of energy resource extraction and use. *Rather than broaden the scope of the environmental program at this stage, the panel urges the ERP to develop partnerships with users of its environmental data and to use these partnerships to conduct a systematic review of the data now being collected to determine what additional data would have significant benefits.*

The panel notes that the balance among research, assessment, and service is an issue that is important to the GD and the USGS as a whole. The panel believes that research and assessment are thoroughly entwined and that high-quality assessment must involve high-quality research. Similarly, research and service are inseparable. *The panel urges the ERP to view research as an essential and integral component of assessment.* **Hence, the panel recommends that the ERP in particular and the USGS as a whole maintain the strong research and knowledge base that is essential to the provision of services the ERP is uniquely qualified to provide.**

Because international energy flows and prices strongly influence the viability of energy sources in the United States, *the panel encourages the ERP to evaluate whether the effort on world energy resource assessment and supporting research should be increased above present levels.*

Oil, natural gas, and coal provide most of the energy currently used and, as a result, are the focus of the resource assessments and related research conducted by the ERP. Because there are many uncertainties in our energy future, **the panel recommends that the ERP portfolio be broadened to include geologically based energy resources beyond oil, gas, and coal, and that the ERP develop priorities for long-term balance among the various energy resources as part of the implementation of its strategic plan.** *Resource assessments*

should be available for very heavy oil, oil shale and carbonaceous shales, geothermal resources, and uranium, as well as conventional oil and gas, coal, coalbed methane, and methane hydrates, although the depth of the assessment will vary by energy source, given variable probabilities of economic use on equally variable time scales. Many of these energy resources exist on federal lands—another reason to make sure that appropriate scientific understanding is available as these assets are catalogued. *The ERP should develop priorities for the allocation of resources and personnel as part of the development of its strategic plan.*

Effectiveness. ***Has the program proven effective in addressing energy resource issues of national importance?***

The panel finds the oil and gas subprogram, as exemplified by the recently released 1995 oil and gas assessment, to be effective and *encourages the ERP to continually evaluate the appropriate level of effort in this subprogram.* It is not yet possible to evaluate the impact and effectiveness of the coal subprogram because the current assessment is still underway. The panel does, however, have some concerns and *urges the coal subprogram to complete a comprehensive assessment; to state clearly the assumptions and procedures upon which the assessment is based; to design a program of supporting research that adequately focuses on coal resources in basins that have not been extensively studied and that uses modern approaches of sedimentology and sequence and seismic stratigraphy; and to provide for appropriate involvement of industry and states.* The panel views the world oil and gas subprogram as effective.

Program Evolution. ***How should the program's activities, scientific and technical expertise, and infrastructure evolve to meet future needs?***

Evolution of the activities of the ERP should be guided by a continuing strategic planning process that involves a portfolio of energy sources and anticipates changing policy environments and new developments in science and technology.

Renewal of scientific and technical expertise is a critical issue for the evolution of the ERP. The range of expertise should be guided by the strategic planning process, and the distribution of skills and experience should be consistent with the strategic plan.

Data and information management, and communication with clients and partners, are important aspects of the near-term evolution of the infrastructure of the ERP. The panel commends and supports the ERP's substantial effort to make its products available in electronic, searchable form. The panel also supports the intent of the ERP's Decision Support System (DSS), but suggests that careful reevaluation of the in-house development approach is needed. The panel commends the ERP for its efforts to provide rapid response to external users of its

information. The panel believes that policies for managing the USGS core repository and other geological samples need to be reviewed to determine whether long-term archiving of and access to core, cuttings, and other geological samples constitute an important part of the mission and role of the ERP. *The panel notes that the ERP should look for opportunities for improvement of communications between the oil and gas and the coal subprograms, and the panel encourages the ERP to continue to strengthen its public outreach.*

The panel believes that the ERP has built a solid foundation upon which a successful future program can be built. A successful ERP will help the United States understand and guide its energy future.

1

Introduction

CONTEXT

> Adequate, affordable energy supply and efficient energy use are indispensable ingredients of the economic well-being of individuals and nations. (PCAST, 1997, p. 1-1)

Energy is the lifeblood of modern societies. It is critical for transportation and communication, industrial and agricultural production, climate-conditioned buildings and vehicles, and automobile-oriented suburbs. Without a supply of energy at the turn of an ignition key, we would not have planes, trains, and automobiles. Without a supply of electricity at the push of a button or the flick of a switch, we would not have elevators, telephones, televisions, computers, electric lights, or modern heating and cooling systems. In short, a complex system of energy supply and distribution has helped to transform our society dramatically in the last 100 years. By reducing the time required for travel, by reducing the time required to complete a task, or by changing the nature of interaction, energy services have changed our personal trajectories through space and time and thus our lives. Energy, which is a means for social ends rather than an end in itself, makes possible a high quality of life, characterized by prosperity and security. Given the role of energy in our economy, it is no surprise that affordable, abundant, and reliable energy supplies are of crucial interest to national policymakers.

A hundred years ago, the major sources of energy in the United States were coal, fuelwood, and animal power. Coal, the new king, was the source of power

for the nation's expanding railroads, for the steel industry, and for steam boilers that powered big industry. Electricity was still a new invention. Except for kerosene in the home, traditional energy systems were the order of the day for most Americans (Table 1.1).

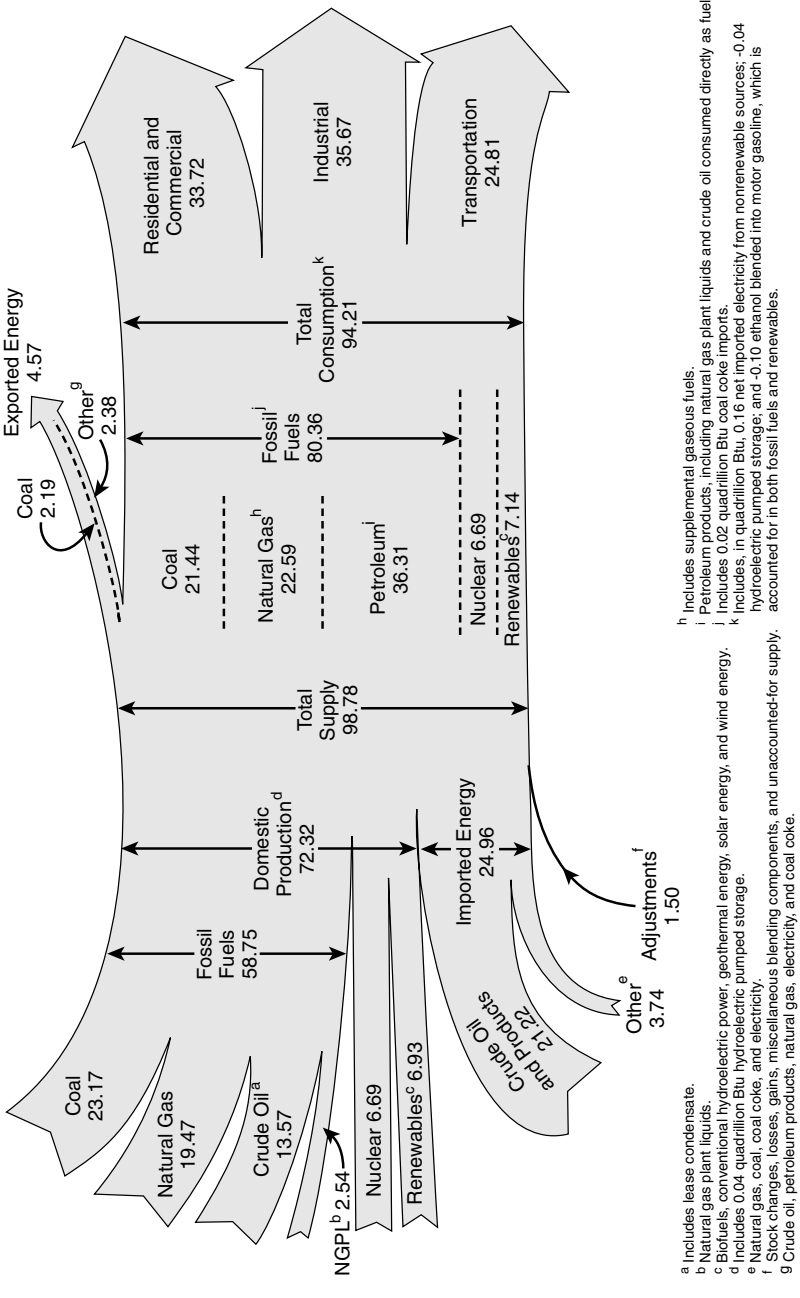
Over the past 100 years, energy development and use have changed American life through the technologies they power. Most of these changes resulted from the growing use of two forms of energy: (1) liquid fuels from petroleum, which powered the automobile era that began in the 1920s, and (2) electricity, which has grown steadily throughout the century and now powers the information age that began in the 1970s. Oil and natural gas have displaced coal for industrial and home heating uses, but coal remains a major contributor to electricity generation (Table 1.1). Oil and natural gas are the fuels of choice especially in industry and transportation. Meanwhile, electricity reaches into nearly every home and nearly every aspect of life. Even though the mix of energy sources has changed considerably in the last 100 years, the United States still depends on fossil fuels, which supply approximately 86 percent of the nation's primary energy needs (Figure 1.1).

Just as the mix of energy sources that fueled the United States changed in the last 100 years, so too will it change in the next 100 years. How it changes will depend on changes in technology and society between now and then, and the details of change are difficult to predict. A forecaster in the late nineteenth century would have found it difficult to imagine what would happen in the next 100 years: the primacy of the automobile, truck, and airplane; the mechanization of agriculture; the relationship between electricity and such new technologies as the computer and television; the appearance of new energy technologies such as nuclear power; the use of petroleum and coal as industrial feedstocks; the con-

TABLE 1.1. Comparison of Primary Energy Sources in the United States, 1880 and 1997

	Percentage of Total	
Energy Source	1880	1997
Coal	57	23
Biomass	35	3
Oil	4	39
Gas	4	24
Hydropower	0.1	4
Wind, solar, geothermal	<0.1	0.5
Nuclear	—	7

Note: Percentages sum to more than 100 due to rounding. Source: Dewhurst et al., 1955; EIA, 1998, p.8; Schurr et al., 1960.



[a] Includes lease condensate.
[b] Natural gas plant liquids.
[c] Biofuels, conventional hydroelectric power, geothermal energy, solar energy, and wind energy.
[d] Includes 0.04 quadrillion Btu hydroelectric pumped storage.
[e] Natural gas, coal, coke, and electricity.
[f] Stock changes, losses, gains, miscellaneous blending components, and unaccounted-for supply.
[g] Crude oil, petroleum products, natural gas, electricity, and coal coke.
[h] Includes supplemental gaseous fuels.
[i] Petroleum products, including natural gas plant liquids and crude oil consumed directly as fuel.
[j] Includes 0.02 quadrillion Btu coal coke imports.
[k] Includes, in quadrillion Btu, 0.16 net imported electricity from nonrenewable sources; -0.04 hydroelectric pumped storage; and -0.10 ethanol blended into motor gasoline, which is accounted for in both fossil fuels and renewables.

FIGURE 1.1. U.S. energy flow (quadrillion Btu), 1997. Source: EIA, 1998.

cern with energy efficiency and environmental protection; and the growing energy needs of developing countries.

The task of making accurate predictions of the mix of future energy sources is made more difficult by the fact that we do not know exactly how debates will unfold on such topics as the perceived risks of particular energy sources, environmental effects of one source of energy versus another, and possible impacts of different energy sources on global warming and climate change. As a result, several studies of national energy policy recommend that the United States preserve multiple options for energy supply by adopting a portfolio approach to energy technologies and to investment in energy research and development. [For example, see the following three reports: *Federal Energy Research and Development for the Challenges of the Twenty-First Century* (PCAST, 1997); *Energy R&D: Shaping Our Nation's Future in a Competitive World* (SEAB, 1995); and *Comprehensive National Energy Strategy (*DOE, 1998a).] A portfolio approach avoids reliance on any single energy source and capitalizes on improvements in energy technologies that affect supplies and efficiency of energy use. A portfolio approach is also prudent as the world economy becomes more competitive and as world markets become more interconnected.

Future energy decisions of the United States will increasingly have an international frame of reference. Currently, more than 50 percent of the oil consumed by the United States is imported (DOE, 1998a). Production from domestic oil fields peaked in 1970 at about 11 million barrels per day, with demand at about 14 million barrels per day as Figure 1.2 indicates. Since then, domestic production has slipped to 9 million barrels per day and the fraction of imported oil has risen steadily. In 1996, the United States spent $64 billion to buy oil on the international market (PCAST, 1997). The cost of oil imports is expected to rise further if predictions that imports will increase to 60 percent of oil consumption by 2010 are fulfilled (DOE, 1998a).

The geopolitics of energy has played an important role in international relations in this century, as the 1973 oil embargo, 1978 Iranian revolution, and 1991 Operation Desert Shield-Desert Storm illustrate. At a conference held in December 1997 in Kyoto, Japan, international negotiations took place about global greenhouse gas emissions, which are intimately connected to the supply, use, and environmental effects of fossil energy. Energy prices, impacted by international events outside the control of the United States, are watched closely by industrial and agricultural users whose costs of production are influenced by energy costs. Individual consumers, who are now accustomed to historically low gasoline prices, react strongly to any price rise or to proposals that energy be taxed to meet environmental or other national policy goals. It is no surprise, therefore, that energy issues are of significant interest to those charged with formulating national and international policy.

