

THE VIRGINIA CENTER FOR COAL AND ENERGY RESEARCH  
VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

MEETING PROJECTED  
**COAL PRODUCTION DEMANDS**  
IN THE USA

UPSTREAM ISSUES, CHALLENGES,  
AND STRATEGIES

SUMMARY BROCHURE AND REPORT PDF



## ABOUT THIS BROCHURE AND CD

This abbreviated version of the report includes both printed text and digital media. The printed foreword, preface, and executive summary provide an overview of the full report. The complete report is included in portable document format (pdf) on the CD attached to the back, inside cover of this brochure. (To read the digital pdf file, a free version of Adobe Acrobat Reader is available at <http://get.adobe.com/reader>.) The pdf will allow the user to read the complete report, search the report for specific areas of interest, and print, reproduce, or transmit the report in whole or in part for use by other interested parties.

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# Foreword

*The National Commission on Energy Policy* (NCEP) has long recognized the critical role that coal serves in the U.S. energy economy. Coal powers more than half the nation's electric system today and remaining reserves are adequate to supply many decades more. As a low-cost, domestically secure, and relatively abundant resource, coal is an important energy supply option in this era of increasing economic and geopolitical insecurity. At the same time, NCEP recognizes that coal's contribution going forward will depend on the development and deployment of new technologies to manage the global climate risks otherwise associated with carbon dioxide emissions from coal combustion. NCEP has been a leading voice for implementing pragmatic policy solutions that steadily transition our nation toward a low-carbon energy system. Successful commercialization of carbon capture and storage (CCS) technology, in particular, offers a path forward for reconciling continued use of coal with the need to reduce carbon emissions.

Beyond the climate-related challenges that are currently the subject of much debate, there are a host of related and mostly underappreciated issues associated with a continued reliance on domestic coal. Given that most policy efforts related to coal in recent years have focused on airborne emissions from coal-fired power plants, a large gap exists in the understanding of the total coal cycle. In particular, the implications of continued, or quite possibly increasing, coal consumption on the nation's producing infrastructure do not appear to have received much attention. With this in mind, NCEP felt that an evenhanded study of coal production by a panel of nationally recognized and independent experts would be of tremendous value. Specifically, NCEP commissioned this report to explore different aspects of the coal supply chain and to highlight critical "upstream" fuel cycle issues that need to be addressed to ensure that the domestic coal industry can continue meeting the nation's energy demands while delivering the social benefits and environmental performance demanded by the public.

NCEP recognizes the vital importance of good information for sound policymaking. It is our hope that this report will be seen as a constructive, balanced assessment of a set of issues that at times can become overtaken by emotion or dogma. We also wish to stress, however, that the study committee's analysis and recommendations were developed independently. As such, this report does not represent NCEP's view or position on any particular issue. Given the caliber of the study group and the extent of the peer review process, we expect that this report will provide a strong foundation for future efforts to bring industry, government, and the nonprofit community together to advance improvements in the upstream coal sector that could provide a host of positive benefits for all. We thank Professor Michael Karmis of Virginia Tech, who chaired this study, and the members of the research team for their hard work and thoughtful exploration of these issues.

Sasha Mackler, Research Director,  
and Nate Gorence, Policy Analyst,  
National Commission on Energy Policy

December 2008

# Preface

*The National Commission on Energy Policy* (NCEP) commissioned this report to review and identify critical “upstream” fuel cycle issues that need to be addressed to ensure that the domestic coal industry can continue meeting the nation’s energy demands while delivering the social benefits and environmental performance demanded by the public.

The central focus of the study was to address matters important to ensuring a coal production system consistent with the nation’s long-term energy and environmental goals and objectives through 2030.

The Virginia Center of Coal and Energy Research (VCCER) of Virginia Tech was contracted to conduct this study by establishing a committee of experts (the “Report Committee”) to research the topic and complete this comprehensive report. The Report Committee met over the course of 18 months, receiving input from various interested parties and stakeholders.

The final report reviews upstream issues, identifies problems, discusses progress and strengths, and recommends areas of improvement. The volume comprises eight chapters, written by experts in the particular chapter area. By focusing on what have come to be known as “upstream” issues of coal production, rather than “downstream” issues of coal utilization, it fills a void in the body of existing literature. An additional objective distinguishes this report from other recent reports. Each chapter was written to be not only a reference guide to basic information on the area in question, but also a comprehensive account of the state of knowledge in the area. As such, the report should be valuable to policymakers, interested and concerned citizens, and academics for use as a reference guide to the basic issues and as a textbook in the classroom.

