A CRITICAL REVIEW OF EFFICIENT AND ENVIRONMENTALLY SOUND COAL UTILIZATION TECHNOLOGY

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EXECUTIVE SUMMARY

Overview

This report clearly shows that technology can enable coal to continue and perhaps expand its major role in the energy portfolio of the U.S. Through currently available and emerging processes and systems, coal will help to keep energy prices stable and reasonable while making it possible to achieve key national goals. Such expectations for coal and coal utilization technology are basic to national economic stability and will support sustainable development throughout the world.

Identifying the Needs of "Coal Utilization Technology"

In this report, consistent with Secretary O'Leary's request, coal utilization technologies have been comprehensively reviewed and evaluated from the perspective of their potential value to industry. The objective was to determine the status of each technology relative to its potential role in future clean power generation and other coal conversion applications within the context of sustainable development.

To identify and analyze various technologies, the broad category of "Coal Utilization Technology" has been divided into subcategories, discussed in Chapters III, IV, and V. Forty-four technologies have been examined with respect to their positions along the path from research through the required subsequent stages of development, demonstration, and, finally, commercialization. An assessment of the research, development, demonstration, and commercialization needs of each technology is provided in Appendix A, Exhibit 1.

Five key conclusions may be drawn from the information presented in Exhibit 1:

1. *All new technologies need some form of risk sharing for first-of-a-kind plants in order to progress quickly from demonstration to commercial use.*

2. *Many of the most promising technologies still require demonstration at full commercial scale.*

3. *Many of the promising technologies still require fundamental research and development, as well as related significant investments, before their potential applicability for future utilization can be evaluated properly.*

4. *As Federal and state environmental requirements are mandated, the relative importance of many of these technologies changes.*

5. *A wide range of technologies is necessary to assure economically viable and environmentally acceptable coal options in both the short term and the long term.*

Nine technologies are ready for initial commercialization but require some form of assistance for deployment and acceptance in the marketplace. Of the nineteen technologies in need of further support as demonstration projects in order to ensure a better assessment of their technical and economic viability, fourteen are being demonstrated in the Clean Coal Technology (CCT) Program. *It is recommended that all of these fourteen CCT demonstration projects be completed.*

Similarly, twenty-five technologies were seen to have significant development needs. Many of these projects offer the potential for future applications, but, as in the case for research needs, the manner and timing of meeting these needs will determine the ultimate commercial outcome.

Out of the forty-four technologies listed, twenty-two still have significant research needs. In most cases, it is difficult to predict the future commercial success of these technologies until some of the research needs are met. In other words, both the manner and the timing of addressing the needs of a given technology may determine whether or not the technology can ever become commercially viable, or to what extent it will penetrate the commercial market.

Priorities for Research, Development, Demonstration, and Commercial Assistance

A critical review of coal utilization technologies enabled the ordering of priorities for each technology with respect to its needs in the steps along the path from research to commercialization. *It is recommended that the needs of the select list of subject areas and technologies shown in Exhibits 2, 3, 4, and 5 in Appendix A be met as soon as possible so they may advance coal utilization early in the next century.*

The priority rankings took into account the relative importance of various key factors such as the potential impact of new environmental requirements on the power industry, maximum possible margins of improvement over currently available technology, potential impact on the coal utilization industries, and applicability of research or development to more than one technology.

Research

The critical research needs of eight technologies are prioritized in Appendix A, Exhibit 2. The highest research need is for new technologies to control toxic air emissions such as mercury and other heavy metal emissions. Metallic and ceramic materials and coatings to withstand high temperature oxidation, hot corrosion, and wear are next in priority

because of their importance to the success of combustion turbines, pressurized fluidized bed combustion systems, advanced boilers, and recuperators.

Characterization of effluent streams from electrostatic precipitators, fabric filters, flue gas desulfurization, and selective catalytic reduction systems, as well as a topping system for capturing fine particulates, is ranked next due to concerns about control of hazardous air pollutant emissions from these emission control systems.

The major need in fuel cell technology is improved cathode life. The next priority is a postcombustion control and sequestration process for carbon dioxide emissions. Another research priority is to develop advanced formulations for selective catalytic reduction systems. Carbon monoxide conversion, catalyst chemistry, and slurry processes for conversion of synthesis gas are assigned the next priority.

