

**Clean Coal Technology
For Sustainable
Development**

FEBRUARY 1994

THE NATIONAL COAL COUNCIL

**CLEAN COAL TECHNOLOGY
FOR SUSTAINABLE DEVELOPMENT**

Joseph W. Craft III, Chairman

Coal Policy Committee

Jerry J. Oliver
Dwain F. Spencer

Working Group Co-Chairmen

The National Coal Council

February 1994

THE NATIONAL COAL COUNCIL

William R. Wahl, Chairman

James J. McAvoy, Executive Director

U.S. DEPARTMENT OF ENERGY

Hazel Rollins O'Leary, Secretary

The National Coal Council is a federal advisory committee to the Secretary of Energy.

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THE NATIONAL COAL COUNCIL, INC.

Post Office Box 17370, Arlington, Virginia 22216

(703) 527-1191

February 17, 1994

The Honorable Hazel O'Leary
Secretary
United States Department of Energy
Forrestal Building, Suite 7A-257
1000 Independence Ave., S.W.
Washington, DC 20585

Dear Madam Secretary:

On behalf of the National Coal Council, I am pleased to submit for your review the enclosed report, "Clean Coal Technology for Sustainable Development." This study, which the Council formally approved on February 17, 1994, was prepared in response to your letter of June 11, 1993.

As your letter proposed, our report has focused on the future of the Clean Coal Technology Program from the standpoint of five important issues: 1) the current status of industry acceptance of CCT; 2) technical gaps in CCT; 3) the desirability of additional federal initiatives to overcome market hurdles to CCT; 4) the merits of co-funding further improvements to previously demonstrated CCT projects; 5) international CCT transfer.

A diverse, experienced work group of Council members was organized to investigate these issues. Prior reports of the Council served as a point of departure, such as "Innovative Clean Coal Technology Deployment" (1988) and the recently completed "Export of Coal and Coal Technology" (1993). The chief findings in this latest report suggest that:

- The domestic demand for CCT during the 1990's will be much weaker than originally anticipated. The need for CCT will not arise until late in the decade or, more likely, after 2000.
- Foreign demand for CCT will not occur until the successful demonstration of such technologies has been completed.
- The environmental, economic and international policy objectives of the Administration can be enhanced through new, aggressive approaches to the CCT Program.

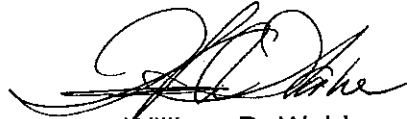
An Advisory Committee to the Secretary of Energy

Based on the these and other conclusions, the National Coal Council has included in this report several recommendations. Among these are that:

1. The Secretary of Energy not engage in any further solicitations under the existing CCT Program. Where unused funds exist, the continuation of operating demonstrations should be pursued as a means of facilitating commercial deployment through expanded operating experience.
2. The Secretary of Energy promote the role of CCT in the environmental technology programs of the Administration; that CCT can improve the global environment as well as prevent pollution.
3. The Secretary of Energy establish a new Federal Clean Coal Technology Incentive Program of approximately \$1.5 billion over 15 years to stimulate commercial deployment.
4. The Secretary of Energy ensures that future governmental policy continues to be monitored from the standpoint of the competitive position of and the ability to deploy CCT.

The National Coal Council welcomes the opportunity to advise you. We hope that this report proves useful in policy matters pertaining to clean coal technology. The Council will provide any additional information on this subject which you may desire.

Sincerely,

A handwritten signature in dark ink, appearing to read 'Wahl', with a stylized flourish extending from the end.

William R. Wahl
Chairman

PREFACE

The National Coal Council is a private, nonprofit advisory body, chartered under the Federal Advisory Committee Act.

The mission of the Council is purely advisory: to provide guidance and recommendations as requested by the Secretary of Energy on general policy matters relating to Coal. The Council is forbidden by law from engaging in lobbying or other such activities. The National Coal Council receives no funds or financial assistance from the Federal Government. It relies solely on the voluntary contributions of members to support its activities.

The members of the National Coal Council are appointed by the Secretary of Energy for their knowledge, expertise, and stature in their respective fields of endeavor. They reflect a wide geographic area of the United States, representing more than 30 states, and a broad spectrum of diverse interests from business, industry, and other such groups as:

- *Large and small coal producers*
- *Coal users such as electric utilities and industrial users*
- *Rail, waterways, and trucking industries as well as port authorities*
- *Academia*
- *Research organizations*
- *Industrial equipment manufacturers*
- *Environmental interests*
- *State government, including governors, lieutenant governors, legislators, and public utility commissioners*
- *Consumer groups, including special women's organizations*
- *Consultants from scientific, technical, general business, and financial specialty areas*
- *Attorneys*
- *Special-interest groups that are regional or state in concentration*
- *Indian tribes*

The National Coal Council provides its advice to the Secretary of Energy in the form of reports on subjects requested by the Secretary and at no cost to the Federal Government.

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FOREWORD

The U.S. Department of Energy's Clean Coal Technology (CCT) Program, initiated in 1986, is a major Department initiative designed to permit coal to play a critical, continuing role in U.S. electric power and industrial markets and to position U.S. coal technology for major international markets. The CCT Program represents the largest coal technology and environmental technology demonstration program undertaken jointly by industry and the Department of Energy. Its intent has been endorsed most recently in the language of the Energy Policy Act (EPACT) of 1992 (Public Law 102-486). This legislation identifies a number of energy goals which already are part of the CCT Program, including:

- Achieving greater efficiencies in the conversion of coal to useful energy.
- Achieving control of sulfur oxides, oxides of nitrogen, air toxics, solid and liquid wastes, greenhouse gases, or other emissions resulting from coal use.
- Promoting the export and transfer of U.S. clean coal technologies and services to developing countries and countries making the transition to free market economies.

The CCT Program is being implemented through a total of five competitive solicitations and some 45 cooperative projects between industry and the U.S. Department of Energy. Congress has appropriated a budget of nearly \$2.75 billion for the CCT Program. The total Program cost is estimated at nearly \$7 billion, representing industry cost-sharing of \$4.25 billion, or over 60 percent of total Program funding.

On June 11, 1993, Secretary of Energy Hazel Rollins O'Leary requested the National Coal Council (NCC) to review certain aspects of the CCT Program and to recommend future directions for the Program. Specifically, Secretary O'Leary requested the Council to prepare a new study described as follows:

Future Directions for the Clean Coal Technology Program -- The study should (1) examine the current state of U.S. industry acceptance of technologies supported to date by the Clean Coal Technology Demonstration Program; (2) identify where technology gaps may exist in the U.S. portfolio of clean coal technologies; (3) assess the need for further Federal initiatives to overcome remaining market hurdles including, for example, use of Federal "buy-back" provisions to create early market incentives or changes in tax policy to encourage use of cleaner, more efficient technologies; (4) assess the merit of additional co-funded improvements in previously demonstrated technologies at existing facilities; and if such a need exists, offer guidance on the most effective and financially prudent means of further Federal support (e.g., different levels of cost sharing); and (5) offer advice on carrying out the international technology transfer effort called for by section 1332 of the Energy Policy Act.

In a letter dated June 22, 1993, Council Chairman William R. Wahl formally accepted Secretary O'Leary's request and commissioned the Working Group of the Coal Policy Committee. Mr. Jerry J. Oliver of Bechtel Corporation and Mr. Dwain Spencer of the Electric Power Research Institute (now of SIMTECHE) were assigned as co-chairmen for the study. This report, *Clean Coal Technology for Sustainable Development*, is the National Coal Council's response. We believe the directions and initiatives identified in this report can effectively assist the Federal Government and industry in realizing the full potential of the investment made in the CCT Program.

This report uses as a foundation a number of earlier National Coal Council studies, including *Clean Coal Technology* (1986), *Innovative Clean Coal Technology Deployment* (1988), and the recently completed *Export of Coal and Coal Technology* study (1993). The Council assembled a broad, diverse Working Group of members and contributors as outlined in the Appendix. The Working Group was formed and had its first meeting in Washington, D.C., on June 24, 1993.

In response to Secretary O'Leary's request, this report is broken into chapters based on the questions broached. The last chapter on international technology transfer extracts liberally from the Council's recently completed Export study and includes applicable recommendations made in that study. Specific chapters of the report are:

- Chapter 1: State of U.S. Industry Acceptance of CCT Program
- Chapter 2: Technology Gaps
- Chapter 3: Federal Initiatives to Overcome Market Hurdles
- Chapter 4: Merit of Additional Co-Funded Improvements
- Chapter 5: International Technology Transfer

Appendices supporting the contents of the study also are provided.

Each chapter is devoted specifically to the questions asked by the Secretary and also includes conclusions, recommendations, and references used. The scope of the report requires a broad review of the Clean Coal Technology Demonstration Program, which has been done from an overview and project-specific basis. Conclusions and recommendations are based on a synthesis of all information analyzed on clean coal technology development and identification of further financial incentives which are needed.

The National Coal Council is pleased to offer its assessment of the future directions of the Clean Coal Technology Program to Secretary O'Leary. The Council believes that this report, *Clean Coal Technology for Sustainable Development*, is responsive to Secretary O'Leary's request and also provides a strong basis for future Department of Energy/national/international policy and programmatic actions.

PERSPECTIVE

Policy Considerations

The continued importance of coal and clean coal technology must be examined in the context of both our domestic environmental ethic and our energy resource policies, as well as international technology transfer and export opportunities. In addition to the 1992 EPACT, the four most important policy bases being emphasized by the Administration are:

- President Clinton's Climate Change Action Plan, October 1993.
- President Clinton's Environmental Technologies Exports: Strategic Framework for U.S. Leadership Report, November 1993.
- Agenda 21, Programme of Action for Sustainable Development -- Rio Declaration on Environment and Development, June 3-14, 1992.
- The Clean Air Act Amendments of 1990, Titles I-VI.

President Clinton's Climate Change Action Plan focuses on a number of key objectives and steps, including:

- Reducing U.S. greenhouse gas emissions to 1990 levels by the year 2000 with cost-effective domestic actions.
- Fostering partnerships with business and stimulating investments in the technologies of the future, thus strengthening the American position in the global environmental technology marketplace.
- Creating new jobs in the sectors and industries that produce, market, or install technologies that save energy or reduce greenhouse gas emissions.
- Rapidly and aggressively implementing the Plan by building on the success of earlier public and private programs that have focused on energy savings or other emission-reduction opportunities.

The President's implementation program emphasizes (a) end-use energy efficiency investments, (b) expanded utilization of natural gas and renewable energy sources, (c) increased efficiency of generating electricity, and (d) joint implementation efforts between countries to reduce net greenhouse gas emissions.

Domestic and/or international deployment of a range of CCT Program systems and

technologies can help meet all of the President's key objectives and address most of the key components of the President's implementation program by assisting in world electrification in an environmentally acceptable to benign manner with an emphasis on Pollution Prevention. The newly formulated environmental technology exports strategy is consistent with the CCT Program and the Agenda 21, Programme of Action for Sustainable Development. The CCT Program should be recognized as being a key environmental technology strategy, both domestically and internationally.

President Clinton's Climate Action Plan calls for the American people to take the lead in addressing global warming and sustainable development. Again, successful deployment and international export of the results of the CCT Program can be an important element of our country's commitment to this need.

The Rio Declaration on Environment and Development proclaimed 27 international principles relating to humankind, sustainable development, the environment, and a new global partnership. Nearly every principle focuses on some aspect of the local or global environment, and the document focuses on the need to eliminate economic disparities between developed and developing countries. The implementation programs entreat the assistance of the developed countries to promote sustainable development through trade and other measures.

The Rio Declaration focuses on two key aspects of sustainable development: economic development for human well-being and environmental protection for present and future generations. Coal and coal technology play a significant role in achieving these goals (a) by enhancing the use of indigenous resources of individual countries, and collectively the world; (b) by providing a low-cost approach to global electrification, thus maximizing the benefits of limited capital resources; (c) by utilizing emission controls or advanced systems to prevent pollution; and (d) by providing jobs to develop the economic infrastructure of developing countries and expanding electrification and related economic well-being.

Finally, the 1990 Clean Air Act Amendments necessitate controls and/or established caps on a number of acid gases and hazardous air pollutants. Economically viable approaches for addressing many of these requirements have been developed and demonstrated within the CCT Program. Widespread commercial deployment of these technologies and systems will meet many of these compliance standards.

In summary, Administration environmental and international policy objectives can be enhanced with an aggressive program to capitalize on the results of the CCT Program. In addition, such an approach would create high-paying U.S. jobs and insure the use of domestic energy resources. This report to the Secretary of Energy describes specific measures which can facilitate those deployment opportunities.

Roles for Natural Gas and Coal

As discussed above, the Clean Air Act Amendments, the Energy Policy Act, and domestic and international policies on global climate change have confirmed the need to deploy clean coal technologies. Our coal reserves represent over 200 years of energy supply, while natural gas has approximately 50 years of recoverable resources (according to the National Petroleum Council) at current rates of consumption. While both gas and coal are critical in developing a balanced power generation portfolio, policy makers also must ask how the U.S. can most effectively utilize its domestic fossil fuel resources.

Is it really prudent to utilize natural gas as a primary electricity production fuel, particularly when natural gas is a very efficient end-use fuel for water and home heating? Natural gas achieves efficiencies of upward of 95 percent in these uses while achieving only approximately 50 percent efficiency in its most effective electric generation applications. It can play an important role in the electric supply market as a fuel for peaking, cycling, and limited base-load plants. Natural gas is also a valuable feedstock for a variety of chemical products. Finally, it should be noted that in certain instances the use of natural gas improves the efficiency of coal utilization (*i.e.*, air heater cycles, co-firing, or co-combustion).

It is essential to have fuel diversity in the power generation portfolio. *We need to take action now* to ensure that coal will play its proper role in the future fuel portfolio of this nation. Currently, the economics of natural gas have dominated in non-utility generator (NUG) and investor-owned utility (IOU) fuel choices. Recently, natural gas has dominated as a fuel of choice for new facilities built by both NUGs and IOUs. During the last few years, there was limited demand for new base-load power; however, during the prior several decades, the construction of plants had concentrated on base-load capacity. With changing load shapes, and with low growth and demand, natural gas-fired plants have become the preferred new generation system.

Natural gas also has been available at a historically low cost. But we must keep in mind that the gas bubble has virtually disappeared in the United States, drilling is down, and gas imports are expected to rise by 14 percent in 1993 and 12 percent in 1994, according to the Department of Energy's Energy Information Agency (EIA). Future supplies will depend on the financial incentives to increase drilling. Of concern to regulators is that natural gas prices are likely to rise. This will change the economic situation influencing fuel choice. The question, then, is: Will clean coal technology be ready when the time comes?

What must industry and policy makers do today to be positioned so that coal-fired power technology can play its proper role in the fuel supply portfolio of the future? Current clean coal programs have focused on the demonstration of new innovative technologies. This has been the logical step when both the regulatory and competitive market environments

do not reward the risk taking associated with capital-intensive long-payback period projects. The demonstration program corrected this regulatory and market shortcoming by supporting the development of new production processes.

Now that many of these technologies are being demonstrated successfully, a new hurdle is faced: how to move the technology from demonstration systems to fully commercialized and deployable units. In the case of innovative, efficient, and clean coal-based production technologies, the issue is: What must the country do to have a variety of off-the-shelf units ready when electric suppliers are ready to make the next round of construction decisions? How will continued efficiency and emissions improvements be attained? What is needed is a commercialization program that can provide suppliers and users with accurate knowledge of the technologies' operating, environmental, and cost parameters to substantially reduce the risks influencing financial considerations.

The CCT Program has successfully provided a number of commercial scale technology demonstrations. Future emphasis must be placed on the successful domestic and international commercial deployment of these systems. *This is the key recommendation of this report.*

EXECUTIVE SUMMARY

Overview

Coal is the fuel used most widely to generate electricity in the United States, and it will remain critically important for the foreseeable future. The growing public belief in the importance of a cleaner environment in the U.S. makes it mandatory, both for government and for those who depend on coal for their livelihood, to develop cost-effective ways to utilize coal while reducing environmental impacts to meet societal goals. Deploying clean coal technology as widely and quickly as possible is an important strategy in meeting the objective of continuing the use of coal and reducing the environmental impact of its use.

Furthermore, coal is abundant and low-cost throughout much of the world and will be utilized widely as standards of living rise and electrification spreads. In addition, there could be a strong export market for clean, cost-effective technology, and a strong U.S. clean coal industry could create many domestic jobs.

Current Situation

Under the Clean Coal Technology Program (CCTP), beginning in 1986, the Federal Government has co-funded 45 technology demonstration programs. While several of these clean coal technologies have confirmed environmental and/or efficiency improvements, only a few have moved into the commercial marketplace. The merits of additional support for the existing programs depend primarily on the potential for commercial success of the technologies and the ability to structure and finance appropriate support mechanisms. This in no way detracts from the Program's successes with regard to the demonstration of viable, commercially attractive technologies; rather, it adds a "bridge" to widespread commercial application. *The National Coal Council believes that future emphasis should be focused on the commercial deployment of clean coal technologies and that a government risk-sharing program for first-of-a-kind (FOAK) and near-commercial offerings of each of these advanced systems is in the Nation's interest.*

The selected demonstration technologies have not achieved widespread commercial use today primarily because the time needed for the power generation and financial industries to develop confidence in these systems and commit to them was greatly underestimated. As a result, many of the conditions that existed when the projects were selected have changed, and many of the assumptions about the future that were widespread in the mid-1980s, when the initial projects were selected, have proven to be incorrect. The impact of these changes on the commercialization potential of the demonstrated technologies is substantial:

Executive Summary

- *Energy prices:* Oil and natural gas prices in the late 1970s and very early 1980s increased dramatically and were projected to increase steadily through the end of the decade and beyond at rates above inflation and construction cost increases. Even after oil prices levelled off, questions of limits on supplies constantly overhung the market. In contrast, coal prices peaked in the late 1970s and began a long decline in the early 1980s, with the exception of low-sulfur coal, which enjoyed a more limited supply and the expectation of increased demand induced by compliance with environmental regulation.

Natural gas prices, while volatile, have levelled out at early 1980s levels with current projections of gradual increases in price and adequate supplies. Recently, crude oil prices have reached pre-1980 levels, even in current dollars. In fact, natural gas prices have reached parity with oil prices on a BTU basis as a result of this recent drop in oil prices. This is the first time this has occurred since 1973. Coal prices largely have continued to erode (again, with the exception of low-sulfur coal, for which demand is high because of the need to meet Clean Air Act requirements).

- *Generation equipment:* The competitiveness of alternative electrical generation equipment has shifted in terms of capital and operating cost. Advancements in gas turbine design have led to substantial reductions in capital cost and reduced plant construction times for gas-fired combined cycles, while higher efficiencies have led to lower operating cost. Coal-fired power plants, using conventional boiler technology, have increased efficiencies somewhat over the period and, with advancements in emission control equipment, have lowered somewhat the associated capital cost.

- *Environmental issues:* The coal and power industries, working together, have made real progress in dealing with environmental issues; however, the global warming debate, in concert with increased focus on the air quality issues associated with coal-fired generation, have increased the difficulty of developing a new coal-fired generation facility. The CCT Program is providing the technology demonstration basis to further enhance the environmental compliance capability of coal-fired systems.

- *Competitive generation developments:* The changing commercial, regulatory, and economic conditions resulted in a market for smaller unit sizes, which are not as conducive to coal use. At present, this market is addressed more readily by gas turbines than by coal-fired generation.

- *Component technologies:* The 45 development programs in many cases are composed of several technological innovations that are key to the total performance of a project. Significant developments in some of the specific component technologies have occurred. These component technologies represent advances that already have made, or that will make in the future, significant contributions to the achievement of the Clean Coal Technology Program's objectives.

Future Market Forces

A critical part of the assessment of hurdles and potential incentives for future clean coal technology deployment is to forecast what the electric generation and industrial application marketplace will look like beyond the year 2000. A review of the changing utility industry shows trends that help define what technical products will compete best in the period beyond 2000. These trends, both internal to the industry and external, are principally the following:

- *A strong emphasis on energy efficiency:* This will be reflected in efforts to improve energy use by customers and to use more efficient conversion technologies to keep costs low and reduce environmental impacts. This will greatly reduce requirements for new generating capacity, but provides great opportunities for replacement of older, less-efficient technologies.
- *The retirement and reuse of old utility sites:* An aging utility resource base (fossil and nuclear) will begin to be retired post-2000. Fossil power plant sites typically are close to consumers and coal transportation infrastructure, have coal-handling facilities in place, and possess access to existing power transmission lines. They are attractive to local government and the public because they provide high-paying jobs. These sites may become major opportunities for future CCT-based plants.
- *A more competitive marketplace:* Competitive bidding and the growth of the non-utility generation (NUG) industry will increase pressure to use lower-cost and cleaner systems.
- *A trend toward modular generation that optimizes cost and efficiency in the 200-400 MW range:* Large installations are still of interest to utilities, depending on what plants need to be replaced. However, most installations likely will be of intermediate size (200-400 Mw) to provide flexibility in dispatching, reducing siting impacts and lowering capital costs per unit, although both smaller and larger unit sizes may be necessary to meet specific generation requirements.
- *International technology transfer:* The increasing pressures to develop new fossil electric resources globally represent a major export opportunity for clean coal technologies. Both new systems for the Pacific Rim and retrofit applications in Eastern Europe and the Commonwealth of Independent States offer significant market opportunities.

The ideal clean coal technology for deployment beyond 2000 will need to be competitive, able to be built in modules that allow 200-400 Mw unit size (or smaller), compatible with siting at existing utility sites, efficient in conversion to reduce environmental impacts, and developed with acceptable risk profiles so utilities, NUGs, and the manufacturing industry can finance projects efficiently.

Deployment Benefits

In assessing the role of CCTs in meeting these needs, there are five principal reasons for deploying these systems for power generation:

1. To improve environmental quality through reductions in emissions of sulfur oxides and, depending on the specific technologies selected, nitrogen oxides and air toxics, and to permit production of reusable byproducts.
2. To increase fuel conversion efficiency through the use of improved conventional power generation technologies and advanced conversion and combustion technology, resulting in decreased production of carbon dioxide, as well as all other emissions.
3. To promote utilization of the most abundant domestic fuel, which is capable of supplying bulk power on a reliable, secure basis for hundreds of years.
4. To preserve and create jobs in coal production, transportation, and consumption.
5. To create new jobs dependent on the export of commercially proven, cost-effective coal-fueled power production to other nations around the world.

Conclusions

The growth of world population and economic activity in the generations ahead will place increasing strains on the global environment. Increased energy consumption will contribute to these strains. While advanced technologies can reduce the environmental impact of coal combustion dramatically, there is no assurance that they will be employed routinely. More likely, the development imperative will propel emerging nations to build coal-fired power plants and bring them "on line" as quickly and cheaply as possible.

Clean coal technologies represent an important opportunity for sustainable development, both domestically and internationally. The magnitude of this market opportunity domestically is estimated to be between 7 GW and 62 GW between now and 2010, including both new capacity and retrofit installations at existing sites where older plants are either retired or repowered. This is roughly 2.5 percent to 20 percent of the total coal-fired generating capacity as of 1992.

Achieving the high potential market would amount to nothing less than a technological revolution in the electric utility industry in the United States and, ultimately, throughout the world. Worldwide coal use is expanding at very high rates; China, for example, is adding 10,000 Mwe of coal capacity annually and plans to continue this expansion through 2020.

Department of Energy surveys initiated in 1992 show that there is limited awareness of the details of the Clean Coal Technology Program at this time, even in the United States. An aggressive information transfer and educational program for prospective users and financial institutions is being developed and represents a critical need.

A review of the environmental and energy efficiency potential of 45 CCT projects provides a means of determining the usefulness of these projects over the next 10 to 20 years. For example:

- *Advanced power generation systems:* Integrated coal gasification combined cycles (IGCCs) and pressurized fluidized bed combustors (PFBCs) offer the greatest pollution reduction capability and should be able to meet 2010 emission control targets.
- *High performance pollution control devices:* Most of the devices tested were designed to meet the 1990 CAAA requirements.
- *Industrial applications:* Two projects -- the Integrated CPICOR process and the Liquid-Phase Methanol process -- stand out as most promising.
- *Coal processing and cleaning:* The Coal Quality Expert, the Rosebud, and ENCOAL Advanced Coal Conversion projects are important contributions.

The National Coal Council believes that the intent and objectives of the CCT Program have been met or will be met with existing projects from Rounds I-V. The CCT Program is successful, and the Council concludes that an extension, in the program's present form, is not necessary. The current CCT Program should continue to its anticipated conclusion for the approved Rounds I-V.

Advanced coal combustion, pressurized fluidized bed combustion, and integrated coal gasification combined cycle power plants are, or will be, technically proven as part of the CCT Program. However, technology vendors must offer performance guarantees and/or turnkey packages in order for these technologies to be widely implemented in the marketplace before they are regarded as commercially proven.

Successful commercialization of the selected demonstration technologies is influenced by a number of factors. Primary among these is the time necessary for the power generation and financial industries to demonstrate and then commit to a new technology. Additional factors would include high capital cost of first-of-a-kind systems and added operating risks associated with new technologies, among others. Initial expectations were overly optimistic as to the rate at which these results would affect the commercial marketplace.

While the CCT Program has focused on 45 development projects, these projects in many cases are composed of several technological innovations that are key to the total

performance. While the commercialization of total projects remains to be accomplished, significant developments in some of the specific component technologies have occurred. These component technologies may represent advances that already have made, or that will make in the near future, significant contributions to the achievement of the CCT Program's objectives.

As noted above, it was believed in the 1980s that demonstration of the CCTs would be sufficient for their commercial adoption, given the push from the rising price of fuels competitive with coal, the escalating requirements for control of environmental effluents, and the increasing need for new electric generation capacity to meet either increasing demands or retirement of older capacity. These premised conditions have not happened. Therefore, the market pull for CCTs is much weaker than anticipated.

We believe most of the domestic need for CCTs will come, albeit not until late in the 1990s or, more likely, in the following decade. Meanwhile, foreign demand for CCTs will not occur until demonstration of commercial technologies has been completed. Therefore, without further action, the many successful CCT demonstrations will not move to commercialization.

The Secretary of Energy has three choices:

1. Continue further demonstration projects and wait for commercialization to take place on its own. In today's environment, we believe that more demonstrations are not necessary and that commercialization will not follow without further action.
2. Drop further support of CCTs at the end of current demonstrations. We believe that this would likely terminate these technologies, at least at domestic firms, and leave the field to others when CCTs are needed.
3. Develop a program now to support initial commercialization in the belief that it will create a sustainable market long-term. We believe this is the prudent direction for the Secretary to take, particularly to assure a role for CCTs in overseas markets.

The international environmental and clean coal technology market is large and waiting for new commercially demonstrated, competitive technologies that decrease pollution without an appreciable increase in total capital and operating costs. The transfer of coal technology internationally can be facilitated both by the actions prescribed in the Energy Policy Act and by the new Environmental Technologies Export Strategy. Finally, although the National Coal Council believes that international markets are a key ingredient in the commercialization of CCTs, it also believes that domestic deployment should remain a primary objective of any continued federal support for clean coal technology.

Recommendations

1. The National Coal Council recommends that the Secretary of Energy not issue any further solicitations under the existing Clean Coal Technology Demonstration Program. The Council believes the projects which are in place or will be in place under Rounds I-V will provide the necessary technology demonstration base. As conditions change in the future and new coal research breakthroughs are achieved, it may be appropriate for the Secretary to assess the benefits of further technical demonstrations.
2. The National Coal Council recommends to the Secretary of Energy that clean coal technologies be recognized broadly as environmental technologies in current and future Administration environmental technology programs, providing opportunities not only for preventing pollution, but also for improving the global environment. The Clean Coal Technology Program has confirmed that these systems and processes are new environmental technologies which will improve the environment substantially as they are deployed commercially. Therefore, they should be emphasized by the Federal Government in developing and demonstrating a U.S. leadership position for global sustainable development.
3. The National Coal Council recommends that the Secretary of Energy foster the establishment of a new federal-level Clean Coal Technology Incentive Program to stimulate initial and sustainable commercial deployment of clean coal technologies. Based on the attached Pro Forma, this new program could provide approximately \$1.1 billion of capital incentives in 1992 dollars and \$0.3 billion of performance (operating) incentives in 1992 dollars over a 15-year period from 1995-2010. The federal program should represent 10 percent to 15 percent of the total capital and help offset operating risks associated with first-of-a-kind and early commercial units of new CCTs. The National Coal Council believes this is a prudent federal risk-sharing program to capitalize on the results of the CCT program and to stimulate initial introduction of these systems.