This study was concluded in the fall of 2008, as the United States and the world entered an unprecedented period of economic crisis and uncertainty. The short-term impact of current economic conditions on pricing and global demand for coal is far from clear. Many observers believe, however, that the impact on price from a decline in demand for coal is likely,

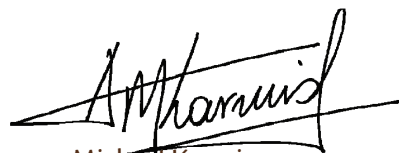
in the long term, to be offset by the continuing challenges of coal production globally. “The long-term global demand for coal is very strong and developing countries will continue to grow at rates that will stretch global supplies of coal,” noted Consol Energy’s CEO Brett Harvey (Consol Energy, 3<sup>rd</sup> Quarter Report, 2008). “While there is uncertainty in today’s economy, any easing of demand growth is likely to be offset by diminished global coal supply,” according to Peabody President and Chief Commercial Officer Richard A. Navarre (Peabody Energy, 3<sup>rd</sup> Quarter Report, 2008). The basic conclusions and the upstream topics examined in this study are fundamental to coal production. The current economic crisis heightens the timeliness and importance of this report.

I am indebted to each of the authors comprising the Report Committee for their dedication, diligence, perseverance, and patience in developing, drafting, and finalizing the report. John Craynon, who provided research and other valuable support to the Report Committee, and Willis Gainer, who provided his knowledge and experience during the preparation of this report, are also recognized for their contributions.

I would like to acknowledge the support of the National Commission on Energy Policy and the Joyce Foundation. Particularly, the discussions, suggestions, and questions of Sasha Mackler and Nate Gorence were invaluable to the progress of this study.

Ellen Kappel of Geosciences Professional Services and Brad Kelley of the Virginia Center for Coal and Energy Research provided important editorial assistance. The task of taking drafts from different authors and compiling a comprehensive, seamless report was substantial, and their dedication was essential to the completion of this document.

The report would not be as comprehensive without the input of many experts, either as reviewers, participants in two kick-off meetings, or as sources of data and information. I am indebted to their time and efforts on behalf of the Report Committee. Finally, on a personal note, everyone I mention here carried out their tasks with wit, patience, and a sense of camaraderie, truly making this project a pleasure to carry out.

A handwritten signature in black ink, appearing to read "M. Karmis", with a large, sweeping flourish underneath.

Michael Karmis  
Chair, Report Committee

# Executive Summary

## INTRODUCTION

Realistic projections of future U.S. energy use consistently predict that coal will likely continue to play a significant role in the nation's energy supply mix for decades to come. Coal's relative abundance and low cost compared to other conventional domestic energy resources are almost certain to drive continued—and possibly expanded—reliance on this fuel going forward. For that reason, much attention has focused on the need to develop technologies for managing coal's downstream environmental liabilities, the most challenging of which are carbon dioxide emissions associated with current forms of coal use. In particular, carbon capture and sequestration (CCS) has emerged as the leading candidate technology for reconciling continued coal use with increasingly urgent concerns about global climate change. In fact, the view expressed by Congressman Rick Boucher (D-Va.) in introducing federal legislation aimed at supporting CCS development is widely shared by policymakers and energy experts: “Given our large coal reserves, its lower cost in comparison with other fuels, and the inadequate availability of fuel alternatives, preservation of the ability of electric utilities to continue coal use is essential.” Less frequently mentioned in these debates, however, are the upstream issues associated with large-scale coal use. These issues include coal reserves determinations, coal extraction and

processing technologies, impacts on local communities, workforce issues, including the health and safety of mineworkers, and the direct environmental impacts of coal extraction and processing.

To explore these upstream issues and to develop recommendations aimed at ensuring that future coal production systems are compatible with social, economic, and environmental objectives at the local and national level, in June 2007, the National Commission on Energy Policy (NCEP) sponsored a comprehensive study of the major upstream issues associated with coal production. NCEP contracted with the Virginia Center for Coal and Energy Research (VCCER) of Virginia Tech to assemble a committee of experts (the Report Committee) and to conduct the study. This report presents the findings of the Report Committee.

