Free Executive Summary

Coal: Research and Development to Support National Energy Policy

Committee on Coal Research, Technology, and Resource Assessments to Inform Energy Policy, Committee on Earth Resources, National Research Council

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SUMMARY

The coal industry in the United States—encompassing coal mining, processing, and transportation—is a relatively small but vitally important component of the nation's economy. Coal provides nearly a quarter of all energy supplies in the United States, with most of that coal used to generate over half of the nation's electricity. The expectation of continually increasing national electricity demand has led to forecasts suggesting that demand for coal may increase by 60-70 percent over the next 25 years, although other analyses suggest that coal use may grow at a slower rate—or even decline—depending on the timing and magnitude of regulatory limits on carbon dioxide emissions. With this degree of uncertainty, coal-related research and development (R&D) policies need to accommodate a broad range of possible future scenarios. Congress asked the National Research Council to undertake a broad examination of coal-related R&D across the entire fuel cycle (see box), with briefings by congressional staff emphasizing that the study should be brief, should concentrate on the "upstream[1]" aspects of the coal industry and deal only briefly with coal utilization R&D, and should highlight any potential stumbling blocks to increased coal production.

Statement of Task

The study will broadly examine coal resource assessments, technologies, and research and development (R&D) activities in the United States in order to formulate an appropriate, integrated roadmap of future needs. The results of the review should help define and construct a national strategy for coal R&D and resource assessments.

The study shall consider the following issues:

1. Summarize recent projections of the coal use as part of the U.S. and global energy portfolios over the next 25 years, including projections that take into account the potential roles of coal in future integrated energy and environmental policies, in order to set the context for development of a more comprehensive, strategic roadmap for coal R&D and resource assessments.

2. Describe the full range of local, regional, national, and global issues and challenges, including environmental issues that must be taken into account when considering future production and utilization of coal.

3. Review the coal reserve assessments based on recent trends in the coal sector and examine the current and future role of coal imports and exports.

4. Assess the categories of coal R&D currently being carried out in the United States and internationally, and investigate whether and how technology developments in other fields can be applied to the coal sector. Review how technologies are being transferred to coal mine operators and other users, recognizing differences among companies.

5. Determine the priority coal R&D needs, including in the areas of exploration, discovery, reserve assessment (including in terms of commercial feasibility for known reserves), extraction, coal preparation, delivery to market, waste disposal, reclamation, health and safety, community impact, environmental practices, education and training, and productivity.

[1] 'Upstream' activities refer to pre-utilization processes—coal mining, processing, and transport to utilization sites.

6. Evaluate the need for a broad-based, coordinated, multi-agency coal research and development program. Review current coal-related research, examine what agencies are conducting it, and determine how much funding is currently being spent throughout the coal life cycle.

7. Examine options for supporting and implementing a broad-based coal R&D program, including approximate costs, and the relative roles and commitments of the public and private sectors now and into the future.

The context for any assessment of future coal production is inextricably linked with the development of a national carbon emissions policy. Potential constraints on greenhouse gas (especially CO_2) emissions, and the technical and economic feasibility of CO_2 control measures, are the dominant issues affecting the outlook for the future of coal use over the next 25 years and beyond. The difficulty of predicting the prices and availability of alternative energy sources for electric power generation provides additional uncertainty. Taking these factors into consideration, an assessment of forecasts for coal use indicates that over the next ten to fifteen years (until about 2020), coal production and use in the United States is projected to range from about 25 percent above to about 15 percent below 2004 levels, depending on economic conditions and environmental policies. By 2030, the range of projected coal energy use in the United States broadens considerably, from about 70 percent above to 50 percent below current levels. The higher values reflect scenarios with high oil and gas prices and no restrictions on carbon emissions. The lower values reflect scenarios with relatively strict limits on U.S. CO_2 emissions, which cause coal use with sequestration to be more costly compared with other options for power generation.

At present, coal imports and exports represent small fractions of total U.S. coal production and use, and projections indicate that both imports and exports are expected to remain relatively small. From a global perspective, the largest tonnage increases in coal use are expected in the emerging economies of China and India. Much smaller tonnage growth is projected in the rest of the world, although relative growth rates are projected to be high in several other countries. Again, however, there is great uncertainty in global coal use projections, especially beyond about 2020.