The incentive, cost-shared program should partially offset capital and operating cost of up to the first five commercial units of, for example, integrated coal gasification combined cycle systems, pressurized fluidized bed combustion systems, advanced pulverized coal-fired power plants, and innovative component technologies developed under the prior CCT program. (The Council also considered the potential need for financial incentive for AFBC, but these are being offered under competitive commercial business terms for units in the 200MW capacity range.)

Cost-shared incentives should be of two types. Two are "hard" incentives, as discussed above. The third, "soft" incentive should be offset funds made available to provide local mitigation of environmental concerns and included within the funds made available to the Department of Energy for this incentive program.

4. The National Coal Council recommends that the Secretary of Energy direct that the Department of Energy's market assessment and communications program be continued and expanded to include, in addition to electric utilities, representatives of regulatory bodies, non-utility generators, industrial coal users, insurance carriers, investment bankers, equipment suppliers, coal suppliers, and environmental groups. Each should be encouraged to engage in similar candid discussions to assist in bringing clean coal technologies to successful commercialization. The survey/seminar program should be continued and augmented, with follow-on contacts at regular intervals or when important program milestones warrant.
5. The National Coal Council recommends that the Secretary of Energy, in cooperation with individual utilities and state and local agencies, evaluate the potential of converting existing but non-compliant plant sites to new sites employing CCT and develop policies to minimize site relicensing requirements and delays. The Council believes that recycling old sites in economically depressed areas could be of prime importance in the construction of CCTs. It also would tie into the current Administration's economic development policy. However, both utilities and state regulators must benefit by retiring these older plants.
6. The National Coal Council recommends that the Department of Energy, in conjunction with its industrial participants, disseminate commercial cost information as it becomes available to facilitate assessment of each technology's total economic viability.
7. The National Coal Council recommends that where unused CCTP funds exist, the Secretary of Energy continue some operating demonstrations to gain more experience which would facilitate commercial deployment. Capitalizing on the investments made in the CCT Program, the Department of Energy should define opportunities for product improvement or enhanced performance of selected systems. This also includes an endorsement of the continuation of coal research programs currently underway.
8. The National Coal Council recommends that the Secretary of Energy ensure that the Department of Energy continues to monitor policies which could affect the domestic or international competitive position of technologies developed through the Clean Coal Technology Demonstration Program and assist in developing policies to minimize barriers to commercial deployment. It may be appropriate for the Secretary to consider partial funding of CCT international deployment efforts to facilitate technology transfer. The Council further concludes that global deployment of clean coal technologies is a critical ingredient in sound domestic economic development and worldwide sustainable economic and social development.

INTRODUCTION

The degree of success of the Clean Coal Technology Program ultimately will be measured by market acceptance of the technology developments. This acceptance may be either in the domestic market or in the international market as an export product; the primary driver, however, should be the domestic coal market.

Market Characterization: Domestic

To assess the potential for introducing clean coal technologies into the U.S. market, an analysis of recent trends and future projections of the power generation market has been conducted. All data presented are in U.S. dollars and short tons unless specifically noted. The base year for statistics is 1992, the Btu is the energy unit normally used, and Mws or Gws [1000 Mws] are used throughout. Other sources of information are included with each chapter.

Over the period 1970-1991, nearly 400,000 Mwe of new nameplate capacity were added in the utility sector of the U.S. electric power industry, and with another 30,000 Mwe were added by non-utility generators (NUGs). Coal capacity additions represented approximately 46 percent of these new generation additions; and coal's percentage of annual kilowatt hours climbed from 46 percent to 55 percent, with over 1.5 trillion kilowatt hours produced from coal in 1991.

During the 1970s, coal capacity additions averaged 12,000 Mwe annually. In the 1980s, they averaged 7,500 Mwe annually. But in 1990, they averaged only 2,500 Mwe annually. In 1992, only 500 Mwe of new coal capacity was added by utilities; 1,500 Mwe of total coal capacity was added to the grid in 1992, with coal additions representing 23 percent of all new generation and natural gas representing nearly 50 percent. The trend of U.S. coal-fired capacity additions is shown in Figure 1.

During the 1970s, bituminous coal-fired plants represented 74 percent of plant additions, with subbituminous coal representing 19 percent and lignite representing 7 percent. In the 1980s, this fuel mix shifted significantly as a result of the 1977 Clean Air Act Amendments. During the 1980s, bituminous coal additions represented 51 percent of the additions, with subbituminous coal representing 44 percent and lignite representing 5 percent.

The significantly increased cost of coal-fired units has been greatly affected by increasingly stringent emission control requirements. Figure 2 shows that coal power plant costs have nearly tripled since 1980, with at least one-half of this increase related to air emission control requirements. This high capital cost is a major factor which will limit new coal-

fired capacity additions in the U.S. It is clear that new clean coal technologies with higher efficiencies are necessary to control air emissions and help coal maintain its market share.

Approximately 13,000 Mwe of high-sulfur coal capacity will be retrofit with SO₂ control technology; the remaining 45,000-50,000 Mwe will be fuel switched to meet the CAAA Phase 1 SO₂ emission reduction requirements. Again, economics is the critical issue. Figure 3 shows that projected Powder River Basin (PRB) minemouth costs will remain at one-third the price of high-sulfur, Illinois Basin coal and one-fourth of compliance, Appalachian low-sulfur coal. Thus, even with rail transport costs of 2 to 4 times minemouth costs, PRB coal will often be the economic choice. Natural gas price forecasts are very uncertain; however, a recent forecast by Energy Ventures Analysis projects only modest increases in the average delivered cost of gas through 2005, which means natural gas will remain a competitive power generation fuel, at least through that period.

Looking to future U.S. generating additions, the Department of Energy has forecast a range of power plant additions from 150,000 to 250,000 Mwe during the 1990-2010 period, with 27,000 to 72,000 Mwe of this in new coal capacity. This would represent an outstanding opportunity for the introduction of clean coal technologies.

On the other hand, a recent forecast of new capacity additions by Energy Ventures Analysis for the Electric Power Research Institute indicates total capacity additions may be as low as 122,000 Mwe in this period, with coal capacity additions forecast at only 23,000 Mwe. In this analysis, the bulk of these new coal-fired capacity additions (17,000 Mwe) occur in the period 2005-2010. In addition, large numbers of aging fossil plants may be repowered or retired and nuclear plants may be retired in this period. This indicates a significant potential market for advanced coal systems which can meet stringent emission control requirements: integrated coal gasification combined cycle plants (IGCC), for example, or pressurized fluidized bed combustion (PFBC) power plants. Significant commercial market introduction of many of the advanced clean coal technologies may be delayed, however, because of their relatively high capital costs.

The potential implications of these alternative market forecasts will be discussed more thoroughly in Chapter One.

Market Characterization: International

The international market for CCT is potentially very robust, but still uncertain. There is a clear need for cleaner utilization of coal throughout Europe and Asia; many countries, however, either do not yet have the necessary emission control requirements in place or cannot afford the incremental costs of conventional air emission control systems. As the international marketplace puts the long-term efficiency and pollution control aspects of CCT into their competitive analyses, the value of the program will increase dramatically.

Introduction

There are two major potential emerging markets: the Eastern European countries, including the Commonwealth of Independent States in the former Soviet Union, and India, China, and other Pacific Rim countries, with their new demands for coal capacity. Although these market demands are uncertain, all of these nations will be required to adopt cleaner coal power plants by necessity in the future.

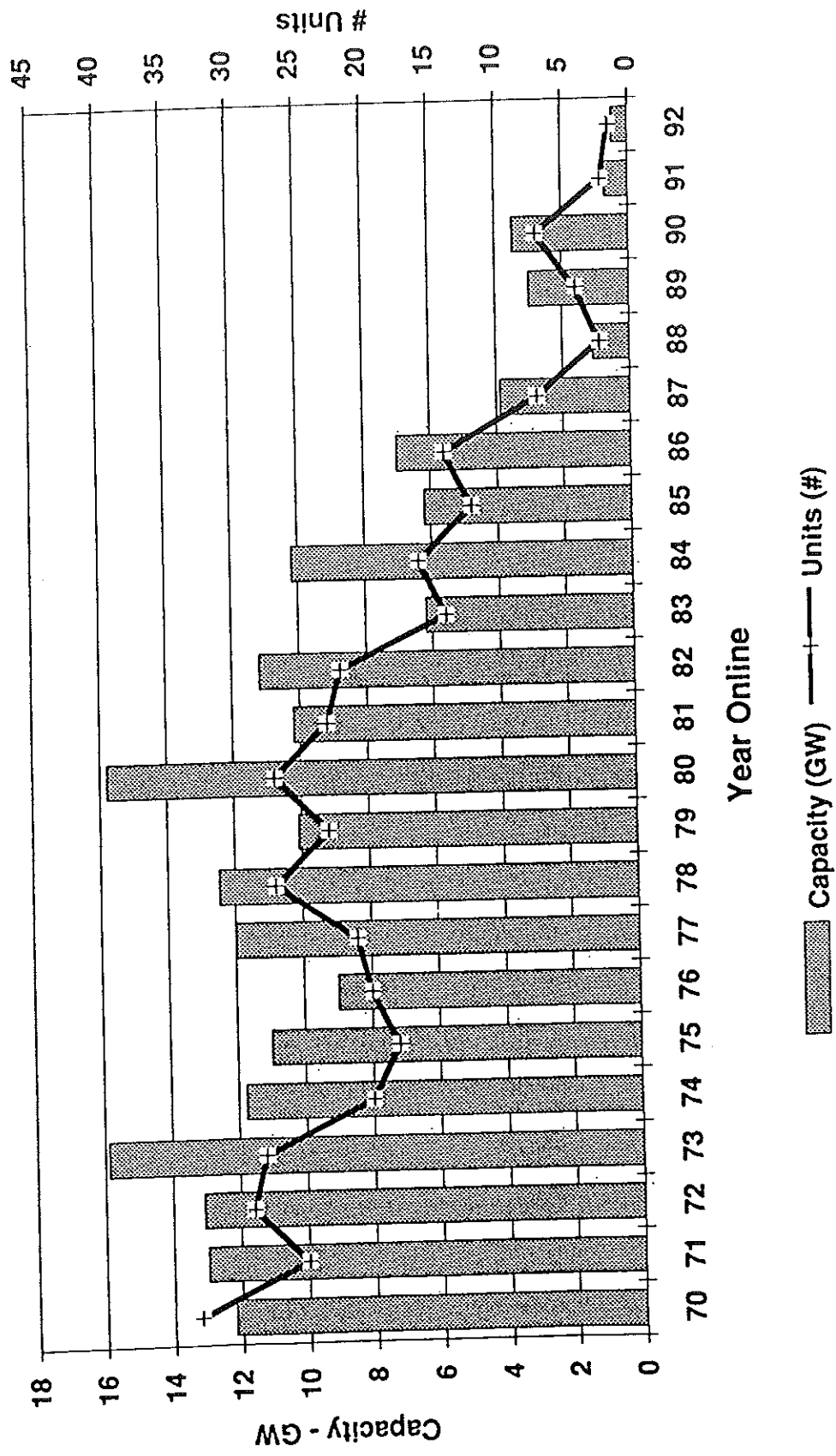
The clean coal technologies supported by the Department of Energy during the Clean Coal Technology Demonstration Program are inherently environmental technologies, by which it is meant that they benefit the environment. Each technology (some more dramatically than others) provides positive improvements in overall emissions, either through improved use of waste products or through improved efficiencies over existing technology. Clean coal technologies also meet the definition of, and the conceptual embodiment of, the pollution prevention concept. There is a direct relationship between improved efficiency and a decrease in waste products produced. The CCT Demonstration Program has provided a foundation for a new generation of environmental technologies because it is the largest environmental technology program undertaken jointly between industry and the Federal Government during the last decade.

The major goal of the CCT Demonstration Program was identification of the next generation of coal-related environmental technologies, demonstration of the best of those technologies, and commercialization of technologies with the best market potential. As discussed in the report, the program has satisfied all of those objectives. The next logical step is deployment of technologies that have passed the demonstration hurdle. Because coal use is global and coal technologies apply to coal in a global manner, it is logical to assume that coal technologies demonstrated during the CCT Program have a potential market niche, both internationally and in the United States.

Keeping in mind that the technologies demonstrated are environmental technologies that fit the pollution prevention goals that are espoused globally, they must be introduced into the global marketplace. The Energy Policy Act, under Sections 1332 and 1608, provides a directed approach to that introduction. The international market also represents the biggest short-term opportunity for the deployment of successfully demonstrated CCTs. If done properly, this deployment internationally will increase the creation of new domestic jobs and income through the simultaneous export of engineering, equipment, and operating experience.

As a point of reference, and as indicated in the recently completed National Coal Council report on the export of U.S. coal and coal technology, domestic income from the export of U.S. coal-use technology easily could surpass income from coal exports by the middle of the next decade. The worldwide demand for electricity is providing market opportunities for clean and efficient coal-use and environmental technologies, as well as for U.S. coal export opportunities.

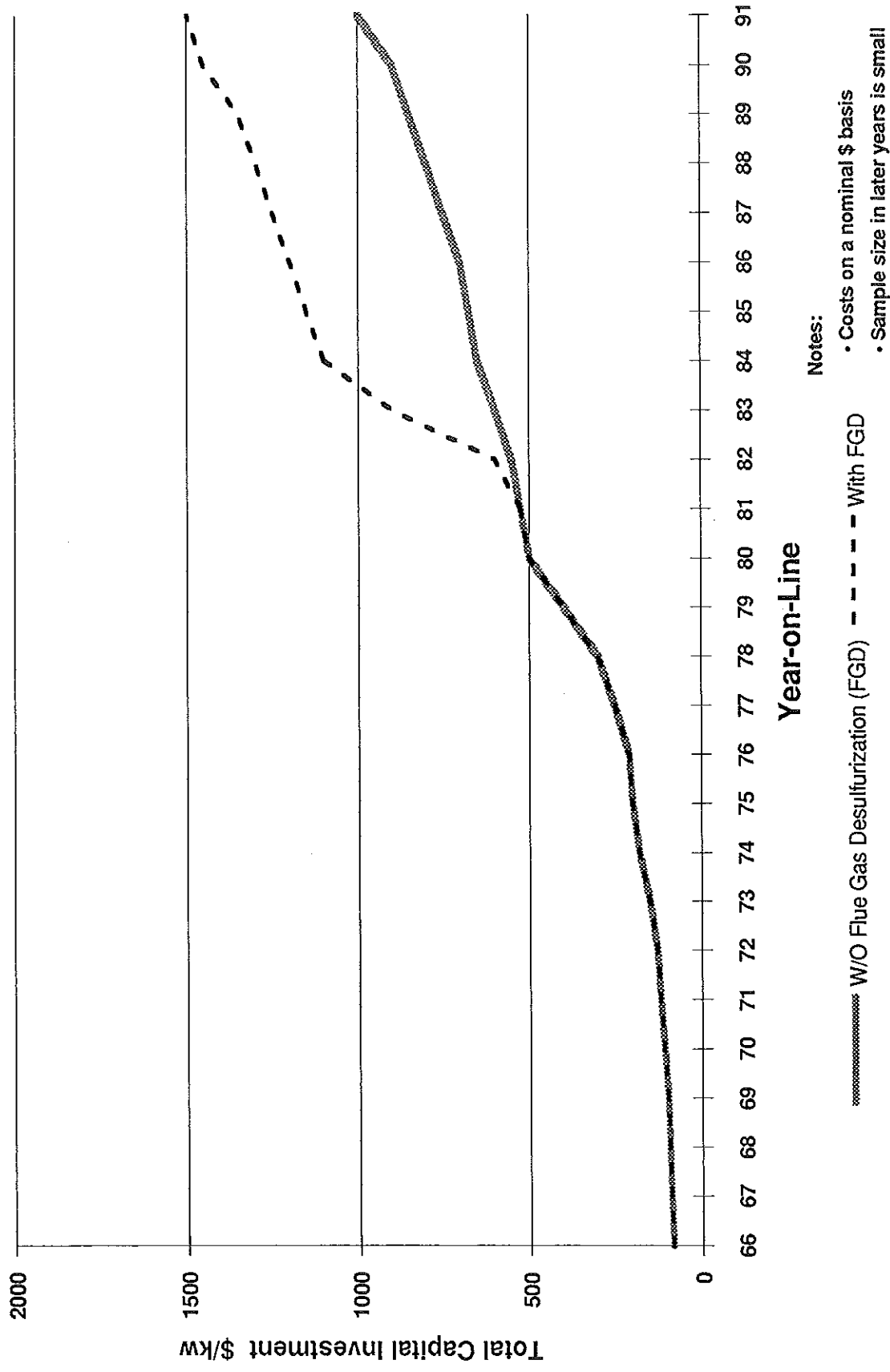
Utility Coal Fired Capacity Additions



SOURCE: Energy Information Administration, 1992

Figure 1

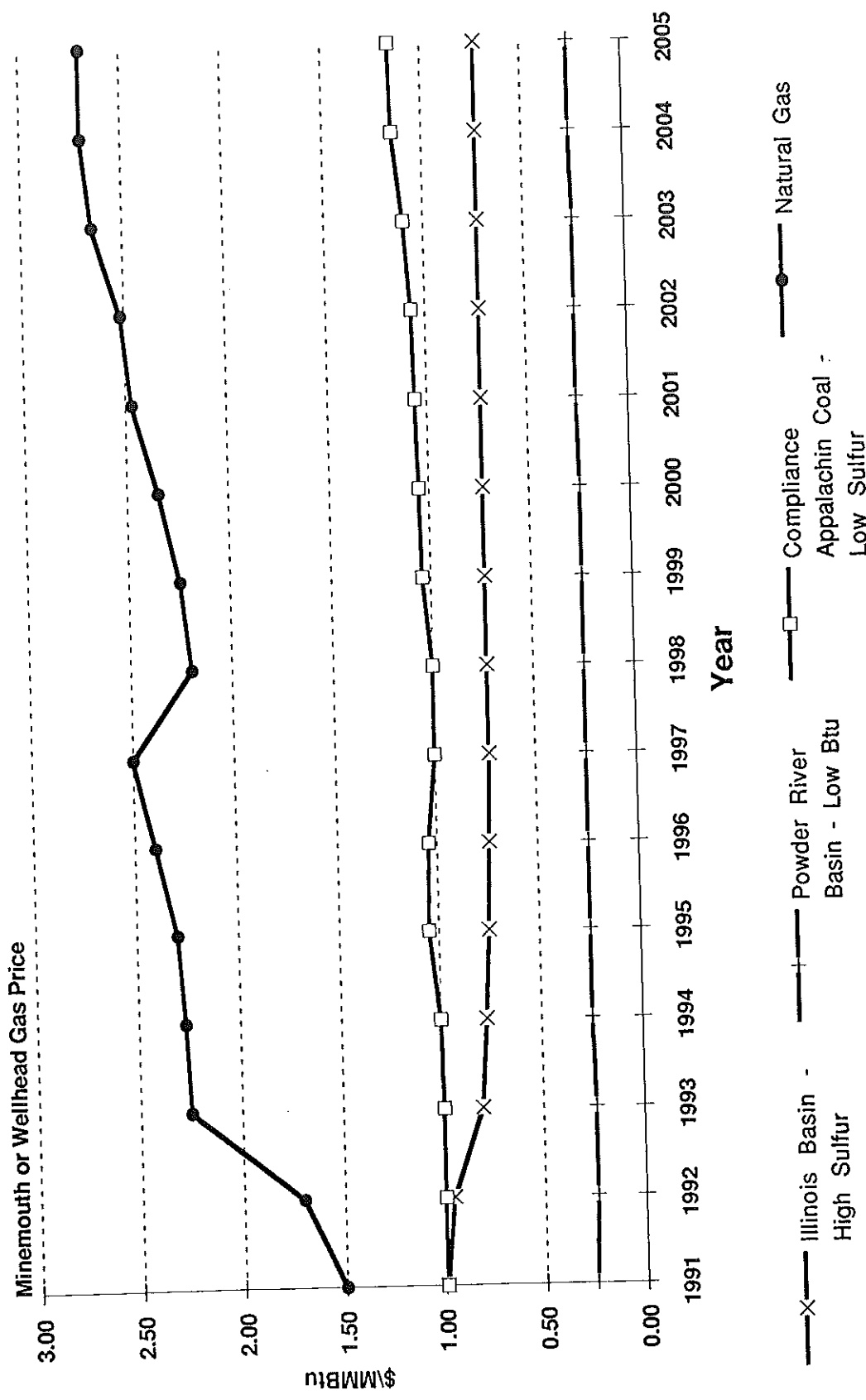
Average Cost per Kilowatt for U.S. Utility - Owned Coal-Fired Units



SOURCE: Energy Ventures Analysis, 1993

Figure 2

HISTORICAL AND PROJECTED REGIONAL FUEL PRICES



NOTE: Costs are on a nominal \$ basis
 SOURCE: Energy Ventures Analysis, March 1993 Forecast

Figure 3

CHAPTER I

STATE OF U.S. INDUSTRY ACCEPTANCE OF CCT PROGRAM AND ESTIMATED POTENTIAL MARKETS FOR CLEAN COAL TECHNOLOGIES

Factors Influencing Acceptance of Clean Coal Technologies (CCTs)

The CCT Program was initiated in 1986. At the end of 1993, only three of the 45 projects have been completed. Eight other projects are scheduled for completion within the first half of 1994. Thus very few commercial applications of these new systems are in place. However, as part of the electric utility industry's Phase 1 SO₂ Compliance Strategy, nearly 13,000 Mwe of existing coal capacity will be retrofit with SO₂ scrubber technology. A number of these plants will utilize CCT Program results.

In order to further assess the industry's awareness of the CCT Program, the Working Group reviewed the results of a recently completed Department of Energy survey of utility industry awareness of the Program. This survey conducted by the Department and its contractor, Energetics Incorporated, provided valuable insight to the potential markets for CCTs. The initial results of these surveys were reviewed by members of the Working Group, who concur in both the methodology and findings. This section presents a digest of the results of the survey effort, augmented by illustrative examples.

The objectives of the Department of Energy's survey program were to:

"1. Establish a dialogue with corporate officials and key decision makers to discuss strategic and operating plans concerning leading-edge technological solutions, such as clean coal technologies (CCTs), under the constraints of pending business, regulatory, and environmental issues.

"2. Discuss the potential for CCTs in utility resource planning efforts to meet projected demand growth and compliance with the requirements of the Clean Air Act Amendments (CAAA90).

"3. Receive feedback from these corporate officials on their knowledge of the CCT Program, their views and assessment of risks (both technical and financial) associated with bringing state-of-the-art technologies into their resource portfolio, and their views on an appropriate federal role as well as incentives that could be offered to enhance the potential for CCTs to enter the electric generation marketplace."

Screening criteria were developed to select electric utilities and independent power producers for structured, in-depth interviews, or "seminars," which were guided by a detailed questionnaire or discussion agenda. Corporate and senior management at the selected organizations were visited by joint Department of Energy and consultant personnel. Discussions were candid and issues and problems were openly aired.

Seminars on the Clean Coal Technology Program were held with six investor-owned utilities, one municipal utility, and one independent power producer, representing a diverse geographical mix.

As this report is being prepared, additional seminars are being held with other utility and industrial companies. The findings of those meetings will be reported separately by the Department of Energy. The balance of this section is based on results from the initial series of seminars as reported in draft form.

Electric Utility Resource Decision-Making Factors

Some common themes regarding utility resource decision-making were recognized from the initial survey results. These are classified as "the four Cs":

1. *Conservation and energy efficiency*: Utilities are pursuing energy conservation, demand-side management, and increased energy efficiency. These options are regarded as cost-effective, beneficial, and not risky.
2. *Combustion turbines*: Virtually all resource plans include addition of natural gas-fired combustion turbines to meet near-term load growth. While achieving environmental compliance, concerns remain about fuel flexibility and diversity, reliability of supply, and long-term economic viability of this fuel choice.
3. *Competition*: Utilities are concerned about future competition in the power generation market. Most utility resource plans seek to obtain "least-cost" resources, whether from off-system power purchases or from competitive bidding. Proposals from independent power producers must often be considered before a utility is allowed to proceed to build its own new generating plants.
4. *Caution*: Utilities have a tradition of conservatism in selection of generating options that can satisfy requirements to meet demand growth with reliable service while complying with environmental regulations. Caution is displayed by avoiding unnecessary risk when considering new technologies or, at a minimum, by sharing risk with others. This cautious approach seeks predictable answers to questions as to whether the technology will cost and perform as expected and whether the regulatory commission will allow recovery of expenditures through adjusted rate schedules.

The seminars initially found that there was limited awareness of the details of the Clean Coal Technology Program, although subsequent seminars have found a growing awareness of CCTs. The information available was not compatible with utility planning models. Utilities require detailed data from the CCT Demonstration Program on costs, especially for a full cycle of operation and maintenance of clean coal technologies in routine service. However, on a positive note, once the advantages of CCTs were made known, many expressed interest in reviewing them for possible application and use.

Clean coal technologies must demonstrate attributes relative to each of the above factors that are positive -- or, at least, not negative -- in order to afford the best chance for adoption and deployment.

Department of Energy Survey Findings

Important factors identified by the survey that influence utility executives in considering CCTs for their systems include technology portfolio, regulatory requirements, environmental considerations, impediments to CCT demonstration and deployment, and critical actions to promote adoption/deployment.

1. *Technology portfolio*: Modest load growth will be met with demand-side management, combustion turbines, and off-site purchases. The surveyed companies had no plans for additions of coal-fired capacity before 2005. Future capacity additions will be smaller (200-400 Mw). High-efficiency generation is of considerable interest.

These findings might be taken to imply that the window of opportunity for developing clean coal technologies has expanded to a longer time period, which would allow development and demonstration of new, improved technologies. However, this is not the case. Near term, there is a need to repower or retrofit to replace aging coal facilities in the United States. It is critical to deploy existing CCTs quickly.

2. *Regulatory requirements*: Utilities face a wide spectrum of regulatory approaches, both in the several States and among Federal agencies. Regulatory oversight is currently at a higher level than in the past, and intervenors with varying agendas are more active than ever. In addition to customary concerns about economics and cost of service, there is an increasing requirement for quantification of environmental externalities in resource planning and competitive bidding for new power supplies.

Coal-fired generation accounts for more than half of electricity production in the U.S. today, and this contribution is projected to continue at least through 2010. Nevertheless, regional biases against coal exist. It is becoming increasingly difficult to justify selection of coal-based technologies as the least-cost generating option; the inclusion of environmental externalities, or additional pollution control equipment costs, are major

limitations on coal retaining its historical position as the low-cost source of electricity. Clean coal technologies will have to show, quantitatively, how they can meet stringent emission control requirements in a cost-effective manner.

3. *Environmental considerations*: Uncertainty about full regulatory implementation of the Clean Air Act Amendments of 1990 strongly influences utility planning. Administration of the emission allowance program -- especially, trading of allowances -- remains a question mark, and treatment of allowances for CCT facilities remains to be determined. Utilities are extremely concerned about yet-to-be-established levels of control for Nox and air toxics. Looming over all is the possible imposition of a tax on emissions of carbon dioxide as a way to address emerging and controversial concerns about "global warming."

Such fundamental uncertainties are inimical to development of defensible plans for the future. They are particularly adverse to the assessment of just-being-proven technologies such as CCT, notwithstanding their potential to address many professed environmental concerns. Ironically, it remains possible that regulations intended to reduce emissions could result in perpetuation of technologies known to produce such emissions by impairing the deployment of clean coal technologies that could largely eliminate the problem.

4. *Impediments to CCT demonstration and deployment*: The survey identified four impediments to CCT demonstration and deployment: economic risk, regulatory, environmental, and perception. Each will be described briefly.