The report focuses not only on the coal mining industry, but also on the entire coal sector, including government, equipment suppliers, academic institutions, communities near coal mining, environmental groups, and other parties involved in upstream coal issues. Specifically, the report discusses in detail six major upstream aspects of coal production that could affect the ability of the U.S. coal sector to meet current projections of

likely production demand to 2030. Issues covered include: coal resources and reserves (Chapter 2); mining technology and resource optimization (Chapter 3); coal preparation (Chapter 4); health and safety issues (Chapter 5); environmental protection, practices, and standards (Chapter 6); and workforce challenges (Chapter 7). In each of these areas, industry leaders, government agencies,

academics, interested citizens, and others provided valuable input for identifying and framing the issues discussed in these chapters. Their input, and that of the Report Committee, also informs the policy recommendations offered at the end of each chapter, as well as the overarching themes and recommendations articulated in the study's concluding chapter (Chapter 8).

## MAJOR ISSUES FOR COAL PRODUCTION

This study identifies the major technical, environmental, business, and social issues that confront the coal sector. These issues will need to be addressed as the quantity and geographic distribution of coal supply and demand shifts over time. To meet future demand, the coal production industry will increasingly have to focus on opening new mines, rather than relying, as in the past, primarily on expanding capacity at existing mines. That means attention must be paid to the long lead times typically required to develop new mines to the point where they are producing, the uncertainties associated with both geological and market conditions, and the large capital sums needed to develop new resources. All of these factors contribute to uncertainty and create a risky environment for investment in coal production capacity. This study identifies several key issues that will confront the industry in expanding production to meet projected U.S. coal demand to the year 2030:

- There is a fundamental need to develop, test, and adopt new, environmentally responsible technologies for mining and processing coal.
- Workforce shortages at all levels and in all segments of the coal sector are a major challenge for the industry.
- Coal mining continues to lack broad social acceptance at local, regional, and national levels.

The study also identified two other areas where progress is needed:

- Readily and publicly available data on the major upstream factors covered in this report are inadequate for timely decision-making.
- Cultivating a “beyond compliance” culture within the coal industry and relevant government agencies would foster greater cooperation in addressing upstream issues and promote public trust.

The central findings and recommendations of this study are summarized below.

### 1. Information Challenges

***There is a fundamental need for better and timelier data related to all aspects of the coal sector.***

The need for publicly accessible and reliable information recurs as a common theme throughout this report. At present, the information needed to support sound decision-making regarding different aspects of coal production—including scientific data and information on the industry's current performance—is not readily available. Researchers for this study found that data on coal reserves, the effectiveness of current or proposed environmental or health and safety regulatory programs, the demographics of current and future labor pools,



and other such issues were either difficult to obtain or simply not available. In today's information-based society, access to data and other substantive knowledge are critical for decision-makers in the public and private sector. Therefore, government and industry must work with other stakeholders to ensure that information is collected, disseminated, and analyzed in a useful way.

## 2. Technology Needs

***There is a need to develop and adopt better technologies in all facets of the upstream cycle.***

Government and the private sector have reduced their R&D investments in recent years, slowing the development of improved technologies for mining and processing coal. Government, industry, and academic and private research institutions must work together to address the need for more R&D. These efforts should include increased support for relevant graduate level and Ph.D. programs in the nation's academic institutions.

The Report Committee recommends a three-pronged approach. First, research efforts must shift to a greater emphasis on revolutionary advances rather than, as is common in industrial research, primarily pursuing evolutionary changes in existing product lines and strategies. Ground-breaking research is often best accomplished by academia, with the support of industry and government. Second, the particular challenges facing the U.S. coal industry, such as the need to mine increasingly thinner coal seams while addressing domestic environmental and health and safety concerns, will require public investment in domestic R&D efforts led by U.S.-based government, industry, and academic institutions and less reliance on "imported" R&D from other nations. Third, the coal industry should draw on technology innovations developed in related disciplines and areas of industrial research, such as automation, robotics, communications, and geosensing.