Successful policy development will require creation of a comprehensive, flexible national energy strategy (DOE, 1998a) that addresses the full range of

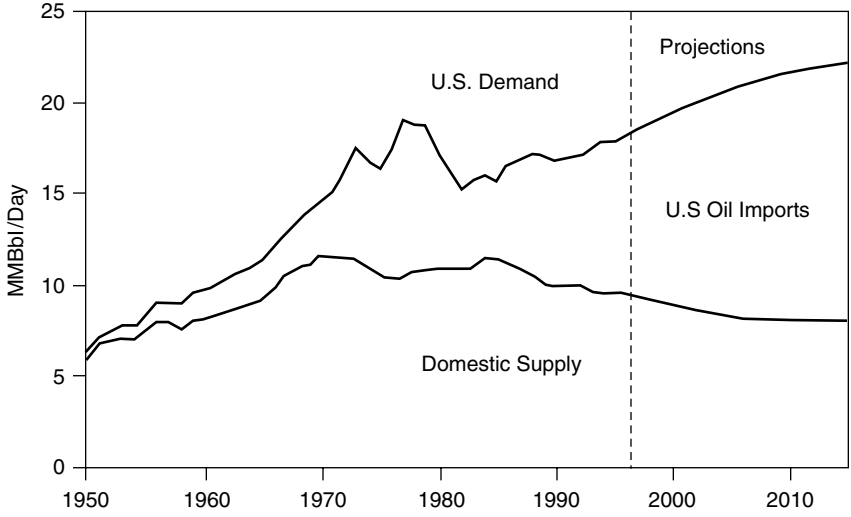


FIGURE 1.2. Past and projected U.S. oil imports in millions of barrels per day, 1950-2015. Source: PCAST, 1997, p. 1-8.

energy-related supply, economic, environmental, and security challenges facing the nation. Many of the questions that arise in the development and implementation of this strategy will have a significant geoscience component. Can the decline in domestic oil production be slowed appreciably by increased exploration in Alaska? Do geologic formations in the United States contain enough natural gas to allow significant substitution of gas for coal in order to reduce carbon dioxide emissions, and for how long? Can these additional oil and gas resources be recovered at costs competitive with other energy sources? How much coal of a given quality can reasonably be recovered and at what cost? Which coal will require the greatest expenditure to control acid-mine drainage? What energy resources are to be found on public lands? Can methane hydrates in ocean sediments and in the Arctic tundra be a significant source of natural gas? Is it likely that coalbed methane will supply more gas to American consumers in the future? What is the distribution of rich oil shales in the United States? If concerns about global warming lead to renewed interest in nuclear power, what domestic uranium resources are available, and how will the problem of disposal of high-level nuclear waste impact the decision to once again embrace nuclear power? Finally, cutting across these questions, what is the national interest in maintaining a significant domestically produced component of total energy requirements?

Questions such as these are connected to the geological settings of the natural resources themselves. The cost of coal recovery is influenced by the thick-

ness of the coal seams and the thickness of the overburden. How much oil may be present in geologic formations depends on whether nearby source rocks have been buried deeply enough to generate oil and whether there are porous rocks to trap the oil that forms. How much oil can be recovered often depends on the variability of the sedimentary rocks in which it is found. Answers to these and many other questions are the focus of the United States Geological Survey (USGS) Energy Resources Program (ERP), the subject of this report.

If American policymakers are to respond rationally to the energy challenges that the nation faces in the next century, they will need access to objective, dependable scientific information about the portfolio of choices available. As they consider the inevitable changes that will occur in the energy mix in the years to come, they will call extensively on the expertise available at, and data created by, the ERP. Consequently, the USGS and its ERP must be prepared to respond in a timely way to policymakers on the availability and suitability of energy options to meet future needs.

ENERGY RESOURCES PROGRAM

The ERP is one of nine major programs within the Geologic Division (GD) of the USGS. According to the *Budget Justifications and Annual Performance Plan, FY 1999*, for the USGS, the ERP

> . . . provides the most up-to-date and comprehensive analysis of oil, natural gas, and coal resources of the Nation and World and produces digital energy resource information that facilitates land use, energy-policy, and environmental decisionmaking. Research on fossil energy resources includes assessments of the quantity, quality, and geographic locations of natural gas, oil, and coal resources, as well as estimates of energy resources availability and recoverability based on geological, technological, economic, and policy constraints. (DOI, 1998, p. 168)

The ERP pursues energy resource and related environmental research within the context of three integrated themes or subprograms:

1. national coal resource investigations and assessments;
2. national oil and gas resource investigations and assessments; and
3. world energy investigations and assessments.

STUDY AND REPORT

This study was undertaken in recognition of the critical role to be played by the ERP in the energy future of the United States. It was requested by the GD of the USGS. In 1997, Dr. P. Patrick Leahy, chief geologist of the USGS, invited the National Research Council (NRC) to conduct an independent and compre-

hensive review of the ERP. Accordingly, in December 1997, the NRC's Committee on Earth Resources, which operates under the aegis of the Board on Earth Sciences and Resources within the Commission on Geosciences, Environment, and Resources formed the Panel to Review the U.S. Geological Survey's Energy Resources Program. The panel consists of 11 geoscientists and resource experts from industry, academia, and state agencies. Its members have recognized expertise in energy resources; petroleum and coal geology and geochemistry; geophysics; sedimentary petrology; geodynamics; environmental geochemistry; energy assessments; petroleum, mining, and geological engineering; and energy economics. (Brief biographies of panel members are provided in Appendix B.)

The panel was asked to consider the mission, role, balance, effectiveness, and future directions of the ERP. The charge to the NRC panel included five specific questions:

1. Is the scientific mission of the ERP appropriate for a federal earth-science agency?
2. Is the role of the program clearly defined in relation to other federal agencies and are the program's responsibilities consistent with its mission?
3. Is the program appropriately balanced between resource and environmental issues? Is it appropriately balanced between research and assessment activities?
4. Has the program proven effective in addressing energy resource issues of national importance?
5. How should the program's activities, scientific and technical expertise, and infrastructure evolve to meet future needs?

Accordingly, the aim of this report is to provide guidance to the USGS about the present and future directions of its ERP. More specifically, the report reviews and recommends improvements to the program in relation to the energy challenges of the next century.

To answer these questions, the panel held four meetings between March and August 1998. These meetings included presentations from staff of the ERP and other USGS programs, briefings from representatives of state and federal agencies, and discussions with leaders from industry and nongovernmental organizations. The panel also received written responses to questions about the ERP from stakeholders. (The individuals who provided the panel with oral or written input are identified in Appendix A.) As background, panel members reviewed relevant USGS and ERP documents and materials through July 1998; pertinent NRC reports, including *Energy-Related Research in the U.S. Geological Survey* (NRC, 1988) and *Mineral Resources and Society: A Review of the U.S. Geological Survey's Mineral Resource Surveys Program Plan* (NRC, 1996); and other technical reports and published literature.

Chapter 2 of this report reviews the role and mission of the ERP, including its relationship to other government energy programs. Chapter 3 addresses ques-

tions of program balance. Chapter 4 examines program effectiveness and evolution, and describes the strengths and opportunities for improvement of current programs. Chapter 5 summarizes the panel's findings and recommendations. Throughout the report, major conclusions and suggestions are printed in italics and recommendations in bold type.

2

The Energy Resources Program: Setting, Mission, and Role

PROGRAM SETTING

The ERP is a small component of the GD of the USGS, which is the nation's largest water, earth, biological science, and civilian mapping agency. The ERP operated in 1998 with appropriated funding of $25 million, about 3 percent of the USGS's total appropriation of $759 million (Figure 2.1). The ERP is the locus of scientific specialization within an agency of rich, diverse, and interdependent scientific activities that are intended to serve national needs.

The USGS, which is the only science bureau of the Department of the Interior (DOI), addresses its mission by concentrating on eight critical business activities. These activities are (1) water availability and quality, (2) natural hazards, (3) geographic and cartographic information, (4) contaminated environments, (5) land and water use, (6) nonrenewable resources, (7) environmental effects on human health, and (8) biological resources. These business activities are conducted within the programs administered, in varying degrees, by the USGS's four divisions: (1) the National Mapping Division (NMD); (2) the Water Resources Division (WRD); (3) the Biological Resources Division (BRD); and (4) the Geologic Division (GD).

The GD, the largest of the four USGS divisions when reimbursable expenditures are excluded, conducts an integrated mixture of monitoring, research, and assessment activities in support of science goals that address major social issues involving geologic hazards and disasters, climate variability and change, energy and nonfuel mineral resources, ecosystem and human health, and groundwater availability. Its activities take place within programs, each administered by a different coordinator. The programs of the GD, in decreasing magnitude of

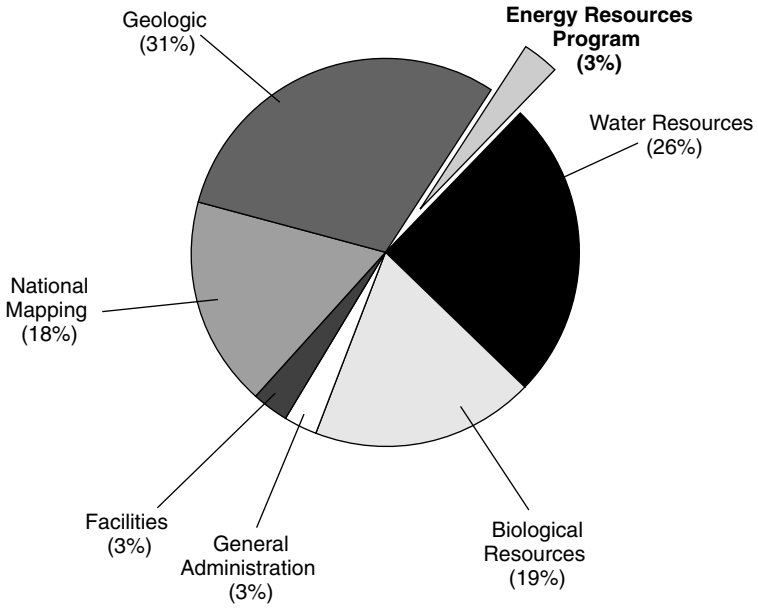


FIGURE 2.1. Energy Resources Program funding in institutional context, FY 1998 appropriations. Source: Data provided by USGS.

appropriated program funding, are (1) Mineral Resources, (2) Earthquake Hazards, (3) Coastal and Marine Geology, (4) Energy Resources, (5) Geologic Mapping, (6) Volcano Hazards, (7) Earth Surface Dynamics, (8) Global Seismic Network, and (9) Landslide Hazards (Figure 2.2). The strategic plans of the USGS [*USGS: Science for a Changing World. Strategic Plan for the U.S. Geological Survey 1997-2005* (USGS, 1997a)] and the GD [*Geology for a Changing World* (USGS, 1997b)] call for these nine programs to:

- place more emphasis on long-term, broad-scale, multidisciplinary research;
- work, as appropriate, with other divisions of the USGS;
- develop partnerships with other organizations; and
- combine short-term scientific responses to pressing national issues with long-term fundamental research on basic earth processes.

The USGS has a formal vision and mission statement, but the ERP does not. The vision and mission statement of the USGS [*USGS: Science for a Changing*

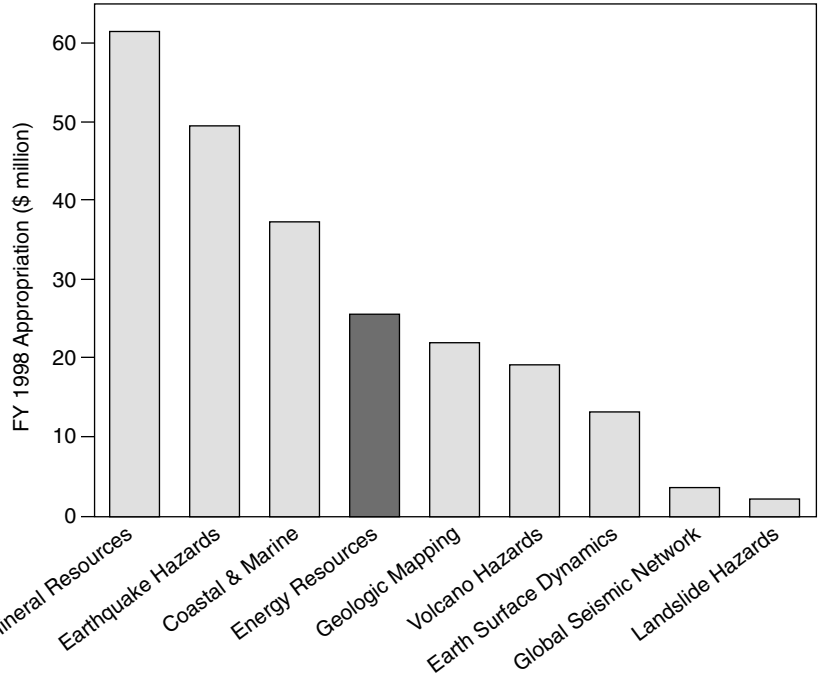


FIGURE 2.2. Size of the ERP in relation to other GD programs, FY 1998 appropriations. Source: Data provided by USGS.

World. Strategic Plan for the U.S. Geological Survey 1997-2005 (USGS, 1997a)] follows:

> **Vision.** The U.S. Geological Survey is an earth science organization that is recognized worldwide as scientifically credible, objective, and demonstrably relevant to society's needs. (USGS, 1997a, p. 1)
>
> **Mission.** The U.S. Geological Survey provides the Nation with reliable, impartial information to describe and understand the Earth. This information is used to:
>
> - minimize loss of life and property from natural disasters;
> - manage water, biological, energy, and mineral resources;
> - enhance and protect the quality of life; and
> - contribute to wise economic and physical development. (USGS, 1997a, p.1)

It is worth citing in full the USGS strategic plan's goals and performance measures for the critical business activity for nonrenewable resources.

Business Activity 6: Nonrenewable Resources

National Goal/Desired Outcome: Enhance economic development and growth.

Role of the USGS: (1) Determine the location, quantity, and quality of nonrenewable resources both internationally and domestically, (2) Determine the environmental effects of resource extraction and use, and (3) Improve assessments of resource potential, making possible the formulation of the best strategies for development of future resource supplies.

Discussion: Investigations of nonrenewable resources will undergo fundamental changes during the coming decade, and such investigations will likely decrease as a percentage of the total USGS effort. Studies of metallic minerals and fossil fuels have been at the core of the USGS's activities for more than a century.

