Innovative Clean Coal Technology Deployment

November 1988

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THE NATIONAL COAL COUNCIL

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U.S. DEPARTMENT OF ENERGY

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

The sole purpose of the National Coal Council is to advise, inform, and make recommendations to the Secretary of Energy on any matter requested by the Secretary relating to coal or the coal industry.

The Work Group Leader wishes to acknowledge the extensive efforts of George Wiltsee in assisting in the preparation of this report.

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December 1, 1988

The Honorable John S. Herrington
Secretary of Energy
U. S. Department of Energy
1000 Independence Avenue, S. W.
Washington, DC 20585

Dear Mr. Secretary:

On behalf of the National Coal Council, I am pleased to submit the attached report, "Innovative Clean Coal Technology Deployment," prepared in response to your letter of November 6, 1987, and approved by the members of the Council on November 16, 1988.

The purpose of this report is to provide advice on what actions the Federal Government can take to commercially deploy the technologies once demonstrated so that the Administration's coal-related energy, environmental, and competitiveness goals can be achieved.

This report recognizes the fundamental importance of coal to our nation's economy and security as well as the environmental concerns that the uses of coal engender. An earlier study conducted by the Council for you in 1986 concluded that the development of clean coal technologies could provide for the increased, environmentally and economically acceptable use of coal to fulfill a growing role in meeting our nation's energy needs.

The Council concluded the appropriate role of the government in the deployment of innovative clean coal technologies is to follow a balanced policy which accelerates market-driven innovation, removes unnecessary barriers, provides appropriate incentives, catalyzes a public education and consensus-building campaign to improve perceptions and attitudes toward the uses of coal, and stimulates and supports private sector efforts to more strongly compete in the world markets.

The study group and the Council have strived to present an objective and balanced report. We are hopeful that this report will be useful to the Department of Energy in its formulation of energy policies involving innovative clean coal technology deployment. We stand ready to provide you with any additional information in this matter as you may desire.

Sincerely,

James G. Randolph
Chairman

JGR:ph

Attachment

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Introduction

This study was initiated in December 1987 by a Work Group composed of representatives to the National Coal Council in response to a request from the Secretary of Energy dated November 8, 1987.

The study objective is to advise the federal government, through the Secretary of Energy, on actions to ensure successful deployment of innovative clean coal technology (ICCT) to achieve the administration's coal-related energy, environmental, and competitiveness goals.

The study is based on the following premises:

- Coal is a strategically essential fuel for the nation's economy and security.
- Coal use has been constrained by increasingly restrictive environmental policies and the costs of compliance with the resulting regulations.
- ICCT fundamentally increases the options available to resolve this conflict by more cost-effectively sustaining the nation's progress in emissions control while protecting coal use and making it more efficient and cost effective.
- ICCTs must achieve commercial maturity before they can compete on an equivalent risk basis with other energy options. Achieving confident commercialization can help reestablish the United States' position as the international market leader in coal technology.
- Deployment is the process through which ICCTs and all other new technologies achieve commercial maturity. The objective is to remove risk barriers that impede the ability of unproven technology to achieve user confidence.
- Federal and state government participation to facilitate deployment may take the form of removing disincentives, providing subsidies/incentives, or modifying regulations. The form and extent of this participation ultimately depend on the value and urgency of ICCT to the nation or state. This sense of value and urgency is at the heart of the National Coal Council's considerations.

A series of Work Group papers was developed as background for this report to provide a foundation reflecting the range of judgment and experience among the National Coal Council, and other contributors, on the value of ICCT and mechanisms, private or governmental, for deployment. The Work Group's intention was to seek out the variety of informed viewpoints on this important national energy initiative.

Appendix A defines key terms used in this report. Appendices B and C provide a description of ICCTs and an inventory of ICCT projects.