## 3. Improving Performance

***There is a fundamental need to change the culture of the entire coal sector to one that focuses on "beyond compliance" approaches to dealing with regulations and public trust.*** Specifically, the industry should voluntarily adopt practices that go beyond minimum standards. At the same time, government agencies must also be accountable and should work on developing up-to-date, science-based regulations and improving technology transfer. In addition, government agencies should support a "beyond compliance" approach by providing more technical and compliance assistance and staying actively involved with local, state, and corporate entities to ensure that all stakeholders have access to accurate and up-to-date information on environmental and health and safety issues.

The application of more sophisticated risk management approaches by both industry and regulators holds promise for enabling improved environmental and health and safety performance. This could ultimately lead to greater societal acceptance of coal production and utilization. Companies noted for taking a beyond compliance approach to mine health and safety issues have enjoyed better reputations with the workforce and the public. In addition, promoting a safety culture as the top priority of senior management and setting correspondingly ambitious corporate goals can have positive impacts throughout the organization and communities of interest.

## 4. Economic and Business Challenges

***The coal mining sector must address economic uncertainty, avoid supply interruptions, and promote production stability.*** Coal producers, coal users, and, given coal's importance in the electricity supply mix, the public more broadly, have a

vested interest in ensuring an uninterrupted and stable coal supply. To achieve this goal, three areas need increased attention.

First, short-term investment and business practices, which have led to boom and bust cycles in the past, must be avoided. Longer-term considerations also must be addressed, including long lead times for acquiring reserves and obtaining necessary permits, changing workforce needs, and requirements for specialized equipment. In addition, the larger infrastructure issues pertaining to coal and energy transportation must be resolved.

Second, uncertainty about laws and regulations pertaining to health and safety and the environment, public acceptance of coal production and utilization facilities, and future climate policy make it difficult to invest large sums of capital in developing new resources or replacing equipment. The successful development and commercial-scale deployment of carbon capture and storage technology, for instance, would have profound implications for the industry's prospects in a policy environment designed to constrain carbon emissions. The coal community should take a critical look at this and other sources of uncertainty and take a proactive role in helping to find solutions.

Third, policy clarity regarding the role of coal in the nation's domestic energy portfolio is needed to alleviate business uncertainty that tends to discourage private and public investment in coal mining.

## 5. Workforce Crisis

***If the coal mining sector is to remain viable, it must address a potentially significant shortfall in the workforce at all levels.*** As members of the Baby Boom Generation retire, the coal mining sector will increasingly need to compete with other businesses and industries for new workers. Labor shortages could present a significant problem if

demand for coal increases in the future, and could potentially affect all types of jobs in the coal production sector, from mineworkers, to suppliers and service providers, to educational and training institutions, to government agencies. Shifting opportunities and demands in the labor force, from entry-level miners, to management and professional positions, will have consequences for productivity, safety, demand for training, and corporate structure and culture.

The workforce requirements projected in this study, while possibly more conservative than other estimates, suggest that more than 64,000 new workers will be needed to enable the industry to supply projected demand to 2030. Moreover, this figure represents an overall total—as such it does not reflect the serious deficit in workers qualified for managerial, professional, and academic positions that, according to most estimates, is expected to reach crisis proportions in a few years.

High-level efforts by several coal companies to change the corporate culture to emphasize safety while also nurturing workforce development represents a positive step toward addressing these workforce challenges. Further progress toward adopting workplace “best practices” that result in lower turnover and greater job satisfaction is needed. Such efforts must address needs that are particular to the sector, such as recruiting workers who require relocation to coal production sites.

## 6. Education and Training Needs

***Education and training resources are not in place to ensure an adequate supply of professionals and workers and their continued development within the industry and broad coal community.*** Government and industry should support new and expanded training and education initiatives to address employee development and maintain sufficient expertise to maintain the performance

level of the sector. Globally and nationally, there is a severe shortage of students enrolled in the engineering and scientific disciplines related to coal mining. Major challenges exist in undergraduate recruitment and enrollment, support for graduate students and programs, and development of new faculty. Mining-related disciplines in higher education, particularly at the Ph.D. level, must be reinforced and supported by the coal industry and government. In addition, technical training at regional training centers, vocational schools, and community colleges should be expanded and enhanced. Companies, unions, private training vendors, federal and state agencies, and institutions should work together on this effort.