Development

Six coal utilization technologies in need of additional development are prioritized in Appendix A, Exhibit 3. These technologies offer the greatest potential for early commercial success, based on their current status of development.

Hot gas clean-up and alkali and heavy metal control are key development areas which are critical to further improvement of the efficiency of integrated gasification combined cycles and advanced pressurized fluidized bed combustion systems. The next priority focuses on development of oxidation and corrosion resistant coatings for metallics and ceramics to withstand high temperature regimes of advanced gas turbine systems. The high operating temperatures of advanced gas turbines are conducive to production of oxides of nitrogen. Development of a catalytic combustion process would offer a valuable option to curb these emissions.

Technology for control of mercury emissions is an important need. Another major need is for development of a topping combustor for advanced pressurized fluidized bed systems. The combustor development which has been going on for some time should be accelerated to benefit advanced pressurized fluidized bed combustion technologies.

Fuel cells offer the potential to achieve very high energy conversion efficiency and low emissions. Cost-effective manufacturing process development would greatly enhance the applications of fuel cells as stand-alone power sources and as topping cycles for gas turbines.

An improved mist eliminator for high velocity scrubber systems is needed for wet flue gas desulfurization systems.

Demonstration

Eight demonstration priorities are noted in Appendix A, Exhibit 4. Completion of the on-going Clean Coal Technology (CCT) demonstration projects and scale-up of the pressurized fluidized bed system to large commercial size (about 350 MW) are high priorities. The project sizes in the CCT program are not large enough to provide adequate quantitative assessment of the challenges and derived benefits of these technologies.

The current integrated gasification combined cycle demonstration projects under the CCT program should be completed. The Low Emissions Boiler Systems (LEBS) program also should be completed. This will demonstrate a variety of technologies to increase the thermal efficiency and emission control for pulverized coal-fired boilers. These may be adopted immediately, in part, in new designs and also may form the basis for ultra-efficient, ultra-clean pulverized coal-fired boilers.

It is recommended that all effluent streams of current projects in the CCT program be characterized to assess the need for hazardous air pollutant control and that the CCT demonstration projects on indirect-fired cycles and molten carbonate fuel cells be completed.

The utilization of key solid streams of the CCT program should be evaluated to determine effective byproduct utilization procedures. Projects for the control of sulfur dioxide and oxides of nitrogen in the CCT program should be completed. The economics of these control systems also must be evaluated.

Commercial Assistance

Technologies in need of commercialization assistance are prioritized in Appendix A, Exhibit 5. *It is recommended that mechanisms be established to provide commercialization assistance, in the form of risk-sharing and international marketing assistance, for five technologies which offer the greatest promise for near-term benefits. These projects are (1) integrated gasification combined cycle systems, (2) advanced pressurized fluidized bed combustion systems, (3) physical coal cleaning, (4) low rank coal beneficiation, and (5) coal-fired diesel engines.*

Major obvious impediments to deployment of any new technology relate to financial and technical risks associated with the first few installations of commercial size. Initial capital costs will be high, and investors will require some assurance not only of a reasonable return on their investments, but also of an adequate probability of commercial success. Scaling up the size of technical facilities always entails an element of uncertainty, directly translated into financial risk, and there is no proven strategy for going from demonstration to commercialization with absolute confidence. Therefore, rapid deployment of the

technologies with the greatest promise of commercial success will require some mechanism for underwriting these risks. *It is recommended that the Federal Government create an insurance program to provide a safety net for the first-of-a-kind new commercial facilities. This should be done in partnership with coal stakeholders.*

The National Coal Council recognizes that the Administration and Congress are concerned about Federal outlays and balancing the Federal budget. An investment in advanced coal technology programs, however, should prove to be both very cost-effective and in the national interest. Most of these advanced coal technology systems offer significant environmental control advantages as well as higher efficiency performance over present systems. In addition, life cycle cost projections indicate a lower cost of power combined with the ability to meet stringent environmental requirements.

The Federal Government, in concert with industry, will have invested nearly $10 billion in developing and demonstrating these advanced coal systems by the year 2000. In order to capitalize fully on this investment, continued Federal financial incentives are necessary for the first full-scale pre-commercial plants.