Increasing dependence on international sources for many mineral and energy commodities signals a shift from exploration for domestic reserves to identifying and characterizing conventional and unconventional sources throughout the world. Successful national economic policy now depends on knowledge beyond that of locations and quantities of these resources. Knowledge also is necessary about economic, social, and environmental costs; quality; and availability of these resources, especially as potentially influenced by shifting political situations and technological innovations.

The focus of domestic studies will be on completing undiscovered resource assessments, both onshore and in the Exclusive Economic Zone (EEZ), and on identification and mitigation of potential problems caused by resource extraction on Federal lands. Important strategic opportunities also include such nontraditional areas as non-metallic minerals and aggregate, in-situ mining and its environmental impacts, and in mined land reclamation and associated resource recovery. Finally, continued development and refinement of genetic models based on domestic and foreign occurrences will remain an essential part of the nonrenewable resource activity. (USGS, 1997a, pp. 37-38)

ERP MISSION AND ROLE

The mission of the ERP, although not formally expressed in the various documents reviewed by the panel [*Geology for a Changing World* (USGS, 1997b*); The U.S. Geological Survey Energy Resource Surveys Program* (USGS, 1994)] is implicit in the description of the program, as well as in the fact that the ERP must address part of the mission of the USGS. Moreover, the draft document *U.S. Geological Energy Resources Program* (USGS, 1997c), dated February 2, 1997, provides a description of the program that includes an informal statement of its purpose, and a discussion of program objectives and program activities. These are summarized below:

Description of the USGS Energy Resources Program

> The Nation faces the challenge of simultaneously addressing an expanding appetite for energy, a growing dependence on imported oil, and an increasing demand that energy resource extraction and use be environmentally benign.
>
> The USGS Energy Resources Program addresses this challenge by providing objective scientific information that is essential for shaping policies regarding domestic and foreign energy resources, for making wise decisions regarding Federal land use, and for maintaining a healthy domestic energy industry. . . . (p. 14)

Program Objectives

> The USGS Energy Resources Program conducts interdisciplinary research on energy resources issues of national and global significance, establishing a scientific framework for identification and assessment of energy resources and for evaluating and minimizing impacts to the environment. The Program has three principal objectives:
>
> 1. Assess the fossil-fuel resources of the U.S. and the world,
> 2. Evaluate the environmental impact of energy resources,
> 3. Understand the geologic framework and processes of energy resources.
>
> (p. 14)
>
> Objective 1. Resource Assessment: Enhance the ability of policy makers to make informed energy policy and land-use decisions by assessing the fossil energy resources of the U.S. and the World. (p. 14)
>
> Objective 2. Environmental Impact: Provide the scientific knowledge for evaluating and minimizing impacts to human health and the environment resulting from the natural occurrence, extraction, and utilization of fossil energy resources and the disposal of by-products of fossil energy production and use. (p. 16)
>
> Objective 3. Geologic Framework and Processes: Develop a fundamental understanding of the origin and evolution of energy-bearing sedimentary rocks and the geological processes that control the genesis, migration, accumulation, preservation, and recoverability of fossil energy resources. Apply this fundamental knowledge to enhance energy resource and environmental impact assessments. (p. 17)

Information available in the form of both presentations to the panel by the USGS and documents or other materials produced by the USGS demonstrates that the ERP is focused on the mission and role of the USGS. The program objectives and program activities of the ERP clearly are aimed at providing information that is used to "manage . . . energy . . . resources," "to enhance and protect the quality of life, and to contribute to wise economic and physical development" (USGS, 1997a, p. 1). Nonetheless, there are inconsistencies and ambiguities in the documents that describe the ERP and its strategic objectives.

Accordingly, the panel concludes that the ERP should have a formal statement of purpose that accurately describes the range of the program's work and that fits within and contributes to the overall USGS mission. A formal ERP mission statement should ensure that the ERP is focused on the overall mission of the USGS, and would provide a basis for judging the relevance of ERP projects and products. The mission of the ERP that is implicit in the missions of the GD and the USGS, and in the description of the ERP provided to the panel, is as follows:

> The ERP provides reliable, impartial information to understand the energy resources of the nation. It produces assessments of the oil, natural gas, coal, and other geologically-based energy resources of the nation and the world that are used to manage the nation's energy resources. It provides information for evaluating and minimizing environmental impacts resulting from the occurrence, production, and use of these energy resources.

In addition to the lack of a formal ERP mission statement, the panel notes that the ERP has not completed a strategic plan, a statement of direction for the program, since 1994 (USGS, 1994). A 1997 strategic plan for the ERP remains in draft form, and the 1994 plan was never formally adopted. **The panel recommends that the ERP develop a formal mission statement and a strategic plan that fits within and contributes to the mission statements and strategic plans adopted recently for the GD and for the USGS as a whole.** The plan that was developed in 1994 is a good starting point. However, the 1994 plan should be reviewed carefully and updated to reflect the overall objectives of the agency and the division. A long-range strategic planning document will help establish a more productive program that is more responsive to the needs of its clients and is capable of meeting the nation's needs for energy resource information.

The information and expertise provided by the ERP have many applications. They are needed for land management decisions, energy policy and strategy, environmental policy, human health policy, energy security, reliable and cost-effective energy supplies, economic projections from the local to the national level, energy supply-demand analyses, and economic impact assessments.

The ERP's work is designed to meet the needs of a broad and disparate set of customers, as detailed in Chapter 3. The ERP also relies on a variety of communication channels, as discussed in Chapter 4. These include published studies, electronic databases, conferences and professional meetings, Internet web sites, e-mail, training courses, and scientific missions. Examples of the transmission of critical information from the ERP to appreciative end users are highlighted in Chapter 4.

APPROPRIATENESS OF ERP MISSION

The mission of the ERP, as described above, is appropriate for a federal

earth-science agency. The role of the program relative to other federal energy agencies is clearly defined. In contrast to programs in other energy agencies, the ERP is focused primarily on the initial stages in the supply process: the development of resource information that can then be used to make estimates of reserves. [By definition, "resources" are naturally occurring substances of potential profit that may someday be used under specified technological and socioeconomic conditions, whereas "reserves" are known and identified quantities of resources that can be exploited profitably with existing technology under prevailing economic and legal conditions (de Souza, 1990, p. 473).] As a result of this focus, the ERP complements the programs in other agencies, and its responsibilities are consistent with its mission (see Sidebar 2.1).

The ERP concerns itself with estimates of identified and inferred physical resources. The Bureau of Land Management (BLM) and the U.S. Forest Service

SIDEBAR 2.1
Roles of Principal Federal "Energy" Agencies

Department of the Interior

USGS. The USGS focus is on onshore (and state offshore) U.S. energy resources (pre-development) and the geologic controls of resource abundance, quality, and location. It produces objective, scientific, non-advocacy information for informed decisionmaking.

Minerals Management Service. The MMS is responsible for managing energy and mineral resources of federal offshore areas. Its role includes assessing undiscovered oil and gas resources, evaluating oil and gas potential of lease tracts, and conducting lease sales in the federal offshore.

Bureau of Land Management and Department of Agriculture's Forest Service. These agencies are responsible for managing energy and mineral resources of federal onshore areas. Their roles include evaluating oil and gas potential of lease tracts. BLM conducts lease sales on federal lands.

Department of Energy

The focus of the largest and most comprehensive of the federal agencies that address energy issues is on energy reserves (post-development) and technologies for enhanced recovery and efficient use. DOE advocates energy policy to reduce the nation's vulnerability to disruptions of energy supply.

Energy Information Administration. EIA's focus is on data and statistics regarding energy reserves, production, and consumption. It collects, analyzes, and distributes data provided by energy producers, and predicts trends in energy production and use.

Source: USGS, 1997c, p. 10.

(USFS) then use this resource information as they determine areas for lease sales and other land management activities for onshore oil, gas, and coal resources. The Energy Information Administration (EIA) of the Department of Energy (DOE) depends on ERP geological expertise and assessments to forecast demonstrated and recoverable reserves. The Minerals Management Service (MMS) is responsible for conventional hydrocarbon resources in the federal offshore. It conducts assessments of undiscovered and undeveloped conventional oil and gas resources in the federal offshore, and these assessments are incorporated into the national assessments produced by the USGS ERP. (USGS investigations of methane hydrate resources—a potentially important unconventional natural gas resource—have included the federal offshore.) *The panel urges the ERP to maintain close collaboration and cooperation with the MMS to ensure that effective and consistent assessment techniques are shared between the two groups.* The objective of a close association between the ERP and MMS is to provide stakeholders with consistent and complementary onshore and offshore energy resource assessments. Consistent resource assessments would have greater value than assessments made with very different methods.

The panel concludes that the scientific mission of the ERP is fully appropriate for a federal earth-science agency. Furthermore, *the panel concludes that the role of the ERP is well defined with respect to other federal agencies.* The ERP is the sole provider of onshore fossil energy resource assessments within the federal government. The ERP provides technical expertise and information not available elsewhere to a variety of federal agencies and to the private sector. If this expertise and information were not available—for example, to BLM and EIA—similar expertise would have to be developed within these agencies. Thus, the ERP effort complements but does not duplicate the work of related federal agencies.

3

Program Balance

CURRENT ERP PROGRAM

Given the variety of energy resources and the variety of aspects that are important, the development of an energy resource program requires strategic decisions about content and emphasis. Coal, oil, and natural gas are the most important fuels for the present and will remain important fuels for decades to come (PCAST, 1997). Hence, the current ERP focuses primarily on these energy sources in three subprograms, as described briefly below.

National Oil and Gas Resource Investigations and Assessments. The primary purpose of this subprogram is to provide assessments to enable stewardship of the nation's resource endowment onshore and in state waters. This subprogram also conducts research on geologic framework and process studies that contributes to a broad geologic understanding of the resources present in sedimentary basins. The domestic oil and gas program also provides basic research in support of its resource assessments, and it provides the expertise and information needed to assess environmental impacts of the production of oil and gas.

National Coal Resource Investigations and Assessments. This subprogram is charged to assess national and global coal resources: quantity, quality, geologic distribution, availability, and recoverability. In addition, it has the responsibility to provide the expertise and information needed to assess the environmental impacts of the extraction and use of coal resources. Like the oil and natural gas element, the domestic coal subprogram is also charged to provide basic research

in support of both its resource and its environmental assessments through the study of geologic framework and processes.

World Energy Investigations and Assessments. World oil and natural gas resources are critical to the economic well-being of the United States. With only 5 percent of the world's identified oil reserves and 7 percent of the identified natural gas reserves in this country, there is substantial national benefit from ERP world oil and natural gas assessments. The ERP's world oil and gas assessment products include assessments by region, by continent, by country, and by basin; regional summaries (e.g., Africa CD-ROM); and digital maps and data. In addition to the focus on assessments, the subprogram also conducts petroleum systems framework and process studies, economic and availability studies because of geopolitical uncertainties, and some environmental studies. The ERP's international coal work is primarily a reimbursable activity and, therefore, restricted to projects of opportunity (e.g., U.S. Agency for International Development Armenia coal resources). Examples of outcomes of ERP's world energy research include use by the Central Intelligence Agency (CIA) of oil and gas assessments for the analysis of future political hot spots and use by the EIA of energy results for modeling global carbon emissions. This ERP subprogram also serves to enhance the assessment capabilities of foreign geologists.

ENERGY SUPPLY OPTIONS: A PORTFOLIO APPROACH

The emphasis on oil, gas, and coal is appropriate given their current importance to the U.S. primary energy supply, but other geologically based energy resources also offer potential for future use. Two recent studies of U.S. energy policy (PCAST, 1997; SEAB, 1995) recommend strongly that federal agencies concerned with energy adopt a robust portfolio approach to energy research and development activities. The same idea was expressed clearly in a 1988 NRC report by the Committee Advisory to the U.S. Geological Survey (NRC, 1988). As the President's Council of Advisors on Science and Technology (PCAST, 1997) put it:

> The challenge to energy research and development . . . is to provide additional energy-supply and energy-efficiency options that can reduce U.S. dependence on the imported oil supplies that are subject to sharp price increases, to develop options that can shrink the cost of reducing emissions from fossil fuels (which includes the possibility of replacing some fossil fuel use with nonfossil options less costly than those that would be available for this purpose today), and more generally to develop options that can "backstop" existing energy-supply technologies—that is, provide the possibility of substituting for them if their costs escalate beyond the cost of the backstop option. (p. 1-7)

The same report recommended:

> The portfolio should include a diversified set of R&D projects with a balance across technologies, time frames, and degrees of technical risk. Such diversity hedges against major failures and changing assumptions and external conditions, including a range of environmental scenarios. (p. 7-1)

A similar rationale can be applied to the primary energy resource options considered under the ERP. Because it is impossible for policymakers to foresee how economic and environmental pressures will interact in the decades to come, the only prudent course is to develop the best available scientific evidence concerning primary energy supply options.

The remainder of this chapter reviews the issues of balance among the energy sources, between research and assessment, and between resource and environmental issues in the context of a portfolio of energy supply options. In addition, the panel considers the related issues of the balance of research and service and the multiple audiences the ERP must serve.

NEED FOR A BALANCED ENERGY PORTFOLIO

The ERP, which conducts research that uses basic science to provide information for policy decisions, needs to be shielded from transitory shifts in public interest, emphasis, and fashion regarding energy resources. At the same time, it has to be responsive to potentially enduring changes in national energy resource priorities that would call for a major shift in the program's array of activities. This obligation requires continuing evaluation of the deployment of ERP resources among energy sources.