## 7. Societal Acceptability

***It is imperative to address the societal acceptability of coal mining and utilization.*** The coal industry—including both segments of the industry involved in coal production and utilization—faces real and perceived challenges in societal acceptance. For coal to remain a viable part of the domestic energy supply mix, the entire coal sector needs to work collaboratively to disseminate factual information about the availability, importance, and impacts of coal production and use. A skeptical public must be assured that the coal industry is sufficiently regulated and provides a net contribution to society. At the same time, the industry must provide opportunities for local communities and people affected by mining operations to provide input, express concerns, and work with coal producers in a cooperative, good faith manner to resolve issues. To that end, the coal industry must foster proactive dialogue, transparency in its operations and activities, and public participation.

In addition to these broad findings and recommendations, this study offers detailed conclusions and recommendations in six major areas. Chapter conclusions are summarized below.

## Coal Resources and Reserves (Chapter 2)

The nation's coal resource base or endowment is very large. In broad terms, the magnitude of the resource base is relatively well understood—the locations of all major coal basins are known and it is not expected that large, new coal fields will be discovered in the conterminous United States. State and federal agencies have collected a large body of data concerning the quantity and quality of coal basins over the past century, but only a small fraction of the resource base has been sufficiently characterized to be classified as economically recoverable under current conditions (this definition distinguishes “reserves” from “resources”). The Report Committee recommends several initiatives to improve the state of knowledge concerning coal resources and reserves in the United States.

***Reassess the demonstrated reserve base (DRB) and economically recoverable reserves (ERR).*** The U.S. Energy Information Administration (EIA) began a modest effort to update information about the DRB in the 1990s, but it has since been discontinued and EIA has not allocated funds or personnel resources to this effort for several years. The EIA has been responsible for DRB assessment since 1977 and remains the logical agency to continue updating this information. Because of the importance of the DRB, other federal agencies could be given the task if EIA is not able to resume work in this area.

***Expand “coal availability” and “coal recoverability” assessment programs.*** Existing programs can assess economically recoverable resources (reserves) at a pre-feasibility level of detail. These investigations should, however, be expanded—with the aid of state geological agencies—to provide information on a national scale.

**Make resource and reserve data readily accessible.** All data used by federal, state, or other public entities to assess resources and reserves should be maintained in databases that are readily accessible to everyone. These data can be used to update the DRB and ERR and can serve as the basis for nationwide assessments of domestic coal reserves. Database development should include several elements, including identifying new coal parameters, incorporating GIS technologies, and procuring computers capable of analyzing large amounts of data. A federal agency such as the U.S. Geological Survey will need to oversee and coordinate this effort with other federal and state agencies, and this will require funding.

**Assess the option of expanding company disclosure of reserves.** Information on coal reserves obtained by means of questionnaires developed by EIA and the National Mining Association (NMA) is relatively easy to collect and, likely, fairly accurate. Efforts should be made to expand this source of information and to test the willingness of mining companies to be more forthcoming and more detailed in the information they provide.

### Mining Technology and Resource Optimization (Chapter 3)

The specific technologies used in coal extraction directly impact productivity, health and safety, and environmental performance of upstream coal production. These issues and challenges not only have the potential to interrupt production at existing mines and slow the development of new resources, they often also have negative impacts on permitting lead times, mine production and productivity, and cost performance. Mining extraction and resource optimization is dependent, therefore, on the continuous technological development of equipment, systems, and process at the nations coal mines. The following recommendations address issues related to mining technology and resource optimization.

**Reduce the uncertainties associated with mining conditions.** Accurately predicting mining conditions is essential for productive and safe mine operations. As existing mines are expanded or new mines are opened, some of them in virgin areas, the importance of intense and detailed exploration to assess resource characteristics and mining conditions cannot be over emphasized. New applications of remote-sensing and in-seam geophysical exploration techniques for this purpose should be developed.

**Develop new mining equipment and mining technologies.** New technological developments have the potential to improve both underground and surface coal mining, including longwall mining and continuous mining. These improvements may increase productivity, enhance health and safety for mineworkers, and reduce adverse environmental impacts. Mining companies, equipment manufacturers, academic institutions, and private research groups should pool their resources to advance these technologies, and government programs should bring additional resources to bear on the development of new technologies and processes.

