TESTIMONY ON COAL RESEARCH NEEDS
to the House Subcommittee on
Energy Development and Applications
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Congressman Fuqua, I appreciate the opportunity to present my thoughts on coal research including achievements of the DOE programs, new directions for coal research and the Federal role. Brief reviews of coal resources and coal related technologies are also presented to provide perspective for the subsequent discussions. A summary as this can only address generic research areas, but specific details on past accomplishments or needed research could be further developed if you so desire.

Coal Resources

The extensive U.S. coal resources have been described in many documents and are summarized in Table 1. The point to be made is that the different coal types require different technologies for recovery, use and environmental protection. Thus, research needs must be categorized according to coal types as well as the individual technologies noted in the next section.

A second point to be made is that variations in coals of the same type (frequently from different locations in the same coal mine) can have major effects on the combustion, liquefaction or gasification of that coal. We do not understand these variations, nor can we predict how much variations will effect subsequent processes.

Table 1. United States Coal Resources

<u>Coal Type</u>	<u>Remaining Identified Resource Billion Tons</u>
Anthracite ¹	20
Bituminous ¹	747
Sub-bituminous ¹	486
Lignite ¹	478
Peat ²	120

¹G. L. Baughman, Editor, Synthetic Fuels Data Handbook, Cameron Engineers, Inc., Denver, Colorado, p. 153 (1978).

²V. K. Mathur, Coal Powers, Its Promises and Problems, Energy Communications, 7(3), 205 (1981).

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Coal Related Technologies

Development and utilization of coal involves technologies ranging from geophysical exploration techniques to evaluating the implications of acid rain. An abbreviated list of activities and technologies are noted in Table 2. Many important, good research projects could be identified for each of the areas; any research list will reflect the background and interest of the individual providing the list. Development of any coal research program should therefore include a continually updated systems approach to identify the research areas that will have the maximum impact on national needs.

Since this discussion is oriented toward DOE programs, I have chosen not to include comments on exploration and assessment (a USGS responsibility) or on mining (a Bureau of Mines responsibility).

Table 2. Stages in the Development and Utilization of Coal

<u>Stage</u>	<u>Activities</u>	<u>Technologies</u>
Exploration	Location and Size Characterization	Geosciences, Drilling Coring, Chemical Analyses, Petrology
	Environmental Evaluation	Subsidence, Aquifer Definitions, Mine Safety
Recovery	Mining	Rock Mechanics, Engineering, Machine Design
	Cleaning	Size Reduction, Flotation, Separation Processes
	Environment	Mine Safety, Subsidence
Transportation	Railway and Truck	Engineering
	Oil or Water Slurry	Fluid Dynamics, Slurry Handling, Surface Sciences
Utilization	Combustion	Many chemical, physical and engineering sciences
	Gasification In Situ	Chemical, physical, engineering and geological sciences
	Surface	Chemical, physical and engineering sciences
	Liquefaction Indirect	Chemical, physical, and engineering sciences
	Direct Environmental	Chemical, engineering and geosciences

DOE Coal Research Achievements

As you are well aware, coal research in the past 50 years has periodically received Federal emphasis followed by long periods of almost complete neglect. This cyclic emphasis then requires an initial large expenditure of time and monies to resurrect past history, to identify applicable techniques and tools developed since the past research, and to repeat many of the learning mistakes. This relearning occurred in the ERDA/DOE years (with current industrial and Government trends suggesting this learning cycle will be repeated in another 20-50 years).