The current ERP recognizes the reality of a U.S. primary energy mix, heavily oriented to fossil fuels. Figure 3.1 shows the distribution of budgets among the three current subprograms—oil and gas, coal, and world energy—as well as three past subprograms. The coal subprogram involves about half of the funding, the oil and gas subprogram about 40 percent, and the world energy effort about 10 percent. This resource allocation will undoubtedly shift over time as the cycle of resource assessments in each area is completed. *In addition, the panel believes that a continuing examination of the research and assessment portfolio should be undertaken.* The objective of this examination is not to achieve an exact balance in the level of effort among particular energy sources at any one time. Instead, it is more appropriate to talk in terms of a mix of program elements that provide unbiased, science-based estimates of future resource availability across the spectrum of energy resources. *Resource assessments should be available for very heavy oil, oil shale and carbonaceous shales, geothermal resources, and uranium as well as conventional oil and gas, coal, coalbed methane, and methane hydrates, although the depth of the assessment will vary by energy source, given variable probabilities of economic use on equally variable time scales.* Many of these energy resources exist on federal lands, another reason to make

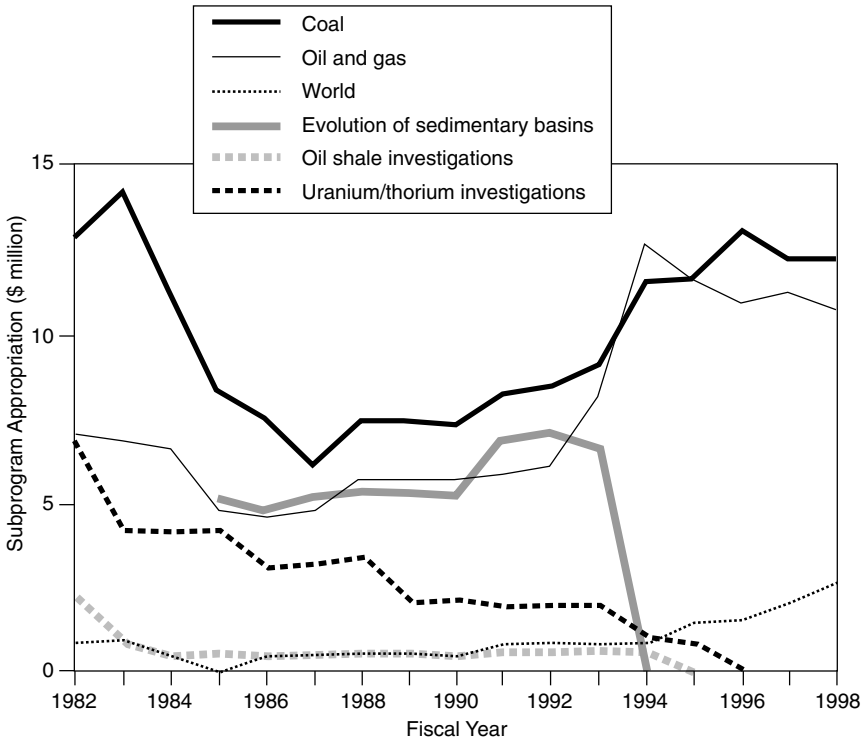


FIGURE 3.1. ERP subprogram funding, 1982-1998. Source: Data provided by USGS.

sure that appropriate scientific understanding is available as these assets are catalogued.

Although the ERP now deals with hydrocarbons and coal, an opportunity exists to play a significant role in other energy resources as the federal government reevaluates its energy policies. Major challenges to the United States include how to maintain energy security in a global energy economy directed by market forces; how to respond to concerns about greenhouse gas emissions and climate change; how to successfully harness competition in domestic electricity markets; and how to take advantage of significant advances in alternate fuels technologies. At a time when the United States has the opportunity to develop responses to the challenges of its energy future, *the panel believes that the ERP should contribute its expertise on the geological settings of energy resources to the lively debate that is certain to continue.*

The panel is fully aware that this broadening of the ERP's portfolio would require reallocation of existing resources and, quite possibly, new resources.

Also, it is clear that some of these energy sources will involve collaboration with other programs within and outside the USGS. Geothermal energy is currently considered in the Volcano Hazards Program, for example. *Furthermore, the spectrum of energy sources should be studied in projects that span a range of research time frames*. A careful planning process is needed to craft a multiyear research and assessment strategy that develops appropriate priorities for the broadened research agenda.

Instructive examples of energy resources whose prospective importance may grow as perceptions of environmental trade-offs change are uranium, coalbed methane, and methane hydrates:

- Nuclear power is a small but significant element in the energy portfolio of the United States, but it could be used to reduce growth in greenhouse gases and other emissions from the electricity-generating sector. Expansion of the use of nuclear energy rekindles worry about the adequacy of domestic sources of uranium to meet increased demand, an issue of resource assessment. Because concerns about waste disposal, fuel reprocessing, cost, reactor safety, and nuclear proliferation are likely to limit such expansion in the near term, the appropriate level of effort in this area is likely to be modest, but policymakers should be aware of the potential. Existing data sets on uranium and thorium should remain accessible.
- Coalbed methane now accounts for about 5 percent of natural gas production in the United States (EIA,1997). Because coalbed methane is a potent greenhouse gas, an evaluation of the potential for capturing, rather than releasing, methane is of interest to the current debate on global warming. However, questions remain about an evaluation of this resource, with its geographically dispersed incidence and highly variable characteristics. For the federal government overall, coalbed methane funding is small—barely $5 million a year—and a large part of this total is directed to coal mine safety rather than methane capture (EIA, 1997). There is no designated agency in which coalbed methane research and assessment are concentrated. Within the ERP, there is one major coalbed methane project, funded at about $750,000 per year. In addition, ERP has several small collaborative projects with the BLM and the States of Wyoming and Alaska. Coalbed methane resource assessment requires the close cooperation of the oil and gas and the coal subprograms, and careful consideration of the impacts of coalbed methane extraction on the future development of coal resources.
- Seismic surveys and scientific drilling offshore indicate that large quantities of methane may be stored in ocean sediments in icelike structures known as hydrates. Research to understand the occurrence of methane hydrates is now included in the Marine Geology Program. Continuing collaboration between the ERP and the existing program will improve the quality of future estimates. There is also significant activity on hydrates in other parts of the federal government, particularly DOE and the Navy. The MMS has access to seismic data and drill-

ing records that could be used in future assessments. The recent PCAST (1997) report recommends, for example, that a major research program involving the USGS, MMS, Environmental Protection Agency (EPA), and Department of the Navy be developed to advance understanding of the potential of methane hydrates worldwide (see DOE, 1998b).

A related opportunity exists in the area of CO_2 sequestration. The PCAST report notes that fossil fuels will be essential in the next century, even if concerns about CO_2 emissions assume greater importance following the results of the Kyoto conference in 1997. As a result, PCAST argued that a significant research effort on the disposal of CO_2 (known as CO_2 sequestration) should be developed to provide disposal options should they be required. Three of the options proposed relate to USGS activities. One is the injection of CO_2 into oil and gas reservoirs. A second is the injection of CO_2 into deep saline aquifers. The third is the storage of CO_2 in coal seams (with appropriate attention to future mineability). Carbon dioxide adsorbs quite strongly on coal surfaces, replacing adsorbed methane. Hence, a coalbed methane research and assessment program could mesh nicely with work on CO_2 sequestration. The PCAST proposal for CO_2 sequestration research offers, therefore, an opportunity for the ERP to collaborate in a program of potential long-term significance.

The importance of the portfolio approach to energy supply options discussed in this section is a theme that runs through several recent evaluations of federal energy policy. It is an approach that the panel believes would be quite useful as a way to think about future activities of the ERP. **Accordingly, the panel recommends that the ERP portfolio be broadened to include geologically based energy resources beyond oil, gas, and coal, and that the ERP develop priorities for long-term balance among the various energy resources as part of the implementation of its strategic plan** called for in Chapter 2. It is clear that this planning effort will require substantive communication with other programs within the USGS and beyond its borders as well. Thus, the evolution of priorities within the ERP should be developed in consultation with DOE, the White House Office of Science and Technology Policy, congressional staff, states, federal land managers, relevant private-sector groups, and nonprofit organizations. The result will be a portfolio of research and assessment activities appropriate to ERP expertise with broad support inside and outside the USGS.

OTHER ISSUES OF BALANCE

Research Versus Assessment Versus Service: False Distinctions

The ERP is in a challenging period of transition as it strives to meet the needs of its diverse audiences. Among the challenges facing the ERP are the dynamic evolution of a unique fossil-energy program; the pressure to find ways

to work through and with other organizations to leverage limited resources; the obligation to produce, maintain, and distribute data products and information for a broad range of users; and the problem of maintaining high-level, specialized expertise. However, one of the most important challenges of all is the need to nurture a program of basic research on energy resources in an environment of short-term justification and fiscal pressures.

The balance between research, assessment, and service is an issue that pervades the GD and all geologic research within the USGS. This nettlesome issue manifests itself in the ERP in terms of research and assessment. The principal function of the USGS is to bring earth science to the service of society in a changing world. Research is one of the most important tools that makes this possible. However, some individuals within the USGS regard service as the price scientists pay for being allowed to do research, whereas others consider service a primary activity. Information provided to the panel at its meetings and in supporting documents indicates that the most visible, praised, and widely used products of the ERP are the assessments and the supporting geologic databases, such as those on oil and gas fields on CD-ROMs. The panel did not document quantitatively the use of the results of research-based geologic framework studies outside the USGS. However, written statements to the panel indicate that these studies are valuable to outside users. Moreover, these studies contribute significantly to knowledge that is useful in resource assessment activities within the ERP.

The panel agrees that basic research on energy resources is one of three essential functions of an energy resource program appropriate for the ERP. The other functions are to provide credible, impartial scientific information related to energy resources and to provide scientific advice and analysis as requested by other federal agencies, such as DOE and EPA. An NRC report *Mineral Resources and Society: A Review of the U.S. Geological Survey's Mineral Resource Surveys Program Plan* (NRC, 1996) points out, correctly in the view of the panel, that basic research is the "basis on which the other two functions, advice and information, are founded. In addition, basic research addresses the strategic needs of a nation by investigating resources that are uneconomic today but are technically recoverable if needed in the event of a crisis" (NRC, 1996, p. 21). The report goes on to state that "all three functions are considered legitimate responsibilities for a federal agency, such as the USGS" (p. 21) and that the "balance among these functions will depend on user requirements and will vary over time" (p. 22).

The panel also believes that the question of research versus assessment is a false dichotomy. High-quality resource assessments involve high-quality scientific research. At the very least, the debate about the preeminence of either research or service is counterproductive. Research and service are inseparable. The quality and usefulness of the resource assessments depend on the fundamental understandings of hydrocarbon and coal occurrence gained through basin, strati-

graphic, and structural studies or research. In turn, most of the data necessary to gain these understandings come from the resource assessment process. The variety of interests of the customers for ERP products also argues for a mix of assessment and research products. Understanding facies relationships and fluid movement in sedimentary basins has applications beyond coal and hydrocarbon assessments and provides justification for research efforts that go beyond the ERP. **The panel recommends that the ERP in particular and the USGS as a whole maintain the strong research and knowledge base that is essential to the provision of services the ERP is uniquely qualified to provide.** Increased demand for USGS information and expertise by the DOI and other agency programs is a healthy sign. It suggests a greater recognition of the need for geoscience contributions that support decisionmaking on energy resource issues.

The professional staff of the ERP recognizes that USGS scientists have been expected to engage in both research and service. There is no reason for this expectation to change in the future. The appropriate mix should be the product of the strategic planning process rather than a preconceived basis for the planning.

Environmental Research: How Modest or Large an Effort to Pursue?

The environmental component of the ERP consists chiefly of data gathered as part of the assessment process. Information gathered about coal composition, for example, includes sulfur content, which is helpful in understanding and predicting the need for acid-mine drainage treatment and in selecting fuel sources that will minimize sulfur dioxide emissions. Stratigraphic and basin studies develop information about overburden that is useful in planning mined land reclamation. The produced water project within the oil and gas subprogram gathers data about produced water quantity and chemistry, information that can be useful in the assessment of environmental impacts of water disposal.

All of the ERP subprograms list environmental studies as part of their mission, but the ERP lacks a strategy to implement an environmental focus. Clearly, environmental problems connected with resource extraction and use are a national concern. It is currently not feasible for the ERP to put a price tag on potential environmental impacts because such an evaluation is outside the program's capabilities. *Accordingly, the ERP should consider the extent to which, in its assessment of a given resource play, the identification of geologically based environmental factors should be viewed as integral to the assessment, so that those equipped to deal with environmental impacts and related economic impacts would have a basis for incorporating such information.* The ERP is a program whose traditional emphasis is geology, not economics and other social sciences. Hence the ERP should adopt a partnership approach in its environmental work. This strategy would require a close and continuing dialogue between the ERP and those agencies and groups that deal with environmental impacts of

resource extraction and use. The ERP needs to know what its clients want, and its clients need to know what the ERP can provide.

Thus, rather than broadening the scope of the environmental effort, the ERP should conduct a thorough assessment of the types of data now being collected that are useful in environmental applications and of what additional data could be collected that would have environmental applications. Without doubt, the ERP's data have value to its stakeholders; however, developing the full environmental and economic significance of these data would draw on costly and scarce resources. Consequently, there is, at the very least, an implicit balancing act that weighs the costs and benefits of information. Facing up to benefit-cost dilemmas is far from trivial in the light of budget constraints and possible changes in the nation's energy priorities. The proportion of the ERP devoted to environmental issues is small but appropriately limited to the collection of data needed for subsequent environmental and economic work. *Environmental and economic issues are important ones, but they should be addressed by appropriate collaborations and partnerships as a way of expanding the ERP expertise for the benefit of all governmental decisionmaking related to research extraction and national energy needs.*

The ERP's Audiences

The activities of the ERP are shaped to an important extent by the needs of user groups that depend on its research and assessments. The range of organizations and interested stakeholders includes the following:

- other programs and divisions within the USGS;
- other agencies within DOI, such as BLM, the National Park Service (NPS), MMS, and BIA;
- Congress;
- other federal agencies, principally DOE, USFS, and EPA;
- local and state government agencies, particularly state geological surveys, as well as state oil and gas boards;
- tribal organizations, such as the Council of Energy Resource Tribes;
- the education community, including faculty and students at universities, colleges, and K-12 schools;
- professional societies, such as the American Association of Petroleum Geologists, American Geophysical Union, Geological Society of America, and Society of Exploration Geophysicists;
- the private sector, including corporations and other businesses that explore for, produce, and consume energy resources;
- nonprofit organizations, such as the World Resources Institute and Resources for the Future;

- foreign governments, international organizations, and other institutions abroad with interests in energy resources; and
- the general public.