**Address changing mining conditions.** Changes in the physical mining environment, such as changes in the depth and thickness of the coal, will pose technical challenges and may lead to adverse mining conditions such as increased gas, heat, and ground stress problems. Use of existing or new equipment not specifically designed for in these changed physical conditions can also give rise to new hazards. Finally, the transition to a less-experienced workforce can bring risks. In this context it will be important to develop innovative technologies, including new equipment and processes, that can help mitigate these risks and be responsive to new laws and regulations.

**Develop energy complexes.** The coal industry is well aware that it may be necessary in the future to exploit coal resources, particularly in the Appalachian and Interior regions of the country, that are less attractive and harder to mine. These resources are likely to be smaller, thinner, and deeper; of inferior quality; and located farther from transportation and other infrastructure facilities. To improve the economics of accessing these resources, it may be necessary to capitalize on synergies that can result from integrating coal production, processing, and utilization facilities at the same site.

**Promote engagement with local communities.** The mining industry today must clearly understand that local communities and people who are affected by a mining operation must be engaged at a much higher level and through a process based on respect, transparency, and dialogue among all stakeholders. This dialogue is an important component in the selection of extraction technologies and approaches. The coal mining sector must create opportunities and seek out engagement with communities so as to achieve the desired outcome—ensuring that local community concerns and aspirations are important elements of mining planning, development, and post-mining land use.

## Coal Preparation (Chapter 4)

The expected steady decline in the quality of U.S. coal reserves will necessitate technology improvements to process feed coals with increasingly difficult washing characteristics. This may involve both incremental enhancements to existing processes as well as revolutionary advances that result in more efficient, less costly, and more environmentally attractive technology options. Coping with lower reserve quality is likely to be especially challenging for western coal operations, because coals in this region have traditionally not required preparation other than size reduction. Increasingly stringent

customer demands coupled with an overburdened railway infrastructure will pressure these operations to improve quality via the application of new coal processing technologies. In addition, several environmental issues represent significant challenges to expanded U.S. coal preparation facilities. Although these impediments vary from state to state, the most significant challenge facing the industry is the management of coal wastes.

The following recommendations address these issues.

**Establish a national coal washability database.** Detailed data related to the cleaning characteristics of much of the nation's coal resources do not currently exist or are not readily accessible. Therefore, it would be useful to develop a detailed database of information about coal washability that fully defines the cleanability of different U.S. coals. This would allow for a more accurate accounting of the existing reserve base and would inform efforts to develop effective and realistic policies for the optimum utilization of the nation's coal resources.

**Provide support for new and improved technologies for upgrading coal quality.** Government and industry commitments to cost-shared support of basic and applied R&D programs in areas related to coal preparation are urgently needed. Specific technical areas that require additional R&D support include fine particle cleaning, fine particle dewatering, dry separation processes, advanced instrumentation, low-rank coal upgrading, particle reconstitution, and waste disposal and handling.

**Address environmental issues associated with waste disposal.** Environmental impacts associated with the disposal of wastes generated during the coal preparation process continue to be a source of concern for communities in the vicinity of coal processing facilities. Therefore, continued support is recommended for environmental studies designed

to quantify the long-term and complex effects of preparation operations on human health and the environment. In addition, new technologies should be developed for remining and reprocessing valuable coal contained in waste impoundments.

## Health and Safety Issues (Chapter 5)

The U.S. mining industry has made significant progress over time in improving mine health and safety by developing and incorporating major advances in mining technology, equipment, processes, and procedures. Increased attention to mine planning and engineering, mining operations, worker selection and training, and safety equipment and practices—all aided by more effective laws and regulations—have made mines safer than ever before. Notwithstanding this impressive progress, however, illnesses, injuries, deaths, and disasters continue to occur. Efforts to continue identifying and reducing the root causes of mine health and safety risks should be accelerated. Management must play an active role by developing and implementing a zero tolerance approach to accident prevention. Accident prevention programs should combine insights gained through research on the “science of safety,” including recent work in the area of human-machine interaction, with a “culture of safety” that seeks to influence human reactions in the workplace.

Specific recommendations in this area are summarized below.