These projections provide the context for an assessment of coal-related R&D activities. A number of organizations and entities—federal government agencies, state government agencies, academic institutions, coal mining companies, and equipment manufacturers—are engaged in aspects of coal-related R&D and technology development. In this report, the primary focus is on federal government support for activities that are variously described as pure research, applied science, pilot-scale testing, technical support, demonstration projects, and applied engineering projects. For existing federal support, the committee analyzed R&D budgets in terms of the range of categories that encompass the coal fuel cycle—resource and reserve assessment; coal mining and processing; coal mining safety and health; environmental protection and reclamation; transport of coal and coal-derived products; and coal utilization.

There are numerous applied research areas, primarily focused on incremental technology development, for which federal involvement is neither appropriate nor required and where industry should and does provide support. For some areas, such as ensuring that a well-trained workforce is available to meet the nation's mining and mining education requirements, federal involvement can effectively complement industry activities. There are other areas of coal-related R&D where the federal government has a primary role—for example, to establish the quantity and quality of the nation's coal reserves, to facilitate and catalyze revolutionary (rather than incremental) technology development, to safeguard the health and safety of mine workers, and to protect the environment during future mining and processing and mitigate existing environmental problems arising from past mining practices. It is also a federal responsibility to provide funding for the R&D required to support the government's regulatory role.

Over $538 million was spent by federal government agencies for coal-related research and technology development in 2005. Of this, more than 90 percent (~$492 million) was directed towards 'downstream' aspects of coal use, mostly coal utilization technology development and transmission research funded through the Department of Energy (DOE). Federal support for R&D activities related to all 'upstream' aspects of the coal fuel cycle—i.e., mine worker safety and health, resource and reserve assessments, coal mining and processing, and environmental protection and reclamation—accounted for less than 10 percent of the total federal investment in coal-related R&D. Federal funding in 2005 for individual components of upstream activities ranged from $24.4 million (4.5 percent) for mine worker safety and health R&D to $1.3 million (0.2 percent) for coal mining and processing R&D.

Consideration of agency budgets over the past 10-15 years shows that federal government funding of R&D to support its regulatory role has remained broadly constant. In contrast, support for coal resource and reserve assessments has declined by nearly 30 percent as inflation has eroded constant nominal dollar funding, and support for mining and processing research declined dramatically in the mid 1990s, coinciding with the dissolution of the U.S. Bureau of Mines, and is now only 0.2 percent of total federal coal-related R&D funding.

There are some components of the coal fuel cycle, e.g., coal transportation, where identification of potential stumbling blocks that may impede increased coal production and use do not lead to R&D recommendations—these issues are more appropriately dealt with by regulatory actions and existing government authority or will ultimately be resolved by standard business practices. However, for most components of the coal fuel cycle, a range of national interests—the need for sound information on which to base policy decisions, the requirement for optimum use of an important national resource, or society's demand for personal or environmental health and safety—lead to a series of recommendations for high priority R&D activities; these are noted below in bold.

COAL RESOURCE, RESERVE, AND QUALITY ASSESSMENTS

Federal policy makers require accurate and complete estimates of national coal reserves to formulate coherent national energy policies. Despite significant uncertainties in existing reserve estimates, it is clear that there is sufficient coal at current rates of production to meet anticipated needs through 2030. Looking further into the future, there is probably sufficient coal to meet the nation's needs for more than 100 years at current rates of consumption. However, it is not possible to confirm the often-quoted assertion that there is a sufficient supply of coal for the next 250 years. A combination of increased rates of production with more detailed reserve analyses that take into account location, quality, recoverability, and transportation issues may substantially reduce the number of years of supply. Future policy will continue to be developed in the absence of accurate estimates until more detailed reserve analyses—which take into account the full suite of geographical, geological, economic, legal, and environmental characteristics—are completed.

Present estimates of coal reserves are based upon methods that have not been reviewed or revised since their inception in 1974, and much of the input data were compiled in the early 1970s. Recent programs to assess reserves in limited areas using updated methods indicate that only a small fraction of previously estimated reserves are actually minable reserves. Such findings emphasize the need for a reinvigorated coal reserve assessment program using modern methods and technologies to provide a sound basis for informed decision-making.