Significant scientific contributions have been made when the research need was recognized and scientists who became aware of the problems agreed to branch into the dirty, complex, very difficult research of coal sciences. This research has been supported by ERDA/DOE, EPRI, state and other agencies in conjunction with private industry. I do not believe it would be useful, nor am I in any position to list the multitude of recent accomplishments in the coal sciences. However, I would like to note some major results for which DOE funding was wholly or partially responsible:

- Mobil's methanol-to-gasoline shape selective catalyst which not only has current commercial applications, but has triggered a new wave of catalyst research.
- Entrained bed gasifiers that are potentially capable of handling caking and non-caking coals (Lurgi processes use only non-caking types).
- Direct liquefaction processes that operate at 1/5 the pressure of the original German processes.
- Identification of a truly advanced liquefaction concept (Integrated Two-Stage) that could have a significant impact on the future use of coal.
- Reassessment of the availability and applicability of the U.S. coal resource.
- Application of modern techniques (Mossbauer, x-ray fluorescence, nuclear magnetic resonance, laser plume spectroscopy, etc.) to study coal and the use of these to provide information on coal reactions.
- Identification of potential health hazards introduced by some coal liquids.
- New materials (carbides, borides...) developed for use in highly erosive environments.

- Engineering improvements in pumps, compressors, valves and other equipment for high temperature or solids handling applications.
- New diagnostic concepts that have process control applications in many industries.

Other areas could be listed and multiple detailed accomplishments could also be given for each of the results noted above. Less tangible, but perhaps a more important product of DOE funding, is the renewed academic and industrial interest in the coal sciences which should continue to provide new insights and contributions to the use of the national coal resource.

The Federal Role

Federal responsibilities I chose to address for considering coal research needs include National Security, Resource Utilization and Environmental Protection. The following comments are based on my individual perceptions and do not necessarily reflect the opinions of Sandia National Laboratories or of the Department of Energy.

National Security

The U.S. domestic and military transportation systems rely entirely on liquid fuels. Emergencies such as war or embargoes that would limit this supply are of national concern. A second security question is related to the balance of payments with long-range and increasing dependence on the oil exporting nations. A third concern is the potential shift of all the advanced technology to countries such as Japan and Germany who are emphasizing coal process research.

In a national emergency, liquid fuel needs would be met in part by reallocation of domestic petroleum and use of stored reserves. Shale oils, because of their chemistry, are suitable for providing additional diesel and jet fuels. Coal liquids would be applicable for internal combustion engines, chemicals and explosives. Technologies now exist (SRC-II, Exxon Donor Solvent, H-Coal, Indirect Liquefaction) that could supply needed coal liquids although the plants would not operate in an optimum mode. Major concerns would be the availability of materials plus fabrication facilities, and of engineers and scientists who understand the nuances of coal processes.

Continued development of coal processes to meet future U.S. needs and to counter petroleum imports is currently limited by economics and environmental concerns. Since no one operation dominates the cost of coal gasification/liquefaction systems, evolutionary R&D (best done by industry) has low probability of providing a significant cost reduction. However, the environmental uncertainties must be addressed by the government in order to assess hazards,

define regulations and identify acceptable commercial processes.

With the envisioned decrease of U.S. interest in coal research and intensification of work in Japan and Germany, our nation could readily reach the stage where we would have to rely on technology from outside this country. This external reliance could have serious implications in national security.

Resource Utilization

Evaluation of resources to plan for future U.S. needs and exploitation control to maximize resource utilization are clearly Federal roles. The evaluation role is under the purview of the U.S. Geological Survey and will not be discussed further. Areas of uncertainty in resource availability or applicability should be addressed, possibly involving R&D. Examples: What energy needs can be or should be met by peat? By the lignites? Can we ever use half of the coal left in underground mines as pillars to meet future energy demands? Are there new mining or in situ processes that could recover resources that now appear unavailable? The purpose of research in these areas would be to evaluate the technological feasibility of extending the available resource, not to develop commercially economic processes.

Environmental Protection

Understanding, control and monitoring of undesirable environmental effects that impact many states or nations is clearly a Federal role. Environmental concerns extend through the entire coal utilization cycle from the impact of exploration techniques on wildlife, to subsidence and safety during mining, to water and air pollution during processing, to the international concerns of acid rain. Historical emphasis has been on identifying effects of pollution, monitoring the extent of such pollution and developing regulations to protect the populace. These activities should continue, particularly in areas of potential global impact such as acid rain and the CO₂ greenhouse question.