DOI management believes that a top priority of the ERP is to serve the science needs of other DOI bureaus. This belief is consistent with the view that the primary function of the USGS is to serve the DOI as its science arm. There is no question that the ERP must well serve other DOI bureaus such as the BLM, NPS, BIA, and MMS. Nonetheless, the ERP also has significant responsibilities that support other government agencies, industry, academic institutions, and the public. Because the USGS is a national resource, these responsibilities should not be ignored. The assessment of oil and gas resources for the Arctic National Wildlife Refuge (ANWR; see Sidebar 3.1) is an example of a USGS product that is of interest to a wide range of audiences. Interest in and concern about earth processes, resources, and environments are reaching more segments of the population, and the ERP's expertise should feed this interest. *The panel urges the ERP to take all possible steps to make its data and expertise available to its multiple audiences, both inside and outside the DOI.*

Domestic Versus International Energy Assessments

Today the energy market is a global market. As indicated previously, the fraction of U.S. oil that is imported will grow substantially over the next 20 years. Increasing dependence on energy resource supplies from outside the country, in an era of rapidly increasing world energy use caused by a combination of population growth and economic development, calls for a clear understanding of the energy resource endowments of nations that supply the United States with resources. Information about the energy resources of other nations has been gathered by the former U.S. Bureau of Mines, DOE, USGS, and CIA and, at varying levels of detail, by other domestic and foreign public and private organizations. Information provided by these organizations includes reserves, production, consumption, exports, imports, and resource distribution.

Within the context of the USGS interest in international geoscience, the ERP has developed a world energy research subprogram that presently focuses on the assessment of world oil and gas resources. Approximately $2.4 million of the current $25 million annual budget is expended on the activities of this subprogram. The subprogram involves many partners, among them DOE, the Department of Defense (DOD), CIA, industry, and foreign governments. Because the balance of domestic and international energy will continue to shift in the decades to come, and because the prices of energy sources will affect crucially what other energy sources are viable, *the panel encourages the ERP to evaluate whether the effort on world energy resource assessment and supporting research*

SIDEBAR 3.1
A Question of Balance: The Arctic National Wildlife Refuge

Balance issues within the ERP are generally not highly political or newsworthy. However, there are specific exceptions when party or government branch differences mesh with public awareness and concern. The development of oil resources in the 1002 area of the Arctic National Wildlife Refuge, which has been a subject of environmental debate for years, is an issue that meets all the criteria for sensitivity and raises balance issues.

Administrations and Congress, federal agencies, state agencies, the oil and gas industry, and a wide variety of public interest groups have continuously been at odds over the development of this area on the northern edge of Alaska. The reason for the interest in its development, and the starting point for the debate, is the magnitude of the resource available for development. The USGS believes that its role as the provider of objective resource assessment information calls for it to develop the most sophisticated and reliable resource estimates possible. This led to a three-year effort involving approximately 40 professionals from the USGS, with collaboration from other experts inside and outside government. The new estimate was larger than the USGS estimate in 1995.

Criticism of this effort came from inside and outside the federal government. DOI officials and some members of Congress questioned why such a large effort was undertaken at a time when there were no foreseeable plans to reopen the issue of ANWR development. Others suggested that providing resource information that encourages interest in development is inappropriate for an agency (i.e., DOI) whose primary role is perceived to be a steward of the land and its aesthetic and living resources. This leads to questions of balance. Should significant resource assessment efforts be put into an area that the current administration does not intend to offer for development? Does the interest of the congressional committees in objective resource estimates outweigh this? Is a balance between current policies and long-term need to know appropriate, or should the balance always tilt in favor of developing objective information on a schedule not influenced by the present political climate? Should any DOI analysis about an area's resources be balanced with an assessment of the environmental consequences of developing them? Is it the duty of the USGS to provide this balanced assessment?

should be increased above present levels. This evaluation should be performed as the strategic planning effort recommended in Chapter 2 is implemented.

SUMMARY

The panel recommends that the ERP adopt a portfolio approach in its work on geologically related energy sources. This approach will help the ERP develop its strategic plan to prioritize its work among energy sources and to

determine what level of effort is appropriate in environmental aspects of energy. It also will help the ERP to identify the areas that require continuing effort in basic geological research and to identify its needs for professional expertise across the portfolio range. Successful ERP portfolio development will have a significant and positive impact on the energy future of the United States.

4

Future Program Effectiveness and Challenges

Earlier chapters discuss the extent to which the ERP has, in broad programmatic outline, addressed the questions of balance that form a major element in the charge directed to the panel. There remains the task of evaluating the ERP's work in its operational aspects. The panel determined that such an evaluation is best conducted in terms of certain of the ERP's specific subprograms. Accordingly, this chapter reviews critically and in some detail ERP's important subprograms and suggests opportunities for improvements. The critique is followed by a discussion of crosscutting issues of data and information management, communications, and human resources.

The current trajectory of rising domestic energy consumption is projected to continue over the next 20 years. Domestic resources of natural gas and coal are ample to meet this anticipated growing demand, but oil production is expected to continue to decline (Figure 1.2). Oil imports now exceed domestic production despite the fact that a substantial volume of technically recoverable mobile oil—a volume four times that of proved domestic reserves—remains in the nation's mature reservoirs and fields. Superimposed on these natural resource life-cycle evolutionary events are external forces driven by political and environmental concerns such as global climate change. Thus, in the face of the challenge of an expanding domestic and global appetite for energy, increasing dependence on imported oil, and sharply heightened awareness of the need for cleaner energy supply, the ERP should continue to meet the challenge of providing the necessary scientific information for policymakers to use in making informed decisions regarding the wise use of the nation's energy resources, federal land use, and geopolitical relations. Because a number of energy and environmental priorities

may be ephemeral, it is essential that the longer-range needs of the nation remain paramount in the operations of the ERP.

Over the past five years the ERP has undergone a substantial and successful metamorphosis. The new ERP program has established a well-deserved reputation for solid, scientifically based assessments, particularly of this nation's oil and gas resources. The panel recognizes that the broad acceptance of the 1995 oil and gas assessment is in large part due to inclusion by the ERP of states and private industry into the process—a substantial and well-advised departure from earlier assessments. This process of reinvention is the hallmark of an innovative USGS energy program that is evolving to meet the changing needs of the nation.

PROGRAM EFFECTIVENESS

Domestic Oil and Gas Subprogram

The key role of the oil and gas subprogram is the comprehensive scientific assessment of the nation's undiscovered oil and gas resource endowment. This mission is supported by a parallel research program on the geologic framework of hydrocarbon occurrence and the geologic processes that form oil and gas resources. The oil and gas subprogram has achieved considerable success in its recent assessments of domestic oil and gas resources. Numerous stakeholders praised the assessments and their supporting research programs.

The 1995 national oil and gas resource assessment went beyond conventional resources and included the development of new methodologies to assess unconventional resources—particularly the major gas basins, many of which are on public lands. The elucidation of resource issues such as oil and gas reserve growth, the natural gas resource endowment, and the development of methods for assessing coalbed methane resources are important contributions of the ERP to the creation of a better evaluation of the nation's energy resources. The preliminary assessment of methane hydrate gas resources is another important contribution. Future refinements may be contingent on close collaboration with the MMS, which has access to the proprietory seismic reflection data and borehole data that may support a more precise assessment in the offshore. By moving beyond conventional oil and gas resources, even though the methodologies are new and, in some cases, still developing, the ERP is providing leadership for the nation. Results of the recent assessment are now being made available to the ERP's constituents in a timely manner (see, for example, Sidebar 4.1) through well-publicized and well-attended workshops and presentations; through the release of maps, charts, and reports; and through publication in professional journals and books. The ERP has also made good use of advanced forms of information dissemination. The results of the most recent oil and gas assessment have been widely disseminated through the release of a set of CD-ROMs at no charge to the public. More than 10,000 CD-ROMs were requested by the pro-

SIDEBAR 4.1
1995 National Assessment of Oil and Gas Resources: Two Applications

1. Federal and state agencies and energy industries continue to use the ERP's 1995 national assessment of oil and gas resources and its accompanying 1996 economic analysis as the standard for national oil and gas resource evaluations and land management and energy policy decisions. In 1997, DOI evaluated the National Petroleum Reserve in Alaska (NPRA) land management options based on USGS assessment results from the North Slope of Alaska—an area believed to have the greatest oil potential of any onshore region in the United States. The resulting DOI document, released in the fall of 1997, summarizes oil and gas resource potential and outlines alternatives for making the area available for exploration.

2. In 1998, the NPS requested that the USGS conduct a specific oil and gas resource assessment of the Padre Island National Seashore. Results included in the 1995 national assessment were used as a basis for assessing the resources of Padre Island, and a report summarizing the resource potential of the National Seashore was delivered to NPS in May 1998. The NPS will use the results to generate a resource management plan for Padre Island. The NPS is so pleased with the report that it has asked the ERP to conduct similar analyses in two other national parks during the coming fiscal year.

gram's constituencies. Users included federal agencies, states, and local jurisdictions; industry, especially the independents who drill most of the exploratory wells in the country; the financial community (often called on to finance wildcat exploration); and members of the general public. The panel commends the ERP for this innovative approach to data release. Supporting research in the domestic oil and gas program has clearly been guided by the needs of the national assessment program. Review of publications relevant to the assessments indicates that the research meets a high standard.

Coal Resources Subprogram

The current national coal resource assessment is early in its life cycle. In fact, it may be appropriate to think of the coal effort as being in a stage similar to that of the oil and gas program a decade ago. Like the domestic oil and gas subprogram, the primary role of the coal resources subprogram is the assessment of the nation's coal resource endowment. For the purposes of the national coal resource assessment, the nation has been divided into five principal coal-producing regions: (1) the northern and central Appalachians, (2) the Illinois Basin, (3) the Gulf of Mexico coastal plain, (4) the Tertiary age coals of Wyoming and

the Northern Great Plains, and (5) the Colorado Plateau. In 1996, these five regions accounted for more than 95 percent of all the coal produced in the United States. Not all coal resources in these regions are being evaluated, but the more significant beds and zones are mapped, and all data are stored in a Geographic Information Systems (GIS) database. These beds and zones were selected on the basis of current production and potential for production in the near future. In addition, input was sought from a spectrum of potential clients, including state geological surveys in coal-producing regions, other federal agencies (especially those with land management responsibilities), and industry.

The panel believes that the national coal assessment should be comprehensive. *The ERP should include less well defined resources with correspondingly higher uncertainties, as well as coal deposits currently being exploited about which there is considerable information.* Althought it may make sense for most of the effort to focus on resources that have near-term economic significance, *the panel believes that some effort to assess resources with potential longer-term significance should be included. Supporting research in the coal subprogram should ensure that an appropriate effort is undertaken on less studied and poorly characterized coal resources such as the deep lignites of the Gulf Coast Basin.* These lignites are important, not only as a coal resource, but also because they could be a source of coalbed methane and may be a potential repository for the sequestration of CO_2. It is the panel's view that scientists in the coal subprogram and in the oil and gas subprogram should work closely together in these two related resource areas by taking an integrated basin analysis approach to the assessment and study of coal, oil, and gas resources.

In the panel's view, the national coal assessment should:

- *identify and clearly state priorities (e.g., geographic locations, seam depth) of a comprehensive nationwide coal resource assessment;*
- *identify and clearly state the assumptions of the framework of a comprehensive coal resource assessment;*
- *identify the portions of the resource endowment that are not included in the study and explain why;*
- *explain clearly the limitations, qualifications, and restrictions of the data used in the assessment;*
- *plan for evaluation of the remaining resource endowment as data become available or as resources become economically viable; and*
- *design a program of supporting research that adequately focuses on coal resources in basins that have not been extensively studied and that uses integrated, basin-scale studies incorporating modern approaches of sedimentology and sequence and seismic stratigraphy.*

This approach should result in a national assessment that includes an appropriate and broad spectrum of the coal resource endowment that can be ex-

ploited on various time scales. The process should include active input from industry and the states. State involvement in the current coal efforts has already yielded considerable benefit, as shown in Sidebar 4.2.

Several databases on coal parameters that are maintained by the ERP are useful and easily accessible to customers (see Sidebar 4.3). However, they contain only those data available to the ERP. Compared to oil and gas, the availability of public data for coal is more restricted. By law, oil and gas drilling logs and records become the property of appropriate state and/or federal oversite agencies and are consequently included in the ERP oil and gas investigations and assessements. In the case of coal, only drill information from reserves on state or federal lands must be supplied to an oversight agency. The result is that data on some coal reserves are known only to the coal companies and are unavailable to the ERP. Further, data available to the USGS exist in many forms. For example, some information is on a "raw" coal basis, some is on a raw coal basis with rock partings removed, and still other information is on a "washed" coal basis.

As a result, USGS resource numbers often need additional engineering analysis to determine the quality and quantity of coal that can be produced from a given area. This engineering analysis requires knowledge of various factors that affect the cost of production as well as the percentage of a reserve base that can be recovered. These factors run the gamut and include labor quality; mining technology; and local coal quality characteristics, chemistry, and variability. *The panel suggests that the ERP should state clearly the limitations on the use of the coal resource data to guard against misuse or misinterpretation when its national coal assessment is prepared.*

Closer linkages between the coal subprogram and industry, as suggested by the panel, would have several benefits. Such an alliance would facilitate rapid

SIDEBAR 4.2
Coal Reserves and Collaboration between the USGS and Kentucky

The Kentucky Geological Survey (KGS) released findings on Kentucky coal reserves that were discounted by the Kentucky Coal Association. The USGS helped facilitate discussions among the KGS and members of the Center for Energy and Economic Development (CEED) and the Kentucky Coal Association to demonstrate that the KGS methodology was detailed and sound. Much of the KGS data had been collected under USGS-funded projects, and corroboration of the KGS study by the USGS helped resolve the controversy, allowing Kentucky state planners as well as industry leaders to begin planning for changes within the local coal-based economy.