A coordinated federal-state-industry initiative to determine the magnitude and characteristics of the nation's recoverable coal reserves, using modern mapping, coal characterization, and database technologies, should be instituted with the goal of providing policy makers with a comprehensive accounting of national coal reserves within 10 years.

The committee recommends that the U.S. Geological Survey should lead a federal-state-industry initiative to quantify and characterize the nation's coal reserves, and estimates that this will require additional funding of approximately $10 million per year.

RESEARCH TO SUPPORT COAL MINING AND PROCESSING

Regardless of the precise levels of future coal production, the coal mines of the future will encounter a range of new or more difficult mining and processing challenges as more easily accessed coal seams are depleted and the industry turns to less accessible reserves. Surface operations will mine deeper seams that require increased stripping ratios and multiple benches, and underground mines will need to access seams that are deeper, thinner, or thicker, generally with higher methane content and potentially with greater difficulties with strata control. These more difficult mining conditions will require improved methods to protect the health and safety of mine workers, careful environmental management of mined lands and waste products, and improved recovery to optimize use of the nation's coal resource.

Improved Mine Worker Health and Safety

A range of factors increase health and safety risks to the coal mining workforce, including the introduction of new equipment and systems, commencement of mining in virgin areas, infusion of new workers, and the mining of multiple seams, seams that are thinner, thicker, or deeper than those customarily mined at present, and new seams that underlie or overlie previously mined out seams. All of these factors are likely to apply to some degree in future mines, and such risks are likely to become more pronounced if coal production levels increase. There are major knowledge gaps and technology needs in the areas of survival, escape, communications systems (both surface-to-underground and underground-to-underground), and emergency preparedness and rescue. Additional risk factors that are likely to apply in the deeper mines of the future are the potential hazards related to methane control, dust control, ignition sources, fires, and explosions. A greater understanding and better prediction of strata control to prevent unanticipated roof collapse are essential for maintaining and improving worker safety.

Health and safety research and development should be expanded to anticipate increased hazards in future coal mines. These R&D efforts should emphasize improved methane control, improved mine ventilation, improved roof control, reduced repetitive and traumatic injuries, reduced respiratory diseases, improved escape and rescue procedures, improved communications systems, and research to reduce explosions and fires. This should be coupled with improved training of the mining workforce in all aspects of mine safety. R&D should also be directed towards lowering the exposure of mine workers to hazardous conditions, particularly through expanded use of remote sensing and the automation of mining operations.

Most mining health and safety research by the federal government is carried out by the Mining Program at the National Institute for Occupational Safety and Health (NIOSH). Technology-related activities within the Mine Safety and Health Administration (MSHA) are limited to technical support and training services for its personnel and those from the mining industry. With NIOSH carrying out the research needed to improve mine safety and support MSHA's regulatory role, these two agencies play a vital role in coal mine health and safety. The committee estimates that the enhanced health and safety program proposed here will require additional annual R&D funding of approximately $35 million, and recommends that NIOSH continue as the lead agency with enhanced coordination with MSHA and industry.

Improved Environmental Protection

As mining extracts coal from deeper and operationally more difficult seams by both surface and underground methods, a range of existing environmental issues and concerns will be exacerbated and new concerns, particularly related to greater disturbance of hydrologic systems, ground subsidence, and waste management at mines and preparation plants, are likely to arise. Inadequate understanding of post-mining behavior of strata, stability of spoils, and the associated hydrologic consequences of mining in both surface and underground mines affects mine permitting, mine development, environmental mitigation, and post-mining land use, including use for waste management. Research offers considerable potential to mitigate the effects of past mining practices, particularly acid mine drainage on abandoned mine lands. However, the regulatory environment and the technical support programs administered by both state and federal agencies, and implemented by mining companies through their compliance practices, are inadequately supported by existing research programs.

Additional research is needed to mitigate the adverse environmental impacts associated with past, existing, and future coal mining and processing. Research activities should particularly focus on developing techniques to mitigate the alteration and collapse of strata overlying mined areas, to model the hydrological impacts of coal mining, to improve mine mapping and void detection, to improve stability of spoils on steep slopes, and to improve the construction and monitoring of impoundments.