In a previous report by the National Coal Council, *Clean Coal Technology for Sustainable Development*, it was estimated that Federal incentives of approximately $1.4 billion over fifteen years may be necessary to establish a domestic deployment program. *It is recommended that DOE consider a range of financial incentive options which not only can minimize Federal expenditures, but also can assure initial pre-commercial deployment of the systems.*

It is recommended that incentives be established (1) to shorten the time required for commercial deployment, (2) to improve prospects for exporting U.S. technology, and (3) to ensure continued benefits of environmental protection, energy efficiency, and "highest and best" economic use of the nation's most abundant domestic energy resource: coal.

One possible approach would be to extend tax credits to the first few commercial scale coal power systems. Some of the present CCT projects have successfully utilized the existing tax code (Internal Revenue Code, 94 FED, paragraph 4050, Section 29) "credit for producing fuel from a non-conventional source." This credit has proven to be an important factor in the ability to finance several CCT projects. Therefore, *it is recommended that Section 29 tax credit be extended and expanded.*

It is recommended that DOE consider expanding benefits of the Section 29 tax credits to advanced coal power systems, advanced emission control systems, and coal conversion processes which may require government risk-sharing in order to bring about commercialization of these technologies.

It is further recommended that the "facility original placed in service date" be extended from the present "before January 1, 1997," to "before January 1, 2007." This will provide a ten-year window of incentive to meet projected capacity growth and environmental performance goals by the year 2010. This also would allow sufficient time to plan, design, permit, and construct qualifying facilities.

Research and development needs do not require as much financial underwriting as do the commercial installations, but, considering the scope of these needs and the benefits of ultimate commercial success, it is clear that significant financial support is deserved and will be required. Here again, coal stakeholders must recognize that their investments and participation in coal research and development are essential for their long-term success. Stakeholders are encouraged to consider creating an entity similar to the Electric Power Research Institute or the Gas Research Institute for the purpose of supporting and directing coal-related research. *It also is recommended that DOE maintain, to the maximum extent possible, support of coal technology research and development.*

Importance of Nurturing Coal Research Expertise

In Chapter V, Part D, under "Development Needs," it is pointed out that coal liquefaction technologies do not survive well "on the shelf" -- that the German technologies developed before World War II had to be reinvented during the 1970s and 1980s because the original experts were no longer available to guide the work. This is true of other coal utilization technologies as well. *It is recommended that DOE assume the responsibility of "technology caretaker" for coal liquefaction technology, since commercialization seems to be unlikely in the near future.*

This thought leads to a more profound question about how new coal technologies can be expected to emerge in the future if the supply of competent and experienced coal research personnel is allowed to disappear. All coal utilization technologies have roots in basic research, and a number of interacting scientific and engineering disciplines are always required throughout the process, from research through development and demonstration. The decline in the number of universities with faculty expertise and graduate research programs related to coal since the 1970s is a serious problem which threatens the future of coal technology. In addition to the current need for research, there will be a related need for trained personnel with experience in coal technologies to design and manage the advanced coal utilization facilities of the future.

Several of the sections outlining "Development Needs" in this report have pointed out the importance of university research in resolving some of the current technical problems. In order to address this need to nurture coal research expertise, a deliberate plan of implementation must be developed by DOE in concert with the industry or this is not likely to happen. *It is recommended that DOE, working with industry stakeholders, develop a*

deliberate plan of implementation (1) to identify the persons and institutions where coal research expertise can now be found, (2) to provide adequate and stable levels of funding to sustain significant research programs, (3) to provide incentives for productive programs and competition between programs, and (4) to ensure rewarding career paths for graduate students who address coal-related topics.

Future Government/Industry Collaboration

As noted previously, the DOE Clean Coal Technology program is an outstanding and successful example of government/industry collaboration. *It is recommended that the high-priority needs addressed in this report be met by re-focusing the government/industry collaboration that proved successful with the DOE Clean Coal Technology program.*

There are several different levels of need which may be addressed by different collaborative mechanisms. For example, advanced technologies must be evaluated by individual prospective users to determine how the technologies can best be integrated into their facilities and business operations, and the economic effects on their businesses must be analyzed and understood. This could require selected new pilot plant studies and engineering feasibility studies for site-specific applications. In such cases, it may be feasible for DOE and a select number of prospective users to form "User Interest Groups" to manage collaboration on areas of mutual interest and to develop collaborative industry/government efforts.