- *Economic risk*: Clean coal technologies bear the risk that actual capital and operating costs may exceed initial engineering estimates. Indeed, empirical evidence from other large-scale systems suggests that "first-of-a-kind" (FOAK) facility cost estimates can be more costly than original estimates. In many cases, clean coal technologies have yet to be operated at a commercial scale for extended periods of time. It is too early to expect utilities or other firms to select them for deployment without some prospect or procedure for reduction or sharing of economic risk.
- *Regulatory*: Institutional problems in rate regulation today cause utilities to be reluctant to commit large amounts of money for new generating projects of any kind, including CCTs, for fear that they will not be able to recover their investment. Additionally, the approval process for siting and permitting of a new facility is complex, time-consuming, costly, and uncertain of success.
- *Environmental*: Some environmental air quality regulations actually may constrain new CCT demonstration and deployment by lack of clarity or inadequate time for compliance. This is adverse to utilities because it presents risks of penalties for exceeding emission limits. In addition, the process of applying for environmental permits or approvals may be subject to lengthy delays and appeals which further increase project uncertainty and costs.

- *Perception:* Utility planners and decision makers have insufficient information about the current status of the Clean Coal Technology Program to assess adequately its potential contribution to their future operational needs. A more effective way of transmitting essential data about CCT capabilities and costs is required, on an ongoing basis.

5. *Critical actions to promote adoption/deployment:* The survey identified several critical actions needed to promote the adoption and deployment of clean coal technologies. While different companies mentioned these actions in varying priority, there was general agreement about the following topics:

- *Demonstration:* Clean coal technologies must be demonstrated to perform successfully at commercial scale according to design across a full cycle of normal operations and maintenance. A consortium of technology users and suppliers to help shape hardware specifications would be valuable.
- *Efficiency:* Clean coal technologies must improve technology efficiency and reduce residuals such as emissions of all types and solid by-products. By improving efficiency and reducing residuals, clean coal technologies will have a positive effect on environmental externalities. This positive effect has not been quantified.
- *Costs:* Clean coal technologies must show predictable capital and operating costs -- together with quantified economic benefits -- that are competitive or superior to alternative technological options.
- *Information Dissemination:* Improved information about technical capability and economic potential must be disseminated to utilities, regulators, coal suppliers, transporters, and the financial community.

Estimated Potential Domestic Markets for Clean Coal Technologies

Estimates of the market potential for CCTs are offered to establish a framework for discussion. Because of the inherent uncertainty in forecasting the future markets for technologies still being developed, three estimates are presented to represent **low, medium, and high** market acceptance.

The low estimate was taken from data assembled by Energy Ventures Analysis (EVA) for the Electric Power Research Institute. The medium and high estimates were derived by the Working Group from information contained in the Department of Energy's *Annual Energy Outlook, 1993*. The "medium" case is considered the "base" case in subsequent analysis. The salient data are:

1. Total new electric generating capacity (frequently referred to as greenfield power plants) required for the period 1990 through 2010:

Period Covered	Low	Medium	High
1990 - 2010	115 GW	149 GW	245 GW

2. This total is broken down by decade:

Period Covered	Low	Medium	High
1990 to 2000	81 GW	81 GW	101 GW
2001 to 2010	34 GW	68 GW	144 GW

3. For the period 1990 through 2000, it is noted that two-thirds of the new capacity has already been announced. It is here assumed that technology choices have been made for these announced capacity additions. It is further assumed that the technologies for unannounced facilities remain to be selected.

The total unannounced new generating capacity is between 27 GW and 33 GW.

The Department notes that "more than 50% of the needed additions through 2000 will come from gas-fired electricity generation." It is assumed here that this would apply to the unannounced capacity also. Therefore, the maximum new unannounced coal-fired capacity for 1990 through 2000 will be between 14 GW and 17 GW. It is further expected that three-quarters of new unannounced coal capacity will either be conventional pulverized coal plants (equipped with flue gas desulfurization units) or low-sulfur coal burning plants, based on timing and confidence issues. In such a case, the practical magnitude of the market for CCT in greenfield power plant applications during the remainder of the 1990s would be:

Low	Medium	High
3 GW	3 GW	4 GW

4. For the period 2001 through 2010, it is assumed that greenfield coal-fired capacity will maintain historical ratios of about 40 percent of total generating capacity. Thus, total new coal capacity in the first decade of the twenty-first century would be:

Low	Medium	High
14 GW	27 GW	58 GW

It seems unlikely that conventional coal-fired generation would be displaced from the market completely by CCTs; however, there is uncertainty about the extent to which CCTs will penetrate the market. Accordingly, three separate forecasts are offered:

A. *Optimistic case*: It is assumed that two-thirds of new coal-fired capacity additions in the period 2001 through 2010 are provided by CCT.

Low	Medium	High
9 GW	18 GW	38 GW

B. *Base case*: It is assumed that four-tenths of new coal capacity is based on CCT.

Low	Medium	High
6 GW	11 GW	23 GW

C. *Pessimistic case*: It is assumed that CCT accounts for one-quarter or less of new coal capacity.

Low	Medium	High
4 GW	7 GW	15 GW

5. For the entire period from 1990 through 2010, combining the estimates from each decade leads to the following overall new greenfield plant market potential for CCTs:

Period Covered	Low (Pessimistic)	Medium (Base)	High (Optimistic)
1990 to 2000	3 GW	3 GW	4 GW
2001 to 2010	4 GW	11 GW	38 GW
Total	7 GW	14 GW	42 GW

Note that the above estimate is for *new* greenfield coal capacity only; retrofit, repowering, or replacement by CCTs at existing coal-fired stations is not included. The likely actual magnitude of retrofit CCTs markets is even more uncertain. However, an estimate can be derived from data in *Annual Energy Outlook*. On page 48, it states that "utilities have reported plans to retire 10.8 GW of fossil-steam capacity in the period 1990 to 2000, and it is assumed that an additional 27.4 GW of capacity will be retired rather than life-extended or repowered in the period 2000 to 2010." If these units are not actually retired,

but retrofit or repowered, and assuming coal retains approximately a 50 percent market share (with natural gas and biomass), the potential retrofit and repowering market for CCTs is estimated to be (rounding):

Period Covered	Potential Market
1990 to 2000	6 GW
2001 to 2010	14 GW
Total	20 GW

Thus, the overall potential market for CCTs at both new and retrofit sites from the present through 2010 would be:

Sites	Low (Pessimistic)	Medium (Base)	High (Optimistic)
New	7 GW	14 GW	42 GW
Retrofit	0 GW	11 GW	20 GW
Total	7 GW	25 GW	62 GW

It must be acknowledged that achievement of the high market estimate in less than twenty years would be an extraordinary accomplishment. For example, if "typical" CCT units were of 300 Mw capacity, the high estimate would represent more than 200 units and the low estimate approximately 25 units. *Based on the industry's reluctance to adopt new systems, incentive programs will be extremely important in determining actual CCT market penetration during the period to 2010 in the estimated ranges.*

The forecast CCT's capacity can be used to derive an estimate of coal demand and of the numbers of coal production and related jobs. To construct this estimate, each CCT plant is assumed to operate at 60 percent capacity factor and at a heat rate of 8,600 Btu/kwhr. Coal with heating value of 22 million Btu/ton is assumed, and coal mine productivity of 38 tons/miner-shift (EIA, 1992 U.S. average production). The coal mine employment multiplier is 7, as developed by Gordon and Rose (Pennsylvania State University).

The application of the assumed conditions to the medium estimate of CCT capacity results in market estimates for CCT, coal, and employment by decade as presented in Table 1. This table shows that:

1. In the remaining years of the twentieth century (the present time to 2000), the total CCT market potential is about 9 GW. New coal demand would be up to 19 million tons, representing as many as 2,500 mining jobs and 16,000 supporting jobs. These production and jobs totals would replace about one-fifth of those likely to be lost through fuel switching for compliance with the Clean Air Act Amendments of 1990.

In the period 2001 to 2010, CCTs could produce a new medium-sulfur to high-sulfur coal demand of up to 52 million tons, representing 7,000 mining jobs and 48,000 supporting jobs.

2. If, in the period 2001 to 2010, the *High Case* CCT new capacity and retrofit systems were introduced, as much as 62 GW of CCT capacity would be employed. Coal demand would be up to 130 million tons, replacing that estimated to be lost by the Department of Energy's 1992 *Annual Energy Outlook*. Employment necessary to realize this level of coal production largely would replace jobs displaced by fuel switching. While this estimate is encouraging, it must be remembered that both employment and production of medium-sulfur and high-sulfur coal are likely to be depressed through 2000.

Even if these estimates of CCT coal deployment and associated coal demand are realized, it seems inevitable that many mines producing medium-sulfur and high-sulfur coal will be closed, starting by 1995. This will result in additional costs for shutdown, care and maintenance, or reclamation.

While CCT demand for such coal ultimately may lead to resumption of production at some mines, it seems likely that some will never be reopened. Furthermore, those mines that might be able to reopen are virtually certain to incur additional costs for refurbishment; in some cases, it appears that time-consuming and costly new permits might be required. The end result is that the cost of coal may well be greater than anticipated, and this can influence overall project economics. Early deployment of CCTs could help alleviate this situation.

The impact on coal mining jobs will vary by state. For example, the average productivity of Ohio coal mines in 1991 was 5,800 tons per miner, as reported by the Department of Energy's Energy Information Administration (DOE/EIA-0118 [91]). Broken down by mining method, underground mines averaged 5,200 tons per miner, while surface mining averaged 6,200 tons per miner. The loss of Ohio coal production from compliance with Phase 1 of emission reductions could be as much as 8.3 million tons per year. Assuming the same average productivity, this would translate into a loss of about 1,500 coal mining jobs in Ohio alone during Phase 1, according to the Ohio Coal Development Office.

Table 1

**Clean Coal Technology Markets
Impact on Coal Production and Employment
Medium (Base) Estimate**

Estimated Capacity (GW)	1990 to 2000	2001 to 2010
New	3	14
Retrofit	6	11
Total	9	25
Coal Requirements (Millions of Tons)	1990 to 2000	2001 to 2010
New	6	29
Retrofit	13	23
Total	19	52
Coal Employment (Thousands of Jobs, Rounded)	1990 to 2000	2001 to 2010
New		
Miners	1	4
Support	5	27
Total	6	31
Retrofit		
Miners	2	3
Support	11	21
Total	13	24
Total		
Miners	3	7
Support	16	48
Total	19	55

Conclusions

- The magnitude of the domestic market opportunity is estimated to be between 7 GW and 62 GW between now and 2010, including both new capacity and retrofit installations at existing sites where older plants are either retired or repowered. This is roughly 2.5 to 20 percent of the total coal-fired generating capacity as of 1992. Achieving the high potential market would amount to nothing less than a technological revolution in the electric utility industry of the United States and, ultimately, throughout the world.
- Many utilities are considering retrofit and repowering alternatives as they seek to comply with the Clean Air Act Amendments of 1990. New base-load capacity will be required in the 2003 to 2007 time frame. As they prepare to make these important technological and economic decisions, power generators need to know about the accomplishments and potential of clean coal technologies to contribute to their activities and operations in the future.
- The establishment of a continuing dialogue with decision-making corporate officers and senior executives of electric utilities about the accomplishments and plans of the Clean Coal Technology Program is extremely important. Based on the surveys conducted, there is limited awareness of the details of the Clean Coal Technology Program at this time.
- The National Coal Council believes that deployment of clean coal technologies in routine commercial service will be facilitated by establishment of a federal incentive program designed to mitigate risks in capital investment and operational performance.

Recommendations

Two principal recommendations regarding the markets for application of clean coal technologies are offered for consideration by the Secretary:

1. The National Coal Council recommends that the Secretary of Energy initiate an in-depth study to identify and quantify the financial and work force dimensions that will be needed by various segments of the design, fabrication, manufacturing, transportation, and construction industries to translate the market potential estimates into reality. The estimates of the potential markets for clean coal technologies presented above should be refined and augmented by thorough, detailed analyses that define the probable future markets. While many elements of existing capabilities can be adapted to the needs of implementing CCTs, in the larger sense a new industry is being created. This new industry's prospects for success will be enhanced by having available the best possible information on market characteristics and potential future efficiency and environmental requirements.

2. The National Coal Council recommends that the Secretary of Energy direct that the Department of Energy's market assessment and communications program be expanded to include, in addition to electric utilities, representatives of regulatory bodies, non-utility generators, industrial coal users, insurance carriers, investment bankers, equipment suppliers, coal suppliers, and environmental groups. Each should be encouraged to engage in similar, candid discussions to assist in bringing clean coal technologies to successful commercialization. The survey/seminar program should be continued and augmented, with follow-on contacts at regular intervals or when important program milestones warrant.

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1. Department of Energy Annual Energy Outlook, 1993.
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CHAPTER II

TECHNOLOGY GAPS

Introduction

Understanding and addressing the potential technological gaps in the Clean Coal Technology Program is paramount to ensuring that the public and private monies being spent in this program will provide reliable and cost-effective commercial products. It should be stressed that the focus of this chapter is on the technological gaps for meeting *U.S. needs*. The National Coal Council believes that meeting these needs will permit coal technology to meet or exceed international marketplace requirements because the U.S. has a broad range of coal types and the CCT Program addresses this full range of coals.

This study focuses on the 45 CCT projects currently under development by the Department of Energy. The criteria used for evaluation are based on the Department's goals for environmental controls and plant efficiency for the years 1990, 1995, 2000, 2005, and 2010.

Overall technology screening matrices have been developed as a way to evaluate potential benefits from the CCT projects. Two types of screening matrices are developed, one based on environmental characteristics and the other based on economic market and cost factors. All the information pertaining to each project depicted on these screening matrices was gleaned from the documents furnished by the Department of Energy.

These matrices assess the capability of various CCTP technologies to meet present and future environmental targets. The environmental characteristics considered are sulfur dioxide (SO₂), nitrogen oxides (NO_x), particulates, air toxics, efficiency (carbon dioxide), waste water emissions, and form(s) of solid waste.

The key factors considered in the economics screening matrix include salable product, unique features, retrofit or repowering and/or greenfield installations, potential markets, and capital, operating, and maintenance costs. The utility generation market is defined as greater than 50 Mw capacity units, and the industrial market is defined as up to 50 Mw units.

Technology (Projects) Screening Matrices

The CCT projects (CCT Round I through CCT Round V) are grouped in screening matrices in accordance with Department of Energy categories, which are as follows:

- Advanced power generation systems
- High performance pollution control devices
- Industrial applications
- Coal processing and cleaning

Projects in advanced power generation systems and high performance pollution control devices are grouped further into subcategories.

The three subcategories for advanced power generation systems are:

- Integrated gasification combined cycles
- Fluidized bed combustion
- Others

Similarly, the three subcategories of high performance pollution control devices are:

- Combined SO₂/NO_x control
- SO₂ control
- NO_x control

For the high performance pollution control devices and coal processing and cleaning categories, the project rankings based on efficiency were not considered meaningful. Therefore, this parameter was not included in the environmental screening matrix for these two categories. These matrices provide important information concerning plant efficiency capabilities, commercialization time frame, and both near-term and long-term application opportunities.

To improve the usefulness of the environmental screening matrix, it was found necessary to delineate the latest year through which the commercial version of a CCT project would meet the environmental targets set by the Department of Energy for a given pollutant. Assigning specific pollution reduction capability and target years was based on the guidance furnished by the Department of Energy for SO₂, NO_x, and particulates.

The guidance provided for these pollutants is presented below:

Pollution Reduction Capability New Source Performance Standards (NSPS) Factor	Target Year
1.0	1990
0.5	1995
0.33	2000
0.25	2005
0.1	2010

The environmental and economic screening matrices are shown in Appendix A, Tables A-1 through A-8, for each project category. The air toxics status shown on the environmental screening matrix was obtained from Department of Energy-furnished data. It was clear from a review of the description of these projects that CCT Round I through CCT Round IV precede the Air Toxics considerations incorporated in the Clean Air Act Amendments of 1990. The Department since has incorporated monitoring of air toxics in many of these earlier projects.

From reviewing the reference materials available on CCT projects, it was clear that for virtually all of the projects there was no discussion presented on the status of waste water streams. However, this parameter is vital to the evaluation of the total environmental viability of a project. A column headed "waste water" is shown on the environmental screening matrix, with no status information available on all but four projects.

The economic screening matrices identify salable product(s) which could be commercialized by a given project, such as a NO_x control technology. These charts also list unique features of a given project, such as an air-blown or an O₂-blown gasifier. The economic screening matrices also identify whether a project would qualify for a retrofit/repowering application and/or a greenfield installation. Capital costs and operating and maintenance costs were extremely sparse for almost all projects. Very few projects have provided cost data; however, such data are extremely important for commercial acceptance. While it is understood that most of the cost information would be proprietary information, the availability of good cost data to potential users is essential.

The Electric Power Research Institute has generated typical capital costs for integrated gasification combined cycle (SO₂ removal 96 percent to 99 percent, NO_x emission 0.02 to 0.17 lbs. per million Btus) and pulverized coal without and with desulfurization (SO₂ removal 90 percent to 95 percent, NO_x emissions 0.4 to 0.5 lbs per million Btu) for a

nominal 300 Mw power plant. These data are shown in 1992 dollars and indicate that a mature IGCC plant would cost \$1400/kw, a pulverized coal (PC) boiler plant without flue-gas desulfurization (FGD) would cost \$1100/kw, and a PC plant with FGD would cost \$1350/kw, respectively. Since 1991, a number of non-utility generator (NUG) pulverized coal plants have been permitted, have been constructed, and are starting operation using flue-gas desulfurization with removals of between 92 percent to 96 percent and NO_x emissions of 0.1 to 0.17 lbs/MMBtu, using selective catalytic reduction.

Commercial Potential and Case Studies

Each of the 45 projects also was evaluated from the standpoint of its commercial market applications, utility and/or industrial, its application for retrofit and/or greenfield sites. These matrices also include an assessment of the status of each of the Department of Energy's 45 CCT projects. This information is summarized in Appendix A, Table A-9.

Examples of successful projects as summarized from Department of Energy publications from the CCT Program are highlighted as Case Studies (Table 2 through Table 4). At least three of the CCTs already have demonstrated their commercial benefits and are being accepted in the marketplace.

Finally, the description of a "typical" CCT project is provided in Table 5 to show the benefits of the demonstration program.

The information contained in these charts and tables should provide the Department of Energy with adequate guidance in making a preliminary assessment of those projects with good market potential over the next two decades.

Table 2

Case Study**Clean Coal System to Become Permanent Pollution Control System
at Ohio Plant**

A major Ohio utility has decided that a Department of Energy co-sponsored clean coal technology project has performed so well that it will become a permanent part of the host power plant's pollution control system.

The decision by Ohio Edison Company to continue using the advanced flue-gas cleanup system at its Niles, Ohio, power plant means that higher sulfur Ohio coal can continue to be burned at the plant. The decision sends a hopeful sign to many Ohio and other high-sulfur coal miners whose jobs have been threatened by tightening air quality standards.

The advanced technology -- termed the "SNOX catalytic cleanup system" -- removes more than 95 percent of the sulfur dioxide and more than 90 percent of the nitrogen oxide pollutants from the flue gases before they are released from the plant. The highly effective flue-gas cleaning capability of the technology means that high-sulfur coal can continue to be burned as part of Ohio Edison's strategy for meeting the 1990 Clean Air Act Amendments.

The demonstration unit at Niles cleans only one-third of the flue gas emitted from the plant's 108-megawatt, Unit No. 2 boiler. Its high degree of effectiveness, however, will permit Ohio Edison to increase the amount of time the high-sulfur coal-burning boiler is in operation and still allow the utility to comply with its Clean Air Act obligations.

In the process, the sulfur dioxide is converted into commercially valuable sulfuric acid which is sold to the chemical industry, while nitrogen oxides are broken down into harmless nitrogen and water vapor. There are no additional waste products from the cleanup process.

The system was installed by a consortium of technology developers headed by Asea Brown Boveri and Ohio Edison. It uses technology developed by Haldor Topsoe and Snamprogetti USA, Inc. To date, the SNOX demonstration unit has operated over 5700 hours.

Table 2 (continued)

Originally, the industrial team planned to operate the cleanup system only through the Fall of 1993 as a demonstration project to collect data on its effectiveness. The test runs now will likely be extended for another year to obtain further data on the life of the pollutant-removal catalysts. Money previously earmarked to dismantle the system after the demonstration is expected to be used to continue operations through 1994. Then, Ohio Edison will take over permanent operations.

The utility plans to continue operating the system as long as Unit No. 2 remains in operation. Current plans are to keep the unit in service well beyond the year 2000.

In the SNOX process, the flue gases leaving the boiler are cleaned of fly ash in a high-efficiency baghouse, then sent to a series of downstream catalytic converters. Inside the converters, sulfur dioxide is first changed to sulfur trioxide and then converted to sulfuric acid in a novel glass-tube condenser. The nitrogen oxides are reacted with ammonia and converted to molecular nitrogen and water.

An added benefit of the technology is its production of hot air which can be cycled back into the plant as preheated combustion air for the boiler. This increases the efficiency of the boiler, which in turn results in cost savings.

The SNOX demonstration unit at Niles uses full-scale equipment. Additional modules can simply be added to increase process capacity. The technology can be applied to any electric power plant and industrial boiler that fires coal, oil, or natural gas.

The Department of Energy selected the project in 1989 as one of its clean coal technology demonstration ventures. It is one of 45 projects that currently make up the \$6.8 billion government-industry Clean Coal Technology Program, an effort that is demonstrating highly advanced, low-polluting ways to use America's abundant coal reserves. The SNOX project is also co-funded by the Ohio Coal Development Office, among others.

The commercial use of the SNOX technology marks another market success story coming out of the Clean Coal Technology Program.

Table 3

Case Study**Advanced Clean Coal Technology Burner System for
Controlling Nitrogen Oxide Emissions**

Late in 1993, the Dayton Power & Light Company, host utility to the Department of Energy Clean Coal Technology demonstration project, announced it would keep the Low-NO_x Cell Burners™ in place and in use, rather than restore the boiler to its original configuration.

The net effect of using this technology is approximately a 50 percent reduction in NO_x formation with minimal or no impact on boiler operation or performance. It is also attractive because of its low delivered and erected cost, as well as a short outage time requirement for installation.

Soon after the project was completed, the Department of Energy, the State of Ohio, and the Babcock & Wilcox Company announced the first independent commercial sale of these advanced burner systems to Detroit Edison for controlling nitrogen oxide (NO_x) emissions from the Monroe Unit 1 coal-fired boiler.

Systems have also been sold to Allegheny Power, a participant in the Clean Coal Technology demonstration, for their Hatfield Ferry Units 1 and 2. The system on the latter unit is already in operation and in the early stages of tuning for optimum NO_x reduction levels.

Sales of additional Low-NO_x Cell Burners™ are expected to increase substantially as utilities begin installing equipment to meet the 1990 CAAA requirements for applications of this type.

Table 4

Case Study

NUCLA CFB Demonstration Project

A 110 Mwe Atmospheric Circulating Fluidized Bed (ACFB) boiler was constructed and operated at the Nucla Station of Tri-State Generation and Transmission Association, Inc., in Montrose County, Colorado. This plant represented a 2:1 scale-up from previous experience with Pyropower's AFBC system. Three small coal-fired, stoker-type boilers were replaced with a new 925,000 lb/hr ACFB steam generator capable of driving a new 74 Mwe steam turbine and repowering three existing 12 Mwe turbine generators.

Nucla's circulating fluidized bed system operates at atmospheric pressure. In the combustion chamber, a stream of air fluidizes and entrains a bed of coal, coal ash, and sorbent (limestone). Relatively low combustion temperatures limit NO_x formation. The limestone reacts with the sulfur dioxide to form sulfur-containing solids which are removed with the coal ash. Continuous circulation of coal and sorbent promotes high utilization of coal and high-sulfur capture efficiency.

Between August 1988 and January 1991, 72 steady-state performance tests were conducted, utilizing three different western coals varying in sulfur content from 0.4 percent to 1.5 percent. Results indicated a strong correlation of reduced sulfur dioxide (SO_2) and NO_x . Below 1620°F, 70 percent sulfur retention was achieved with limestone at a calcium to sulfur ratio (Ca/S) of 1.5., and 95 percent sulfur retention was achieved with a Ca/S of 4.0. At higher operating temperatures, additional calcium (limestone) addition was necessary to maintain 70 percent sulfur capture. NO_x emissions for all tests were less than 0.34 lb/million Btu, and the average level for all tests was 0.18 lb/million Btu. This should be consistent with expected NO_x control requirements in 2000.

An economic evaluation indicated that the Nucla Station ACFB system capital cost was approximately \$1120/net kwe. Total power production costs were about 6.4¢/kwhr, which is competitive with pulverized coal units with flue-gas desulfurization. AFBC technology has good potential in both industrial and utility sectors for new greenfield plants, as well as for repowering of existing steam-turbine, coal-fired plants.

Table 5

Case Study

Florida Power Plant Becomes Nation's Test Bed for Coal-Based Selective Catalytic Reduction Technology

Tests now under way at a Florida power plant will help determine whether a promising nitrogen oxide (NO_x) emission control technology already in widespread use overseas can be effective on U.S. power plants that burn high-sulfur coal.

This technology, selective catalytic reduction (SCR), is a post-combustion NO_x reduction technique that has the potential to cut emissions of this acid rain-causing and smog-causing pollutant by as much as 90 percent. Such a high NO_x reduction technology may be needed for coal-burning power plants located within some ozone non-attainment areas, including portions of the 16-state "ozone transport region" in the Northeastern United States.

But while SCR has been widely used in Japan and Western Europe with natural gas, oil, and low-sulfur coals, it is not yet known whether it can be effective -- or economical -- on high-sulfur U.S. coals in the U.S. utility environment.

To find out, Southern Company Services has embarked on a multi-pronged effort through the Department of Energy's Clean Coal Technology Program to test the technology under a variety of conditions typical in the U.S. power industry. Startup and shakedown of a new SCR test facility located at Gulf Power's Plant Crist near Pensacola, Florida, was completed in June and a two-year operating and testing period began on July 1, 1993. The result will be the most thorough technical and economic evaluation ever made of selective catalytic reduction as it would apply to high-sulfur U.S. coals.

The SCR demonstration facility was designed to provide maximum flexibility to the test program. It uses flue gas from the station's 75 Mw Unit 5, which burns U.S. coals with a sulfur content of nearly 3 percent. The facility is made up of nine separate reactor systems: three that can treat the equivalent of 7.5 Mws of flue gas and six smaller units that each treat the equivalent of 0.2 Mws. These reactor "modules" are large enough that data can be directly applied to commercial facilities.

Table 5 (continued)

With SCR technology, ammonia is injected into the hot flue gas as it leaves the economizer section of the boiler. Injection takes place far enough upstream of the SCR reactor that the ammonia completely mixes with the flue gas. As the gas passes through a fixed bed of catalyst in the reactor, nitrogen oxides formed during combustion react with ammonia to form elemental nitrogen and water vapor. The amount of ammonia used can be adjusted to achieve the desired degree of reaction of the NO_x in the flue gas.

The gas that leaves the reactor then moves through the air preheater, which transfers heat to the incoming combustion air. Flue gas leaving the air heater continues to the boiler's particulate removal device, most typically an electrostatic precipitator.

The test program has been designed to address key uncertainties associated with the use of SCR technology at U.S. utilities operating with high-sulfur coals. For example, there are trace elements in many U.S. coals that are not found, or that are found only in much lower concentrations, in other coals. These elements may have the effect of poisoning and degrading the SCR catalyst. Also, the presence of high amounts of SO_2 and SO_3 resulting from combustion of high-sulfur coals may lead to plugging of downstream equipment with ammonia-sulfur compounds.

An important objective of the tests is to determine the performance and optimum operating conditions of a variety of SCR catalysts made of different compositions, geometries, and manufacturing methods when used with typical high-sulfur U.S. coals at utility operating conditions. Nine commercial catalysts will be tested from three U.S., two European, and two Japanese vendors. The three U.S. firms will provide five, with the remaining firms providing one each. Each catalyst will be tested in a separate reactor operating in parallel with the others so that side-by-side comparisons can be made.

Both parametric and steady-state tests will be conducted, with a parametric test matrix repeated every three months on each reactor train. Once a parametric test matrix is completed, the reactor will be returned to baseline design conditions for three months of steady-state operations to test for aging of the catalyst. For each catalyst, data will be collected on deNO_x efficiency, pressure drop, oxidation of SO_2 to SO_3 , and the amount of unreacted ammonia emitted (ammonia slip).

Table 5 (continued)

Before the beginning of each parametric test, a catalyst sample will be given to its supplier for laboratory analyses. A common testing protocol was established with all of the vendors to assure consistent and accurate testing analyses. The catalysts' deactivation rates and lives will be determined by observing deNO_x efficiency during the steady-state operating periods between parametric tests.