Both the Office of Surface Mining Reclamation and Enforcement (OSM) and the U.S. Environmental Protection Agency (EPA), although primarily regulatory agencies, fund limited R&D activities in support of their missions. The committee estimates that additional funding of approximately $60 million per year will be required to conduct the research necessary to adequately respond to the environmental impacts posed by past, existing, and future mining operations. The committee recommends that OSM should be the lead agency in this effort, and it should closely coordinate with related EPA and state research activities.

Improved Mine Productivity and Resource Optimization

Although technology developments (primarily underground longwall mining) and industry changes (primarily the growth in large surface operations) resulted in a two- to three-fold increase in the productivity of U.S. coal mines over the past three decades, production and productivity increases in recent years have been small as mining companies and equipment manufacturers made only incremental improvements. Over the past decade, there has been little R&D directed towards truly advanced mining technologies and at present, only 0.2 percent of total federal coal-related R&D funding is directed towards development of the advanced mining technologies and practices that are necessary to optimize utilization of the nation's coal resource. Small percentage increases in coal recovery through improved mining and coal preparation processes have the potential to significantly expand economically recoverable reserves of both eastern and western coals. The development of these technologies, increasingly needed as coal reserve quality decreases over time, will help to maximize utilization of the nation's coal resource.

The global transfer of coal mining and processing technology within the industry is facilitated by international equipment manufacturers, who work closely with suppliers and the larger mining clients on evolutionary product developments. However, there is little evidence of the efficient transfer of technologies from outside the mining industry. This is at least partly due to the relatively small market the coal mining industry represents to potential technology suppliers and the scarcity of coal mining research at academic institutions and national laboratories.

There should be renewed support for advanced coal mining and processing research and development to optimize use of the nation's coal resources by increasing the amount of coal

that is economically minable through technological advances that accommodate health, safety, and environmental requirements. The focus of this R&D should be on increased integration of modern technology in the extraction and processing phases of coal production, with particular emphasis on emerging advances in materials, sensors, and controls; monitoring; and automated mining systems.

Research to develop advanced mining technologies requires not only cooperation among relevant federal agencies, but also participation by academic institutions as well as funding, guidance, and technology transfer by industry. The committee estimates that advanced coal mining and processing R&D will require a total of approximately $60 million per year, and recommends that this funding should be comprised of $30 million in total federal support, with cost-sharing from non-federal sources. The DOE Office of Fossil Energy should be the lead federal agency, and should coordinate with NSF, OSM, NIOSH, academic institutions, and the coal industry to ensure that all research activities carefully consider the environmental, reclamation, and health and safety aspects of coal mining.

TRANSPORT OF COAL AND COAL PRODUCTS

Growth in the use of coal depends on having sufficient capacity to deliver increasing amounts of coal reliably and at reasonable prices to an end user. The capacity, reliability, and price of rail transportation—the dominant mode of coal transport—depend largely on the supply and demand for rail transportation, as well as on prevailing business practices, the investment climate, and the nature of regulatory oversight of the railroad industry. The capacity, reliability, and price of rail transportation of coal depend to a far lesser degree upon research and development. Reliable and sufficient waterborne transportation—the second most prevalent method of coal transport—depends on the construction and maintenance of waterway infrastructures, especially lock-and-dam infrastructure and port capacity.

Much of the nation's coal-fired electric generating capacity is located at some distance from the urbanized areas that have the largest and most concentrated demands for electricity. Projections of higher coal use depend on sufficient capacity to transmit electricity from coal-based power plants to such areas reliably and at a reasonable cost. Conversely, the projected increases in coal use will diminish if those high-demand areas satisfy much of their growing demand for electricity not by expanding their ability to import electricity from areas where coal is plentiful, but by a combination of energy efficiency, demand response, and local electric generation from sources other than coal.

The coal transportation and electric transmission systems are large and complex networks in which localized disruptions can have severe and widespread impacts. Weather and other natural phenomena, as well as societal factors such as sabotage and terrorism, impose a range of risks on these systems. These characteristics make it difficult to guarantee that there will be sufficient capacity to transport coal or coal-based energy (primarily electricity) reliably and cost-effectively to the various end users, particularly in light of scenarios that predict substantially increased coal use. Research is needed to better understand the factors that control these large and complex networks to minimize the risks of cascading system disruptions.