SIDEBAR 4.3
National Coal Quality Inventory

- Regulatory agencies (e.g., EPA), electric utilities, and industry use the database of coal attributes as the primary source of independent scientific information for estimating the amounts of hazardous air pollutants and trace elements emitted from coal-bearing power plants as well as for development of regulatory policy for the nation. During FY 1997, the EPA released recommendations regarding air emissions from coal-fired power plants. They were based in part on data obtained from the USGS National Coal Quality Inventory.
- West Virginia's Department of Environmental Protection is utilizing the USGS Coal Quality Database for a new interactive GIS site on the World Wide Web. The web site provides the capability to display GIS maps of coal quality with up to nine different parameters (e.g., British thermal units per pound, sulfur content, ash content) from 77 coalbeds and 10 coal formations in West Virginia. The GIS maps are used by federal and state regulators, electric utilities, and the coal mining industry to determine the locations of coal resources that are in compliance with environmental regulations or that can be treated with appropriate coal cleaning technology prior to use to meet compliance.

review of the ERP's national coal resource assessment, could help identify areas where questions remain, and might lead to the release of additional proprietary data to the ERP by the coal companies. Furthermore, active cooperation will help identify the restrictions and limitations of the data, thereby encouraging more appropriate use of the data by all interested parties.

World Energy Subprogram

Given the role of the United States in the global energy economy, access to information about the world's energy resource endowment is critical for national policy making. Despite modest funding for this subprogram, it has produced valuable assessments of world energy resources dating back to the first USGS analysis completed in 1965. With global demand for oil projected to increase 25 percent over 1995 levels by 2010 (PCAST, 1997), it will be increasingly important for policymakers in the United States to understand how and from where this demand will be fulfilled.

Four previous USGS global oil and gas assessments were prepared from 1984 to 1994 by the same core group of geologists using a consistent methodology (USGS, 1997d). Despite this continuity, differences among the four assessments can be attributed largely to an evolving understanding of world oil and gas resources. The current assessment methodology is more rigorous and data intensive. Almost 1,000 petroleum provinces worldwide containing more than 32,500

oil and gas fields have been identified and ranked. These assessments are well supported by parallel research projects in areas of strategic interest such as the Middle East and the countries of the former Soviet Union. The audiences for information developed by the subprogram are diverse and include industry (in support of its exploration programs), policymakers, the investment community, DOD, and the countries under study. The assessment strategy being followed is patterned after the well-tested domestic energy assessment approach, although the variable quality and availability of data inevitably involve greater uncertainty.

The panel believes that consumers of the world energy subprogram's data are well satisfied by the ERP's products. Energy companies are eager for the information generated by the team, indicating that the products have high value. The world assessment effort appears to be receiving favorable attention from federal partners as well, indicating that the subprogram provides a product that meets a critical need.

CROSSCUTTING ISSUES

The scientific staff of the ERP must face several key challenges if it is to maximize the future effectiveness of its efforts. Among them are (1) the management of large amounts of data in many formats, (2) the establishment of efficient communications within the USGS and with outside organizations, and (3) the development of a strategy to maintain and renew the scientific expertise that supports the ERP's resource portfolio.

Data and Information Management

The mission of the USGS is to provide "the Nation with reliable, impartial information to describe and understand the Earth" (USGS, 1997a, p.1). To fulfill this mission, it is imperative to have an organized and reliable system for storing and retrieving such information. Traditionally, information was organized, catalogued, archived, maintained, and disseminated with paper-based information management systems. Over the past two decades, the USGS has appropriately shifted to electronic data management and dissemination, including putting a large amount of material on-line for Internet access and publishing CD-ROMs instead of paper products. USGS information policies, standards, and practices are (and must be) consistent with various federal information mandates, laws governing technology transfer, and the North America Resource Assessment (NARA) archival guidelines.

A stated goal of the ERP is to make most of its public domain data and GIS coverages accessible and searchable through the Internet. The ERP intends to integrate advanced digital capabilities into its program, in order to provide rapid and accurate response capability for its resource portfolio. This effort involves two complementary initiatives.

First, data—including older, paper-based data sets—are being stored in electronic formats. The ERP is a custodian for several large searchable digital databases, and it contributes to and/or utilizes information from searchable digital databases maintained by other government programs and agencies. In addition, other collections of energy resource-related information have been archived electronically, some of which will be entered into a searchable format. These databases are described in Sidebar 4.4.

The second initiative of the current ERP data management strategy is to design and build a software program for querying and displaying digital data geospatially (e.g., within a GIS). The "front-end" software system being built by the ERP is named the Decision Support System (DSS). It is intended to make available via the Internet map coverages and data sets that are important for land management and environmental issue strategies related to energy resources. It would allow for user-driven GIS mapping and user-defined queries of coverages and data sets. The DSS will require digital analytical data (see Sidebar 4.4), as well as digitized maps; aerial photos and satellite images; surface and subsurface land ownership data; land-use coverage; biological information such as endangered species habitats; and maps of locations of railroads, pipelines, and major highways. The DSS program currently exists as a prototype, with a goal of full Internet public implementation in FY 2000.

The panel supports the ERP's strategy to improve accessibility to its data through the provision of computer-based information. Making reliable data and information products available electronically has considerable value for the ERP's customers. The task of producing digital and graphic products is one that must be faced by all programs in the USGS. *The ERP should examine whether it can make use of database development efforts expended elsewhere in the USGS. It should consider participating in a centralized USGS-wide data and information management strategy that includes database development, data integration, archiving, and delivery. However, the USGS as a whole should consider the pros and cons of a centralized versus a decentralized system for data management.* A centralized data management architecture may be too rigid to support the science community and other users of the system. Issues of information management are of great importance to many federal agencies. Recent studies (NRC, 1995, 1998) may offer useful guidance or policy options in this area.

With respect to the second initiative, the panel supports the intent of the DSS, but questions whether software developed in-house will be more useful, less costly, and of sufficient longevity compared to a commercial product, when considered over the long term. The panel also questions whether there is sufficient coordination between the ERP and other USGS programs with respect to the DSS. The panel believes the ERP should be commended for recognizing the need to develop a capability such as the DSS. *The panel suggests that the DSS project should be studied by USGS leadership to determine whether other divisions would benefit by joining in the project or whether the ERP should join*

SIDEBAR 4.4
ERP's Major Databases—June 1998

The ERP data management system is in transition to both tabular and spatial databases that are Internet accessible and searchable. Some databases are accessible to the public already, whereas others are in the process of being made accessible.

Searchable Digital Databases for Which ERP Has Primary Maintenance Responsibility

- Energy Resources Program Bibliography (supersedes "coal bibliography database"): This database contains publications of the ERP from 1994 to 1997 on coal, oil, and natural gas resources by program staff. It is currently active and accessible at http://energy.er.usgs.gov/products/databases/Coalbibs/index.htm
- Coal Quality Database: This archive of all available coal quality information for the United States and the world is available via the Internet and as a CD-ROM, and is currently active and accessible at http://energy.er.usgs.gov/products/databases/Coal Qual/index.htm
- U.S. Coal Database: This contains published coal resource estimates for coal-bearing states listed by state, county, coal field, geologic age, formation, rank, coal thickness, and overburden thickness. It is currently active and accessible at http://energy.er.usgs.gov/products/databases/USCoal/index.htm
- National Oil and Gas Chemistry: This involves geochemical analyses of oil and natural gas; it is currently in the quality assurance/quality control (QA/QC) phase.
- Gas Geochemistry Database: This was inherited from the U.S. Bureau of Mines and is currently in the QA/QC phase.
- National Produced Waters Geochemistry: These geochemical analyses of waters produced from oil and gas wells are currently in the QA/QC phase.
- Alaska Thermal Maturity Database: This is currently in the QA/QC phase.
- World Oil and Gas Database: This database is under construction.

Other Data Collections Maintained by ERP but Not Currently Searchable by Database Software

- 1995 National Assessment of United States Oil and Gas Resources: Tabular input and results of the national assessment are available as a CD-ROM.
- COALPROD (Historical Production Data for the Major Coal-Producing Regions of the Conterminous United States): This collection is currently active and accessible at http://energy.er.usgs.gov/products/openfile/OFR97-447/index.htm
- Oil Shale Database: Fischer assay data for thousands of samples from Colorado, Wyoming, and Utah, are currently in the QA/QC phase and planned for future accessibility.
- The ERP contributes to and uses many other federal agency databases and also buys or shares licenses to use commercial databases.

Source: Information provided by USGS.

other programs in buying a license for commercially available data retrieval software.

In addition to digital databases and paper records, the USGS manages physical databases that are relevant to the mission and role of the ERP. The USGS maintains a Core Research Center that is the largest public core repository in the country. The repository includes more than 1.1 million feet of core from 31 states. Approximately 95 percent of the core was donated by petroleum and mining companies, state geological surveys, other federal agencies, and universities, and these groups continue to use the collection extensively. The repository also has cuttings from more than 50,000 wells in 27 states. The collection of cuttings represents nearly 235 million feet of drilling at a replacement cost of more than $10 billion.

Data management policies need to be reviewed to determine whether long-term archiving of and access to core, cuttings, and other geological samples are an important part of the mission and role of the ERP. Data managment policies should include protocols for accession and deaccession of core and cuttings, policies for metadata, and on-line search capabilities.

Communication

The panel has earlier (see Chapter 3) pointed to the extent to which the content of the ERP's work is designed to meet the needs of a broad-ranging group of users. A closely related challenge for the ERP is to ensure that its products are conveyed in ways that facilitate their applications by business, policymakers in various levels of government, academics, and the public at large. It goes without saying that interaction and clear communication with other GD subprograms and USGS units are important tasks in their own right. Cultivating and maintaining all of these links place heavy demands on the staff of the ERP, but the effort is justified by the resulting expansion of the utility of ERP products.

Communication successes include the following:

- fact sheets that are timely and useful;
- an e-mail list for notification of new publications, which is regarded by customers as a welcome improvement to the slow and difficult-to-use monthly publications pamphlet;
- publication of reports on CD-ROMs, which incorporate and augment an activity formerly dominated by open-file reports and speed up the publication and distribution process; and
- science policy outreach activities, as exemplified by rapid response analyses (see Sidebar 4.5).

Opportunities exist for improved communications in the following areas:

SIDEBAR 4.5
Rapid Response Analysis

Oil and Gas Resource Potential Input to Land Swap Legislation

In 1996, legislation was introduced by Senators Dale Bumpers and Rob Nichols to swap 47,486 acres of federal land for 180,586 acres of private land, which would become part of the Ouachita National Forest in Arkansas and Oklahoma. As part of the land swap, the oil and natural gas rights would be retained by private owners for the lands transferring to federal ownership. The USGS was asked to make an estimate of the oil and gas resource potential of the lands in question. The ERP conducted a rapid response analysis based on data generated as part of its 1995 national assessment. An administrative report was prepared summarizing the results and delivered to Senator Bumpers within 36 hours of the request. The administrative report was read into the Senate record and was used as part of the justification for proceeding with the land swap. The legislation was enacted into law in late 1996.

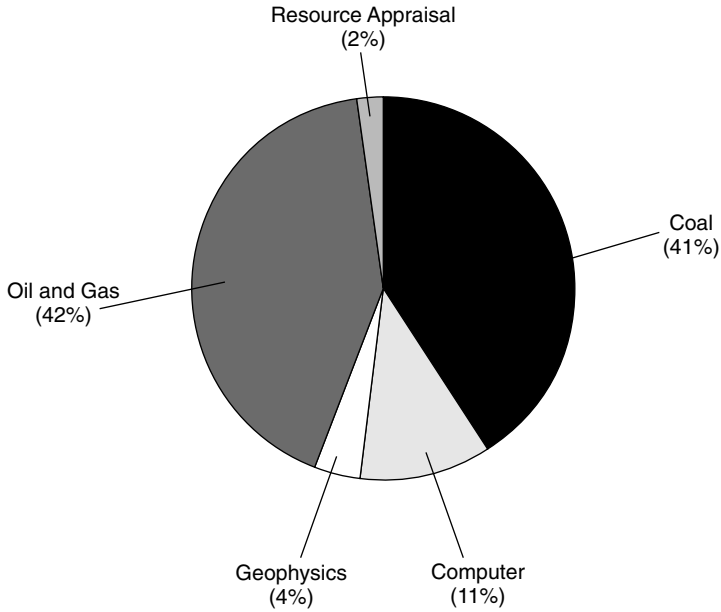
Oil and Gas Resource Potential of Federal Lands in Louisiana

During 1996, rapidly expanding exploration of the Austin Chalk play in Louisiana placed great pressure on the federal government to make parts of the Kisatchie National Forest and a nearby military reservation available for leasing. Senator Bennett Johnston asked the USGS to estimate the oil and gas potential of these federal lands as a basis for facilitating a timely leasing decision. The ERP conducted a rapid response analysis based on data generated as part of its 1995 national assessment. An administrative report was prepared summarizing the results and delivered to Senator Johnston within 48 hours of the request.

- coordination and collaboration between subprograms;
- the geographic dispersion of staff, which means that special effort is required to maintain effective links between subprograms (the oil and gas and the coal subprograms have much to learn from each other because the resources being studied often occur in the same basins and formations, and areas such as coalbed methane call for close collaboration);
- interaction between the ERP and other USGS programs and divisions on data management issues; and
- public outreach to make the accomplishments of the ERP more visible to Congress, federal agencies, state and local governments, and the public.

Human Resources

Given the current focus of the ERP, the range of expertise in the program is appropriate (Figure 4.1). The academic qualifications of the professional staff are high (Figure 4.2). More than half of the research staff of the ERP has a Ph.D.