Separate air preheaters will be incorporated into the project to see whether SCR reaction chemistry results in deposit formation and, if so, whether these deposits affect the preheaters' performance. Testing will take place over the next two years. When the project is complete, a final report will include an evaluation of the SCR process's economics.

The \$23.3 million dollar project was selected in the second round of the Clean Coal Technology Program.

Conclusions

A review of the environmental and energy efficiency potential of the 45 CCT projects displays their usefulness over the next 10 to 20 years. The economics screening matrix, however, is somewhat inconclusive because of the lack of pertinent cost data. Commercial selection would have to be based on other criteria, such as salable product, unique features, market potential, and ability to serve the retrofit/repowering market and/or new market.

By applying the criteria specified above, several conclusions become apparent:

- *Advanced power generation systems:* IGCCs and PFBCs offer the greatest pollution reduction capability, while other advanced power systems may require enhancements to meet the year 2010 targets. System efficiency improvements utilizing advanced power cycles show promise of meeting the Department of Energy's long-term efficiency goals. Based on the data that are available in this category, advanced gasifiers and advanced pressurized fluidized bed combustors tend to offer the greatest potential. As we develop more understanding of these options, unit capital and operating and maintenance costs could modify this preliminary conclusion.
- *High performance pollution control devices:* It is apparent from the technology screening matrices that most of these devices were designed to meet the 1990 CAAA requirements. Further evaluation of those devices which appear to offer the best market potential may be necessary in order to select the most promising candidates. Selective

catalytic reaction (SCR) would meet the environmental objectives beyond 2000 in its current configurations. All NO_x control devices and the dry NO_x/SO₂ control devices were considered to have a zero waste discharge. Many of these devices would qualify for installation in retrofit/repowering or new applications if required to meet the environmental objectives of the year 2000.

- *Industrial applications:* Two projects stand out in this category as the most promising: the Integrated CPICOR process and the Liquid-Phase Methanol process. The Campbell County Pulse Combustor fluidized bed gasifier needs to be evaluated in terms of its relative cost advantage. While the beneficial features of the two Bethlehem Steel projects are attractive, combining these features into one system could offer an attractive choice to the steel industry.

- *Coal processing and cleaning:* The Coal Quality Expert offers a valuable software tool to the operator of a power plant seeking optimum environmental compliance. The Rosebud and ENCOAL advanced coal conversion projects are also attractive. They enable the conversion of high-moisture, low-rank coal into low-sulfur, high-Btu coal.

Recommendations

The National Coal Council recommends that the following actions be considered to reduce the technology gaps alluded to in the earlier sections of this chapter:

1. That the Department of Energy, in conjunction with its industrial participants, disseminate commercial cost information as it becomes available to facilitate assessment of each technology's total economic viability.
2. That the Department encourage appropriate projects to monitor air toxics at existing sites. Project sponsors should be asked by the Department to outline control mechanisms for air toxics, based on monitoring results.
3. That the Secretary of Energy, through the Department of Energy's Coal Research Program, sponsor projects which include testing and evaluation of commercial selective catalytic reduction devices to generate data on reliability and operational characteristics of these NO_x control devices. The Secretary of Energy should continue to foster technology breakthrough work in coal water fuels, co-firing and co-combustion with natural gas, sludges and other feedstocks, and other activities aimed at broadening the uses of coal and the efficiency of coal use. The projects would enable the Department to meet long range NO_x control objectives for conventional fossil plants.
4. That the Secretary of Energy promote projects which deal with improvements in combustion turbines to facilitate coupling them with advanced IGCCs, PFBCs, and EFCCs.

These improvements in combustion turbines would enable advanced power generation systems and industrial systems to achieve the Department's efficiency goals.

5. That where unused CCTP funds exist, the Secretary of Energy continue some operating demonstrations to gain more experience which would facilitate commercial deployment. Capitalizing on the investments made in the CCT Program, the Department of Energy should define opportunities for product improvements or enhanced performance of selected systems. This also includes an endorsement of the continuation of coal research programs currently underway.

6. That the Secretary of Energy request project sponsors to provide detailed information on liquid and solid waste discharges.

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CHAPTER III

FEDERAL INCENTIVES TO OVERCOME MARKET HURDLES

Introduction

Coal accounts for more than 94 percent of U.S. primary fossil fuel reserves. Thus, it represents a strategic part of this country's sustainable energy supplies. The Department of Energy's CCT Program being conducted in concert with industry represents the means for realizing the continuing and ever-improving uses of this fuel to provide a sustainable electricity supply for the next century.

Historically, coal has been perceived as a dirty fuel because, until 1970, environmental control systems were not applied to coal combustion systems. As discussed previously, the electric utility industry during the 1990s will be required to comply with increasingly stringent environmental regulations through the implementation of the Clean Air Act Amendments of 1990 (CAAA).

Fortunately, the electric utility industry, in cooperation with federal and state governments, is engaged in an intensive effort to develop and demonstrate CCTs for the next generation of coal-fired power plants. Many of these technologies could achieve better environmental performance and greater energy efficiency. As discussed in Chapter Two, signs are extremely positive that several of these technologies could be available for power generation in an economically competitive manner and better able to enhance the use of coal than any coal-based technologies currently in use.

However, as with most of technologies in the capital-intensive power generation industry, these new technologies are expected to take 20 to 25 years from their initial development stages up to the point where utility companies can use them for commercial operation. Fortunately, most of this development period has been accomplished for many of the CCT project technologies.

As discussed in Chapter One, there are significant market opportunities for both retrofit and greenfield plants over the next 20 years. However, if these opportunities are to be realized, it is essential to understand the interrelated factors that influence acceptance of CCTs and affect the rate of their deployment into routine commercial power generation service.

The good news is that CCTs may be only 10 to 15 years away from widespread use in commercial power plants, and many are available to the utility industry for application over

the next 8 to 10 years to meet compliance requirements emanating from the 1990 CAAA. But the unfortunate reality is that many of these promising technologies may never be commercialized. Under the current regulatory environment, it is very difficult for the utility industry to take risks of deploying CCTs. The first full commercial clean coal generating plants will incur first-of-a-kind (FOAK) expenses during construction and shakedown that could be up to 33 percent higher than using mature technologies -- even though the CCTs are more energy and environmentally efficient. Normally, these first units are more expensive than the fifth or sixth units, when historically they are considered "mature plant" and where real costs and environmental benefits will be clear (Figure 4).

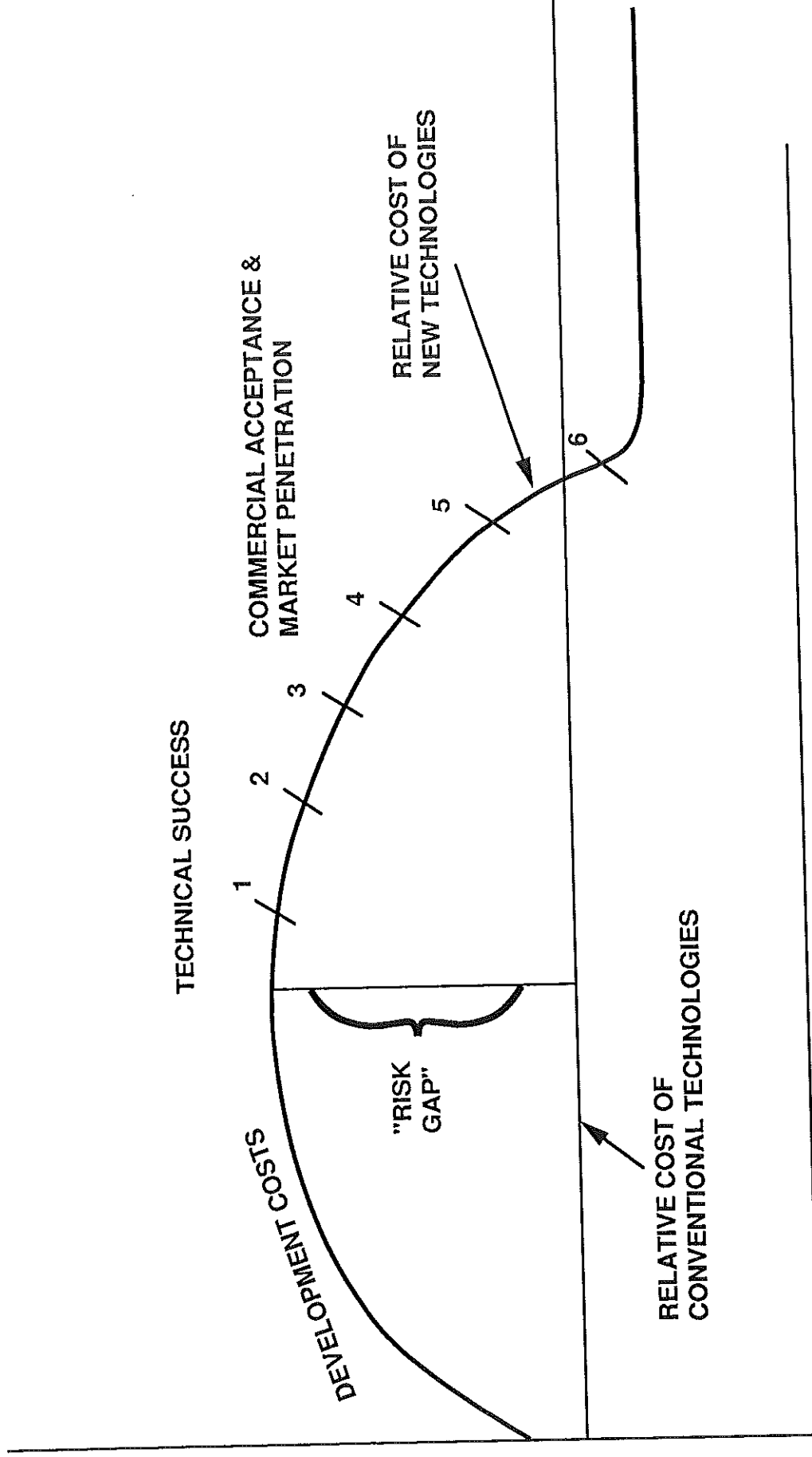
That means these technologies cannot readily fit into today's utility resource planning, which calls for the use of least-cost options. A plant with conventional technology can almost always be built for less money than a first-of-a-kind (FOAK) design. This may result in a permanent technological stall in new power technologies. Furthermore, the lack of existing operating data adds additional risks with any FOAK commercial plant which may drive costs up even more. The electric power generation companies -- whether they be conventional utilities or non-utility generators -- are risk-adverse under the current regulatory environment.

Most of the CCTs currently under development are applicable to base-load coal plants. However, low load growth in the near term discourages base-load generation capacity additions. In addition, low natural gas prices encourage a growing number of power generators to provide electricity using natural gas. This trend may continue during the next 8 to 10 years, further delaying the deployment of CCTs.

However, federal and state incentives can help these technologies overcome this type of FOAK financial hurdle. These incentives can be devised to insulate utility customers from some of the costs inherent in FOAK and initial commercial systems and allow utility customers to reap the benefits of reduced environmental impacts. Government efforts to promote clean coal technologies are justified because they support existing national policies on the environment, international trade, and the creation of U.S. jobs while at the same time ensuring that America's most abundant energy resource, and an important local resource in many states, remains attractive.

State utility commissions and legislatures wishing to enhance the future use of coal in their respective states also can provide resources and incentives to move clean coal technologies to their appropriate place in supporting coal's role in the nation's energy future.

Technology Development Learning Curve



Number of units

Figure 4

Market Hurdles to Commercial Use of CCTs

The major barriers to widespread implementation of clean coal technologies in the United States over the next decade are:

1. Both utilities and NUGs are risk-averse. There are risks with new technologies, generally because there is little or no existing design, construction, and operating data base. This drives total capital costs up because significant project and process contingencies are required. Further, any operating limitations or failures reduce plant availability and increase operating costs.
2. Costs for most CCTs currently are higher than costs for other commercial technologies. These higher costs are caused primarily by the use of capital-intensive new technology, current low gas prices, and limited operating and maintenance experience.
3. In the U.S., generating demand that is suitable for CCTs (base load and intermediate load) is limited until 2005 $\pm$ two years.
4. States only occasionally have legislation in place to allow them to provide incentives/encouragement for clean coal technologies. Their positions often are not clear and are resolved on a case-by-case basis.

Incentive Options

Incentives for commercial application are justified to overcome these market hurdles. Key considerations in developing such meaningful incentives are as follows:

- Although natural gas is an attractive fuel today, rising prices are expected to reduce its significance to power generation in the future. Limited commercial application of the best clean coal technologies would provide valuable experience so that these technologies are ready to use when the economics are attractive.
- Commercial use of these coal technologies will reveal ways to improve them, reduce costs, and accelerate commercial deployment.
- Incentives would move CCT into the marketplace sooner than will be possible without incentives, with commensurate benefits to the environment.

Incentives in Past Programs

A wide variety of specific incentives has been proposed in the past to promote commercial

adoption of new energy technologies. Congress created the Synthetic Fuels Corporation (SFC) under President Carter in an effort to spur construction of an industry to produce domestic liquid and gaseous fuels from solids such as coal in an environmentally attractive manner. The SFC failed to reach its goals because the technologies available could not hope to produce fuels at a competitive price, even with significant government support, as crude oil prices fell below \$20 per barrel and wellhead gas costs dropped to \$1 per million Btu. When imported oil prices failed to rise as expected, industry lost interest in the program.

Support offered by the SFC was primarily of two types: product price guarantees and non-recourse government loan guarantees. Neither type is viewed as attractive by industry today.

The Clean Coal Technology Program was created by Congress following the demise of the SFC and has been much more successful than the SFC, primarily because the technologies supported are viewed by the private sector as both necessary and cost-effective in the long run from both an energy efficiency and an environmental perspective. Government support has been in the form of equity participation, with recoupment provisions that apply if commercial use becomes profitable. Another prominent feature of the program is the limitation that the government's share of the financing must be less than 50 percent.

This form of support has led major utilities and companies able to raise the substantial capital needed for such an undertaking to test new low-emission technologies for producing electricity. It has been less effective in promoting other uses of coal; several projects that might be viewed as "synfuels" production have failed to raise the necessary private-sector capital, even when selected by the Department of Energy as attractive projects.

An incentive program to promote commercial application of clean coal technologies should recognize and build on the successes of the CCT Program. However, it also should recognize that new types of incentives may be appropriate when the goal is to encourage rapid commercial use rather than to demonstrate technology for the first time at large scale.

Recent Proposals for Incentive Programs

The National Coal Council, in its 1988 report, *Innovative Clean Coal Technology Deployment*, recommended the following incentives to accelerate deployment of clean coal technologies:

- "Allow full construction work in progress (CWIP) in the rate base, and/or accelerated depreciation, both of which allow a company to recover capital investment more quickly."

- "Incentive rate of return to recognize that riskier plants -- like demonstrations of new technologies -- may require higher return to compensate for higher risks. This should consider risk adjustments to the authorized rate of return for utilities employing innovative CCTs."
- "Preconstruction assurance that expenditures will be considered prudent within a phased prudency review mechanism that establishes agreed-upon expenditure caps for each corresponding phase of the project."
- "Appropriate expense treatment for contributions to collaborative industry efforts and R&D costs, including equipment used solely for R&D purposes. Regulatory modifications to allow innovative CCT to receive treatment now only accorded existing cogeneration and renewable energy sources. This could include, for example, investment tax credits for the necessary equipment. Such modifications should also encourage and expedite innovative CCT deployment by industrial and other non-utility coal users, recognizing that these companies can be a valuable source of technology, funding, and commercial leadership."

The National Regulatory Research Institute has developed a concept for providing incentives where a conventional technology is chosen as a "benchmark" and the incentive is chosen so that the proposed CCT project will have equal or better economic performance over its life cycle. A system of intermediate cost targets and milestones is established by the builder and approved by the regulatory agency. There is then a sharing of costs and savings achieved between the owner and the consumer.

A very extensive evaluation of incentive mechanisms has been published by Argonne National Laboratory. The authors examined the types of risks that users of new technologies may encounter and offer appropriate incentives to counter these risks. The key point of their proposed program is that incentives be linked to achieving operational goals, such as improved efficiency or decreased down time (outage). The authors emphasize that incentive mechanisms should incorporate risk-sharing in order to protect consumers.

A detailed methodology for determining proper incentives has been developed by the Clean Coal Technology Coalition. This plan proposes the use of both capital cost incentives and risk incentives and, in general terms, is similar to the Argonne concept.

In summary, there seems to be a developing consensus that incentives to promote the deployment of clean coal technologies should be based, at least in part, on sharing the risk of failure and rewards of success between the technology user and the consuming public. There also is a need to provide at least some government support, up front, to capital costs.

Recommended Incentives

Financial incentives to offset FOAK risks associated with clean coal technology adoption and associated sustainable development should be of three types. Two are "hard" incentives -- financial support for commercialization. Some of the funds must be available up front to reduce the incremental capital investment requirements for early units, and some must be tied to performance criteria on an incremental cost basis for early commercial units as an operating incentive. The third type would be "soft" incentives -- money made available to provide local mitigation of environmental concerns. Examples of this third type might be offsets for carbon dioxide or NO_x emissions. There is a need to demonstrate that such offsets are both effective and acceptable to the public; this program would provide that demonstration. Specific examples of existing offsets include the manufacture and distribution of energy-efficient appliances or the planting of trees.

Table 6 presents a summary of the federal "hard" incentives alternatives considered in preparing this report. The four alternatives are (a) capital cost-sharing, (b) performance-based incentives, (c) a combination of (a) and (b), and (d) none. A careful consideration of each of these alternatives led the National Coal Council to recommend a combination of capital cost-sharing and performance-based incentives by the Federal Government.

After carefully reviewing each of the alternative hard incentive approaches discussed previously, the National Coal Council recommends that the Department of Energy provide progressively declining capital support for each of the first five commercial integrated coal gasification combined cycle power plants, pressurized fluidized bed combustion power plants, and advanced pulverized coal-fired power plants with combined sulfur dioxide, nitrogen oxides, and particulate controls capable of meeting at least CAAA Phase 2 requirements. A pro forma estimate for this total capital incentive (see Appendix B) is \$1.1 billion in 1992 dollars, expended over a 15-year period from 1995-2010. Total industry investment for these plants will be approximately \$6 billion in 1992 dollars, not including interest during construction. Therefore, industry risk-sharing represents 85 percent of the capital costs for these plants.

The National Coal Council believes this is an appropriate capital risk-sharing relationship between the Federal Government and industry to capitalize on the nearly \$7.0 billion dollar expenditure for the CCT Program.

Table 6

Federal Incentive Alternatives

Capital Cost Sharing	Performance Support	Combination of Capital and Performance Incentives	Do Nothing
Technology deployer focus	Technology developer/supplier or technology deployer	Both	N/A
Capital-based	Performance-based	Both	N/A
\$1.1 billion (1992 dollars)	\$0.3 billion (1992 dollars)	\$1.4 billion (1992 dollars)	\$0
Total plant efficiency improvements focus	Component/sub-system/system efficiency focus	Both	No efficiency improvements
Will help maintain coal markets	Will focus on least-cost coal options (low-sulfur and high-sulfur coals)	Provides significant support for many CCTs to enter the market	Will not help coal become more competitive
Positive job impact	Positive job impact	Positive job impact	Will negatively impact on coal jobs
Continues CCT Round I-V momentum	Continues CCT Round I-V momentum	Maximizes benefits from CCT Round I-V Program	Stops momentum

In addition, considering the operating risks associated with the first few years of operation of these new CCT power plants, it was deemed appropriate to recommend some additional sharing of these risks. Experience from previous FOAK power plants indicates that the annualized capacity factor during the first three to four years of operation may be substantially below the commercially competitive level of 65 percent. These lower-capacity factors in turn are the result of a number of other factors, including (a) increased

forced outages with FOAK equipment, (b) increased maintenance resulting from materials limitations and limited long duration testing, (c) failures of key components to meet design performance, and (d) system control problems which were previously not anticipated.

As a consequence, initial annualized capacity factors, based on plant rating, may be only 40 percent through 50 percent until these problems have been resolved or rectified. Appendix B also shows a pro forma estimate of the implications of reduced capacity factor for plant operating costs. As was recommended for the capital incentive, progressively declining financial support (in amount and time) or financial guarantee to offset early operating and performance risks is recommended.

In the case of this operating support, it should be either in the form of performance guarantee support to the technology developer/supplier or in the form of operations/maintenance financial assistance to the technology deployer (utility or non-utility generator). This incentive should be available on a component to subsystem basis, as well as on an overall system basis, to provide the assurances necessary to both supplier and user that adequate compensation will be provided should unanticipated failures or downtimes occur.

The incentive basis developed in Appendix B is based on an average reduction in annualized capacity factor of 20 percent (from 0.65 to 0.52) over the first five years of operation for the FOAK of each of the advanced CCT power plants. As in the capital incentive case, this support is discounted by 20 percent for each subsequent plant and, in addition, is reduced in duration for each subsequent plant. Therefore, the FOAK plant has 20 percent operating support for five years, the second plant has 16 percent support for four years, and so forth through the first five plants of each of the four CCTs.

As shown in Appendix B, the total recommended performance-based incentive is \$287 million in 1992 dollars. Although operating costs for these plants are not shown, they are estimated to be approximately \$3 billion in 1992 dollars. Thus, performance-based support would be approximately 10 percent of total operating costs. However, this incentive is extremely important to assure the suppliers, utilities, and regulators that accepting the risk of these new technologies is reasonably prudent. The level of these incentives would represent 10 percent through 15 percent of the capital and operating costs of the first 15 advanced CCT power plants. It is in the national interest that the Federal Government support such an incentive program over the period 1995-2010 to capture the full benefit of the CCT Program and enhance the environmental and economic performance of coal power plant technology. Although this pro forma analysis is based on full system deployment, it may be appropriate for the Department of Energy to offer similar incentives for introduction of selected subsystems developed within the CCT Program or comparable new technologies. In any case, the incentive support program should reflect a reduced Federal Government financial role as these technologies mature.

Conclusions

- Advanced coal combustion, pressurized fluidized bed combustion, and integrated coal gasification combined cycle power plants are, or will be, technically proven as part of the CCT Program. However, technology vendors must offer performance guarantees and/or turnkey packages in order for these technologies to be widely implemented in the marketplace before they are regarded as commercially proven.
- Early deployment of CCTs will greatly assist the Federal Government in meeting its environmental goals.
- A major problem with clean coal technologies is that FOAK costs exceed conventional power plant costs. In particular, capital costs are high relative to those for natural gas and conventional coal plants, and current delivered fuel costs do not compensate for this difference.
- The Federal Government, through the Department of Energy, should provide a combined capital and performance-based incentive program to stimulate deployment of clean coal technologies. These funds should support the market entry of the first five units of each of four advanced coal power plants. Any clean coal technology should be eligible, not just those emanating from the CCT Program.
- The incentive program should be structured not only to reduce the financial risks of power generators, but also to provide the supplier industry with the financial capability to provide performance and reliability guarantees.

Recommendations

1. The National Coal Council recommends that the Secretary of Energy not issue any further solicitations under the existing Clean Coal Technology Program. The Council believes the projects which are in place or will be in place under Rounds I-V will provide the necessary technology demonstration base. As conditions change in the future and new coal research breakthroughs are achieved, it may be appropriate for the Department of Energy to assess the benefits of further technical demonstrations.
2. The National Coal Council recommends that the Secretary of Energy foster the establishment of a new federal-level Clean Coal Technology Incentive Program to stimulate sustainable commercial deployment of clean coal technology. Based on the attached Pro Forma, this new federal-level incentive program could provide approximately \$1.1 billion of capital incentive in 1992 dollars and \$0.3 billion of performance (operating) incentives in 1992 dollars over a 15-year period from 1995 to 2010.

The federal program should represent 10 percent to 15 percent of the total capital and help offset operating risks associated with first-of-a-kind (FOAK) and early commercial units of new CCTs. The National Coal Council believes this is a prudent federal risk-sharing program to capitalize on the results of the Clean Coal Technology Program and to stimulate initial introduction of these systems.

The incentive, cost-shared program should partially offset the capital and operating cost of up to the first five commercial units of, for example, integrated coal gasification combined cycle systems, pressurized fluidized bed combustion systems, advanced pulverized coal-fired power plants, and innovative component technologies that were developed under the prior CCT program. (The National Coal Council also considered the potential need for financial incentives for AFBC, but these are being offered under competitive commercial business terms for units in the 200MW capacity range.)

Cost-shared incentives should be of two types. Two are "hard" incentives as discussed above. The third, "soft" incentive should be offset funds made available to provide local mitigation of environmental concerns and included within the funds made available to the Department of Energy for this incentive program.

3. The National Coal Council recommends that the Secretary of Energy work with the Administrator of the Environmental Protection Agency to ensure that plant owners are provided with a consistent set of environmental requirements.
4. The National Coal Council recommends that the Secretary of Energy, in cooperation with individual utilities and state and local agencies, evaluate the potential of converting old existing non-compliant plant sites to new sites employing CCT and develop policies to minimize site relicensing requirements and delays.
5. The National Coal Council believes that recycling old sites in economically depressed areas could be of prime importance in the construction of CCTs. Such development would tie into the current Administration's economic development policy. However, both utilities and state regulators must feel that the alternatives are attractive to them.

References

1. National Coal Council Report, "Innovative Clean Coal Technology Deployment," November 1988.
2. Harunuzzaman, Mohammad, "Regulatory Incentives for Clean Coal Technologies," presented to the National Coal Council Working Group on Future Directions of the Clean Coal Technology Program, Washington, D.C., September 10, 1993.

3. McDermott, K. A., K. A. Bailey, and D. W. South, "Examination of Incentive Mechanisms for Innovative Technologies Applicable to Utility and Non-Utility Power Generators," Argonne National Laboratory Report ANL/EAIS/TM-102, August 1993.
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CHAPTER IV

MERIT OF ADDITIONAL CO-FUNDED IMPROVEMENTS

Introduction

Technologies that might become candidates for additional co-funding will need to be examined in detail by the Department of Energy in conjunction with industry, with due consideration for several factors:

- The likelihood that any specific technologies selected will attain a position of truly improved market viability as a result of the co-funded amount.
- The possibility that co-funding of a particular aspect or component in one project will have a generic benefit for several variations of the technology, though only one is being demonstrated.
- The need to span a range of applications, such as new environmental requirements beyond the immediate "boundary conditions" imposed by the work that has been performed thus far.

These considerations are an outgrowth of the realization that the history of research and development suggests that only a small percentage of innovative concepts ever lead to true commercial success. Moreover, and more frequently than not, the pitfalls that face technologies that have survived the process to the demonstration phase, such as those in the CCT Program, arise not so much from major technical shortcomings as from a loss of favor because of misapplication of the technology or the lack of data in the range(s) where the technology might be employed more advantageously than first thought. Finally, conditions which warranted development of the technology originally change with time and alter its relevance to the marketplace.

A recent historical example that is relevant to these considerations is the development of the flue gas desulfurization market since just before passage of the original Clean Air Act in the U.S. in 1970.

During the late 1960s and early 1970s, there was an initial surge of research and development activity that led to a wide variety of once-through and regenerative technologies, several of which were attempted eventually as full-scale "commercial" applications in the utility market. As the commercially tested technologies moved along the learning curve, several fell into disfavor as longer-term operation identified their weak

points. On a parallel path, limestone wet scrubbing technology's early difficulties with deposit formation and sludge dewatering were essentially overcome with the further incorporation of forced oxidation into many of the systems offered. Limestone wet scrubbing now is sold and accepted as the leading commercial technology of the 1990s.

Such a maturation process is likely to occur with other developing CCTs. This example indicates that improvements may best be made as systems are introduced and deployed in commercial service, rather than through an extended CCT Program.

Technical and Cost Improvements

The merits of co-funded improvements in the CCT Program begin with technical advances that in turn lead to cost improvements as greater efficiencies are realized. Evaluation of potential candidates for co-funding by the Department of Energy would involve a number of considerations, as discussed in the following paragraphs.