Abbreviations Used in This Report

AFBC	=	atmospheric fluidized-bed combustion
CCT	=	clean coal technology
CWIP	=	construction work in progress
DOE	=	Department of Energy
EIA	=	Energy Information Administration
EPA	=	Environmental Protection Agency
EPRI	=	Electric Power Research Institute
ERAB	=	Energy Research Advisory Board
FBC	=	fluidized-bed combustion
FPC	=	Federal Power Commission
FERC	=	Federal Energy Regulatory Commission
FGD	=	flue gas desulfurization
GRI	=	Gas Research Institute
ICCT	=	innovative clean coal technology
ICTAP	=	Innovative Control Technology Advisory Panel
IGCC	=	integrated-gasification-combined-cycle
NERC	=	North American Electric Reliability Council
NSPS	=	New Source Performance Standards (1979)
PC	=	pulverized coal
PFBC	=	pressurized fluidized-bed combustion
PUC	=	Public Utility Commission
SIP	=	State Implementation Plan

Executive Summary and General Findings

It is increasingly clear that the energy needs of the industrial nations together with the legitimate economic aspirations of the developing world will depend on significant increases in world coal consumption. For this to occur, it is essential that a concerted effort be undertaken to develop and deploy more environmentally and economically effective technologies for the use of coal. U.S. leadership in this effort is consistent with its national security and commercial interests, and its responsibilities as a major coal producing and using nation.

Coal is the focus of two independent and conflicting national policy agendas—energy and environment. As the most abundant domestic fossil energy resource, it is essential to the U.S. economy today and to the nation's future energy security. At the same time, however, the nation has a deep and continuing commitment to a clean environment which has historically conflicted with coal use.

The national interest demands prompt resolution of this conflict. Yet how? The National Coal Council finds the accelerated deployment and early commercial application of innovative clean coal technologies (ICCTs) to provide the most cost effective, long-term answer. This initiative capitalizes on U.S. experience and world leadership in coal utilization research.

ICCTs offer the potential to utilize coal in a more cost-effective and environmentally efficient manner than by existing means. The principle guiding ICCT development is that sustained environmental improvement will only be effectively achieved when emission reduction and cost reduction complement each other. ICCTs respond to the environmental consensus of society while controlling the cost of energy and keeping its supply secure. They also offer an important foreign trade opportunity, and are essential to U.S. coal technology leadership in the face of rapidly growing global competition.

ICCTs must be commercially proven and broadly available during the next decade to meet both the requirements of existing and potential environmental policies, and the challenge to the nation's power supply and industrial capabilities. ICCTs must be deployed in this window of time to avoid committing the market to existing technology with consequent negative impacts on energy cost and productivity, or shifts to less dependable energy sources.

In order to achieve this objective, private industry has spent more than $1 billion to develop to the point of demonstration the suite of technologies now grouped together as ICCT. The primary goal of government participation should be to protect and facilitate this industry-led effort through the risks of commercial maturation.

If ICCTs are to be successfully deployed over the next decade, then the technical, commercial, environmental, and regulatory constraints to further private sector initiative must be addressed. At present, the short-term alternatives are too attractive, and the risks are simply too large for individual companies or industries to commit to ICCT deployment while still meeting obligations to shareholders, investors, ratepayers, or other stakeholders.

The primary basis for private industry support of ICCT is to increase the available clean energy choices and to reduce costs, thus increasing profitable markets for coal and its resulting products and services. There is particular concern that this goal may be compromised by mandating additional emission reduction requirements whose magnitude, timing, and technology requirements would restrict the opportunity and incentive for ICCT deployment.

The status of the federal budget and concern for the international competitiveness of U.S. industry argue strongly for new incentive-based policies which emphasize economic efficiency in environmental protection. The appropriate government response is to act in a proactive manner to accelerate market-driven innovation, remove unnecessary barriers, provide appropriate and equitable incentives, and catalyze private sector-managed collaborative efforts that are required for competitiveness in a global market.