***Enhance and accelerate recruitment and induction strategies for new workers into coal mining.*** Experience has repeatedly shown that outstanding engineering controls and a knowledgeable, well-trained workforce are the two prime requisites for safe mining operations. Given the impending critical shortage of qualified personnel at all levels, there is an immediate need to recruit and train qualified workers for the industry. New workers

must not only be recruited in sufficient numbers, they must gain the skills needed to ensure a safe, healthy, and productive work environment. Future miners will be required to have multidisciplinary and critical thinking skills to work effectively and safely in an industry that is increasingly mechanized and reliant on larger-scale equipment.

### ***Enhance the application of systems safety methods for safety evaluation of mining systems.***

The fact that mining injuries, illnesses, deaths, and disasters continue to occur suggests that the root causes of these incidents have not been fully addressed. The result is that hazards in the system can remain undetected and may manifest at a later time, possibly with disastrous consequences. Proactive approaches that examine systems critically for either component and/or systemic weaknesses, using tools and techniques from risk and reliability analyses and techniques, are needed.

***Evaluate and develop more effective systems for management and control of the safety functions in organizations.*** The coal-producing industry increasingly recognizes the importance of organizational factors, including the goals, objectives, and means of managing safety, that are in place at different firms to enhance mine health and safety performance. Introducing modern safety management techniques in coal mining requires a detailed evaluation of current best practices in other industries and applying those practices, where possible, to the mining environment.

***Expand the funding and scope of mine health and safety research.*** To make substantial and sustained progress in mine health and safety, vibrant research initiatives involving government, industry, universities, and manufacturers are needed. Since 1995, government funding for mining health and safety research has declined. Though Congress

has occasionally funded specific projects, there is a need to increase health and safety R&D more broadly and on a more permanent basis.

## Environmental Protection, Practices, and Standards (Chapter 6)

Significant progress has been made over the last 30 years in implementing changes in coal mining practices that protect the public, environment, and natural resources while substantially expanding coal production. Practices such as “beyond compliance stewardship” are becoming accepted in coal companies, and have resulted in improvements in environmental planning, reclamation, and revegetation practices. Post-mining improvements at surface coal mines are providing greater opportunities for wildlife, landowners, communities, and industry. Further advances in this area will lead to better land, air, and water stewardship, and reduce societal and other impediments to continued production of coal for the nation’s energy needs. The environmental impacts that need to be addressed at different sites vary depending on resource quality, quantity, and distribution; geologic integrity; mining methods; climatic and biological factors; and proximity of cultural and historic landmarks. For coal production increases to keep pace with demand, more attention will need to be focused on a number of environmental issues, including: drainage waters; reclamation practices; air quality concerns, including fugitive dust and methane; potential disturbances to hydrologic systems; ground subsidence; broader habitat displacement; and waste management at mines and preparation plants.

The following are specific recommendations for continued progress in addressing the upstream environmental impacts of coal use.

### ***Reduce impacts on water resources and quality.***

The coal industry, working in conjunction with federal and state regulatory agencies and research

organizations, must develop better science-based technologies for modeling hydrologic changes and address water quality concerns, including those related to sedimentation, acid mine drainage (AMD), and the impact of trace elements that occur both during and after mining.

***Address prominent regional environmental problems.*** The industry’s approach to high-profile environmental issues in each of the nation’s three major coal-producing regions has the potential to define its environmental performance and strongly influence the public’s perceptions about, and overall acceptance of, mining operations. Mountaintop mining and valley fills in Appalachia may be limited in the future because they are highly controversial with the public. Air quality issues, especially related to fugitive dust and methane release, are of major concern throughout the United States, but have become increasingly important in the Western region. At the same time, greater coordination is needed to protect threatened and endangered species from the adverse effects of coal mining operations, particularly in the Interior and Appalachian regions of the country.

***Implement an effective and transparent community engagement process.*** The coal industry must adopt effective and transparent processes to engage local communities, emphasize the conservation of biodiversity, and implement integrated approaches to post-mining land-use planning that involve all stakeholders. Environmental concerns must be addressed and various parties must work together to ensure that there is a better understanding of environmental issues and challenges associated with all phases of coal mining operations.

***Enhance reclamation planning and performance measures.*** Despite the tremendous progress made in surface mine reclamation, there is growing public concern that efforts to restore land and return it to other uses after mining are not occurring

in a timely manner. The status of reclamation efforts, often gathered from bond release information, is an inadequate measure of the extent of actual field work or of whether restoration has been successful. Industry, federal agencies, and state regulatory agencies must develop reasonable deadlines for reclamation and establishment of post-mining land uses.