However, I submit that a basic understanding of coal chemistry, the combustion process, liquefaction and gasification mechanisms and other fundamental coal reactions is essential to find methods to eliminate or minimize the identified hazards in the coal processing itself. This research thrust is not financially supported by industry because of no visible future profit. Such a thrust would not compromise current industry research in areas of scrubbers, cyclones, etc., needed to meet Federal and state regulations.

Directions for Coal Research

As mentioned earlier, coal research needed for exploration, resource characterization and mining will not be discussed although continued studies are needed in those areas. Also, generic needs to maintain academic expertise and a "pure" research base are the responsibilities of other Federal agencies such as the National Science Foundation and the DOE Basic Energy Sciences effort. Thus, the research I will address emphasizes studies using coal, coal products and coal systems to meet national needs as previously described.

Also, you are well aware of the numerous other extensive studies made by prestigious scientists or groups such as the American Physical Society³, the FERWG Committee⁴, the ERAB Committee⁵, the Gorbaty group⁶, and V. K. Mather⁷. I have little to add to their conclusions and consequently have chosen to list those areas I consider most important and in my priority sequence.

Priority I -- Fundamentals

● Coal Structure, Chemistry and Physics

Objective: Understand the organic and mineral constituents in various coals in terms of effects on behavior in combustion, pyrolysis, gasification, liquefaction and cleaning. Identify potential uses for each coal and possible environmental concerns during use.

Areas of Study: Structure; porosity; initial surface reactions; mechanical behavior; mechanism of formations of carcinogens, NO_x, SO_x; chemistry of organic and inorganic portions.

³Pines, D. (Editor), Report to the American Physical Society by the Study Group on Research Planning for Coal Utilization and Synthetic Fuel Planning, Reviews of Modern Physics, 53 (4), Pt. 2 (October 1981).

⁴Penner, S. S., and others, Research Needs for Coal Gasification and Coal Liquefaction, Energy, 5, p. 1091 (1980).

⁵Foster, J. S., and others, Federal Energy R&D Priorities, Report of the Energy Research Advisory Board (November 1981).

⁶Gorbaty, M. L., and others, Coal Science: Basic Research Opportunities, Combustion, 51, p. 12 (April 1980).

⁷Mather, V. K., Coal Power, Its Promises and Problems, Energy Communications, 7(3), p. 201 (1981).

⊗ Transport and Physical Properties

Objective: Provide a data base for engineering design and reaction dynamics needed to develop new process concepts and understand basic reaction mechanisms.

Areas of Study: Physical properties; diffusion; swelling; softening mechanics; elastic and plastic behavior; pore structure; adsorption physics; non-Newtonian flow.

⊗ Environmental

Objective: Understand the mechanisms of formation of carcinogens, NO_x , SO_x for possible mitigation of the undesirable species.

Areas of Study: Surface physics and chemical reactions; kinetics; thermodynamics.

Priority II -- Primary Processes and Products

⊗ Revolutionary Combustion, Liquefaction and Gasification Concepts

Objective: Identify new processes that could markedly change the processing and use of coal.

Areas of Study: Low temperature reactions; gasification in solution; dissolution by highly polar compounds; catalytic combustion; microwave and ultrasonic effects.

⊗ Physical Processing

Objective: Develop unique processes for preparing a clean or modified coal for subsequent use.

Areas of Study: Coal-mineral interactions; mineral reactions; coal fragmentation; surface physics; crushing and grinding; selective separations.

⊗ Properties of Coal Derived Products

Objective: Understand potential health and disposal problems associated with coal liquid and gaseous products.

Areas of Study: Chemical characterization; toxicity studies; decomposition mechanisms; kinetics.