Completion of the Department of Energy (DOE)-cosponsored ICCT Demonstration Initiative is an essential step in reducing the risks associated with ICCT deployment. These cosponsored projects represent a logical extension into collaborative technology development and commercialization on a national scale. The value goes well beyond that of the individual projects.

Beyond the DOE-cosponsored ICCT Demonstration Initiative, government action should emphasize removal of disincentives to:

- Cost-effective actions which sustain the nation's remarkable environmental progress over the past 15 years.
- Timely investments in new industrial and electricity-generating capacity. Of particular importance is prompt cost recovery by regulated utilities.

State government encouragement and support for ICCT development and deployment is an essential ingredient. This is underscored by the fact that nearly 80 percent of all rate regulation of electricity occurs at the state level. In addition, ICCT siting decisions are primarily made at the state level. Thus, assurance of cost recovery, which has historically been fundamental to utility investment, is dependent on state actions. State regulatory commissions in particular should encourage ICCT investments that promise lower life-cycle costs and, thus, lead to reduced customer costs in the long run.

State support for ICCT deployment is in keeping with the state role of maximizing the energy choices and economic well-being of its citizens. States are increasingly complementing federal participation by using their unique capabilities to reduce state or local taxes and provide grants or other active assistance.

An initiative as potentially far reaching as ICCT deployment also requires broad public support. The general public must agree with the importance of ICCT to social and economic well-being. Essential to this goal is implementation of a series of successful ICCT demonstration projects supported by an effective public relations and consensus-building campaign involving the broad set of private and public interests. The Secretary of Energy is a necessary catalyst for this effort.

Public perceptions concerning energy in general, and coal in particular, have been influenced by the nation's historic policy patterns: during periods of energy "crisis" when petroleum supply/cost is threatened, energy policy turns to coal as an abundant fuel resource and a useful source of geopolitical power to offset strategic vulnerability from petroleum dependence. Unfortunately, none of these initiatives has been consistently pursued; however, restrictive regulations have accumulated during the more frequent periods when energy supply has not been a political issue. A public/private joint venture to accelerate ICCT deployment provides a highly visible and lasting opportunity to reverse this policy trend.

General Findings

The general findings of the Work Group concerning deployment of ICCT are summarized as follows:

1. Coal's public image has improved as technological advances and environmental progress have protected occupational health and substantially reduced the amount of emissions from coal utilization. Successful deployment of ICCT is essential to maintaining this progress for the nation's most abundant fossil fuel resource.
2. The ongoing DOE-cosponsored ICCT Demonstration Initiative can provide the essential risk sharing to permit the private sector to confidently determine, through multiple projects, the commercial application envelope for the array of promising ICCT options. Its success as a foundation for deployment will depend on the DOE continuing to participate throughout the demonstration initiative as an investor in projects initiated and managed by the private sector.
3. The collaborative, joint venture approach to the DOE-cosponsored ICCT Demonstration Initiative has been essential in stimulating the market forces that ultimately determine the commercial potential of technology purchased and used by the private sector. These new DOE management and procurement practices have established closer cooperation and credibility for these joint government/private sector development and commercialization efforts.
4. The technology developer/supplier and user must assume a significant risk that ICCT can be deployed successfully and achieve commercial acceptance. This challenge is encountered with the commercialization of any new process, but is especially acute for ICCT deployment because it must be carried out at commercial utility and industrial scale. When combined with the unusually volatile nature of the energy market, it represents an extraordinary financial challenge for the private sector. This challenge becomes especially difficult if the ability to recover the required financial commitment is uncertain because of regulatory or other governmental actions.
5. Other nations have developed targeted industry strategies that involve government-industry consortia designed to capture market share in global markets. Coal utilization and related power generation equipment is one such targeted industry. The strategy involves cooperative R&D, highly leveraged investment with low cost capital, import restrictions, and export sub-

sidies. In this environment, U.S. antitrust laws are failing to promote competition and efficiency. Many well-intended regulatory laws also require selective modification to make them less anti-competitive, and patent and trademark laws need to be strengthened.