***Develop science-based and technologically feasible regulations and practices.*** Environmental concerns, public attention, and local issues will influence how and to what extent coal production can be expanded in different regions. Federal and state regulatory agencies, working with industry and communities, must develop science-based regulations that include technically feasible guidelines and best practices to effectively address environmental concerns and encourage adoption of new technologies and approaches that minimize impacts.

***Improve the permitting process on federal lands.*** About 40 percent of the nation's coal production is from mines located on federal lands and this share is projected to increase in the future. The federal government, in consultation with local communities and industry, should consider restructuring federal coal leasing and permitting programs to eliminate duplication and overlapping requirements.

***Encourage additional funding to support research and workforce development.*** Increased funding is needed to support research efforts at federal and state agencies, universities, and other research organizations aimed at addressing the environmental impacts of past, existing, and future mining operations. Increased funding will also be required to sustain personnel levels at federal and state regulatory agencies and to support the development and use of environmentally responsible technologies.

## The Workforce Challenge (Chapter 7)

The coal mining sector will face significant workforce challenges between now and 2030. Given retirements and potential growth in demand for coal, over 64,000 workers will need to be recruited—and these estimates do not include managerial and professional positions. Labor shortages are likely to impact all types of jobs in all areas of the coal mining sector, from coal producers to the coal community at large, including suppliers and service providers, educational and training institutions, and government agencies.

The following recommendations address issues of workforce recruitment, retention, and career-long development in the coal sector at large.

***Create a new pool of workers for the coal mining industry.*** Developing a pool of potential workers at all levels will require actions by coal producers, coal suppliers, state and federal governments, and educational and training institutions. Companies must develop, or reinforce, corporate philosophies and cultures that promote the development of employees, offering competitive salary and benefit packages and providing a rewarding work environment to enhance recruitment, retention, and development.

***Integrate the impacts of a massive labor swing into human resources and operations strategies.*** A major labor transition could have significant impacts on worker productivity, health, and safety, and even on social and cultural environments in the workplace and in mining communities. Developing and supporting innovative, accelerated training programs for all levels of employees will be necessary if the sector as a whole is to achieve its workforce objectives and successfully integrate large numbers of new workers.



**Strengthen mining-related disciplines at higher-education institutions.** Globally and nationally, there is a severe educational crisis in the engineering and scientific disciplines that relate to coal mining. Major problems include undergraduate recruitment and enrollment, support for graduate students and programs, and faculty development and promotion in these fields. Mining-related disciplines in higher-education institutions must be reinforced and supported by the broader coal sector.

**Expand training institutions and resources on a regional basis.** To ensure an adequate supply of skilled employees, enhanced and expanded training centers and facilities will be required. Companies, unions, private training vendors,

federal and state agencies, and institutions should work together on this effort, which must involve community colleges and vocational schools and must make use of new technologies such as virtual reality, advanced simulation, and distance learning.

**Overcome perception problems of the coal mining sector.** The coal mining sector needs to overcome perception issues and public mistrust to become an employer of choice. The coal community must address its public image by promoting active community engagement, fostering pride in coal-related disciplines, and committing to the career-long development of current and future employees. Image improvement should be a major goal for the entire coal sector.

## CONCLUSION

Coal will continue to play an important role in the U.S energy portfolio, at least until 2030, which is the time frame of this study. It is therefore critical to address the challenges and the need for improvement in the upstream aspects of the coal fuel cycle. There are also important issues of safety and security with regard to meeting the nation's energy demands from domestic sources, including coal, that are beyond the scope of this study and therefore are not addressed in this report. An overarching theme of this study is the need for greater cooperative efforts by coal producers, coal suppliers and equipment manufacturers, government

agencies, academic institutions, and other nongovernmental organizations to examine system-wide needs and impacts, as well as economic contributions and benefits. A comprehensive life-cycle analysis should include factors associated with coal extraction, processing, transportation, and utilization. Worker health and safety issues, positive and negative environmental impacts, and contributions to the public wellbeing should also be fully assessed so that policymakers can make informed decisions regarding the role of coal in meeting the nation's future energy needs.

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JANUARY 2009

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