① Multiphase Flow

Objective: Develop the mathematical and data base needed for the design of process equipment.

Areas of Study: Three-phase flow; solids-gas flow; non-Newtonian systems; viscosity measurements; heat transfer rates; flow regimes.

Priority III -- Secondary Processes and Products

② Novel Catalysts

Objective: Develop catalysts that allow reactions at low temperature or provide unique product distributions.

Areas of Study: Shape selective catalysts; homogeneous catalysis; surface physics and chemistry; kinetics; thermodynamics.

③ Coal Product Upgrading

Objective: Develop energy efficient methods to minimize environmental concerns and provide unique product slates.

Areas of Study: Reaction chemistry; analytical procedure development; kinetic; catalytic mechanisms, gas and liquid clean-up.

④ In Situ Processing

Objective: Develop adequate understanding and new concepts for concerting the coal in its natural, in situ environment.

Areas of Study: Thermomechanical properties of coal systems; geostructure of thin coal beds; unique process concepts; heat and mass transport modeling.

⑤ Ash and Solid Residue Handling

Objective: Identify potential uses (e.g., mineral recovery) or limitations to the utilization or disposal of process solid residues.

Areas of Study: Inorganic chemistry; petrography; leaching; structural stability; solids handling.

Priority IV -- Support Research

⊗ Coal Bank

Objective: Maintain a set of representative coal samples and a summary of past research on those samples for use by the scientific community.

Areas of Study: Data retrieval; characterization; petrography; library science.

⊗ Materials

Objective: Identify and resolve materials limitations unique to coal processing.

Areas of Study: Corrosion; erosion; stress cracking; fracture toughness; high temperature behavior.

⊗ Dynamics of Fluid Beds

Objective: Develop data and understanding for the design of fluid or entrained bed combustors, gasifiers or other processing equipment.

Areas of Study: Fluid dynamics; heat transfer; fluidization of solids; kinetics.

⊗ Diagnostics

Objective: Develop analytical or process control tools needed for coal understanding and processing.

Areas of Study: Diagnostics; mechanics; transport physics, instrumentation.

Priority V -- Evolutionary Concepts

Current combustion, gasification and liquefaction concepts are constrained in many areas by a lack of understanding of the process dynamics, inability to extrapolate processes from one coal to another, materials and instrumentation limitations, yields, hydrogen utilization and thermal efficiency. Good research in selected areas could provide significant improvements in the current process concepts.

Conclusions

Discussions of this paper and interactions with the coal research community lead to the following conclusions on the future and needs for coal research.

- ④ Resource -- The coal resource is immense and a plan for optimum use of the peat to anthracite supplies should be developed and evolved.
- ④ Current and Future Research -- Coal research efforts in industry are rapidly decreasing and work at universities, Technology Centers and National Laboratories is directly dependent on Federal funding. Industrial emphases will shift to combustion and coal cleaning with limited development of gasification concepts.
- ④ Human Resource Base -- A cadre of scientists and engineers knowledgeable in coal processes needs to be maintained for evaluating environmental effects of coal use and for a design base in times of national emergencies.
- ④ Basic Coal Sciences -- A major effort in understanding coal structure, chemistry and physics as related to behavior in processing is essential to developing environmentally acceptable processes and to identify revolutionary concepts for utilization of the national resource.
- ④ Federal support of coal research is required to assure national needs of security, environmental protection and resource utilization are met.

As the U.S. energy base shifts from petroleum to coal, one can envision the development of a new coal refining industry. Such an industry would probably not look like current petroleum refineries, but, similar to oil refineries, would be capable of accepting a variety of feed stocks (peat to anthracite) and providing a product slate (fuels, chemicals, graphite, heat) to meet varying seasonal or national needs. This potential coal refining industry could optimally use the U.S. resources of coal and people. Evolution of such an industry can only occur if the data base on coal, coal properties and coal behavior is adequate to trigger the innovative thinking that has developed many U.S. industries.