Another example may be found in the refinement and enhancement of existing technologies. That is, new technologies must face competition, in some cases, from existing technologies which can be upgraded in performance through improvements in equipment or process operating conditions. Here again, collaboration with "User Interest Groups" can be effective.

DOE participation in "User Interest Groups" will promote transfer of DOE-developed technology to the marketplace and ensure retention of key "know-how" within the department. This approach also can allow DOE to maintain a broad portfolio of research activities with reduced funds by allowing industry to take the lead role in identifying and furthering development efforts.

Some industry groups already exist and are working together to resolve common problems. DOE also could participate in numerous small projects directed by the technology stakeholders. It is believed that this approach, if broadly implemented, would accelerate progress of technologies as they mature from embryonic to development scale. The purpose of each user group would be to determine barriers to commercialization and to conduct studies and contract for limited research on key questions that must be answered if these barriers are to be overcome. For this to be implemented, DOE needs to allocate

a small percentage of its annual budget specifically for this purpose. *It is recommended that DOE consider cost-sharing with user groups that can demonstrate shared technical interests with DOE.*

Recommendations

1. The National Coal Council recommends that all fourteen Clean Coal Technology demonstration projects on indirect-fired cycles and molten carbonate fuel cells be completed.

2. The National Coal Council recommends that needs of the select list of subject areas and technologies shown in Exhibits 2, 3, 4, and 5 in Appendix A be met as soon as possible so they may advance coal utilization early in the next century.

3. The National Coal Council recommends that all effluent streams of current projects in the CCT Program be characterized to assess the need for hazardous air pollutant control.

4. The National Coal Council recommends that mechanisms be established to provide commercialization assistance, in the form of risk-sharing and international marketing assistance, for five technologies which offer the greatest promise for near-term benefits.

5. The National Coal Council recommends that the Federal Government create an insurance program to provide a safety net for the first-of-a-kind new commercial facilities. This should be done in a partnership with coal stakeholders.

6. The National Coal Council recommends that the U.S. Department of Energy consider a range of financial incentive options which not only can minimize Federal expenditures, but also can assure initial pre-commercial deployment of the systems.

7. The National Coal Council recommends that incentives be established (1) to shorten the time required for commercial deployment, (2) to improve prospects for exporting U.S. technology, and (3) to ensure continued benefits of environmental protection, energy efficiency, and "highest and best" economic use of the nation's most abundant domestic energy resource: coal.

8. The National Coal Council recommends that Section 29 of the existing tax code, "credit for producing fuel from a non-conventional source," be expanded to include advanced coal power systems, advanced emission control systems, and coal conversion processes which may require government risk-sharing in order to bring about commercialization of these technologies.

9. The National Coal Council recommends that the "facility original placed in service date" be extended from the present "before January 1, 1997," to "before January 1, 2007." This will provide an additional ten-year window of incentive to meet projected capacity growth and environmental performance goals. This also would allow sufficient time to plan, design, permit, and construct qualifying facilities.

10. The National Coal Council recommends that DOE maintain, to the maximum extent possible, support for coal technology research and development.

11. The National Coal Council recommends that DOE assume the responsibility of "technology caretaker" for coal liquefaction technology, since commercialization seems to be unlikely in the near future.

12. The National Coal Council recommends that DOE, working with industry stakeholders, develop a deliberate plan of implementation (1) to identify the persons and institutions where coal research expertise can now be found, (2) to provide adequate and stable levels of funding to sustain significant research programs, (3) to provide incentives for productive programs and competition between programs, and (4) to ensure rewarding career paths for graduate students who address coal-related topics.

13. The National Coal Council recommends that the high-priority needs addressed in this report be met by re-focusing the government/industry collaboration that proved successful with the DOE Clean Coal Technology program.

14. The National Coal Council recommends that DOE consider cost-sharing with user groups that can demonstrate shared technical interests with DOE.