RESEARCH TO SUPPORT COAL UTILIZATION

In accord with requests that this study focus primarily on the upstream aspects of the coal fuel cycle, the analysis of coal utilization R&D is confined to a brief overview that is primarily focused on describing the factors associated with coal use that are most likely to impose constraints on future demands for coal. Overwhelmingly, the environmental impacts of coal use, especially carbon dioxide emissions associated with global climate change, pose the greatest potential constraint on future coal utilization. Decisions to invest or not invest in coal-based power plants will strongly influence future coal

use, and will depend in large part on the timing and magnitude of any future constraints on CO_2 emissions.

In contrast, potential regulatory requirements to further reduce emissions of NO_x, SO_2, mercury, and particulate matter in the future are not expected to significantly limit the overall use of coal in the next several decades. However, future emission control requirements for these regulated air pollutants could result in changed preferences for particular types of coal, depending on the nature of future regulations.

If coal is to continue as a primary component of the nation's future energy supply in a carbon-constrained world, large-scale demonstrations of carbon management technologies—especially carbon capture and sequestration (CCS)—are needed to prove the commercial readiness of technologies to significantly reduce CO_2 emissions from coal-based power plants and other energy conversion processes. In addition, detailed assessments are needed to identify potential geological formations in the United States that are capable of sequestering large quantities of CO_2; to quantify their storage capacities; to assess migration and leakage rates; and to understand the economic, legal, and environmental impacts of storage on both near-term and long-term timescales. These R&D activities would complement other legal and regulatory activities needed to make these sites available and viable as a CO_2 control strategy. Such geologic sequestration sites should be considered as "resources," and categorized and described in the same way that conventional mineral or energy resources are assessed.

The U.S. Geological Survey (USGS) should play a lead role in identifying, characterizing, and cataloguing the CO_2 sequestration capacity of potential geologic sequestration resources.

The committee estimates that approximately $10 million per year for five years will be required for this activity, which would be in addition to the CCS research and demonstration program presently underway at DOE. There should be close cooperation and coordination among the USGS, the Carbon Sequestration Program managed by DOE's Office of Fossil Energy, and the states involved in DOE's Regional Carbon Sequestration Partnerships.

COORDINATION OF COAL-RELATED R&D BY FEDERAL AGENCIES

One component of this study was the specific requirement for the committee to evaluate whether a broad-based, coordinated, multi-agency coal R&D program is required, and if so, to examine options for supporting and implementing such a program. The committee carefully considered existing R&D programs, and assessed the extent of—and opportunities for—coordination of coal-related research among the agencies. The committee also considered coal-related R&D support provided by states, the coal industry, and equipment manufacturers, but did not attempt an exhaustive compilation of these non-federal activities. The committee concluded that, rather than proposing a single "mega-agency," improved interagency coordination to respond to specific R&D opportunities and challenges could be better implemented through cooperation among two or more federal entities in R&D partnerships, with involvement of non-federal bodies as appropriate. A number of key factors contributed to this conclusion—the highly varied mandates of the various agencies or offices, in some cases with specific single focus missions (e.g., regulatory role of MSHA, basic research role of NSF, and applied research role of NIOSH) whereas other agencies or offices have broader mandates (e.g., EPA's regulatory and R&D roles, and DOE's wide-ranging mission that also includes support for demonstration projects); their capacities for conducting or managing R&D programs; and the different congressional committees that have responsibility for their funding and oversight.

TABLE S.1 Summary of FY2005 and proposed additional funding for coal-related R&D at federal agencies. All figures are in millions of dollars per year. FY2005 figures are rounded to nearest million for easier comparison with proposed funding levels (unrounded figures for FY2005 funding are presented in Table 7.2).

	FY2005 Funding ($M)	Proposed New Funding ($M)	Total Proposed Funding ($M)
Resource and Reserve Assessments and Characterization	10*	20*	30*
Improved Mine Worker Health and Safety	25	35	60
Environmental Protection and Reclamation	10	60	70
Improved Mining Productivity and Resource Optimization	1	29	30
Total	46	144	190

* Amounts do not include funding for the DOE Office of Fossil Energy's Carbon Sequestration program, which supports a range of sequestration research and demonstration activities that includes geologic sequestration site characterizations.