- *Selection of one or more technologies for co-funded improvements should take into account the extent to which the additional effort would help achieve overall program goals.* As noted in the "Clean Coal Technology Demonstration Program: Program Update 1992," the intent and goals of the Program include "achieving greater efficiencies in the conversion of coal to useful energy; achieving control of sulfur oxides, oxides of nitrogen, air toxics, solid and liquid wastes, greenhouse gases, or other emissions resulting from coal use; and promoting the export and transfer of U.S. clean coal technologies and services to developing countries and countries making the transition to free market economies." Evaluation of any proposed improvements would include examination of how the proposed work would be expected to fulfill one or more of these goals above and beyond what already has been achieved. Thus, co-funding might be used to attain a significantly higher level of performance than that already demonstrated, but it might be used just as easily to overcome a known shortcoming in achieving the original goal(s) as long as there appears to be sufficient reason(s) to believe that the additional work or modification will provide the desired result.

To minimize the cost and time required to evaluate worthy candidates for co-funded improvements, preliminary screening of all the CCTs almost certainly is needed to eliminate from consideration those technologies generally considered to be far from achieving their original technical goals (see Chapter Three). This will greatly reduce the potential improvement options.

- *Selection of one or more technologies should take into account the relative costs of the co-funded improvements of the candidate technologies.* While this statement has an obvious meaning, it also suggests that review of candidate technologies might allow for the possibility that a relatively small additional expenditure may be just the "nudge" needed

to clear an impediment to a technology's deployment. Ignoring such possibilities and leaving them to "others" may reduce an otherwise promising technology to an "also ran." As discussed in Chapter Three, good capital and operating cost data, as well as environmental data, are necessary to make this review meaningful.

- *Selection of one or more technologies for co-funded improvements should take into account applicability for coals of different types.* Evaluation should include examination of how any chosen technology or technologies might be applied commercially for coals of varying sulfur, ash, and moisture content, as well as calorific value. Consideration should be given to effects beyond the immediate costs of the coal and technology themselves and might include estimates of such factors as transportation costs and the impact on local economies.

- *As discussed in Chapter Three, future co-funded efforts should be provided only on a declining graduated financial scale as the number of deployed systems or power plants expands, with government bearing less and less of the cost of deployment and operation.* Because a candidate technology will have established its technical viability, co-funding on the basis of diminishing support as technical performance improves appears reasonable. The most obvious measure would be demonstrated ability to approach projected guarantee levels under conditions that increasingly approach what might be expected of a fully commercial plant. The nature of the co-funding essentially could be a guarantee, in one form or another, with co-funding covering the difference between what the technology supplier would be willing to guarantee for a mature technology versus early commercial systems. This is one form of performance or operating incentive.

This use of co-funding as an insurance guarantee differential can be carried out best in commercial deployment settings, rather than through an extension of the existing CCT Demonstration Program. One might envision one or more potential users of a technology agreeing to participate by purchasing a system for which the supplier provides guarantees up to a certain level of performance for some period of time/operation. Under the assumption that such operation will lead to additional technical improvements, performance would be expected to improve and the need for co-funding to diminish. In this way, and depending on the type of technology used, co-funding might be extended to cover the "insurance" required at a number of sites, with the additional benefit that a more generic application of the technology may result. This approach is consistent with the recommendations made in Chapter Three.

- *Demonstrating a range of technical performance is acceptable and, in fact, desirable.* There usually is a tendency to focus efforts on attaining and continuously demonstrating the highest possible performance during project execution. It is probably more important to perform tests over a variety of conditions that represent how the technology might be employed more broadly and realistically. While it is true that "worst-case conditions" tend to be at high-load conditions, low-load conditions can present unanticipated difficulties.

Operation over the whole range can provide better insight into the overall viability of a technology and demonstrate applicability to potential users who do not require performance data at the extremes.

- *Preference should be given to continued work at existing clean coal technology demonstration sites.* Air toxics are becoming an important environmental concern regarding emissions from coal-fired power plants. The Department of Energy should selectively expand its existing program to measure air toxics at existing demonstration sites.

Future Program Emphasis

Although there certainly are opportunities for technical and cost improvements in the CCT Program, the National Coal Council believes that future funding should focus on FOAK commercial plants. FOAK commercial deployment is the last stage of the research, development, and demonstration cycle. There are many new elements of financial risk and, therefore, plant cost as a new technology reaches this phase. Specifically, there are additional costs associated with first-time engineering, procurement, regulations, manufacturing, and start-up and operations.

- *Engineering:* Significant person-years are used for first-time system and components engineering with lengthy performance and control analysis. The FOAK unknowns associated with instrumentation and control (I&C) and the required engineering are major efforts in deployment of any power production facility.
- *Procurement:* The first-time preparation of procurement specifications and purchase orders can require extensive in-house efforts as well as external marketing and sales efforts.
- *Regulations:* The regulatory process for all power generation facilities can make it extremely laborious to obtain up-front evaluations and approvals with a large cost in cash flow and time for approval. Such approvals are required for siting, conceptual design, operational performance, and testing such as life cycle demonstration -- and some are unpredictable.
- *Manufacturing:* Some first-time and/or one-time-only extensive manufacturing efforts are inspection and quality assurance, materials handling, shop sequencing, assembly and layout, and fabrication procedures.
- *Start-up and operations:* Here major consideration must go to on-site testing to demonstrate guaranteed performance, establish operational procedures from first-time start-up, and determine what support system and/or component will not work and must be

replaced, re-engineered, or both. Most "surprises" during initial start-up and operations are I&C-related and may result in redesign, modification, and/or resetting of control parameters, all of which are unpredictable and costly.

Many of the above unknowns can be quantified by appropriate test and demonstration in existing test facilities, but only after the commercial project has been identified and engineered and performance requirements are established. These considerations are very rarely explored in-depth in the development phase of a new project; they can be faced only when the first commercial contract is put into place to supply a production system.

This discussion of the FOAK commercial unknowns experienced by manufacturers, suppliers, and users is presented to inform the Federal Government and others as to just what first-of-a-kind commercial risks are. Also, this discussion can help explain why many successful development projects never reach commercialization. Private industry cannot always undertake such projects without some support to minimize these FOAK risks as discussed.

Conclusions

- Under the CCT Program, the Federal Government has co-funded 45 technology demonstration programs. These technologies, however, have not moved into the marketplace in a significant way. The merits of additional support for existing programs depends primarily on the potential for commercial success of these technologies and the ability to structure and finance appropriate support mechanisms. Failure to do so will mean losing the investment made in the CCT Program and limiting the environmental benefits of these technologies.
- The lack of current successful commercialization of the selected demonstration technologies is caused by a number of factors. Primary among these is the time necessary for the power generation industry to demonstrate and then commit to a new technology. Initial expectations were overly optimistic as to the rate at which these results would affect the commercial marketplace.
- The National Coal Council concludes that the intent and objectives of the CCT Demonstration Program have been met or will be met with existing projects from Rounds I-V, and the Council supports completion of the projects initiated in the existing program. The CCT Demonstration Program is successful, and the Council concludes that an extension in the present form is not necessary. The Council supports completion of the projects initiated within the existing CCT Demonstration Program.
- Deployment of first-of-a-kind (FOAK) commercial power plants of various types (IGCC, PFBC, and Advanced Pulverized Coal Power Plant [APCPP]) provides the best

mechanism for identifying the benefits of technical, operating, and financial improvements in technology. The National Coal Council believes that future emphasis should be placed on the commercial deployment of clean coal technologies.

- A graduated declining financial incentive program which supports introduction of up to five commercial plants for each of the four base technologies is the most effective mechanism to spur commercialization.
- While the CCT Program has focused on 45 development projects, these projects in many cases are composed of several technological innovations that are key to the total performance of the project. While the commercialization of total projects has not met some expectations, significant developments in some of the specific component technologies may have occurred. These component technologies may represent advances that already have made, or that will make in the future, significant contributions to the achievement of the CCT Program's objectives.

Recommendations

1. The National Coal Council recommends that the Secretary of Energy investigate and identify any component technologies that have benefited from the existing CCT Demonstration Program so that these innovations can be emphasized in technology transfer efforts.
2. The National Coal Council recommends that the Secretary of Energy complete the existing CCT Demonstration Program as currently defined (Rounds I-V) and focus all further efforts on CCT commercial deployment.
3. The National Coal Council recommends that the Secretary of Energy evaluate opportunities to perform measurements of air toxics emissions at existing demonstration sites to obtain valuable environmental data.
4. The National Coal Council believes that additional co-funded improvement efforts should be carried out in conjunction with commercial projects and funded through the Department of Energy's Coal Research Program.

Reference

1. "Clean Coal Technology Demonstration Program: Program Update 1992" (as of December 31, 1992), Report No. DOE/FE-0272, U.S. Department of Energy, February 1993.

CHAPTER V

INTERNATIONAL TECHNOLOGY TRANSFER

Introduction

The purpose of this section of the report is to offer advice on carrying out the international technology transfer effort called for by Sections 1332 and 1608 of the Energy Policy Act. Key elements of Section 1332 include:

- Enter into agreement to carry out the clean coal technology transfer program and establish a procedure to resolve disputes on implementation.
- Send agreements to Congress and make them available to the public.
- Pursuant to the agreement reached in Section 1332(a), develop mechanisms to identify potential CCT energy projects in host countries and identify a list of these projects.
- Establish financial mechanisms to carry out projects.
- Solicit proposals from U.S. firms for CCT projects in Section 1332(c) which utilize U.S. technology.
- Provide financial assistance to U.S. firms where the host country or multilateral lending institution conducts the solicitations.
- Select proposals in response to solicitation in Section 1332(e) based on eligibility criteria in Section 1332(g).
- Ensure that at least 50 percent of equipment cost will be U.S. components and maximize participation of U.S. firms.
- Report to Congress on progress made in the introduction of clean coal technologies into foreign countries.

It is important to maintain an international market perspective in furthering the commercial deployment of clean coal technologies. While the impetus behind the CCT Program has been focused largely on the domestic use of coal as an energy source, as discussed earlier, the combination of energy conservation measures and compliance with the Clean Air Act Amendments of 1990 has caused the immediate domestic market for clean coal technologies to be less than expected at the inception of the program. Fortunately, within

the same time frame, changes in political structure, particularly in Eastern Europe and the Far East, have been accompanied by increased demand for an environmentally compatible indigenous resource energy supply.

Overseas interest in the CCT Program appears to be growing and represents greater opportunities for a broader range of U.S. businesses than originally envisioned. Probably the action most needed to spur deployment internationally is to be able to point to one or more commercial-scale applications of technologies operating in the U.S.

As pointed out in Chapter Two of this report, it is worth noting that every one of the clean coal technologies supported by the Department of Energy during the Clean Coal Technology Demonstration Program is also an environmental technology. Each technology (some more dramatically than others) provides positive improvements in overall emission reductions either through improved use of waste products or through improved efficiencies over existing technology. Clean coal technologies also meet the definition of, and the conceptual embodiment of, the pollution prevention concept. There is a direct relationship between improved efficiency and a decrease in waste products produced. As the largest environmental technology program undertaken during the last decade, the Clean Coal Technology Demonstration Program has provided a foundation for a new generation of environmental technologies.

The major goals of the Clean Coal Technology Demonstration Program were identification of the next generation of coal-related environmental technologies and demonstration of the best of those technologies that would lead to commercialization. As discussed earlier, the program is expected to satisfy all of these objectives once its 45 projects have completed operations. The next logical step is commercial deployment of technologies that have passed the demonstration hurdle.

Another important point that must be kept in mind regarding international markets is that not all clean coal technologies necessarily must achieve immediate U.S. or global acceptance. Again, flue gas desulfurization provides an example that can be used to envision the perspective that must be kept. As the U.S. utility market for this technology developed during the late 1970s, several potential users of wet scrubbing technologies, particularly those with lower-sulfur coals in the Western U.S., found it hard to justify the high capital costs of such systems. Instead, they found (spray) dry scrubbing technology to be preferable for their site-specific circumstances. In the high-sulfur coal market of the Eastern U.S., the technical and economic limitations of the dry technology have kept it from being widely accepted. The lesson: niche markets exist for some of these technologies, in spite of their apparent lack of acceptance by a broader list of potential users. Consideration of the differences in the economies of countries worldwide makes it imperative to realize the possibilities for niche markets, particularly for technologies that otherwise might be regarded as not meeting the expectations of the U.S. market. Such niche markets for "lower-cost, lower-efficiency" technologies can be very effective in

establishing the reputation of suppliers in developing countries and form the basis for more profitable markets as their economies improve.

Keeping in mind that the technologies demonstrated are environmental technologies that fit the sustainable development and pollution prevention goals that are espoused globally, they must be introduced into the global marketplace. The Energy Policy Act, under Section 1332, provides a directed approach to that introduction. The international market also represents the biggest short-term opportunity for deployment of successfully demonstrated clean coal technologies. If done properly, this deployment of clean coal technologies internationally will increase the creation of new domestic jobs and income.

Assuming the desirability of starting or continuing work on a technology at an international location, the primary impediments seem to be the problems associated with obtaining financing. Among the criteria that may be imposed by the various financial institutions that might participate in the arrangements, the need to meet emissions guidelines often conflicts with potential applications in those countries that might benefit most from some of the lower-cost, lower-efficiency technologies. The World Bank, as a major funding agent for international power projects, recently identified its emission and ambient control targets for projects and countries that receive World Bank support:

Stack Emissions:	SO ₂ :	200 ton/day
	NO _x :	280 ng/Joule heat input
	Particulate:	< 100 mg/Nm ³ (1)
Ambient Concentrations:	SO ₂ :	100 µg/m ³ annual average
		500 µg/m ³ 24-hour maximum
	NO _x :	100 µg/m ³ annual average
	Particulate:	100 mg/m ³ annual average 500 µg/m ³ 24-hour maximum
Note:	ng = nanograms (10 ⁻⁹ grams)	µg = micrograms (10 ⁻⁶ grams)
	mg = milligrams (10 ⁻³ grams)	m = meters

These criteria are not as stringent as those required in the U.S., and they could provide the potential for mutual benefit in matching a less-than-fully-commercial technology (according to current U.S. standards) with application and continued development at an international location.

The other major criterion most commonly heard in discussions of potential funding of technologies in developing country settings revolves around government stability. Here it appears the responsibility rests with the receptor country to provide assurances that financial obligations will be met.

Finally, global climate change has become a major international environmental issue. The electricity generation industry throughout the world is going to be asked to make significant reductions in the growth of emissions of greenhouse gases, particularly carbon dioxide. There is no economically feasible technology for the capture and disposal of CO₂. Therefore, increased efficiency in the generating process is the most effective way to reduce CO₂ emissions per unit of electricity generated. Little data have been collected with respect to the increased efficiencies that may result from projects, or components of projects, that have received awards from the Department of Energy under the CCT Program. However, all of the advanced systems like IGCC are projected to have efficiencies of 40 percent or greater while greatly limiting SO₂ and NO_x emissions. Prospects for commercializing these systems globally are quite good; however, initial capital costs and limited operating experience will impede their widespread use in the near term.

Export of clean coal technologies might be expedited by combining the coal combustion technology with "soft" technologies for carbon dioxide abatement. A nation like China might be offered cost-sharing by the Department of Energy for initial CCT projects or other incentives such as energy-efficient appliances to enhance high-efficiency electrification. The most likely market for CCTs in Eastern Europe is retrofit technology or replacement of existing plants (like the U.S.); however, in both cases, U.S. financial support will likely be required.

Role of the Department of Energy

The role of the Department of Energy in the international deployment of clean coal technologies is provided in the Energy Policy Act, Sections 1332 and 1608. The role of the Department in the clean coal deployment arena is defined in this Act and by the new environmental technology export strategy. It should be a proactive role, designed to work with industry in the deployment of commercial clean coal technologies throughout the world.

Further, a new national environmental technology export strategy has been developed and fits clean coal technology international deployment needs perfectly, keeping in mind that clean coal technologies are in fact nothing more than environmental technologies in the coal sector. This strategy is based on five basic concepts:

1. Streamlining what the Federal Government does and coordinating the activity of a variety of agencies and programs that currently are dictating export strategy.
2. Leveraging private resources as much as possible.
3. Allocating resources, including financial resources, rationally.

4. Removing obstacles in the form of export controls and ensuring that the U.S.'s competitive advantage is maintained and enhanced.
5. Measuring performance in a manner that ensures the ideas are working.

This strategy is based on a teaming effort by the Department of Commerce, the Environmental Protection Agency, and the Department of Energy to decrease overlaps and increase effectiveness. An Environmental Technologies Trade Advisory Committee has been set up to provide a very high level of Administration focus in the process. Further, regional environmental export councils are being established to ensure that the broadest possible U.S. private-sector involvement is obtained. Finally, an interagency trade policy coordinating committee has been established to identify markets, create export marketing plans, and set up "one-stop shops" which will gather and disseminate data about export markets.

As the results of the CCT Demonstration Program become evident, it is important for the Department of Energy to take a lead role in disseminating this information internationally. The National Coal Council is aware that the Department already has conducted a number of workshops and led international trade missions to Eastern Europe, the Commonwealth of Independent States, India, China, and other Pacific Rim countries, and it commends the Secretary of Energy for her aggressive leadership in these efforts. These trade missions to establish an international understanding of the CCT Demonstration Program and to define potential commercial application opportunities are extremely important to U.S. industry.

Beyond these trade missions, it would be extremely valuable for the Department of Energy to consider conducting demonstration projects of CCT in certain countries or providing financial incentives for commercial projects. The Council is also aware that the Department is considering the development of a "showcase" program to demonstrate advanced coal technologies in certain countries, consistent with the intent of sections 1332 and 1608 of the Energy Policy Act of 1992.

Selection of the most appropriate CCTs for these "showcase" projects, identified by the respective host countries, and development of financing mechanisms for such projects are essential. Projects should consider greenfield power plants, retrofit, or repowering opportunities. Where possible, projects should use not only U.S. clean coal technology, but also U.S. coal resources.

Although the Council agrees that international markets are a key ingredient in the commercialization of CCTs, it also believes that domestic deployment should remain the primary objective of any continued federal support for clean coal power plants.

1993 Study: The Export of U.S. Coal and Coal Technology

The National Coal Council recently submitted its report and recommendations to the Secretary of Energy addressing coal and coal use technology export benefits. The following are key excerpts from that report, with additional perspective from the Council.

The major benefit from increasing exports of U.S. coal and coal-use technology is the creation of new domestic jobs and income. A creative and active marketing approach will be required if the domestic coal production and coal-use technology industries are to preserve and/or increase the U.S. share of the world market throughout this decade and beyond.

Looking at U.S. coal exports in terms of domestic jobs demonstrates the tremendous impact exports have in providing work for Americans. In 1991, United States coal producers exported 108.9 million tons, a total that fell to 102.5 million tons in 1992. The U.S. participation rate in the world coal export market declined from 25 percent to 23 percent, representing approximately 10,000 domestic coal production-related jobs.

If U.S. coal producers simply are to maintain their 1992 world market participation rate (23 percent), they will have to increase exports by 1 percent per year to the year 2000 and by 2.7 percent per year from 2000 to 2005. This performance level would be sufficient to add the equivalent of about 19,000 jobs by 2000 and 24,400 jobs by 2005. If U.S. coal exports expand at higher annual growth rates, a substantially larger number of new domestic jobs in mining and coal support industries could be created.

Likewise, domestic income from the export of U.S. coal-use technology easily could surpass the income from coal exports by the middle of the next decade. The worldwide demand for electricity is providing market opportunities for clean and efficient coal-use technologies. U.S. technology is as effective, clean, and low-cost as any available.

However, for the export of technology to create a significant number of jobs, technology sales must be linked to the sale of equipment, fuel, and engineering and/or operating expertise. It is crucial for the Federal Government to promote coordination among these components of the U.S. coal and coal-use technology industries because the sale of technology alone frequently has led to the international buyer's becoming a competitor in the export market, and sometimes in the domestic market as well.

Increasing the U.S. share of the coal and coal-use technology export market will not be an easy task. A significant economic and geopolitical transformation is occurring worldwide, reflecting the end of the Cold War. Additionally, the world community is dealing with an explosion of information technology and environmental concerns, as well as other changing conditions.

For example, recent prices of steam coal delivered to Rotterdam (Table 7) indicate that U.S.-delivered coal prices are not competitive with many sources such as South Africa, Colombia, Venezuela, and Indonesia. Coupling U.S. coal exports to advanced coal technologies which effectively utilize these coals could make them much more competitive.

The Council study estimated world steam and metallurgical coal imports at 423 million tons in 1995, 476 million tons in 2000, and 545 million tons in 2005. Were U.S. coal producers to capture all of the export increases forecast between 1995 and 2000 (53 million tons), the American work force would gain 81,600 jobs. Job gains for U.S. workers become even more dramatic when viewed in terms of increased U.S. coal exports between 2000 and 2005. By providing all of the forecast additional 69 million tons during this period, the domestic coal industry would create an additional 106,300 jobs.

The National Coal Council believes that Pacific Rim imports offer significant market opportunities given the expanded completion of current and planned coal-fired electric generation consumption. The downside risk to the Council's forecast for world coal imports is that some portion of this coal-fired generation construction could be postponed or canceled.

While its world coal export forecast may seem pessimistic, the Council believes this forecast should be viewed as an opportunity for creative marketing on the part of U.S. coal and coal-use technology producers.

Table 7

Recent Prices of Coal Delivered to Rotterdam
(Rounded)

Source	Btu/Lb	Current Steam Coal Prices FOBT \$/mmBtu	Typical Spot Freight to Rotterdam \$/mmBtu	Price Delivered to Rotterdam \$/mmBtu
<u>United States</u>				
Hampton Roads	12,000	\$1.51	\$0.21	\$1.72
Baltimore	12,000	\$1.32	\$0.22	\$1.54
Gulf Coast	12,000	\$1.44	\$0.28	\$1.72
<u>Colombia</u>				
Puerto Bolivar	12,000	\$1.12	\$0.22	\$1.34
<u>Venezuela</u>				
Maracaibo	12,500	\$1.16	\$0.28	\$1.44
<u>South Africa</u>				
Richards Bay	11,500	\$1.07	\$0.27	\$1.34
<u>Indonesia</u>				
None Specified	12,500	\$1.07	\$0.35 *	\$1.42
<u>Australia</u>				
New Castle/ Port Kemba	12,000	\$1.21	\$0.37	\$1.58
<u>Poland</u>				
Baltic Ports	12,200	\$1.47	\$0.19 *	\$1.66
<u>CIS</u>				
West Coast	12,250	\$0.91	\$0.19 *	\$1.10
<u>China</u>				
None Specified	11,200	\$1.52	\$0.43	\$1.95

* Estimated Value

Source: International Coal Week, November 2, 1993

Summary of Recommendations from Coal Export Study

The National Coal Council believes the following support actions, undertaken by the U.S. Department of Energy and the U.S. coal production and coal-use technology industries, will improve America's competitive position in the international coal and coal-use technology market.

1. *Consideration should be given to the impact of government actions on the ability of U.S. coal and coal-use technology industries to compete worldwide.* By continuing to work closely with the Environmental Protection Agency and the Departments of Interior, Labor, and Transportation, as well as with the staff of the Executive Office of the President, the Department of Energy can play a valuable role in achieving economically and environmentally acceptable energy policies that do not inhibit the growth potential of the domestic coal industry in meeting global energy demands.

The National Coal Council recommends that the Secretary of Energy ensure that the Department of Energy continue to monitor proposed federal and/or state regulations, legislation, and policies which potentially could affect the competitive position of domestic coal and coal-use technologies in the export market.

2. *Concentrate efforts on target markets.* In developing cooperative mechanisms among government agencies and between such agencies and industry, the focus should be on specific emerging demands for coal and coal-use technology exports in specific geographic regions of the world. It is crucial for export success to choose the appropriate level of technology and to address the environmental concerns of the importing country.

The National Coal Council recommends that coal and coal-use technology export programs, particularly those of the Clean Coal Technology Subgroup of the Trade Promotion Coordination Committee, be specific in regard to the region of the world to which we are exporting and that the appropriate technology/coal/expertise combination best suited to that country be determined.

3. *Facilitate the establishment of industry/government teams to compete for export business.* Federal efforts to promote the export of coal-use technology should not be focused on the sale of technology alone. Export of coal-use technology is most cost-effective for the nation when combined with the sale of coal, equipment, and construction services or operational expertise. The private sector has not been effective in forming appropriate teams, and the Council strongly supports the initiatives of the Trade Promotion Coordination Committee's Clean Coal Technology Subgroup to facilitate such teaming efforts.

The National Coal Council recommends that the Secretary of Energy encourage the assembling of teams from "Who's Who in the U.S. Coal Technology Industry" and other

sources. Teams should be complete, including an architect/engineer, vendor, services company, user such as a utility plant owner, and government agency.

4. *Sharply focus program objectives.* Target markets and team building come together in the establishment of specific objectives. In general, the National Coal Council endorses the door-opening and feasibility study/international demonstration initiatives -- key components of the Department of Energy's plan. However, the Council believes these initiatives should be defined for specific countries with specific export objectives.

The National Coal Council recommends that the Secretary of Energy direct the Department of Energy to develop a plan to create a list of prospective markets, establish teams to visit prospective markets, and make recommendations on how such visits might be funded.

5. *Support U.S. companies faced with unfair business practices or barriers.* The Federal Government has been a leader in promoting coal-use technology development since the mid-1980s, but other governments also have been active in supporting research, development, and demonstration. In addition, other governments frequently provide strong, direct support for export of coal and coal technology.

U.S. coal and coal-use technology companies need stronger diplomatic support from the Federal Government to eliminate unfair business practices by international competitors.

The National Coal Council recommends that the Secretary of Energy encourage the Secretary of State to counsel U.S. embassies to be more active in supporting the efforts of U.S. coal and coal-use technology exporters and to provide appropriate technical support to facilitate that increased activity.

6. *Provide financial support where warranted by international competition.* If the U.S. is to move beyond assessment and information exchange to specific projects or programs, the Federal Government must accept an even greater financial burden. The Council supports the initiative of the Clean Coal Technology Subgroup that calls for government support for feasibility studies for specific projects. Such studies should include performance, cost, and availability analyses, as well as site restrictions.

The National Coal Council recommends that the Secretary of Energy encourage the Trade Promotion Coordination Committee to consider applying government support to all international nations and for any viable project. Once projects are identified, the Federal Government must provide support to the private sector to ensure that domestic coal and coal-use technology are given adequate consideration by the importing country, particularly by leveling the playing field in terms of financing and lending practices.

7. *Adopt an aggressive policy of information transfer on markets and available support mechanisms.* At least four areas of information transfer need to be emphasized to make

sure U.S. coal and coal-use technology companies are aware of the opportunities and support available from the government:

- There should be a detailed inventory of coal technology business opportunities in the international market, emphasizing each country's energy and environmental needs.
- The CCT initiative to maintain an information database on worldwide export opportunities should focus on specific coal-use technologies that can be brought to the international market.
- The Department of Energy should continue and expand its efforts and activities to increase awareness by U.S. companies of how to use existing government resources (Department of Commerce, Department of Energy, Trade Promotion Coordination Committee, U.S. & Foreign Commercial Service [US&FCS], U.S. embassies, etc.) in exporting coal and coal technology.
- The staffs of U.S. embassies and the US&FCS should be educated aggressively on the advantages of U.S. coal-use technologies.

The National Coal Council further recommends that the Secretary of Energy explore the development of a program by the Department to locate, for one to two years, up to 50 energy/environmental advisors (from both government and the private sector) in the international marketplace to assist embassy personnel and coal and coal-use technology teams and to help identify contacts in other countries that could benefit from U.S. coal and coal-use technology.

8. *Demonstrate the need for coal and coal-use technologies.* Increased use of coal can contribute significantly to the economic future of the world, and technologies to use coal cleanly and safely are available. The outdated concept that coal use is inherently damaging to the environment should be dispelled with information on available conventional and advanced clean coal-use technologies. This message must be delivered convincingly worldwide.

The Department of Energy should support efforts to educate the international community on the virtues of coal and the crucial role it is likely to play in raising the standard of living.

The National Coal Council recommends that the Secretary of Energy direct the appropriate offices within the Department to support efforts to educate the international community on the need for both conventional and advanced coal-use technologies and encourage the Environmental Protection Agency and the Administration to aggressively seek an international consensus on the environment recognizing the virtues of efficient and clean coal-use technologies.

9. *Demonstrate the comparative advantages of U.S. coal-use technologies.* U.S. coal-use technologies often are recognized as superior to those offered by other countries. However, it is critical that U.S. companies not undersell these technologies.