6. The demonstration and deployment of ICCT will take time. Even after a technology becomes available for confident commercial use (see Figure 2, p. 19), an additional five to 10 years or more—depending on the complexity of the technology and the scope of the market—may be required before it reaches its full commercial potential. This time frame must be recognized in establishing regulatory compliance schedules if ICCT deployment is to proceed effectively.

7. ICCT deployment policy should distinguish between two fundamentally different technology applications: ICCT retrofit emission controls intended to respond to potential environmental policies affecting existing plants, and strategically more important new plant and repowering ICCT systems. The former typically serve to reduce the cost of compliance with air quality regulation, while the latter have the potential to improve the productivity and economics of coal use with greater environmental control capabilities which consider water and solid waste, as well as air impacts. As a result, different government actions may be required to facilitate deployment.

8. ICCT deployment will be encouraged if environmental regulations utilize market incentives providing maximum opportunity to choose among compliance alternatives and avoid biases in favor of specific solutions which may mask the true cost of compliance decisions. The potential cost savings to the nation can be substantial, reaching an expected \$3 billion/yr by the end of the century alone. ICCTs will also support increased efficiency in coal utilization and therefore contribute to moderating growth in the atmospheric concentration of greenhouse gases, particularly carbon dioxide.

9. Developing countries will increasingly look to coal to supply their growing energy needs. The result is a likely doubling in world coal consumption to seven billion tons annually by 2010. Technology to support this demand growth will be an area of intense global competition among the industrialized nations. ICCT will be used if it is available, reliable, and if competitive financing packages can be arranged. Prompt ICCT demonstration and deployment will be an important national asset in this competition. If even half the world's expected expansion in coal utilization for power generation used U.S.-manufactured equipment, the value would be about \$35 billion/yr by 2010.

10. A successful national ICCT demonstration and deployment initiative can ultimately provide a coal-processing technology foundation capable of refining and synthesizing a wide range of products including electricity, transport fuels, and chemical feedstocks, while recovering essential mineral credits. Thus, ICCT has the potential to provide a secure energy and resource foundation for the United States and a fundamental economic capability for the developing world as well.

Recommendations

The essence of the Work Group's recommendations is that federal and state governments should aggressively support, in the national interest, the commercial deployment of ICCT.

These recommendations involve aspects of energy, tax, environmental, and trade policies, permitting, regulatory incentives/disincentives, and public education.

Implementation of these recommendations will require cooperative efforts by a number of public and private entities to resolve the risks the private sector faces in successfully accomplishing deployment. These are:

- Technical risks involving performance and reliability at specified levels, duration, and cost
- Commercial risks resulting from uncertain future energy, trade, and regulatory policies and resulting market conditions
- Environmental policy risks which may mandate currently available technology or compliance to levels and within time frames which effectively preclude ICCT or negate its intent
- Regulatory uncertainties that expose investors to unexpected, after-the-fact financial risks without compensating opportunity for financial reward

Following are the Council's recommendations:

1. **COMPLETE THE ONGOING DOE-COSPONSORED ICCT DEMONSTRATION INITIATIVE AS PLANNED.**

   Complementary demonstrations of the most promising technologies which address the range of designs, coals, and operating variables faced by coal users are necessary to confidently map ICCT's commercial application envelope. The phased nature of this initiative encourages cost-effective targeting of resources and recognizes the reduction in risk achieved through successive projects.

   In order to achieve the greatest national benefit the initiative should:

   - Provide developers with greater protection of their proprietary technology based on their cost sharing participation.
   - Pursue parallel paths of providing advanced technologies suitable for new plants, as well as retrofit/repowering options for existing facilities.
   - Encourage technologies which emphasize increased energy efficiency and control, minimization, or utilization of liquid and solid waste by-products, as well as air emissions. The result will be increased opportunity for long-term environmental protection and commercial viability.
   - Encourage technologies suitable for modular construction and plant design standardization to shorten lead times and reduce the risks of installing new industrial and generating capacity.