Note: Resource appraisal includes statisticians and other non-geoscience trained professionals whose research is applied primarily to enhance energy resource assessment.

FIGURE 4.1 ERP expertise, FY 1998. Source: Data supplied by USGS.

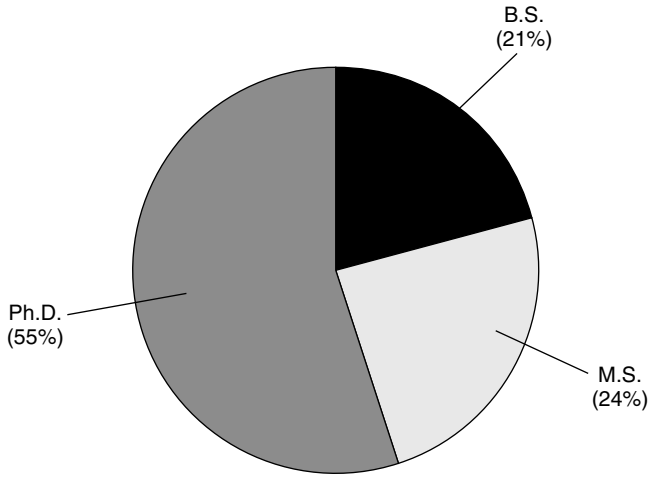


FIGURE 4.2 Academic qualifications of ERP staff, FY 1998. Source: Data supplied by USGS.

degree, and the remaining staff is equally divided between B.S. and M.S. degrees, an appropriate mix for a scientific agency such as the ERP. There is a balance between geological expertise in petroleum and in coal. Expertise in supporting disciplines such as computer applications and geophysics is adequate.

The age profile of members of the professional staff, as indicated by the decade when their first academic degrees were awarded (Figure. 4.3a), is a matter of concern. Most of the research staff in the ERP received their first degrees in the 1970s, and there is a sharp and substantial decrease in the number of graduates from the 1980s compared to the 1960s and 1950s. Fully 91 percent

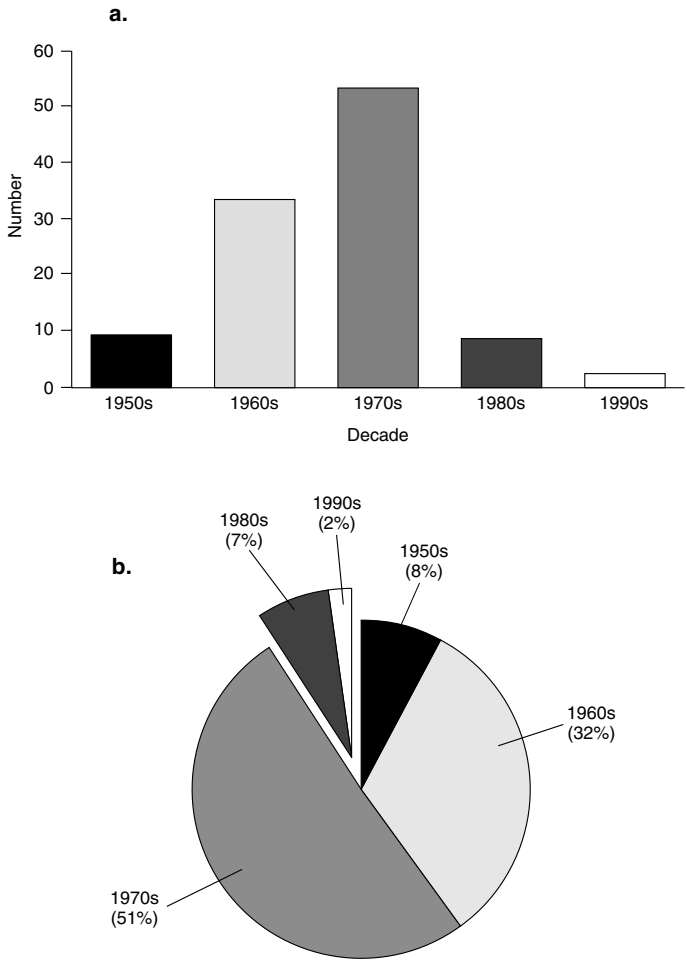


FIGURE 4.3 Age profile of the ERP's research staff, FY 1998: (a) number of research staff earning bachelor's degrees by decade; (b) proportion of research staff earning bachelor's degrees by decade. Source: Data supplied by USGS.

of the research staff of ERP earned their first degrees before the 1980s (Figure 4.3b).

As noted in the USGS strategic plan (USGS, 1997a), revitalization of the agency's work force is a continuing process. The panel suggests that the ERP begin planning for renewal of its work force as well. This planning should be undertaken as part of the development of the ERP strategic plan (Chapter 2), and it should take into account any expansions of coverage of energy sources included in the plan. Given the ERP's links to industry, the program may wish to seek some staff with industrial experience in oil, gas, coal, and other energy sources. The ERP might also consider the use of internships and thesis support as a way to enhance educational opportunities for students interested in energy resource geology. *The goal of the ERP should be to create an agile, diverse work force able to respond to the challenge of energy resource assessment across the portfolio.*

SUMMARY

Many opportunities exist for the ERP to serve the future needs of the nation. The need for careful, thorough, science-based assessment is greater than ever. The need to be prepared for significant energy transitions in the next century means that understanding potential energy resources, in the United States and worldwide, will have great value. The effectiveness of the ERP and the expertise it has assembled equip it well to enter into its next phase. With appropriate attention to communications, to renewal of its human capital, and to management of the data it collects, the ERP will contribute significantly to the energy future of the United States.

5

Principal Findings and Recommendations

With the adoption in 1997 of the strategic plan for the USGS [*USGS: Science for a Changing World* (USGS, 1997a)] and the strategic plan for the GD [*Geology for a Changing World* (USGS, 1997b)], the USGS has demonstrated a commitment to science in the public interest—science with significant policy relevance. These plans aim to provide policymakers at all levels of government with unbiased geological information for use in making the trade-offs that national policy always entails. This report considers the placement of the ERP within the structure created by the USGS and GD strategic plans. In this concluding chapter, the panel returns to the questions posed to it.

Mission. ***Is the scientific mission of the USGS Energy Resources Program appropriate for a federal earth-science agency?***

The ERP does not have a formal mission statement, but *the panel concludes that the mission of the ERP—to provide up-to-date and impartial assessments of geologically based energy resources of the nation and the world—is fully appropriate for a federal earth-science agency.* The information and data are essential to the management of federal lands, to the understanding of the environmental impacts of the extraction and use of energy resources, and to the planning of national energy policy. The ERP is the nation's provider of resource assessments for onshore lands and state waters. If the ERP were to cease providing this information, the private sector or a variety of other federal and state agencies would be forced to undertake similar studies. The results of ERP research and assessment activities also prove useful to a variety of private organizations that

explore for and extract energy resources, as well as to academic and federal research enterprises. *The panel concludes that the ERP fulfills a mission essential to the federal government.* **The panel recommends that the ERP develop a formal mission statement and a strategic plan that fits within and contributes to the mission statements and strategic plans adopted recently for the GD and for the USGS as a whole.**

Role. ***Is the role of the program clearly defined relative to other federal energy agencies and are the program's responsibilities consistent with its mission?***

The panel also concludes that the role of the ERP is clearly defined. The ERP focuses on onshore U.S. and state offshore energy resources and the geologic factors that control the abundance of the resource, its quality, and its location. The ERP also assesses undiscovered and unconventional resources in the EEZ (e.g., methane hydrates). Other related agencies have different roles. The most similar is the MMS, which manages energy and mineral resources of federal offshore areas. In addition to conducting offshore resource assessments, MMS also conducts lease sales. Thus, the ERP and MMS have similar objectives in the assessment arena but cover mutually exclusive geographic areas. *The panel urges the ERP and the MMS to continue to work closely together.* The objective of a close collaboration is the provision of consistent and complementary onshore and offshore resource assessments. The BLM, BIA on Indian reservations, and USFS are responsible for managing energy and mineral resources of federal onshore lands. BLM conducts lease sales for federal lands but does not undertake assessments of undiscovered resources. The DOE and particularly its EIA collect information about energy reserves (known and identified quantities of energy resources that can be exploited profitably now), energy production, and energy use. ERP data are used by EIA, BLM, BIA, and USFS to perform their functions. A significant duplication of effort would be the result if agencies were to develop internally the information provided to them by the ERP. Nonetheless, the ERP must take every step to ensure that its data are readily available to federal agencies, both inside and outside the DOI.

Balance. ***Is the program appropriately balanced between resource and environmental issues? Is it appropriately balanced between research and assessment activities?***

In the panel's view, the test of a balanced program should extend beyond the sets of issues and activities raised by the two questions posed above. Specifically, the panel urges more balanced consideration of the diversity of energy sources of potential significance in the nation's future.

The level of effort on the environmental side has been lower than that on resource assessment. Environmental activities in the ERP have been undertaken

in selected areas: oil and gas chemistry, chemistry and disposal of produced waters, and coal chemistry and acid-mine drainage. The objective, an appropriate one in the panel's view, has been to provide information and expertise related to the potential impact of energy resource extraction and use. *Rather than broaden the scope of the environmental program at this stage, the panel urges the ERP to develop partnerships with users of its environmental data and to use these partnerships to conduct a systematic review of the data now being collected to determine what additional data would have significant benefits.*

The panel notes that the balance between research, assessment, and service is an issue that is important to the GD and the USGS as a whole. The panel believes that research and assessment are thoroughly entwined and that high-quality assessment must involve high-quality research. Similarly, research and service are inseparable. *The panel urges the ERP to view research on geologic fundamentals of resource occurrence, as exemplified in basin, stratigraphic, and structural studies, as an essential and integral component of assessment.* **Hence, the panel recommends that the ERP in particular and the USGS as a whole maintain the strong research and knowledge base that is essential to the provision of services the ERP is uniquely qualified to provide.**

The panel also notes that the balance of domestic and international energy sources will continue to evolve over the decades to come. Because international energy flows and prices strongly influence the viability of energy sources in the United States, *the panel encourages the ERP to evaluate whether the effort on world energy resource assessment and supporting research should be increased above present levels.*

The panel notes that the current ERP coverage responds to the present reality of energy use in the United States. Oil, natural gas, and coal provide most of the energy used and, as a result, are the focus of the resource assessments and related research conducted by the ERP. Although these energy sources are now of primary importance, and probably will continue to be for decades to come, the panel also notes that there are many uncertainties in the U.S. energy future. It is not clear, for example, whether concerns about carbon dioxide emissions will cause policymakers to limit burning of fossil fuels at some point, and the future economics of energy sources is certain to differ from the present situation. **Accordingly, the panel recommends that the ERP portfolio be broadened to include geologically based energy resources beyond oil, gas, and coal, and that the ERP develop priorities for long-term balance among the various energy resources as part of the implementation of its strategic plan.** *Resource assessments should be available for very heavy oil, oil shale and carbonaceous shales, geothermal resources, and uranium, as well as conventional oil and gas, coal, coalbed methane, and methane hydrates, although the depth of the assessment will vary by energy source, given variable probabilities of economic use on equally variable time scales.* Many of these energy resources exist on federal lands, another reason to make sure that appropriate scientific understanding is

available as these assets are catalogued. Resource allocations to some of these areas for the near term will no doubt be modest, and some will involve collaboration with other programs inside and outside the USGS. The panel recognizes that a careful planning process will be required to craft a strategy for research and assessment that develops appropriate priorities for the broadened portfolio.

Effectiveness. ***Has the program proven effective in addressing energy resource issues of national importance?***

The panel finds the 1995 domestic oil and gas assessments to be effective, of high quality, and a substantial improvement over previous assessments. The panel commends the ERP for its productive consultations with states and industry and for the innovative methods used to disseminate the results.

The panel notes that the current assessment being conducted in the coal resources subprogram is still underway; hence, it is too early to judge its impact and effectiveness. The panel believes that the national coal assessment can be strengthened and urges the coal subprogram to complete a comprehensive assessment. *In the panel's view, the national coal assessment should identify and clearly state priorities of a comprehensive nationwide coal resource assessment; identify and clearly state the assumptions of the framework of a comprehensive coal resource asessment; identify the portions of the resource endowment that are not included in the study and explain why; explain clearly the limitations, qualifications, and restrictions of the data used in the assessment; plan for the evaluation of the remaining resource endowment as data become more available or the resources become economically viable; and design a program of supporting research that adequately focuses on coal resources in basins that have not been extensively studied and that uses integrated, basin-scale studies incorporating modern approaches of sedimentology and sequence and seismic stratigraphy. In addition, the panel urges the coal assessment team to provide clear statements of the limitations of the data collected and to build links with the coal industry as a way to review the accuracy of assessments and to improve access to data.*

The panel observes that data compiled by the world energy subprogram are much in demand. Both federal agencies and energy companies have found its products to have significant value. The panel anticipates that the level of interest in such products will continue to increase.

Program Evolution. ***How should the program's activities, scientific and technical expertise, and infrastructure evolve to meet future needs?***

Evolution of the activities of the ERP should be guided by a continuing strategic planning process that involves a portfolio of energy sources and anticipates changing policy environments and new developments in science and technology.

Renewal of scientific and technical expertise is a critical issue for the evolution of the ERP. The range of expertise should be guided by the strategic planning process, and the distribution of skills and experience should be consistent with the strategic plan.

Data and information management, and communication with clients and partners, are important aspects of the near-term evolution of the infrastructure of the ERP. The panel commends and supports the ERP's substantial effort to make its products available in electronic, searchable form. The panel also supports the intent of the ERP's DSS, but suggests that careful reevaluation of the in-house development approach is needed. The panel commends the ERP for its efforts to provide rapid response to external users of its information. The panel believes that policies for managing the USGS core repository and other geological samples need to be reviewed to determine whether long-term archiving of and access to core, cuttings, and other geological samples constitute an important part of the mission and role of the ERP. *The panel notes that the ERP should look for opportunities for improvement of communications between the oil and gas and the coal subprograms, and the panel encourages the ERP to continue to strengthen its public outreach.* Stronger interaction with diverse audiences will help the ERP develop a service culture that complements its science culture.