Accordingly, much stronger R&D partnerships should be established in the areas of coal resource and reserve assessment (**USGS**[2], DOE-EIA, states, industry); improved mine worker health and safety (**NIOSH**, MSHA, industry); improved environmental protection (**OSM**, EPA, states, industry); improved resource recovery and mine productivity (**DOE-FE**, NSF, OSM, NIOSH, academic institutions, industry); and carbon sequestration resource characterization (**USGS**, DOE-FE, states). The total new funding to support these activities amounts to approximately $144 million per year (Table S.1).

SOCIETAL ISSUES

While coal mining benefits communities during the productive life of a mine, after mine closure there is the potential for adverse affects that may include including land use, safety, infrastructure and community development, and sustainability issues. The key to maintaining healthy communities after cessation of mining is early and comprehensive planning that involves all stakeholders.

An aging workforce and a substantial shortage of technically trained personnel in the mining and minerals engineering disciplines pose a threat to projected scenarios that involve substantially increased coal production. Extramural funding by federal agencies to universities in support of research in earth sciences and engineering would assist in recruiting, retaining, and developing mining professionals. This extramural funding is expected to be supported by proposed increased funding to the federal agencies summarized in Table S.1.

Coal will continue to provide a major portion of energy requirements in the United States for at least the next several decades, and it is imperative that policy makers are provided with accurate information describing the amount, location, and quality of the coal resources

[2] Recommended lead agencies are shown in bold.

and reserves that will be available to fulfill these energy needs. It is also important that we extract our coal resource efficiently, safely, and in an environmentally responsible manner. A renewed focus on federal support for coal-related research, coordinated across agencies and with the active participation of the states and industrial sector, is a critical element for each of these requirements.

PREPUBLICATION COPY

COAL

RESEARCH AND DEVELOPMENT TO SUPPORT NATIONAL ENERGY POLICY

Committee on Coal Research, Technology, and Resource Assessments to Inform Energy Policy

Committee on Earth Resources

Board on Earth Sciences and Resources

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PREFACE

The extraordinarily broad scope of the congressional request for advice on coal resources and future coal research and development needs provided a significant challenge for the committee appointed by the National Research Council (NRC). Fortunately, clarifications by staff members from the offices of U.S. Senators Byrd and Specter—the originators of this study—were most helpful, suggesting that the report should be brief and contain limited detail, but with abundant references to other more comprehensive studies. They also emphasized that a major element of their request was to learn of any potential roadblocks that might impinge on the production or delivery of coal should the nation's energy requirements dictate that a substantial increase in coal use was needed.

The task for the committee was made easier by the many experts in all aspects of the coal life cycle who freely gave up their time to make presentations in open session. These presentations formed the basis for the committee's deliberations as it fashioned the findings and recommendations. The committee's task was also facilitated by the cooperation of the interagency liaison group, established and coordinated by the Office of Surface Mining Reclamation and Enforcement (OSM), which provided input to the committee at its public meetings and responded to specific questions.

I am truly indebted to the committee members, all of whom remained completely engaged in the entire process from start to finish. Each gave generously of his expertise, time, and energy, and provided wit and cheerfulness when it was sorely needed. Collectively, they performed as a skillful team with dedication and determination. On behalf of the committee I thank the NRC staff: David Feary, whose input and guidance was indispensable in producing a focused and lucid report; Anthony de Souza, Tanya Pilzak, Caetlin Ofiesh, Kristen Daly, and Sandi Schwartz, who assisted with broad guidance and background information; and James Davis, Amanda Roberts, and Nick Rogers, who made sure the committee process proceeded efficiently and effectively.

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Chair

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This report has been reviewed in draft form 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 institution in making its 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 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 reviewers listed above provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations nor did they see the final draft of the report before its release. The review of this report was overseen by William G. Agnew, General Motors Corporation (retired), Corrales, New Mexico, and William L. Fisher, Jackson School of Geosciences, The University of Texas, Austin. Appointed by the NRC, they were responsible for making certain that an

independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

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