2. **CLEARLY DEFINE THE SCOPE AND EXTENT OF ICCT "DEPLOYMENT."**

   This would go far to alleviate concern over government participation. The goal of national ICCT deployment policy should be to advance commercial maturity as quickly as possible for the broadest possible market. This requires that the various promising ICCT technologies be applied under enough varied circumstances to permit industry to make confident decisions about the technical and economic merits of each, as well as its commercial availability, quality, and performance.

3. **ACTIVELY ENCOURAGE, AT THE STATE LEVEL, UTILITY AND INDUSTRIAL PARTICIPATION IN ICCT DEPLOYMENT EFFORTS BY ALLOWING OR PROVIDING:**

   - Full construction work in progress (CWIP) in 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 rates of return for utilities deploying ICCTs.
- 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 ICCT 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 ICCT deployment by industrial and other nonutility coal users, recognizing that these companies can be a valuable source of technology, funding, and commercial leadership.

4. ENSURE THAT AIR QUALITY LEGISLATION PLACES PRIORITY ON SUSTAINING THE REMARKABLE NATIONAL PROGRESS MADE OVER THE PAST 15 YEARS IN EMISSION REDUCTION WITH THE LEAST IMPACT ON COST AND PRODUCTIVITY BY PROVIDING:

- Sufficient compliance time for ICCT deployment so the market can confidently choose the least-cost solutions from among an array of emission control options. An effective strategy should be designed to ensure the availability of the necessary options to the market, not to artificially restrict that market.
- Maximum practical freedom of choice among alternatives for meeting defined emission control objectives without biases in favor of specific "equipment" solutions. Such biases have proven to both inhibit technology development and increase compliance cost.
- Encouragement of risk management-based environmental policies that enhance energy competitiveness as well as environmental protection. Such policies provide a valuable cost/benefit framework for achieving public understanding and consensus.
- The resources necessary to confidently measure the energy balance of the earth as the essential foundation for understanding the greenhouse effect and any related energy policy implications.

5. LOWER FEDERAL AND STATE ENVIRONMENTAL REGULATORY BARRIERS TO WIDER USE OF ICCT OPTIONS BY PROVIDING:

- Flexible source emission reduction targets, which would include "bubbling" to reduce costs by allowing averaging of emissions over all facilities in a state or region, and tradable emission permit systems, provided that ambient air standards are maintained.
- Tonnage reduction compliance standards, allowing utilities to receive full credit for gross emissions reductions achieved by demand-reducing strategies.
- Expanded Innovative Control Technology waiver provisions in the Clean Air Act, and revised requirements so that waivers may extend beyond four years after startup.
- Interstate air quality management coordination to encourage neighboring states to implement cooperative strategies for emissions reductions, including emissions trading among states. This should consider compensation to the entities responsible for establishing the tradable environmental margins.

6. MODIFY FEDERAL, STATE, AND LOCAL ENVIRONMENTAL PERMITTING PROCEDURES TO EXPEDITE AND ENCOURAGE ICCT DEPLOYMENT, AND PROVIDE A PERMITTING REFERENCE FOR CONSISTENT AND UNIFORM APPLICATION OF FEDERAL REGULATIONS.

Key points to be addressed include the following:

- "Grandfather" ICCT installations from further emission reductions for a period of time which recognizes the investment made in the installation. Such safe harboring provisions should be linked, for example, to the depreciation period of the installation.
- Revise Environmental Protection Agency (EPA) regulations to prevent voluntary modifications from triggering even tighter controls at plants which already have an emissions reduction program.
- Allow existing sources currently in compliance with regulations to apply for innovative technology waivers in order to improve cost

and integrated environmental control performance.