The National Coal Council recommends that the Secretary of Energy encourage the Department to showcase demonstrations of needed conventional and/or advanced coal-use technologies, using the team approach; encourage programs to facilitate equity ownership by U.S. partners; and, through its ongoing coal-use initiatives, help dispel the pessimistic and highly unlikely assumption held by some U.S. companies that, for the next ten years, foreign competitors will supply most of the advanced flue gas desulfurization, retrofit NO_x, and AFBC/PFBC technologies.

In addition to the recommendations made above, it is worthwhile to note that the report also indicated that "domestic income from the export of U.S. coal-use technology easily could surpass income from coal exports by the middle of the next decade. The worldwide demand for electricity is providing market opportunities for clean and efficient coal-use technologies. U.S. technology is as effective, clean, and low-cost as any available."

Conclusions

Based on the information developed in this report, the National Coal Council concludes that:

- The Clean Coal Technology Demonstration Program should be completed successfully, as currently planned, to demonstrate thoroughly a number of environmental technologies that will be competitive and effective for the international market.
- The international environmental and clean coal technology market is large and is awaiting new commercially demonstrated, competitive technologies that decrease pollution without an appreciable increase in total capital and operating costs.
- For U.S. clean coal technologies to compete in the international marketplace, they may have to be marketed through joint ventures with local companies.
- The near-term primary market for clean coal technologies is centered on the rapidly expanding need for electrical power in developing or growing economies.
- Clean coal technologies do not require a particular type of coal to be effective, for the most part, and can use coal that is available from the global marketplace.
- The transfer of coal technology internationally can be facilitated by actions prescribed in the Energy Policy Act and the new environmental technology export strategy. The

newly formed Environmental Technologies Trade Advisory Committee is an appropriate vehicle to foster the recommendations made in the National Coal Council's Coal and Coal-Use Export Study and in this study.

- The satisfactory completion and operation of one or more commercial-scale applications of coal technologies developed in the U.S. will serve as a model to spur deployment internationally.

Recommendations

1. The National Coal Council recommends to the Secretary of Energy that clean coal technologies be recognized broadly as environmental technologies in current and future Administration environmental technology programs, providing opportunities not only for preventing pollution, but also for improving the global environment. The Clean Coal Technology Demonstration Program has confirmed that these systems and processes essentially are new environmental technologies which will improve the environment substantially as they are deployed commercially. Therefore, these technologies should be emphasized by the Federal Government in developing and demonstrating a U.S. leadership position for global sustainable development.
2. The National Coal Council recommends that the Secretary of Energy ensure that the Department of Energy continues to monitor policies which could affect the domestic or international competitive position of technologies developed through the Clean Coal Technology Demonstration Program and assist in developing policies to minimize barriers to commercial deployment. It may be appropriate for the Secretary to consider partial funding of clean coal technology international deployment efforts to facilitate technology transfer. The Council further concludes that global deployment of clean coal technologies is critical both to sound domestic economic development and to worldwide sustainable economic and social development.
3. The National Coal Council recommends that where technologies developed under the Clean Coal Technology Demonstration Program meet barriers that create a playing field that is not level and that does not allow for straightforward competitive decisions, the Secretary of Energy recommend to the Administration countering actions necessary to level the playing field and create an open-market environment.
4. The National Coal Council recommends that in markets that have growth potential but provide risks unacceptable to the general financial community, the Secretary of Energy seek Administration assistance in decreasing the perceived financial risks in those developing markets and plan to subsidize international CCT projects to enhance their commercial acceptance. Financial incentives or removal of risk may be required to overcome weak exchange-rate structures in developing/reemerging economies.

The Secretary of Energy is commended for her ongoing efforts and is encouraged to continue to work with others in the Executive Branch to seek balanced economic solutions to environmental, health, and other issues that may affect the cost of producing domestic energy and energy technologies which have global benefits.

References

1. "National Coal Council Export Study," November 1993.
2. "International Coal Week," November 2, 1993.
3. World Bank Guidelines From International Finance Corporation (IFC) and the Environment -- Annual Review, 1992.

Appendix A

Technology Screening Matrices

APPENDIX A

TECHNOLOGY SCREENING MATRICES

The Technology Screening matrices discussed in Chapter Two are presented in this Appendix. There are three types: Environmental Screening matrix, Economic Screening matrix, and Commercial Opportunities matrix. All matrices were developed by reviewing the status and performance of each of the 45 Department of Energy Clean Coal Technology projects.

The matrices were developed for each Department of Energy technology category:

- Advanced power generation systems (Tables A-1 and A-2).
- High performance pollution control devices (Tables A-3 and A-4).
- Industrial applications (Tables A-5 and A-6).
- Coal processing and cleaning (Tables A-7 and A-8).

Table A-9 evaluates commercial opportunities for clean coal technologies, again using the categories identified above. These matrices also include an assessment of the demonstration status of each of the 45 CCT projects.

For a glossary of terms and abbreviations for interpreting the matrices, see Appendix C.

Table A-1

Environmental Screening Matrix - Advanced Power Generation Systems

Project	Target Year		Particulates	Air Toxics	Efficiency	Waste Water	Forms of Solid Waste
	SO _x	NO _x					
IGCC							
Springfield IGCC	2010	1995	2000	na	> 43 %	na ¹	slag & dry SW
Repowering							
Pinon Pine IGCC	2005	2010	2005	na	44 %	na	agglom SW
Toms Creek IGCC	2010	2005	2000	na	44 %	na	dry SW
Tampa Electric IGCC	2005	2005	2010	na	> 40 %	na	slag
W. Riv. Gasif.	2005	1995	2005	na	38 %	na	slag
Repowering							
Camden Clean Energy	2010	1995	2010	Monitoring planned	38 %	na	slag
FBC							
Nucla CFB	1995	1995	1990	na	34 %	na	dry & wet SW
York City Cogen.	1995	1990	1990	na	37 %	na	dry SW
Tidd (PFBC)	1990	2000	1995	na	40 %	na	dry SW
AEP/PFBC Utility	2000	2000	2000	na	40-45 %	na	dry SW
Demo							
Pleasant Hill PCFBC	2000	1995	2000	na	43 %	na	dry SW
Calvert City Adv.	2000	1995	2000	Monitoring planned	40-45 %	na	dry SW
Energy							
Others							
Healy Slagging	1995	1995	2000	Monitoring planned	< 38 %	na	slag & dry SW
Combustor							
Warren EFCC	2000	1995	2000	Monitoring planned	44 %	na	dry SW
Easton Diesel Tech.	1995	1995	1995	na	48 %	na	na
Demo							

¹ na indicates data not available

Table A-2

Economics Screening Matrix - Advanced Power Generation Systems

<u>Project</u>	<u>Salable Product</u>	<u>Unique Features</u>	<u>Demo. MW Size</u>	<u>Retrofit/ Repower</u>	<u>Greenfield</u>	<u>Potential Market</u>	<u>Capital Cost</u>	<u>O&M</u>
IGCC								
Springfield IGCC	Entrained Flow Gasifier	Air Blown	65	yes	yes	Utility	na ¹	na
Repowering Pinon Pine IGCC	FI.B Gasifier	Air Blown	80	yes	yes	Utility	na	na
Toms Creek IGCC	FI.B Gasifier	Air Blown	55	yes	yes	Utility	na	na
Tampa Elec. IGCC	Entrained Flow Gasifier	O ₂ Blown	322	yes	yes	Utility	na	na
W. River Gasif.	Entrained Flow Gasifier	O ₂ Blown	268	yes	yes	Utility	na	na
Repowering Camden Clean Energy	Fix. Bed Gasifier	Market. S., Market. S., Fuel Cell	480	no	yes	Utility	na	na
PFBC								
Nucla CFB	ACFB Boiler	NO _x /SO ₂ Contr. in Blrs.	110	yes	yes	Utility & Indust.	\$1123/ kw	6.3¢/ kwh
York City Cogen.	ACFB Boiler	Lower Temp. than pc Comb.	250	yes	yes	Utility & Cogen.	na	na
Tidd PFBC	PFB Combustor	Bubbling PFB Technology	70	yes	yes	Utility	na	na
AEP/PFBC Utility Demo	PFB Combustor	Modular Construction	340	yes	yes	Utility	na	na
Pleasant Hill PCFBC	CPFB Combustor	Topping comb variety of coal	80	yes	yes	Utility	na	na
Calvert City Adv. Energy	Gasif. & PFBC	LBtu comb.	95	yes	yes	Utility & Cogen.	na	na

¹ na indicates data not available

Table A-2 (continued)

Economics Screening Matrix - Advanced Power Generation Systems

<u>Project</u>	<u>Salable Product</u>	<u>Unique Features</u>	<u>Demo. MW Size</u>	<u>Retrofit/ Repower</u>	<u>Greenfield</u>	<u>Potential Market</u>	<u>Capital Cost</u>	<u>O&M</u>
<i>Others</i>								
Healy Slagging Combustor	Slagging Combustor	Suitable for Cyclone Blrs.	50	yes	yes	Utility & Indust.	na	na
Warren EFCC	Cer. Heat Exchanger	Ext. Fueled Gas Turbine	62	yes	yes	Utility & Indust.	na	na
Easton Diesel Tech. Demo	Coal Fired Diesels	Diesel Engine Application	14	no	yes	Industrial	\$1300/kw	na

Table A-3

Environmental Screening Matrix - High Performance Pollution Control Devices

Project	Target Year			Air Toxics	Waste Water	Forms of Solid Waste
	SO _x	NO _x	Particulates			
SO₂/NO_x Control						
Ohio Ed./SNOX Flue Gas Cleaning	2000	2000	2000	Monitoring planned	na ¹	Ash & H ₂ SO ₄
Ohio Ed./LIMB Project Ext. & Coolside Demo	1990	1990	na	na	na	Dry Ash
Ohio Ed./SOX-NOX-ROX Box	1990	2000	na	Monitoring in progress	na	Dry SW & Ash
Flue Gas Cleanup	1990	1995	na	na	na	Dry Ash & SW
Ill. Pwr./Gas Reburning & Sorbent Injection	2005	1995	na	na	na	Ash & S
Ohio Ed./NOXSO Flue Gas Cleanup	2005	1990	na	Monitoring planned	0	Ash & Gyp.
NYSEG	1990	1990	na	Monitoring in progress	0	Dry Ash
PSCo/Integ. Dry NO _x /SO ₂ Emission Control System						
SO₂ Control						
TVA/Gas Suspension Absorption	2000	na	na	Monitoring in progress	na	Dry & Wet SW
Penn. Elec./Confined Zone Dispersion FGD	1990	na	na	na	na	SW
RPL/LIFAC Sorb. Injection	1990	na	na	na	na	Dry SW
Desulfurization						
NIPSCO/Adv. Flue Gas Desulfurization	1995	na	na	Monitoring in progress	0	SW & Gypsum
SCS/CT-121 FGD Process	1990	na	na	Monitoring planned	na	Gypsum & Ash

¹ na indicates data not available

Table A-3 (continued)
Environmental Screening Matrix - High Performance Pollution Control Devices

<u>Project</u>	<u>SO_x</u>	<u>Target Year</u>		<u>Particulates</u>	<u>Air Toxics</u>	<u>Waste Water</u>	<u>Forms of Solid Waste</u>
		<u>NO_x</u>	<u>NO_x</u>				
<i>NO_x Control</i> WPL/Coal Reburn.	na	1990		na	Monitoring in progress	0	Slag & Dry Ash
DPL/Low-NO _x Cell Burner Retrofit	na	1990		na	na	0	Ash
PSCo/Gas Reburn&LowNO _x Burners on Wall-Fired Boiler	na	1990		na	na	0	na
SCS/Adv. Combustion Tech- nique for Wall-Fired Boiler	na	1990		na	Monitoring in progress	0	Dry SW
SCS/SCR Tech. for Control of NO _x Emissions for High Sulfur Coal-Fired Boilers	na	2000		na	na	0	Dry SW & Spent Catalyst
SCS/Adv. Tangent. Fired Combustion Techniques for NO _x Reduction	na	1990		na	Testing complete	0	Ash & Dry SW
TVA/Micro. Coal Reburn.for NO _x Control on WF Unit	na	1990		na	na	0	Dry Ash

Table A-4

Economics Screening Matrix - High Performance Pollution Control Devices

<u>Project</u>	<u>Salable Product</u>	<u>Unique Features</u>	<u>Demo. MW Size</u>	<u>Retrofit/ Repower</u>	<u>Greenfield</u>	<u>Potential Market</u>	<u>Capital Cost</u>	<u>O&M</u>
<i>SO₂/NO_x Control</i>								
Ohio Ed./SNOX Flue Gas Cleaning	SO ₂ , NO _x Contr. Tech.	Catalytic Reactors	35	yes	yes	Utility & Indust.Blrs.	na ¹	na
Ohio Ed./LIMB Proj. Ext. & Coolside Demo	SO ₂ , NO _x Contr. Tech.	Dry Sorb. Injection	105	yes	yes	Utility & Indust.Blrs.	na	na
O.Ed/SOX-NOX-ROX	SO ₂ , NO _x , Part. Contr. Tech.	SNRB a Single Proc.	5	yes	yes	Utility & Indust.Blrs.	na	na
Box Flue Gas Cleanup	NO _x , SO ₂ Contr. Tech.	Combines 2 Technologies	80	yes	no	Pre-NSPS Boilers	na	na
Ill. Pwr./Gas Reburn. & Sorbent Injection	SO ₂ , NO _x Contr. Tech.	Dry, Regenerative	115	yes	yes	Ind. & Util. High Sulfur Boilers	na	na
Ohio Edison/NOXSO Flue Gas Cleanup								
NYSEG/CCT Demo	SO ₂ /NO _x Contr. Tech. + Gyps.	Formic Acid Scrub + Urea	300	yes	yes	Utility & Indust.Blrs.	na	na
PSCo/Integ. Dry NO _x /SO ₂ Emission Control System	NO _x /SO ₂ Contr. Tech.	Urea & Dry Sorbent	100	yes	no	Older, Small-Mid Size Boilers	na	na
<i>SO₂ Control</i>								
TVA/Gas Suspension Absorption	SO ₂ Removal Reactor	Gas Suspension Absorption	10	yes	yes	Utility & Indust.Blrs.	20-40% of FGD	<FGD
Penn. Elec/Confined Zone Dispersion FGD	SO ₂ Contr. Tech.	In-Duct CZD	74	yes	no	Utility & Indust.Blrs.	\$25-\$50 per Kw	na

¹ na indicates data not available² Assumes natural gas available

Table A-4 (continued)

Economics Screening Matrix - High Performance Pollution Control Devices

<u>Project</u>	<u>Salable Product</u>	<u>Unique Features</u>	<u>Demo. MW Size</u>	<u>Retrofit/ Repower</u>	<u>Greenfield</u>	<u>Potential Market</u>	<u>Capital Cost</u>	<u>O&M</u>
<i>SO₂ Control (cont.)</i>								
RPL/LIFAC Sorb. Injection Desulfuriz.	SO ₂ Contr. Tech.	Min. Space Requirements	60	yes	no	Sm.&Mid Size Util & Ind Blrs	<FGD	<FGD
NIPSCO/Adv. Flue Gas/Desulf. Evaporat.	SO ₂ Contr. Tech & Gyps	Compact	528	yes	yes	High S Coal Util. Boilers	50% of FGD	50% of FGD
SCS/CT-121 FGD Process	SO ₂ Contr. Tech.	Part. Reduct. and Gypsum	100	yes	yes	Pre-NSPS Util. Boilers	≅FGD	<FGD
<i>NO_x Control</i>								
WPL/Coal Reburn. for Cycl. Boiler NO _x Control	NO _x Contr. Tech.	Fuel Reburn	100	yes	no	Util. Cyclone Boilers	> Nat Gas	²
DPL/Low-NO _x Cell Burner Retrofit	NO _x Reduct. Tech.	LNCB	605	yes	no	Utility Boilers	\$8-\$12/kw	na
PsCO/Gas Reburning & Low NO _x Burners on Wall-Fired Boiler	NO _x Contr. Tech.	Natural Gas Co-firing	172	yes	no	Pre-NSPS Boilers	na	na
SCS/Advanced Combustion Technique for Wall-Fired Boiler	NO _x Contr. Tech.	Appl. to All Coals	500	yes	yes	Pre-NSPS WF Boilers	≅FGD	≅FGD
SCS/SCR Technol. for Control of NO _x Emission for HS Coal-Fired Boilers	NO _x Contr. Tech.	Comm. Avail. Catalysts	2.5	yes	yes	Utility & Industry Boilers	na	na
SCS/Adv. Tangent. Fired Combustion Techniques for NO _x Reduction	NO _x Contr. Tech.	Short & Long Term Reduct.	180	yes	yes	Tang. Fired Boilers	na	na
TVA/Micro. Coal Reburn.	NO _x Contr. Tech.	Micro. Coal Reburn. Fuel	175	yes	no	Existing Boilers	na	na

Table A-5

Environmental Screening Matrix - Industrial Applications

<u>Project</u>	<u>SO_x</u>	<u>Target Year</u>		<u>Particulates</u>	<u>Air Toxics</u>	<u>Efficiency</u>	<u>Waste Water</u>	<u>Forms of Solid Waste</u>
		<u>NO_x</u>						
Bethlehem Steel Blast Furnace Coal Injec. Sys.	2000	1995		1990	¹	na ²	na	Slag & Molten Iron
Beth. Steel Innovative COG Cleaning System	1990	2005		1990	³	na	No reduction	Nickel, Alumina & Sulfur
Williamsport Adv. Cyclone Combustor w/ Internal S, N, & Ash Control	1990	1995		1990	na	99% Comb. Eff. Fuel Rich	na	Trace Metal Leachables
Thomaston Cement Kiln FG Recovery Scrubber	2000	na		1990	na	na	May increase	Fertili. & Alk. Met. Salt
Campbell City Pulse Combust. Steam Gasif.	2010	1995		1990	Monitor. planned	> 70 % energy conv.	na	Slag
Cuyahoga Integrated Corex-CPICOR Process	2000	1990		2000	Monitor. planned	na	na	Slag & Iron
Kingsport Liquid-Phase Methanol Process	2010	2000		2000	na	38 %	na	Slag

¹ 40 % reduction expected by the project sponsor² na indicates data not available³ H₂S & NH₃ removed

Table A-6

Economics Screening Matrix - Industrial Applications

<u>Project</u>	<u>Salable Product</u>	<u>Unique Features</u>	<u>Demo. Size</u>	<u>Retrofit/ Repower</u>	<u>Greenfield</u>	<u>Potential Market</u>	<u>Capital Cost</u>	<u>O&M</u>
Bethlehem Steel Blast Furn. Coal Inject. Sys.	Subst. of coal for oil or gas	NO _x & SO ₂ Reductions	7000 TPD	yes	yes	Blast Furnaces	na ¹	na
Beth. Steel Innovative COG Cleaning System	COG Cleaning System	H ₂ S, NH ₃ Removal	74X10 ⁶ SCF/D Coke Oven Gas	yes	yes	24 of 30 Coke Oven Plants	na	na
Williamsport Ad. Cyclone Combustor w/Internal S,N, & Ash Control	Slagging Combustor	Combustion of Solid Fuels	23X10 ⁶ Btu/hr.	yes	yes	Ind. & Small Utility Markets	na	na
Thomaston Cement Kiln F.G. Recovery Scrubber	Potassium Based Fert. & Scrub. Reagent	Waste Dust Reagent	274 TPD coal	yes	yes	Cement Kiln Plants	na	na
Campbell City Pulse Combust. Steam Gasif.	Fluidized Bed Gasifier	Low SO ₂ / NO _x & Partic.	161X10 ⁶	yes	yes	Industrial Market	na	na
Cuyahoga Integrated Corex-CPICOR Process	Reduction Shaft Furnace	DRI & Power	150 Mw 3200 TPD Metal	no	yes	Steel Furnaces	na	na
Kingsport Liquid-Phase Methanol Proc.	LPMEOH Reactor	Meth./S/NH ₃ & Synth. Gas	150 TPD Methanol	yes	yes	200-300 Mw Plant Size	na	na

¹ na indicates data not available

Table A-7

Environmental Screening Matrix - Coal Processing and Cleaning

<u>Project</u>	<u>Feedstock</u>	<u>Output Product</u>	<u>SO_x</u>	<u>Target Year</u> NO _x	<u>Particulates</u>	<u>Air Toxics</u>	<u>Waste Water</u>	<u>Forms of Solid Waste</u>
Self Scrubbing Coal	High Sulfur Bituminous	Low Sulfur, Low Ash Coal	2000	na ¹	na	Monitor. planned	na	na
Development of Coal Quality Expert	Baseline, and Alternate Coal	Predictive Software	na	na	na	na	na	na
ENCOAL Mild	High Moisture, Low Heating Value Coal	Low Sulfur Coal and Oil	2000	na	na	na	na	na
Coal Gasification								
Rosebud Advanced Coal Conversion Process	High Moisture, Low Rank Coal	Low Sulfur, High Heating Value Coal	2005	na	na	Monitor. planned	na	Dry SW

¹ na indicates data not available

Table A-8

Economics Screening Matrix - Coal Processing and Cleaning

<u>Project</u>	<u>Salable Product</u>	<u>Unique Features</u>	<u>Demo. Size</u>	<u>Retrofit/ Repower</u>	<u>Greenfield</u>	<u>Potential Market</u>	<u>Capital Cost</u>	<u>O&M</u>
Self Scrubbing Coal	Advanced Coal Cleaning Process	Low Sulfur, Low Ash Coal	350 TPH	yes	no	Industrial & Utility	na ¹	na
Development of Coal Quality Expert	Predictive Software, Acid Rain Advisor	Predict Oper. & Emission Red. Benefits	na	na	na	Utility & Industrial	na	na
ENCOAL Mild Coal Gasification	Coal Processing Equipment & Gasifier	Low Sulfur Syn. Coal & Oil	1000 TPD Coal Feed	yes	yes	Industrial & Utility	na	na
Advanced Coal Conversion Process	Advanced Coal Conversion Process	Low Sulfur 12,000 B/lb Syn. Coal	45 TPH Syn. Coal	yes	yes	Utility & Industrial Burning Low Rank Coals	na	na

¹ na indicates data not available

Table A-9

Commercial Opportunities for Clean Coal Technologies - Advanced Power Generation Systems

<u>Application Category</u>	<u>Technology</u>	<u>Project</u>	<u>Commercial Sector</u>		<u>Commercial Retrofit</u>	<u>Application Greenfield</u>	<u>Design & Construction</u>	<u>Demonstration Status</u>	
			<u>Utility</u>	<u>Industry</u>				<u>Operation</u>	<u>Testing Complete</u>
Advanced Power Generation Systems	Atmospheric Circulating Fluidized Bed Combustion	Nuclea CFB Demonstration York Country Energy Partners Co-gen	X	X	X	X	X		X
	Pressurized Fluidized Bed Combustion	AEP/PFBC Utility Demonstration	X		X	X			
	Fluidized Bed Combustion	Tidd PFBC Demonstration	X		X	X		X	
	Pressurized Circulating Fluidized Bed Combustion	Pleasant Hill Calvert City Adv. Energy	X	X	X	X	X		
	Advanced Entrained Slagging Combustor	Healy Clean Coal	X	X	X	X		X	
	Integrated Gasification Combined Cycle	Springfield IGCC Repowering	X		X	X	X		
		Pinon Pine IGCC Power	X		X	X	X		
		Toms Creek IGCC Demo.	X		X	X	X		
		Tampa Electric IGCC	X		X	X	X		
		Wabash River Coal	X		X	X	X		
Externally Fired Gas Turbine Combined Cycle (EFCC)	Gasification Repowering	Camden Clean Energy	X		X	X	X		
	Externally Fired Gas Turbine Combined Cycle (EFCC)	Warren Station EFCC Demonstration	X	X	X	X	X		
	Coal Fired Diesel	Clean Coal Diesel Technology		X	X	X	X		

Table A-9 (continued)

Commercial Opportunities for Clean Coal Technologies - High Performance Pollution Control Devices

<u>Application Category</u>	<u>Technology</u>	<u>Project</u>	<u>Commercial Sector</u>		<u>Commercial Retrofit</u>	<u>Application Greenfield</u>	<u>Design & Construction</u>	<u>Demonstration Status</u>	
			<u>Utility</u>	<u>Industry</u>				<u>Operation</u>	<u>Testing Complete</u>
High Performance Pollution Control Devices	Sulfur Dioxide Control	TV A/Gas Suspension Absorption	X	X	X	X		X	
		Penelec/Confined Zone	X	X	X				X
		Dispersion FGD Demo							
		RP&L/LIFAC Sorbent Injection	X	X	X			X	
		Desulfurization Demo							
		NIPSCO/Pure Advanced FGD	X	X	X	X		X	
	Nitrogen Oxide Control	Demo							
		SCS/CT-121 FGD Process	X	X	X	X		X	
		WPL/B&W Coal Reburning for	X		X	X			X
		Cyclone Boilers							
		DP&L/B&W Low-NO _x Cell	X		X	X			X
		Burner Retrofit							
		PSCO/EGR Gas-reburning and Low-NO _x Burners on Wall-Fired Boilers	X	X	X	X		X	
		SCS/Adv. Combustion Tech. Wall-Fired Boilers	X	X	X	X		X	
		SCS/SCR High Sulfur Coal-Fired Boilers	X	X	X	X		X	
		SCS/Adv. Combustion Tech. Tangentially-Fired Boiler	X	X	X	X		X	
		TV A/Micronized Coal Reburning	X	X	X	X		X	X

Table A-9 (continued)

Commercial Opportunities for Clean Coal Technologies - High Performance Pollution Control Devices

<u>Application Category</u>	<u>Technology</u>	<u>Project</u>	<u>Commercial Sector</u>		<u>Commercial Retrofit</u>	<u>Application Greenfield</u>	<u>Design & Construction</u>	<u>Demonstration Status</u>	
			<u>Utility</u>	<u>Industry</u>				<u>Operation</u>	<u>Testing Complete</u>
High Performance Pollution Control Devices	SO ₂ /NO _x Control	Ohio Edison/SNO _x Flue Gas Cleaning Demo	X	X	X	X			X
		Ohio Edison/LIMB Demo	X	X	X				X
		Extension & Coolside Demo							
		Illinois Power/EGR Gas	X	X	X	X		X	
		Reburning and Sorbent Injection							
		Ohio Edison/NOXSO SO ₂ NO _x Removal	X	X	X	X	X		
		NYSEG/Miliken CCT							
		(SO ₂ /NO _x) Demo.	X	X	X	X	X		
		PSCo Integrated Dry NO _x /SO ₂ Control System	X	X	X	X		X	
		Ohio Edison/SO ₂ -NO _x -ROX BOX Flue Gas Cleanup	X	X	X	X		X	
Coal Processing for Clean Fuels	Fuel Switching/Blending Coal Preparation	Coal Quality Expert Demonstration	X	X	X	X		X	
		Self Scrubbing Coal	X	X	X		X		
		Rosebud Advanced Coal Conversion Process	X	X	X	X		X	
		ENCOAL Mild Gasification	X	X	X	X		X	

Table A-9 (continued)

Commercial Opportunities for Clean Coal Technologies - Industrial Processes

<u>Application Category</u>	<u>Technology</u>	<u>Project</u>	<u>Commercial Sector</u>		<u>Application Greenfield</u>	<u>Design & Construction</u>	<u>Demonstration Status</u>	
			<u>Utility</u>	<u>Industry</u>			<u>Operation</u>	<u>Testing Complete</u>
Industrial Processes	Coke/Iron Production	Bethlehem Steel Blast Furnace		X	X	X		
		Granulated Coal Injection Sys.						
		Bethlehem Steel Innovative		X	X	X		
		Coke Oven Gas Cleaning Sys.						
		Cuyahoga Integrated COREX-CPICOR Process		X	X	X		
	Cement Production	Thomaston Cement Kiln Flue Gas Recovery Scrubber		X	X			X
		Williamsport Advanced Cyclone		X	X			X
		Combustor with SO _x , NO _x , Ash Control						
	Gasification	Campbell City Pulse		X	X	X		
		Combustion for Steam Gasif.						
Liquefaction	Kingsport Liquid-Phase Methanol (LPEOH) Process		X	X	X	X		

Appendix B

Bases for Recommended Federal Incentive Program for Deployment of Clean Coal Technologies

APPENDIX B

BASES FOR RECOMMENDED FEDERAL INCENTIVE PROGRAM FOR DEPLOYMENT OF CLEAN COAL TECHNOLOGIES

Introduction

A major element of the National Coal Council Working Group on the Future Directions of the Clean Coal Technology Program focused on appropriate financial incentives to encourage commercial deployment of these systems. The Working Group reviewed incentive studies performed by numerous organizations and individuals, including the National Regulatory Research Institute, the Argonne National Laboratory, the Lawrence Berkeley Laboratory, Clean Coal Coalition, and State of Illinois Commissioner Karl A. McDermott. Based on these studies, the Council is recommending a dual financial incentive program to enhance commercial deployment of CCTs.