The panel believes that the ERP has built a solid foundation upon which a successful future program can be built. It is in a good position to plan effectively for its future, and the panel encourages it to plan strategically for its role in a world in which population pressures, global environmental concerns, and a linked world economy will all intersect in the need to supply energy for the United States. A successful ERP will help the United States understand and guide its energy future.

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Appendix A

Oral Presentations and Written Statements

ORAL PRESENTATIONS

The following individuals made presentations to the panel charged to review the USGS Energy Resources Program:

USGS-GD. *P. Patrick Leahy, Chief Geologist, and Steven R. Bohlen, Associate Chief Geologist for Science.*

USGS-ERP. *David W. Houseknecht, Coordinator, Energy Resources Program; C. Gene Whitney, Chief Scientist, Central Region Energy Resources Program Team; Ronald W. Stanton, Chief Scientist, Eastern Energy Resources Program Team; and the following scientists: Thomas S. Ahlbrandt, Kenneth J. Bird, George N. Breit, Thaddeus S. Dyman, David A. Ferderer, Robert B. Finkelman, Romeo M. Flores, Michael D. Lewan, and Christopher J. Schenk.*

USGS-MRP. *Linda C. Gundersen, Program Manager, Mineral Resources Program, and Martha S. Power, Program Scientist, Mineral Resources Program.*

Federal Agency Perspectives. *Mark Schaefer, Deputy Assistant Secretary of the Interior for Water and Science, U.S. Department of the Interior; Guido DeHoratiis, Acting Director, Upstream and Downstream Office, Natural Gas and Petroleum Technology, U.S. Department of Energy; Erick Kaarlela, Senior Petroleum Engineer, Oil and Gas, Operations and Inspection, Minerals, Realty and Resource Protection, Bureau of Land Managment, U.S. Department of the*

Interior; and Loren Setlow, Geologist, Office of Radiation and Indoor Air, Environmental Protection Agency.

Other Public and Private Perspectives. *William Condit, Staff Director, Subcommittee on Energy and Mineral Resources, U.S. House of Representatives; Samuel Baldwin, Study Executive Director, President's Committee of Advisors on Science and Technology:* Federal Energy Research and Development for the Challenges of the Twenty-First Century, *Report of the Energy Research and Development Panel, Washington, D.C.; General Richard L. Lawson, President, National Mining Association, Washington, D.C.; Lawrence Metzroth, Principal and Senior Economist, Resource Data International, Boulder, Colorado; Fred Julander, President, Julander Energy Company, Denver, Colorado; Susan Landon, Independent Petroleum Geologist, Thomasson Partner Associates, Denver, Colorado; and James Cobb, Assistant State Geologist, Kentucky Geological Survey, Lexington.*

WRITTEN STATEMENTS

At the request of the panel, the following individuals responded to an invitation that was sent to more than 50 people in government, industry, and academe throughout the United States to prepare written critiques of the USGS Energy Resources Program: *M. Lee Allison, State Geologist, State of Utah, Salt Lake City; John D. Edwards, Adjunct Geology Professor, Department of Geological Sciences, University of Colorado at Boulder; Norman H. Foster, Independent Geologist, Denver, Colorado; Gary B. Glass, State Geologist, Wyoming Geological Survey, Laramie; Melvin O. Glerup, Consulting Geologist, Highlands Ranch, Colorado; Arthur R. Green, Petroleum Scientist, Exxon Exploration Company, Houston, Texas; Robbie Gries, President, Priority Oil and Gas, Denver, Colorado; Ben D. Hare, Chief Geologist and New Ventures Exploration Manager, Vastar Resources, Inc., Houston, Texas; Thomas J. Heck, Petroleum Geologist, North Dakota Geological Survey, Bismark; Gretchen K. Hoffman, Senior Coal Geologist, New Mexico Bureau of Mines and Mineral Resources, Socorro; Melody R. Holm, Energy Resources Specialist, U.S. Forest Service, Lakewood, Colorado; James C. Hower, Senior Scientist, Center for Applied Energy Research, University of Kentucky, Lexington; Jeremy Platt, Manager, Fuel and Power Supply Target, Electric Power Research Institute, Palo Alto, California; William W. Shilts, Chief, Illinois State Geological Survey, Champaign; M. Ray Thomasson, President, Thomasson Partner Association, Inc., Denver, Colorado; and Robert J.Weimer, Professor Emeritus and Petroleum Consultant, Colorado School of Mines, Golden.*

Appendix B

Biographical Sketches of Panel Members

Franklin "Lynn" M. Orr, Jr. (Chair), is the Beal Professor and Dean of the School of Earth Sciences at Stanford University. His research interests include multicomponent fluid phase equilibrium and its interactions with multiphase flow in porous media. Previously he served as chairman of the Petroleum Engineering Department at Stanford and held positions at the New Mexico Institute of Mining and Technology, Shell Development Company, and the U.S. Environmental Protection Agency. He is a member of the Society of Petroleum Engineers, the American Institute of Chemical Engineers, and the Society of Industrial and Applied Mathematics. He is vice-chairman of the board of directors of the Monterey Bay Aquarium Research Institute and chairman of the Science Advisory Committee for the David and Lucile Packard Foundation Fellowships in Science and Engineering.

Vicki J. Cowart is the state geologist and director of the Colorado Geological Survey, the scientific agency within the Colorado Department of Natural Resources that has three primary technical programs relating to hazards and resources, and an educational and outreach effort. Previously, she worked in the oil and gas industry for 16 years. Cowart serves on the editorial board of *Geotimes*. She was a member of the Colorado School of Mines Visiting Committee to the Geophysics Department and a director and officer of the Colorado School of Mines Alumni Association. She has been active in the Denver Geophysical Society, serving as both editor and treasurer, and the Society of Exploration Geophysicists. She helped found the Denver chapter of the Association for Women Geoscientists and served as the association's first nationally elected

president. She was treasurer of the Association for Women Geoscientists Foundation and is an adviser to the foundation. As a state geologist, Cowart is active in the Association of American State Geologists. She was on the National Cooperative Geologic Mapping Program Peer Review Panel and is the association's treasurer. Cowart received her B.S. in physics from Worcester Polytechnic Institute and her M.S. in geophysics from the Colorado School of Mines.

John C. Crelling is a professor of geology and leader of the Coal Characterization and Maceral Separation Laboratories at Southern Illinois University in Carbondale. He has previously held the positions of captain in the U.S. Army Corps of Engineers and manager of the Coal and Coke Laboratories at the Homer Research Laboratory of the Bethlehem Steel Corporation. His research interests include the petrology of coals, kerogens, cokes, carbons, and graphites as well as forensic geology. He is a fellow of the Geological Society of America and Sigma Xi, a member of the American Chemical Society, and past president of the Society for Organic Petrology.

Joel Darmstadter is a senior fellow and resident consultant, Energy and Natural Resources Division, at Resources for the Future (RFF) in Washington, D.C. Since joining RFF, his research and publications have centered particularly on energy resources and policy. In recent years, he has focused as well on issues of climate change, sustainability, and productivity in natural resource sectors. He has served on a number of National Research Council bodies, as well as contributing to several NRC studies. Darmstadter has been an adjunct faculty member of the School of Advanced International Studies, Johns Hopkins University (1983-1993); was a member of the editorial committee of the *Annual Review of Energy* (1975-1986); and has been a contributing editor to *Environment* magazine since 1979. In the fall of 1995, he presented a series of lectures in Argentina under the auspices of the U.S. Information Agency. During 1997, he served as a member of an evaluation team, assessing the performance of the Department of Energy-sponsored National Institute of Global Environmental Change. Darmstadter's economics degrees are from George Washington University and the New School for Social Research.

Charles G. "Chip" Groat is associate vice-president for research and sponsored projects and a professor of geological sciences at the University of Texas at El Paso. His experience and research interests are in resource assessment and resource development environmental impacts. He has carried out studies in these areas for Gulf Coast lignite; geopressured-geothermal fluids; uranium; and oil and gas in coastal zones, the outer continental shelf, and offshore Alaska. He is fellow and council member of the Geological Society of America. He is a member of the American Association of Petroleum Geologists, the American Geophysical Union, and the Board on Earth Sciences and Resources of the

National Research Council. He served 12 years as state geologist and director of the Louisiana Geological Survey. On July 30, 1998, President Clinton announced his intention to nominate Dr. Groat to serve as director of the U.S. Geologicial Survey.

Claudia J. Hackbarth is staff research engineer at Shell E&P Technology Company, managing a group researching unconventional resources. She holds a bachelor's degree in environmental sciences from the University of Virginia, and master's and Ph.D. degrees from Harvard University in geological sciences. Previous Shell and other projects have included research on stratigraphy of turbidites, geophysical interpretation, groundwater contamination, hydrothermal ore deposits, nuclear waste disposal, and oil and gas development geology. She is a certified petroleum geologist (certificate No. 5174), a member of the American Association of Petroleum Geologists, and a fellow of the Geological Society of America (GSA). She has a strong interest in policy applications of geological information, including a three-year term on GSA's Committee on Geology and Public Policy.

William N. Poundstone is a retired executive vice-president and director of Consolidation Coal Company. He currently serves as a consultant to the mining industry. During the first half of his career, he held positions at all levels of mine operation of his company, from timberman to vice-president of operations. He was then named executive vice-president and given the responsibility for all engineering, exploration, land environmental, planning, mining research, and new mine development activities. He is an honorary member of the American Institute of Mining, Metallurgical, and Petroleum Engineers, and a member of the Society of Mining Engineers and the National Academy of Engineering. He has served as spokesman for the coal industry at a number of congressional hearings and was a participant in three major national energy studies.

Raymond A. Price a professor of geological sciences at Queen's University, Kingston, Ontario. His research interests include structural geology and tectonics, environmental geoscience, radioactive waste disposal, and science and public policy. His previous positions include assistant deputy minister of the Department of Energy, Mines and Resources (Canada); director-general of the Geological Survey of Canada; president of the Geological Society of America; and president of the Inter-Union Commission on the Lithosphere (International Council of Scientific Unions). He is a fellow of the Royal Society of Canada and the American Association for the Advancement of Science, and a foreign associate of the National Academy of Sciences.

Reginal Spiller is the senior vice-president for exploration and production at Frontera Resources Corporation in Houston, Texas. The company has activities

in Bolivia, Azerbaijan, and the Republic of Georgia. Prior to his employment, he was deputy assistant secretary for gas and petroleum technologies at the U.S. Department of Energy, where he managed the development and demonstration of advanced technologies for natural gas and petroleum exploration, production, and delivery. Prior to joining DOE, Spiller was the international exploration manager for Maxus Energy Corporation, where he identified projects for oil and gas exploration and production in Africa, Europe, and the Middle East. He began his oil and gas career with Exxon USA in Houston, Texas. He holds an M.S. in hydrogeology from the Pennsylvania State University and a B.A.S.S. in geology from the State University of New York.

John E. Tilton is the William J. Coulter Professor of Mineral Economics and director of the Division of Economics and Business at the Colorado School of Mines. He is also a university fellow at Resources for the Future and a past president of the Mineral Economics and Management Society. His teaching and research interests over the past 25 years have focused on economic and public policy issues associated with the mineral industries. He has served as vice-chair of the NRC's Board on Mineral and Energy Resources and as a member of a number of other NRC boards and committees.

Noel Tyler is director of the Bureau of Economic Geology at the University of Texas at Austin and state geologist of Texas. His work has focused on oil resources, with detailed reservoir characterization studies of major reservoirs statewide and of outcrop analogues in the western United States. He has published more than 60 articles, bulletins, and reports. He has a B.Sc., a B.Sc. with honors, and an M.Sc., cum laude, from the University of Witwatersrand, South Africa, and a Ph.D. from Colorado State University, all in geology. He is a member of the American Association of Petroleum Geologists, the Society of Petroleum Engineers, and the Society for Sedimentary Geology and is a fellow of the Geological Society of America. In 1994, he was selected the honor alumnus of the College of Forestry and Natural Sciences at Colorado State University.

Anthony R. de Souza (Staff) is currently a senior program officer at the National Research Council in Washington, D.C. Previously, he was executive director of the National Geography Standards Project, secretary general of the 27th International Geographical Union Congress, editor of *National Geographic Research & Exploration*, and editor of the *Journal of Geography*. He has held positions as a professor and as a visiting teacher and scholar at the George Washington University, University of Wisconsin-Eau Claire, University of Minnesota, University of California-Berkeley, and University of Dar es Salaam in Tanzania. He has served as a member of NRC committees. He holds B.A. (honors) and Ph.D.

degrees from the University of Reading in England, and has received numerous honors and awards, including the Medalla al Benito Juarez in 1992 and the Gilbert Grosvenor honors award from the Association of American Geographers in 1996. His research interests include the processes and mechanisms of economic development and human-environment relationships. He has published several books and more than 100 articles, reports, and reviews.

Acronyms

ANWR	Arctic National Wildlife Refuge
BIA	Bureau of Indian Affairs
BLM	Bureau of Land Management
BRD	Biological Resources Division
Btu	British thermal units
CEED	Center for Energy and Economic Development
CIA	Central Intelligence Agency
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of the Interior
DSS	Decision Support System
EEZ	Exclusive Economic Zone
EIA	Energy Information Administration
EPA	Environmental Protection Agency
ERP	Energy Resources Program
GD	Geologic Division
GIS	Geographic Information Systems
GSA	Geological Society of America

KGS	Kentucky Geological Survey
MMS	Minerals Management Service
NARA	North America Resource Assessment
NMD	National Mapping Division
NPRA	National Petroleum Reserve in Alaska
NPS	National Park Service
NRC	National Research Council
PCAST	President's Council of Advisors on Science and Technology
QA/QC	quality assurance/quality control
RFF	Resources for the Future
SEAB	Secretary of Energy Advisory Board
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
WRD	Water Resources Division