- Develop a uniform federal and state permitting procedure for technologies which promise to reduce emissions at lower cost.

7. CONDUCT AN ICCT PUBLIC EDUCATION AND CONSENSUS-BUILDING CAMPAIGN.

The Secretary of Energy should catalyze the process by bringing together the key opinion leaders from the public and private sectors to focus and implement this effort. The steps in the process are:

- Identify the ultimate targets and key opinion leaders
- Shape the message for each market
- Identify stakeholders and spokespersons
- Communicate the message

Primary goals of this program should be to communicate the results of ICCT demonstration programs and the industrial commitment to their success; promote the economic and environmental advantages of the technologies; and encourage a consensus on expanding the environmentally benign use of the nation's most abundant fossil energy source. Such a campaign must recognize and overcome the adversarial conditions which have inhibited a workable consensus on coal. This will require credible involvement by all public and private stakeholders.

8. PROVIDE, WHERE APPROPRIATE, FEDERAL AND STATE ECONOMIC INCENTIVES TO ACCELERATE ICCT DEPLOYMENT WITHOUT DISTORTING THE ENERGY MARKET.

These could include investment tax credits, accelerated depreciation (over shorter periods than under present law), and increases in existing caps on tax-free industrial development bonds now available to states. These types of incentives would reduce the cost of ICCT application for private sector facility owners and customers, thereby encouraging application of technologies chosen by the user.

9. REMOVE RESTRICTIONS ON COLLABORATIVE TECHNOLOGY DEVELOPMENT AND DEMONSTRATION INVESTMENTS BY COMMERCIAL COMPETITORS.

This recognizes that industrial competition is increasingly international in nature, and increasingly demands resources exceeding those of individual companies. The ability to maintain the nation's industrial economic base in this global marketplace depends on the formation of national "arsenals of innovation" which can pool public and private investment to share the risks of technology commercialization. ICCT deployment provides a valuable prototype for such national collaborative efforts, which have also been aided by recent modification to anti-trust laws.

10. ESTABLISH A BIPARTISAN COAL AND RELATED TECHNOLOGY EXPORT POLICY COORDINATING COUNCIL UNDER THE AUSPICES OF CONGRESS AND THE PRESIDENT.

This council would draw its membership from the private sector, from various industry associations, and from the Departments of Energy, Interior, Commerce, State, and Treasury. It would identify decision makers, market conditions, and specific needs in other countries; recommend specific steps to facilitate the export of U.S. coal and coal-related technology; report on any coal-related discrimination practices by other countries and recommend potential remedies; and note any positive steps being taken by these countries that the United States could adopt.

11. REVIEW AND MODIFY APPLICABLE FEDERAL LAW, AS APPROPRIATE, TO PERMIT THE U.S. COAL INDUSTRY TO FORM TRADING COMPANIES FOR THE EXPORT OF COAL AND COAL TECHNOLOGIES.

These trading companies should have access to Export-Import Bank financing, the ability to finance coal-related construction projects in foreign countries as part of the ICCT deployment strategy, and should be empowered to engage in bartering transactions to accommodate variations in exchange rates.

Chapter I

Principles Guiding Government Participation In ICCT Deployment

A long-accepted view of the federal government's role in supporting technical development downstream from basic research is that it should not actively support activities that primarily benefit private industry. According to this view, the U.S. system should rely on the free market to provide the competitive incentives to improve efficiencies and create innovative products, processes, and services. The success of the U.S. system results largely from the encouragement it provides for improved productivity and private sector responsibility for technology commercialization.

These attributes must be preserved. But it must also be recognized that the globalization of competition confronts the nation with a rapidly evolving new situation in which domestic market forces are often less important than market competition across national boundaries. In addition, the loss of leadership in critical fields may have a cumulative effect that not only strips the United States of technological know-how in those areas, but also seriously depletes the nation's overall capacity to compete in related fields.