The dual incentives are (a) capital support based on the estimated differential support costs of CCTs versus conventional coal power plant costs and (b) operating financial differential support based on estimated additional costs of operation during the initial years of operation of these new systems. Although the Council recommends that these incentives be provided by the Federal Government, they could be shared between the Federal Government and individual state government jurisdictions, most easily in relationship to the second financial incentive (shared operating cost subsidy).

Recommended Capital Sharing

The approach used to develop the recommended capital support level is to estimate the expected capital cost differential between a commercial conventional pulverized coal-fired power plant with 90 percent sulfur removal for a 3 percent sulfur coal and the capital costs for initial deployment of three types of CCT systems. Although specific costs for conventional and advanced power plants will vary from site to site, a pro forma capital differential estimate developed from EPRI's Technical Assessment Guide (TAG) was used for each system. While not quantitatively specific, the TAG indicates that the first five units of a particular technology will have capital costs substantially greater than mature commercial plants. For purposes of this analysis, we assume the first-of-a-kind (FOAK) plant to have a 25 percent capital cost premium over mature commercial units. Further, each subsequent plant is assumed to be 20 percent lower in capital cost differential than its predecessor.

The specific estimate basis for three types of advanced CCTs is shown in Table B-1. The pro forma costs are based on mature plant cost estimate for each type plus a 25 percent FOAK premium. Each system is expected to be directly competitive with conventional technology when mature (*i.e.*, after the fifth-of-a-kind is operating).

Table B-2 shows the estimated capital cost incentive required for each of the three CCTs over the first five deployed systems. (The National Coal Council also considered the potential need for financial incentive for AFBC; however, these are being offered under competitive commercial business terms for units in the 200 MW capacity range.) The total estimated required capital incentive to the first 15 commercial CCT deployments is \$1.1 billion in 1992 dollars. The total capital investment by the power plant owners, not including interest during construction, is \$6.0 billion in 1992 dollars. Therefore, industry risk-sharing represents 85 percent of the capital costs for these plants. The National Coal Council believes this is an appropriate capital risk-sharing relationship between the Federal Government and industry to capitalize on the nearly \$7 billion dollar expenditure for the CCT Program.

Table B-1

Pro Forma

**Comparison of Estimated Capital Costs for Early CCT Plants
Versus Conventional Pulverized Coal Plants**

Plant Type	Plant Capacity Mwe	Capital Cost Basis Mature	(1992 \$/kwe) FOAK
• Pulverized Coal with Flue Gas Desulfurization	300	1350	N/A
• Integrated Coal Gasification Combined Cycle (IGCC)	400	1400	1750
• Pressurized Fluidized Bed Combustion (PFBC)	250	1370	1710
• Advanced Pulverized Coal Power Plant (APCPP)	300	1390	1740

Table B-2

Pro Forma

**Estimated Total Capital Incentive Necessary for Commercial
Deployment of Three Advanced CCT Power Plant Types**

1) Integrated Coal Gasification Combined Cycle -- 400 Mwe

Plant	Capital Differential \$/kwe	Capital Incentive (Millions of 1992 \$)
1	400	160
2	320	128
3	240	96
4	160	64
5	80	<u>32</u>
	Total	480

2) Pressurized Fluidized Bed Combustion -- 250 Mwe

Plant	Capital Differential \$/kwe	Capital Incentive (Millions of 1992 \$)
1	360	90
2	290	73
3	220	55
4	140	35
5	70	<u>18</u>
	Total	271

Table B-2 (continued)

3) Advanced Pulverized Coal Power Plant -- 300 Mwe

Plant	Capital Differential \$/kwe	Capital Incentive (Millions of 1992 \$)
1	390	117
2	310	93
3	230	69
4	160	48
5	80	<u>24</u>
Total		351
Total Recommended Capital Incentive (20 Plants 15 Plant Basis)		\$1.1 Billion
Total Investment by Private Sector in 15 Plants		\$6.0 Billion

Recommended Performance-Based Operating Incentives

The recommended performance-based operating incentive is based on sharing potential unanticipated operating costs over the first few years of operation of each of the three advanced CCT power plant types. The pro forma estimate is based on an average reduction in annualized capacity factor of 20 percent over the first five years of operation of the FOAK of each of the advanced CCT power plant types.

As in the capital incentive case, this support level is discounted by 20 percent for each subsequent plant and, in addition, the support term is reduced in duration for each subsequent plant. Therefore, the FOAK plant has 20 percent operating support for five years, the second plant has 16 percent support for four years, and so forth through the first five plants of each of the four CCTs.

Table B-3 shows the pro forma estimate basis for each of the three plant types. The total recommended performance-based incentive is \$287 million in 1992 dollars. Although operating costs for these plants are not shown, they are estimated to be approximately \$3 billion. Thus, performance-based support would be approximately 10 percent of total operating costs; however, this incentive is extremely important to assure the suppliers, utilities, and regulators that accepting the risk of these new technologies is reasonably prudent.

Table B-3

Pro Forma Estimate of Performance-Based Operating Incentives

Estimate Basis for Performance-Based Operating Incentive

- Assumed 20% reduction in annualized capacity factor for FOAK plant of each CCT
- Commercial power plant capacity factor = 0.65
- 10% annualized fixed charge rate
- Five-year operating subsidy -- FOAK, five years -- second plant, four years, etc.

1) Integrated Coal Gasification Combined Cycle -- 400 Mwe

- Capital cost = \$1,400/kwe (1992 dollars)
- Annualized cost @ 65% CF = 2.4¢/kwhr
- Annualized cost @ 52% CF = 3.0¢/kwhr
- FOAK Incentive = 0.6¢/kwhr

Plant	Duration of Incentive Years	Performance-Based Incentive (Millions of 1992 \$)
1	5	55.0
2	4	35.0
3	3	20.0
4	2	9.0
5	1	2.0
Total		121.0

2) Pressurized Fluidized Bed Combustion -- 250 Mwe

- Capital cost = \$1,370/kwe (1992 dollars)
- Annualized cost @ 65% CF = 2.3¢/kwhr
- Annualized cost @ 52% CF = 2.9¢/kwhr
- FOAK Incentive = 0.6¢/kwhr

Plant	Duration of Incentive Years	Performance-Based Incentive (Millions of 1992 \$)
1	5	34.0
2	4	22.0
3	3	12.5
4	2	6.0
5	1	1.3
Total		75.8

Table B-3 (continued)

3) Advanced Pulverized Coal Power Plant -- 300 Mwe

- Capital cost = \$1,390/kwe (1992 dollars)
- Annualized cost @ 65% CF = 2.6¢/kwhr
- Annualized cost @ 52% CF = 3.0¢/kwhr
- FOAK Incentive = 0.6¢/kwhr

Plant	Duration of Incentive Years	Performance-Based Incentive (Millions of 1992 \$)
1	5	41.0
2	4	26.0
3	3	15.0
4	2	7.0
5	1	<u>1.5</u>
Total		90.5

Total Recommended Performance Incentive
(15 Plant Basis)

\$287.0 Million

Approximate Five-Year Industry Operating Cost
(15 Plants)

~\$ 3.0 Billion

References

1. Technical Assessment Guide, Vol. 1, Rev. 6, Electric Power Research Institute, Palo Alto, California, September 1989.
2. Technical Assessment Guide, Vol. 1, Rev. 7, Electric Power Research Institute, Palo Alto, California, June 1993.

Appendix C

Glossary of Terms

APPENDIX C

GLOSSARY OF TERMS

ACFB	Atmospheric circulating fluidized bed
ADV.	Advanced
AEP	American Electric Power
AGGLOM. SW	Agglomerated solid waste
APPL.	Applicable
B	Btu
BLRS.	Boilers
BTU	British Thermal Units
BUBBLING PFB TECHNO.	Bubbling pressurized fluidized bed technology
CAMPBELL CTY. PULSE COMBUS.	Campbell County pulse combustor steam
STEAM GASIF.	gasifier
CER. HEAT EXCHANGER	Ceramic heat exchanger
COG	Coke oven gas
COGEN.	Cogeneration
COMB.	Combustion
CONTR. TECH.	Control technology
CPFB	Circulating pressurized fluidized bed
CPFBC	Circulating pressurized fluidized bed
	combustion
CT-121	Chiyoda Thoroughbred-121 FGD Process
CZD	Confined zone dispersion
DEMO.	Demonstration
DEV.	Development
DPL	Dayton Power & Light
DRI	Direction reduced iron
EASTON DIESEL TECH. DEMO.	Easton diesel technology demonstration
EFCC	Externally fired combined cycle
EFF.	Efficiency
FE	Ferrous (Iron)
FERT. & ALK. MET.	Fertilizer & alkali metal
F.G.	Flue gas
FGD	Flue gas desulfurization
FIX. B. GASIFIER	Fixed bed gasifier
FL. B. GASIFIER	Fluidized bed gasifier
FOAK	First-of-a-kind
FORMS OF SOLID WASTE	Solid waste and liquid waste
GASIF.	Gasifier

Appendix C: Glossary of Terms

GYP	Gypsum
GW	Gigawatts
H ₂ S	Hydrogen sulfide
H.S.	High sulfur
IGCC	Integrated gasification combined cycle
ILL. P.	Illinois Power Company
IND.	Industrial
INJECT.	Injection
IOU	Investor-owned utility
Kw	Kilowatt
LB	Pound
LBTU COMB.	Low Btu combustor
LIFAC	Joint venture name (Tampella Power Corp. and ICF Kaiser Engineers, Inc.)
LNCB	Low NO _x Cell Burner
LOWER TEMP. THAN PC COMB.	Lower temperature than pulverized coal combustor
LPMEOH	Liquid phase methanol process
MARKET. S.	Marketable sulfur
METH.	Methanol
MICRO. COAL REBURN.	Micronized coal reburning
MIN	Minimizes
Mw	Megawatt
MONITOR. PLANNED	Monitoring Planned
N	Nitrogen
NAT	Natural
NH ₃	Ammonia
NIPSCO	Northern Indiana Public Service Company
N. LEACH, NON-HAZ. SLAG	Non-leachable, non-hazardous slag
NO _x /SO ₂ CONTR. IN BLRS.	NO _x /SO ₂ control in boilers
NUG	Non-utility generator
NSPS	New source performance standards
NYSEG	New York State Electric and Gas Company
OHIO ED./LIMB. PROJECT EXT.	Ohio Edison/limestone injection multi-stage burner project extension
PART.	Particulates
PCFBC	Pressurized circulating fluidized bed combustion
PENN. ELEC.	Pennsylvania Electric Company
PFBC	Pressurized fluidized bed combustion
PROC.	Process
PSCO	Public Service Company of Colorado
REDUCT.	Reduction

Appendix C: Glossary of Terms

RPL/LIFAC SORB. INJECTION	Richmond Power & Light/LIFAC sorbent injection
S	Sulfur
SCF/D	Standard cubic feet per day
SCR	Selective catalytic reduction
SCRUB.	Scrubber
SCS	Southern Company services
SM.	Small
SNRB	SO _x , NO _x , ROX, BOX
SUBST.	Substitution
SUSPEN.	Suspension
SW	Solid Waste
SYN.	Synthetic
SYS.	System
TANGENT. FIRED	Tangentially fired
TECH.	Technology
TPD	Tons per day
TPH	Tons per hour
TR. MET. LEACH.	Trace metal leachate
TVA	Tennessee Valley Authority
UTIL.	Utility
W.F.	Wall-fired
WPL/COAL REBURN.	Wisconsin Power & Light/coal reburning for cyclone boiler NO _x control
W. RIV. GASIF. REPOWER.	Wabash River gasification repowering
YORK CTY. COGEN.	York County cogeneration

Appendix D

Description of the National Coal Council

APPENDIX D

DESCRIPTION OF THE NATIONAL COAL COUNCIL

Recognizing the valuable contribution of the industry advice provided over the years to the Executive Branch by the National Petroleum Council and the extremely critical importance of the role of coal to America and the world's energy mix for the future, the White House Conference on Coal put forward the idea of a similar advisory group for the coal industry in 1984. The opportunity for the Coal industry to have an objective window into the Executive Branch drew overwhelming support.

In the fall of 1984, the National Coal Council was chartered; and in April 1985, the Council became fully operational. This action was based on the conviction that such an industry advisory council could make a vital contribution to America's energy security by providing information that could help shape policies leading to the increased production and use of coal and, in turn, decreased dependence on other, less abundant, more costly, and less secure sources of energy.

The National Coal Council is chartered by the Secretary of Energy under the Federal Advisory Committee Act. The purpose of the Council is solely to advise, inform, and make recommendations to the Secretary of Energy with respect to matters relating to coal or the coal industry, as requested by the Secretary.

Members of the National Coal Council are appointed by the Secretary of Energy and represent all segments of coal interests and geographical disbursement. The National Coal Council is headed by a Chairman and a Vice-Chairman elected by the Council. The Council is supported entirely by voluntary contributions from its members. It receives no funds from the Federal Government and conducts studies, at no cost to the government, which otherwise might have to be conducted by the Department of Energy.

The National Coal Council does not engage in any of the usual trade association activities. It specifically does not engage in lobbying efforts. The Council does not represent any one segment of the coal or coal-related industry; nor does it represent the views of any one part of the country. It is a broad-based, objective advisory group whose approach is national in scope.

Matters which the Secretary of Energy would like to have considered by the Council are submitted as a request in the form of a letter outlining the nature and scope of the requested study. The first major studies undertaken by the National Coal Council at the request of the Secretary of Energy were presented to the Secretary in the summer of 1986, barely one year after the startup of the Council.

Reports of the National Coal Council completed through February 1994:

June 1986	<i>Coal Conversion</i>
June 1986	<i>Clean Coal Technologies</i>
June 1986	<i>Interstate Transmission of Electricity</i>
June 1986	<i>Report on Industrial Boiler New Source Performance Standards</i>
June 1987	<i>Reserve Data Base: Report of The National Coal Council</i>
June 1987	<i>Improving International Competitiveness of U.S. Coal and Coal Technologies</i>
November 1988	<i>Innovative Clean Coal Technology Deployment</i>
December 1988	<i>The Use Of Coal in the Industrial, Commercial, Residential and Transportation Sectors</i>
June 1990	<i>Industrial Use of Coal and Clean Coal Technology -- Addendum Report</i>
June 1990	<i>The Long Range Role of Coal in the Future Energy Strategy of the United States</i>
January 1992	<i>The Near Term Role for Coal in the Future Energy Strategy of the United States</i>
January 1992	<i>Improving Coal's Image: A National Energy Strategy Imperative</i>
May 1992	<i>Special Report On Externalities</i>
February 1993	<i>The Role of U.S. Coal In Energy, the Economy, and the Environment -- Special Report</i>
February 1993	<i>A Synopsis of the Reports (1986-1992)</i>
November 1993	<i>The Export of U.S. Coal and Coal Technology</i>
February 1994	<i>Clean Coal Technology for Sustainable Development</i>

Appendix D: Description of the National Coal Council

Members of the National Coal Council who have served as Chairman:

June 1985 - June 1986	The Late Honorable John N. Dalton Former Governor of Virginia B. R. Brown President, Consolidated Coal Company
June 1986 - June 1987	James W. McGlothlin Chairman, The United Companies
June 1987 - June 1989	James G. Randolph Former President, Kerr-McGee Coal Company Former Assistant Secretary for Fossil Energy, United States Department of Energy
June 1989 - May 1991	William Carr President, Jim Walter Resources, Inc.
May 1991 - May 1992	W. Carter Grinstead, Jr. Former Vice-President Exxon Coal and Minerals Company
May 1992 - Present	William R. Wahl Vice President, AMAX, Inc.

Appendix E

The National Coal Council Membership Roster

APPENDIX E

THE NATIONAL COAL COUNCIL MEMBERSHIP ROSTER

JAMES R. ALDRICH
State Director
The Nature Conservancy
Kentucky Chapter

DR. SY ALI *
Manager
Industrial Engine Technology
Allison Gas Turbine Division
General Motors Corporation

BARBARA F. ALTIZER
Executive Director
Virginia Coal Council

JOHN Q. ANDERSON
Executive Vice President
Burlington Northern Railroad

CHARLES J. BAIRD
Baird, Baird, Baird & Jones, P.S.C.

WILLIAM B. BALES
Vice President
Coal Marketing
Norfolk Southern Corporation

THE HON. GERALD BALILES
Hunton & Williams

JOHN BARKER, P.E. *
Consultant

GLEN BARTON
Group President
Caterpillar, Inc.

C. A. BAYENS
President
Shell Synthetic Fuels Inc.

DR. JANOS M. BEER
Professor Emeritus, Chemical
Engineering
Director, Combustion Research Facility
Massachusetts Institute of Technology

FRANK J. BENNER
President and Chief Operating Officer
Cogentrix, Inc.

JACQUELINE F. BIRD *
Director, Ohio Coal Development Office
Ohio Department of Development

DR. SANDY BLACKSTONE *
Natural Resources Attorney/Consultant

WILLIAM H. BOWKER *
Executive Director
Kentucky Coal Marketing and Export
Council

KEN BREEDING
AES/Shady Point, Inc.

JULIAN J. BRIX
General Manager
Cooperative Power Association

B. R. BROWN *
Chairman, President, and CEO
CONSOL Inc.

CLEAN COAL TECHNOLOGY FOR SUSTAINABLE DEVELOPMENT

Appendix B: The National Coal Council Membership Roster

DONALD P. BROWN *
President
Cyprus Coal Company

LAWRENCE R. BURR
Senior Project Manager
Stone & Webster Engineering Corp.

DR. DONALD CARLTON *
President
Radian Corporation

WILLIAM CARR *
President and Chief Operating Officer
Jim Walter Resources, Inc.

ROBERT J. CASEY
Long Law Firm

FRED CLAYTON
Chairman and CEO
Shand Mining, Inc.

WILFRED CONNELL *
Vice President
Illinois Power Company

GREGORY E. CONRAD
Executive Director
Interstate Mining Compact Commission

ROBERT P. COOPER *
Executive Vice President
Farrell-Cooper Mining Company, Inc.

MARYANN R. CORRENTI
Partner
Arthur Andersen & Co.

JOSEPH W. CRAFT III *
President
MAPCO COAL Inc.

JAMES B. CRAWFORD
Chairman and CEO
James River Coal

DAVID C. CRIKELAIR
Vice President
Texaco Inc.

DR. H. DOUGLAS DAHL *
President and Chief Operating Officer
Drummond Company, Inc.

ROBERT G. DAWSON
Vice President, Power Generation
Mississippi Power Company

ROBERT J. DOYLE
Vice President
Exxon Coal and Minerals Company

DR. E. LINN DRAPER, JR.
Chairman, President, and CEO
American Electric Power Company

JOHN DWYER *
President
Lignite Energy Council

IRL F. ENGELHARDT *
Chairman, President, and CEO
Peabody Holding Company, Inc.

DR. ROBERT H. ESSENHIGH
Professor of Mechanical Engineering
Department of Mechanical Engineering
The Ohio State University

MYRLEEN B. FAIRCHILD
Chairwoman/Chief Executive Officer
Fairchild International, Inc.

Appendix E: The National Coal Council Membership Roster

JOHN C. FAY, JR.
President
Empire Coal Sales, Inc.

MASON FOERTSCH
President
Foertsch Construction Company

JOSEPH A. FRANK
President
Centralia Coal Sales Company

THE HON. KENT FRIZZELL
Director
National Energy Law and Policy Institute

GEORGE FUMICH, JR.
George Fumich Associates, Inc.

PETER M. GARSON
President
PMG Advisory Group

SONDRA J. GILLICE
President
RusSon, Inc.

BARBARA GRANNELL
Director of Development
Western States Public Lands Coalition

BRUCE S. GRAVING
President and General Manager
Horizon Coal Services

DR. ALEX E. S. GREEN *
Graduate Research Professor
University of Florida

JOEN E. GREENWOOD
Vice President
Charles River Associates

LAWRENCE C. GRUNDMANN, JR.
Director, Business Development
Ahlstrom Development Corporation

DR. BILL HARRISON *

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President and CEO
Metropolitan Stevedore Corp.

J. BRETT HARVEY
President and CEO
Interwest Mining Company

ROBERT F. HEMPHILL, JR.
Executive Vice President
AES Corporation

H. RICHARD HORNER *
Allan F. Dow & Associates, Inc.

HENRY MCC. INGRAM
Partner
Buchanan Ingersoll

JOHN JANAK *
Executive Vice President
Texas Utilities Mining Company

GEORGIA L. JOHNSON
Founder, Editor, and President
Acquire's Coal Today

JOSEPH P. KEARNEY
President and Chief Executive Officer
U.S. Generating Company

WILLIAM M. KELCE *
President
Alabama Coal Association

JAMES F. KENNEY
Vice President
Planning and System Operations
Entergy Corporation

MICHAEL S. KOLEDA
Principal
Koleda Childress Inc.

DR. IRVING LEIBSON *
Executive Consultant
Bechtel Group, Inc.

PETER B. LILLY *
President
Eastern Associated Coal Corp.

DR. ROBERT E. LUMPKIN *
Amoco Corporation

A. DAVID LESTER
Executive Director
Council on Energy Resource Tribes

RENE H. MALES
President and Group Executive
IES Industries Inc.

PHILIP O. MARTIN
Executive Vice President/General
Manager
United Power Association

WILLIAM B. MARX *
President
Council of Industrial Boiler Owners

E. MORGAN MASSEY
Chairman
A. T. Massey Coal Company, Inc.

DR. CHRISTOPHER C. MATHEWSON
Director
Center for Engineering Geosciences

BARRY G. MCGRATH *
President and Chairman
The Pittsburg & Midway Coal Mining
Company

ROBERT L. MCPHAIL
General Manager
Basin Electric Power Cooperative

EMMANUEL R. MERLE
President
Energy Trading Corporation

CLIFFORD R. MIERCORT *
President and Chief Executive Officer
The North American Coal Corporation

JAMES MOCKLER *
Executive Director
Montana Coal Council

DAVID J. MORRIS
General Manager and CEO
Pacific Coast Coal Company

NICHOLAS P. MOROS
Senior Vice President
Sales and Marketing
Cyprus Coal Company

THE HON. MARY SCOTT NABERS
Commissioner
Railroad Commission of Texas

JOHN T. NEWTON
Chairman, President, and CEO
Kentucky Utilities Company

DR. ROBERT E. NICKELL
Technical Director
SGI International

GEORGE NICOLOZAKES *
President
Marietta Coal Company

JAMES J. O'CONNOR
Chairman and CEO
Commonwealth Edison Company

MARY EILEEN O'KEEFE *
President/CEO
Lake Shore International, Ltd.

JERRY J. OLIVER *
Manager, Environmental Technology
Bechtel

WILLIAM ORCHOW
President
Kennecott Energy Company

LOUIS PAGNOTTI, III
Pagnotti Enterprises/Jeddo Highland
Coal Company

FREDRICK D. PALMER *
General Manager and CEO
Western Fuels Association, Inc.

DAVID PETERSON *
CEO/President
NRG Energy, Inc.
A Subsidiary of Northern State Power
Company

ABE PHILLIPS *

CHRISTIAN POINDEXTER
Chairman of the Board
Baltimore Gas & Electric Company

DR. JAMES H. PORTER
President and Chief Executive Officer
Energy & Environmental Engineering,
Inc.

DR. GEORGE T. PRESTON
Vice President
Generation and Storage
Electric Power Research Institute

FRED C. RASKIN
President
Midland Enterprises Inc.

BILL REID
President
American Longwall Face Conveyors Inc.

J. KENNETH ROBERTSON, PH.D. *
Vice President
ICF Resources, Inc.

DANIEL A. ROLING
First Vice President
Merrill Lynch Corporate Strategy &
Research

STEPHEN G. SALAY
Vice President
Cincinnati Gas & Electric Company

ROBERT C. SCHARP *
President
Kerr-McGee Coal Corporation

DEBBIE SCHUMACHER *
Women In Mining

J. J. SHACKLEFORD
President
TECO Coal Corporation

CLEAN COAL TECHNOLOGY FOR SUSTAINABLE DEVELOPMENT

Appendix E: The National Coal Council Membership Roster

F. KENNETH SMITH *

JOHN W. SNOW
Chairman/President/CEO
CSX Corporation

DWAIN F. SPENCER *
Principal
SIMTECHE

JOE J. STEWART *
President and Chief Operating Officer
The Babcock & Wilcox Company

THE HON. MIKE SULLIVAN
Governor of Wyoming

DAVID F. SURBER
National Director
Izaak Walton League

L. A. THAXTON
President
INDRESCO Inc.
Jeffrey Division

PAUL M. THOMPSON *
President
Phillips Coal Company

NEAL S. TOSTENSON *
President
Ohio Mining & Reclamation Association

RICHARD TRUMKA
President
United Mine Workers of America

MITCH USIBELLI
Vice President, Engineering
Usibelli Coal Mine, Inc.

THE HON. J. T. WAGGONER
Alabama State Senator
Healthsouth Rehabilitation Corp.

WILLIAM R. WAHL *
Vice President
AMAX, Inc.

GERALD D. WALTZ *
Senior Vice President
Business Development
Indianapolis Power & Light Company

THE HON. ROBERT T. WILSON
Wilson and King

DR. WENDELL H. WISER
Professor, Fuels Engineering
Department of Chemistry and Fuels
Engineering
University of Utah

MARC F. WRAY
Chairman, President, and CEO
Joy Technologies

ALAN D. WRIGHT
Partner
Porter, Wright, Morris & Arthur

TAY YOSHITANI
Deputy Executive Director
Maritime Affairs
Port of Los Angeles

* Denotes member of Coal Policy Committee

Appendix F

The National Coal Council Working Group for the Report *Clean Coal Technology for Sustainable Development*

APPENDIX F

THE NATIONAL COAL COUNCIL WORKING GROUP FOR THE REPORT *CLEAN COAL TECHNOLOGY FOR SUSTAINABLE DEVELOPMENT*

Co-Chairmen

JERRY J. OLIVER
Manager, Environmental Technology
Bechtel Group, Inc.

DWAIN F. SPENCER
Principal
SIMTECHE
Vice President (Retired)
Electric Power Research Institute

GERALD A. HOLLINDEN
Senior Program Manager
Radian Corporation

DR. ROBERT E. LUMPKIN
Director, Solid Resources
Amoco Corporation

JAMES J. MARKOWSKI
Executive Vice President
Engineering and Construction
American Electric Power Service Corp.

Members

DR. SY ALI
Manager
Allison Engine Company
General Motors Corporation

JACQUELINE F. BIRD
Director, Ohio Coal Development Office
Ohio Department of Development

KENT L. FICKETT
Director
Environmental and Regional Affairs
U.S. Generating Company

DAVID FINKENBINDER
AMAX, Inc.

PAUL NOLAN
Manager, Clean Coal Projects
Babcock & Wilcox

RICHARD SCHMIDT
Private Consultant

JOHN WOOTTEN
President
Coal Services, Inc.

Associates

DAVID ESKINAZI
Manager, NO_x Control
Electric Power Research Institute

Appendix F: The National Coal Council Working Group for the Report
Clean Coal Technology for Sustainable Development

MOHAMMED HARUNUZZAMAN
National Regulatory Research Institute

THE HON. KARL A. MCDERMOTT
Illinois Commerce Commission

JEREMY PLATT
Manager, Fuels Assessment
Electric Power Research Institute

DAVID W. SOUTH
Argonne National Laboratory

Appendix G

Correspondence Between National Coal Council and Department of Energy

THE NATIONAL COAL COUNCIL, INC.

Post Office Box 17370, Arlington, Virginia 22216

(703) 527-1191

June 22, 1993

The Honorable Hazel R. O'Leary
The Secretary
United States Department of Energy
Forrestal Building, Room 7A 257
1000 Independence Avenue, S.W.
Washington, DC 20585

Dear Madam Secretary:

Thank you for your letter of June 11, 1993, in which you requested that the National Coal Council prepare a study entitled Future Directions for the Clean Coal Technology Program. The Council accepts your request and is proceeding with the new study.

We have referred your request of this new study to the Coal Technology Subcommittee of our Coal Policy Committee. Under the co-chairmanship of Council members Jerry Oliver, of the Bechtel Corporation, and Dwain Spencer, of EPRI, a work group has been formed to prepare the study. We respectfully ask that you appoint a Government Co-Chair to coordinate with this work group.

We are pleased to have this opportunity to serve you and shall make every effort to do so in an expeditious manner. As our work proceeds, we shall keep you informed of our progress.

Yours very truly,



William R. Wahl
Chairman



The Secretary of Energy
Washington, DC 20585

June 11, 1993

Mr. William Wahl
Chairman
National Coal Council
P.O. Box 17370
Arlington, VA 22216-7370

Dear Mr. Wahl:

Since its creation, the National Coal Council has played an instrumental role in supporting and providing direction for the Clean Coal Technology Program. One of the Council's first reports in 1986, *Clean Coal Technology*, was key in building early support for the Government-industry, cost-shared program. Likewise, the 1988 report *Innovative Clean Coal Technology Deployment* offered recommendations to accelerate the commercial introduction of advanced coal technologies once demonstrated. Numerous other studies by the Council have reaffirmed the importance of innovative, environmentally clean technology for coal use not only in this country but globally as well.

Recently, the Department announced its choice of projects for the fifth round of the Clean Coal Technology Program, thereby completing the selection phase of the originally planned program. In Public Law 102-381, the Interior and Related Agencies Appropriations Act for Fiscal Year 1993, Congress directed the Department to prepare a report by May 1994 assessing future options for the Clean Coal Technology Program, including the use of monies unexpended from the original five rounds. Last year the Energy Policy Act called for an international program to transfer innovative clean coal technologies to host countries.

Accordingly, as we prepare to meet these congressional directives, it is appropriate to look again to the Council for advice. Therefore, I am requesting the Council to prepare a new study described as follows:

- o Future Directions for the Clean Coal Technology Program - The study should (1) examine the current state of U.S. industry acceptance of technologies supported to date by the Clean Coal Technology Demonstration Program; (2) identify where technological gaps may exist in the U.S. portfolio of clean coal technologies; (3) assess the need for further Federal initiatives to overcome remaining market hurdles including, for example, use of Federal "buy-back" provisions to create early market incentives or changes in tax policy to encourage

use of cleaner, more efficient technologies; (4) assess the merit of additional cofunded improvements in previously demonstrated technologies at existing facilities, and if such a need exists, offer guidance on the most effective and financially prudent means of further Federal support (e.g., different levels of cost sharing); and (5) offer advice on carrying out the international technology transfer effort called for by section 1332 of the Energy Policy Act.

Because of the congressionally mandated timing for our report, it will be necessary to receive the Council's study in early February 1994. While we recognize that this is an ambitious request, we consider the Council's participation in our efforts to be of paramount importance. We look forward to receiving the results of the study.

Sincerely,

A handwritten signature in cursive script, reading "Hazel R. O'Leary". The signature is fluid and elegant, with the first name "Hazel" and last name "O'Leary" clearly distinguishable.

Hazel R. O'Leary

Appendix H

Comments on Draft Report

Energy & Environmental Management

John E. Barker, P.E., Consultant

February 21, 1994

Mr. James F. McAvoy
Executive Director
National Coal Council
P.O. Box 17370
Arlington, VA 22216

Dear Jim:

As requested by Mr. Craft, Chairman - Coal Policy Committee, I would like this letter to be included as a "dissenting opinion" to one of the recommendations included in the report "Clean Coal Technology for Sustainable Development".

The recommendation on page fifty-six (56) that an "incentive rate of return" should be used to accelerate the deployment of clean coal technologies is the only section I object to. Otherwise, I support the adoption of this report.

Large industrial users of electricity have long supported the basic concept that electricity rates should be based on "cost of service" and not be used for cross class subsidization or to support socially desirable goals.

I have no objection to the DOE using taxpayer funds to promote the development of desirable nation-wide objectives such as increased energy efficiency or improved environmental conditions. Therefore the concept of offsetting a portion of the capital cost of "first of a kind" technologies to move to the full scale demonstration phase is in the national public good.

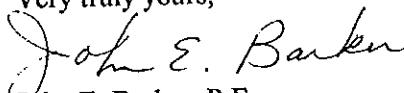
However, granting an incentive rate of return to a given specific utility is an entirely different matter.

The rate payers in that specific utilities franchise area would be paying for benefits that accrue to all citizens and particularly environmental improvements that accrue to citizens down-wind from the franchise area.

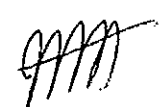
Utility rate-making is the province of the respective state regulatory bodies and it would not be appropriate for the Secretary of DOE to intervene in this function.

I trust my comments will be accepted in the context they are intended, that is to be helpful.

Very truly yours,


John E. Barker, P.E.
Consultant

cc: John Anderson - ELCON
Bruce Steiner - AISI


22 Feb 1994

MASSACHUSETTS
INSTITUTE OF TECHNOLOGY

DEPARTMENT OF
CHEMICAL ENGINEERING



Room 66-548
Cambridge
Massachusetts 02139
Telephone (617) 253-6661

János M. Beér
Professor Emeritus of Chemical and Fuel Engineering
Scientific Director
MIT Combustion Research Facilities

February 9, 1994

Mr. Jim McAvoy
Executive Director
The National Coal Council
TEL: 703-527-1191
FAX: 703-527-1195

RE: DRAFT REPORT: Clean Coal Technology for Sustainable Development

Dear Mr. McAvoy:

Thank you for your kind letters welcoming me to the membership of the Council. I am honored by my appointment and hope to be able to make some useful contribution to the Council's deliberations. In the following I am giving my brief comments on the Draft Report as you requested.

General Comments

The CCT is an important, valuable program; the program has introduced to Utilities projects and processes which have shown promise in industrial R&D on a pilot scale, and helped industry to learn more about their own products and processes on the way towards commercialization.

In setting targets for cycle efficiency and for emissions, however, the CCT program was too conservative, with cycle efficiencies mostly in the upper thirties and emissions not normally below Clean Air Act requirements. With the strong emphasis on efficiency in the DOE's present policy and the tightening emissions regulations, CCT projects would need to be scrutinized to ensure that they are capable of further improvements before support, as envisaged in the Draft Report, is awarded.

Specific Comments

On the Roles of Natural Gas and Coal: Among the several schemes of combined cycles in which both fuels are used, those in which the use of the Gas improves the efficiency of Coal utilization deserve special attention. Examples are the Indirect or Air Heater Cycles. In contrast to combined cycles in which coal is fired as a supplementary fuel in a Heat Recovery Steam Generator at the expense of reduced cycle efficiency, coal heat makes part of the direct heat input to the gas turbine in Air Heater Cycles and is increasing thereby the combined cycle efficiency.



János M. Beér
Professor Emeritus of Chemical and Fuel Engineering
Scientific Director
MIT Combustion Research Facilities

On Technology Gaps

The EPRI generated "typical" cost for a mature IGCC plant at \$1400/kw seems to be somewhat optimistic while the estimates for advanced pulverized coal plants without and with FGD at \$1100/kw and \$1350/kw, respectively, are high by about \$150 compared to present day prices.

When setting targets for pollutant emission it would be preferable to express these in units of lbs of pollutant emitted per kwh generated, rather than lbs per Btu heat input. This would take account of the Heat Rate of the plant.

Commercial Potential and Case Studies

The ACFB performance data are not sufficiently convincing to assume that this system will be competitive ten years from now. Seventy percent sulfur capture at $Ca/S = 1.5$ is low, and 95% at $Ca/S = 4.0$ is too expensive in additive usage and energy loss due to the heat of calcination of the limestone. In addition, FBC systems emit N_2O , a pollutant that depletes stratospheric ozone and is also a "greenhouse" gas. N_2O forms due to the low temperature combustion in fluidized combustion. PFBC with Topping Combustor is a competitive system but its future depends on the commercial development of Hot Gas Clean-Up.

International Technology Transfer

During the next 30 years most of the investment in coal fired generating plant will be made in China and India. There will be excellent opportunities to sell CCT plants depending whether some financial assistance will be available to persuade the purchaser to buy a cleaner but more expensive power plant.

In Eastern Europe there are strong driving forces (international obligations) to comply with stricter environmental standards, but because of the shortage in capital, strong preference will be given to solutions requiring low capital cost even at the expense of higher operating cost.

These are minor comments on a thoughtful report of the Council. I am in general agreement with the conclusions and recommendations of the Draft Report.

I look forward to meeting you on the 16th.

Yours sincerely,

B. R. Brown
Chairman of the Board,
President and Chief Executive Officer

CONSOL Inc.
Consol Plaza
1800 Washington Road
Pittsburgh, PA 15241-1421
412-831-4018
FAX: 412-831-4916

February 10, 1994

Mr. James F. McAvoy
Executive Director
The National Coal Council, Inc.
P. O. Box 17370
Arlington, VA 22216

**RE: National Coal Council Report Draft
Clean Coal Technology For Sustainable Development**

Dear Jim:

I am strongly opposed to the underlying recommendation of the subject report calling for direct government subsidization of "Commercial" clean coal projects. This recommendation runs contrary to efforts by the U. S. to reduce subsidies to coal and other industries overseas, and it runs contrary to efforts in the U. S. to reduce the Federal deficit, even if funding is to come out of the Clean Coal Demonstration Program. Politically, I believe this recommendation is DOA.

Listed below are specific comments on the subject report:

1. Misleading statements are made about natural gas being more attractive than coal as a power generation fuel today. Natural gas combined cycle units are usually more attractive than coal for peaking units (20-35% capacity factors). For baseload capacity (65-80%), state-of-the-art coal-fired units are more attractive than natural gas if the proper financial and performance criteria are used.

2. The report attempts to justify incentives for clean coal technologies based solely on environmental reasons without regard for economics. Generally, the cost of a new technology increases from the development stage to commercial acceptance because additions and revisions to improve operation and reliability increase cost. No amount of incentives will necessarily make a first-of-a-kind (FOAK) plant cost-competitive unless it is cost-competitive initially.
3. In comparing advanced CCT with state-of-the-art pc-fired power plants, the correct basis must be used. The best U. S. coal-fired power stations operating at 80-90% capacity factors have high heating value (HHV) thermal efficiencies of 37-38%. These efficiencies include FGD. Also, emissions of SO₂, NO_x and trace elements can be reduced to very low values. Wet limestone forced oxidation with DBA additive is capable of reducing SO₂ emissions by 98%. Wet thiosorbic lime can achieve a 99% reduction of SO₂ with an L/G greater than 20. Combinations of low-NO_x burners and selective catalytic and non-catalytic reduction can reduce NO_x by 90%. Electrostatic precipitators or baghouses followed by FGD reduce F, Cl and solid tract elements to essentially zero and reduce Hg and Se from 50-90%.
4. Ultra-supercritical pulverized coal-fired power plant technology is largely being ignored in the U. S. Ultra-supercritical pc-fired units with FGD are scheduled to come on-line in the mid-to-late 1990s in Europe and Japan. These units are expected to have low heating value (LHV) thermal efficiencies of 46-47% (44-45% HHV). One supercritical unit that went into operation in 1992 in Denmark reports thermal efficiencies in excess of 45% LHV (~43% HHV) under pure condensing conditions.
5. The proposed CCT incentive program (IP) will spend \$1.4 billion over 15 years to support construction, and \$400 million for operation of 20 commercial plants, five each of four technologies. How do they expect to go through five generations of each technology in 15 years? Assuming it takes five years for design, construction, and start-up, how effectively

will learning from each phase be transferred to subsequent designs?
Would each generation need to be the same technology for this approach to be successful (i.e., if you pick a Texaco gasifier for the first IGCC plant, can you pick a Shell gasifier for the next, etc.)?

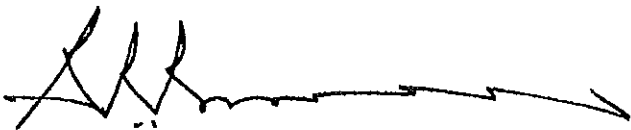
6. The recommendations focus on four CCT types. Are these the only candidates for CCT IP funding, or would there be open competition? What is the selection process?
7. The report recommends that "unused" CCT funds be spent on continuing operation of "some demonstrations." How would these be selected? Would not this require another CCT solicitation? Would completed projects from earlier CCT rounds be candidates for revival?
8. Page 15 - Deployment Benefits. The five (not four) benefits listed ignore the key benefit, which is to minimize the long-term cost of electricity to the consumer. Unless we abandon economic dispatch as the basis for making power generation decisions, the factors they list will only be components of the cost decision.
9. Page 21 - Paragraph 2, says that rail transport costs are one to two times minemouth costs for PRB coal. Based on their Figure 4, PRB coal is ~\$4/ton. Rail transport to St. Louis is currently \$13-14/ton or three to four times the FOB mine price of PRB coal. Although PRB coal can be competitive with eastern bituminous coal, this is restricted mainly to power stations with access to the Great Lakes and Mississippi/Ohio river waterways. Furthermore, PRB coals cannot be burned in most boilers designed for eastern bituminous coals without incurring capacity derates. In most cases, PRB coal is blended with 30% to 50% eastern bituminous coal to eliminate the derate.
10. Figure 3 implies that FGD capital costs are \$500/kW. Retrofits are more likely to be in the range of \$250-350/kW with new FGD grass roots

National Coal Council
February 10, 1994
Page 4

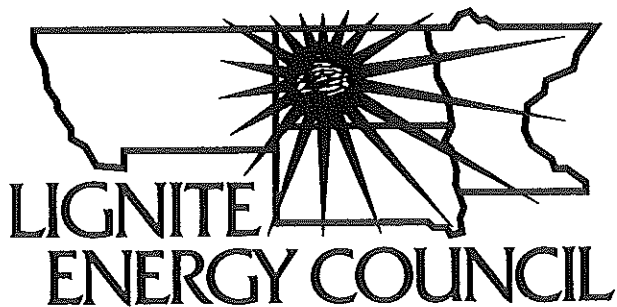
plants costing \$180-270/kW. Also, first paragraph on p. 21 seems to imply that new low-sulfur coal plants will not require FGD.

11. The recommended subsidy amounts depend on a number of assumptions, but are recommended as very specific numbers. The report, if published, should recommend a general approach and leave the amounts for further study. The incentives at the end of the program (Plant No. 5) are very small (5-7% of the capital cost). How realistic is this incentive?
12. Page 42 - Paragraph 2 says that for virtually all CCT projects, there was no discussion presented on the status of waste water streams. In the NYSEG Milliken FGD CCT-4 project, the discussion stated "no waste water discharges."

Sincerely,

A handwritten signature in black ink, appearing to be 'BRB', followed by a long horizontal line that ends in a small arrowhead.

BRB/meg



JOHN W. DWYER, *President*

February 10, 1994

SERVING:

MINNESOTA

Cooperative Power

Minnesota Power

Minnkota Power Cooperative

Northern States Power Co.

Otter Tail Power Co.

United Power Association

NORTH DAKOTA

Basin Electric Power Cooperative
& Dakota Gasification Co.

BNI Coal, Ltd.

Knife River Coal Mining Co.

Montana-Dakota Utilities Co.

Minnkota Power Cooperative

North American Coal Corp.

Northern States Power Co.

Otter Tail Power Co.

SOUTH DAKOTA

Basin Electric Power Cooperative

Montana-Dakota Utilities Co.

Northern States Power Co.

Northwestern Public Service Co.

Otter Tail Power Co.

MONTANA

Basin Electric Power Cooperative

Knife River Coal Mining Co.

Montana-Dakota Utilities Co.

Mr. James J. McAvoy
National Coal Council, Inc.
P.O. Box 17370
Arlington, VA 22216

Dear Jim:

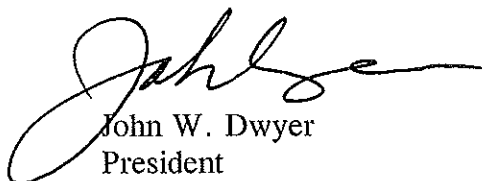
On behalf of the Lignite Energy Council and its members, we appreciate the opportunity to comment on the proposed draft report - *Clean Coal Technology for Sustainable Development*.

While our organization appreciates that Department of Energy officials have already indicated there will not be a Round VI for the clean coal program, we cannot endorse a "National Coal Council" recommendation that calls for an elimination of Round VI. We believe the present clean coal program with additional grant rounds to be a much more effective method to develop and deploy clean coal technologies for the benefit of this country. A sixth round should be considered that focuses on meeting domestic needs, addresses all coals, and includes all regions of the country.

I also wish to express concern over the recommendation in the report that suggests deployment of technologies for only those plants in the 200 MW to 400 MW size. Smaller units should be considered where the market demand exists since capital costs, base load versus peak load power needs, and construction times all enter into the project size decision. Also, while the report indicates the attractiveness of natural gas, it should also be emphasized in the report that coal costs are much less than natural gas costs in many areas of the country.

Thank you for the opportunity to comment on the proposed report.

Sincerely,



John W. Dwyer
President



ICAAS

CLEAN COMBUSTION
TECHNOLOGY LABORATORY

UNIVERSITY OF FLORIDA
Space Science Research Bldg.
Gainesville, FL 32611
(904) 392-2001
FAX (904) 392-9741

Mr. James F. McAvoy
Executive Director
National Coal Council
P.O. Box 17370
Arlington, VA 22216

February 6, 1994

[Handwritten signature]
08 Feb 1994

Dear Jim,

With regret I can not be at the February 17, 1994 Coal Policy Committee meeting in St. Louis because of conflicts with meetings in Orlando. However I will FAX and Express Mail to you on February 7 comments which mainly relate to Chapter 2 Technology Gaps and Appendix A. They are, of necessity, brief since the report arrived on February 4, and I had other demanding work this week-end. My comments constitute a Minority Report.

(1) I agree that "Clean Coal Technologies (CCT) represent an important opportunity for Sustainable Development, both Domestical and Internationally." However CCT represents only one component of a Sustainable Development effort and in my view the report should seriously consider the relationship of CCT to other components.

(2) The report addresses strongly the environmental issues raised in the Clean Air Act of 1970 that focussed on SO_x, NO_x and particles (the so called criteria pollution). However, the report is weak in relationship to the Clean Air Act of 1990, particularly Title 3 on Air Toxics. As Secretary O'Leary indicated in her talk before the NCC last November the permit for the coal power plant in southern Florida was rejected because of concern over TOX (toxics). As I noted in the NCC meeting of May 1991 and in subsequent meetings Mercury and Chlorine have become important toxic issues. While Chapter 2, Recommendation 2 "The DOE encouraged appropriate projects to monitor air toxics etc". is laudable it is a very anemic response to major problems now facing the application of Clean Coal Technology for Sustainable Development.

(3) The report makes little if any mention of what might be achieved towards sustainable development and oil import reduction by Co-combustion with natural gas, biomass or municipal solid waste. For recent summaries I refer you to studies on the toxics and co-combustion questions presented at Joint Power Generation Conferences which were sponsored by the Fuels and Combustion Technology (FACT) Division of the American Society of Mechanical Engineers (ASME) [1-5].

(4) While the NCC is an advisory group to the Secretary of Energy somehow it must give greater recognition to the increasing regulatory impact of the Environmental Protection Agency. Environmental regulations are becoming major drivers in energy decisions. Realistic consideration of the present and future role of EPA and of other fuels will, in my view, reinforce the need for the NCC to address the comments 1-3 above.

Very sincerely,

[Handwritten signature]

Alex E. S. Green

cc Joseph W. Craft III

References

- [1] A. Green and W. Lear (Eds), 1990, "Advances in Solid Fuels Technologies", published by the Fuels and Combustion Technology (FACT) Division of the American Society of Mechanical Engineers (ASME) New York, NY
- [2] A.K.Gupta, G. Presser and R.L.Axelbaum (Eds), 1992, "Air Toxic Reduction and Combustion Modeling" ASME-FACT, Vol. 15
- [3] A.K.Gupta et.al Eds., 1993, "Combustion Modeling, Cofiring, and NOx Control" , ASME-FACT Division publication Vol 17.
- [4] A. Green, J.C. Wagner and S. Madadevan, 1993, "Chlorinated Benzene Formation in Incinerators" presented at the ASME International Joint Power Generation Conference, Kansas City, MO, October, ibid 3..
- [5] A. Green, 1993, "Co-Combustion 1993" presented at IJPGC conference, Kansas City, MO, October, ibid 3.

Comment: on Report: "Clean Coal Technology for Sustainable Development"

by: R.H. Essenhigh; Ohio State University

Report does not address the question of education/training of future operators/users/developers of the new technologies. Suggest that some consideration should be given to this: possibly a paragraph to a complete chapter discussing this aspect.

The central point is: What scope will there be for further improvements of the new CCT processes and for development of further processes? and Who is going to run the new technologies? Will they be educated in coal science (Know Why) or only trained in coal techniques (Know How)?

At this time, the existing DOE/industrial company CCT and related developments are being carried out by graduate engineers educated/trained in coal technologies and research over the last 1, 2, or 3 decades. At this time, too many of the university research groups have been disbanded, and/or those directing the groups have retired and they are not being replaced because of lack of funding and the general downgrading of university coal research by DOE. Consequently, it is my impression that there is now very little left in the supply pipeline of new graduates with education and training in coal. Few coal courses are suitable for the BS level and/or they are too specialized so that the enrollment is too low for such courses to be given: this is a university costing problem. Most of the education in coal topics is provided only at the graduate level on account of the specialized nature of the subject and its difficulty. The courses are typically taught by those engaged in the coal research. As the university coal research funding has dwindled, so have those doing the research, and hence courses on coal are being dropped for lack of faculty with knowledge and interest in teaching the courses. Continued advances in technologies requires continued scope for those involved in education in the relevant technologies. Without the support of university research, this is all coming to a stop. It is possible to train BS students in the existing technologies -- that is to say, instruct them in "Know How"; but by definition, this means training up to the level of current knowledge, but no further since it is impossible to train anyone in a technology, or improvements in a technology that do not yet exist. The "Know Why" required for optimizing old technologies and for inventing new ones comes from education and research in that subject, not from training. Does the current reduced emphasis on support for university research, with its attendant drop in numbers of students in coal research, mean that DOE/industry now regards current CCT technologies being developed as the final limit and end of the line on what can be done with coal?

In my view, the level/body of knowledge of any subject or topic can only go up or down. Information/knowledge of a subject gets lost if it is not continually being studied. In the current low levels of coal research funding at the universities, the research is moving into research corporations and industrial companies. However, applied research areas still depend on basics in fundamental chemistry, physics, mathematics, and the like. If there is too much detachment of the research from the sources of the basic sciences, these typically become increasingly focussed on application, and steadily turn from development of technology to application of techniques. At that point, knowledge starts to be lost, and the technical competence in the technology steadily declines until it is replaced by alternatives.

I believe it is imperative that this position and possibility is considered, at least for discussion for inclusion in the CCT report.

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by: R.H. Essenhigh; Ohio State University

Suggest that comment should be added in Chapter 4 with reference to possibility/potential for alternative New Technology projects in addition to those listed in Appendix A Table A9. The present discussion would appear to limit new/advanced technologies to those listed -- and that's it, presumably for the next 10, 20, 30 years, unless they are developed outside the US and are imported. I cannot believe that the time has come to close out all other options. If other options are to be considered how are they to get into consideration?

An example missing from the Table A9 though included in one of the older DOE lists is the use of Coal-Water Fuels (CWF), and its extension of Sorbent-Loaded CWF for additional sulfur control. This has the following advantages:

1. Tests already completed in various places show that the chief technologies of: CWF manufacture associated with deep cleaning; transportation; pumping; metering; atomizing; flame stabilization (by gas/air atomization if necessary); have all been developed individually and largely independently. They only need to be put together for a complete boiler test to determine reliability on long term firing -- e.g., 6 months, 1 year, 2 years.
2. For long term reliability tests, these can be carried out on practically any existing operating pulverized coal boiler by replacement of one burner. If that burner goes off line during test, the boiler will hardly notice it if it is large enough. Using gas atomization, the CWF loss can be made up by increasing the gas. Adjustment of the gas rate can be used for additional SOX control.
3. A single full size burner can be 10 to 20 MW(t) which is quite moderate scale up from tests that have already been carried out. We have done tests at Ohio State up to 1 MW(t); others up to 3 or 5 MW and higher. The CWF quantities required are therefore relatively modest and can be handled by a slip stream on an appropriate existing coal cleaning plant.
4. The associated cost for a single burner test is relatively modest. Depending on what is required by way of ancillary plant (for CWF preparation, etc.) the cost for this will be 1/10th to 1/100th of virtually any other alternative CCT process.
5. If the single burner tests succeed, then another burner can be added. This can be continued by add-on of one burner at a time. This is the only CCT process that can be developed on a step-wise incremental basis, with only relatively modest additional funds committed for each step.
6. In tests covering the principal coal seams in Ohio, the deep cleaning of the coal can reduce mineral matter to 2% with relative ease, 1% is a reasonable short future target, and on the learning curve, 1/2% or less is considered feasible at commercially acceptable costs. Sulfur is reduced to between 1/3 and 2/3, by removal of the inorganic sulfur.
7. Payback on the mineral matter reduction occurs in 6 ways: (1) reduction almost to elimination of boiler slagging and fouling with attendant reduction in maintenance costs; (2) reduction to elimination of soot blowing, with

attendant improved boiler efficiency; (3) removal before firing (at the coal prep plant) of the majority of the heavy metals that are becoming a concern in air and water/land pollution control; (4) reduction almost to elimination of most ash capture/disposal equipment and related storage locations (fly ash and bottom ash); (5) reduced self-consumption of power used for ash handling requirements; (6) reduction to elimination of mineral matter and ash water/land and air pollution from this source.

8. In tests on Ohio coals, deep cleaning also removed 1/3 to 2/3 of the total sulfur as the inorganic sulfur. Addition of calcite to the slurry (the SLCWF formulation) captured up to 2/3 of the remaining sulfur. Potential sulfur removal/capture by this method should be at least 80%, with expected increase to 90%+ on the future learning curve. This replaces some of the inorganic matter, but its boiler fouling and slagging potential is small compared with normal coal ash, and the capture equipment can be optimized for the one specific inorganic.

9. In firing, each burner can be electronically metered on line with signals to continuously give fuel rate at each burner. Individual monitoring/control of each burner should allow closer fuel/air matching with reduced overall excess air and attendant increase in thermal efficiency.

10. The presence of the slurry water attenuates the flame temperature and allows direct firing of the sorbent (in the slurry) through the flame without reducing the sorbent activity; this is considered impossible in "conventional" limestone injection (LIMB). Consequently, the slurry becomes the sorbent delivery system thus eliminating need for, costs of, and operating nuisance of separate limestone injection equipment. This also avoids the culture collision between the mechanical engineer handling the boiler and power side and the chemical engineer handling the FGD and related chemical control processes.

11. Transportation, handling, and storage is essentially equivalent to that for oil: it is cleaner, uses enclosed storage tanks, reduces/eliminates vagrant dust. Fire hazard on spills or tanker collision is essentially zero. Pollution contamination on spills is essentially limited to the spill site: it does not migrate like oil.

The individual components for CWF use already exist, mostly developed for other technologies and applications. Consequently, this technology could conceivably be brought on line commercially in about 5 years, rather than the 15 to 25 years for other possible systems. As it is essentially a pulverized coal supplement/replacement, it may be only a stop-gap until the really advanced technologies can be fully developed and brought on line; but if this takes 20 to 30 years or more, the CWF is worth developing for the interim of the next 25 years or so.

What is needed is a detailed costing of the costs and benefits, and long term (up to 2-year) testing of a single burner. The principal problems anticipated are fuel line blockage and wear, with associated problems of pump reliability (wear problems) and fuel settling which may require special tanks to maintain slow turn-over of the contents. Using pintle atomizers, the pintles had to be SiC or titanium. The chief components required for a reliability test, however, can be put in place quite quickly. This would seem to be a technology worth studying.

THE NATIONAL COAL COUNCIL

P.O. Box 17370
Arlington, Virginia 22216
(703) 527-1191