Although U.S. companies have traditionally sought to optimize their performance by individually satisfying the needs of their customers, stockholders, and employees, the sum total of their actions may not provide an adequate solution for the global competitiveness problem of U.S.-based production. To ensure that the health, welfare, and security needs of the country are satisfied, the federal government, in cooperation with industry, should concern itself with technological opportunities that:

- Provide benefits which cannot be fully captured by the firms that make the investment, and thus must be considered in the nature of a public good
- Have a social and economic impact on large segments of the U.S. population
- Transcend the capabilities of a single company or industry

This report examines whether the accelerated deployment of ICCT meets these criteria.

The capability of the private sector in the United States to develop and commercialize energy technology has declined in recent years as a result of market constraints and unstable or unresponsive policies. At the same time, the need for new technology has become more intense to meet national energy requirements. As recommended by the Energy Research Advisory Board (ERAB), "this paradox can be resolved only if government takes the initiative in establishing a stable institutional policy framework that enables the private sector to get on with its essential work." This will involve changes in the historic role of government in the United States and will include:

- Establishing a stable planning environment which recognizes the strategic importance and long-term management issues associated with energy and the environment.
- Encouraging new, collaborative efforts among private sector companies to develop and commercialize new energy technologies such as ICCT. Increasingly, individual firms in the private sector can no longer afford to do this job alone. Moreover, DOE's role is necessarily limited. The Electric Power Research Institute (EPRI) and the Gas Research Institute (GRI) have been remarkably successful in a regulated environment. Additional support to take advantage of institutions of this type should be encouraged. Leadership in innovation worldwide is increasingly the result of collaborative enterprises that focus public and private resources and risk sharing in the international competition to attract and build corporate economic base.
- Removing disincentives and, where appropriate, providing equitably distributed incentives to private sector investment in improved energy production and utilization systems which are in the local, state, or national interest. The energy market, like other basic commodity markets, is one in which government encouragement for private sector technology innovation is appropriate given the

fundamental importance of secure, low-cost energy to society. The DOE-cosponsored ICCT demonstration initiative and complementary state coal technology development programs are effective examples of this measured government encouragement for private sector innovation.

- Encouraging environmental policies that enhance energy competitiveness as well as environmental protection. Current risk elimination policies are a fundamental threat to innovation and undermine the unprecedented advances in health and safety that the nation's entrepreneurial system has provided. History shows that preoccupation with "no trial without prior guarantee against error" discourages risk taking and innovation. Indeed, risk aversion and innovation are incompatible.

These major goals will be achieved through many individual government decisions. To strike the right balance over time, DOE must be a persuasive and persistent advocate of a strategic, consistent, and effective national energy policy. Accelerated ICCT deployment provides a unique prototype for refining the collaborative innovation concept on a national scale, and must be an important element of this policy.

If government is to effectively accelerate ICCT deployment, it must be prepared to participate more actively in efforts directed at enhancing the health of the commercial sector while relying on industry and the marketplace to identify the products and services that will be offered. What is fundamentally needed is the capability and willingness to anticipate future circumstances rather than, as so frequently occurs, merely responding to an immediate crisis. The appropriate government role is to act in a proactive but non-interventionist manner to accelerate market-driven innovation, remove unnecessary barriers, provide appropriate incentives, and catalyze private sector-managed collaborative efforts that are required for competitiveness in a global market.

Because ICCT deployment will be so heavily dependent on implementation through the electric utility industry, state governments play an especially significant role. They should support a strong science and technology infrastructure, as well as policies that encourage economic development. The states also have unique capabilities pertinent to ICCT deployment that are not easily duplicated at the federal level. For example:

- State governments are generally more aware of, and responsive to, the needs of local industry.
- History shows that states can implement innovative programs more readily than the federal government.
- States can join together to generate programs that will benefit an entire region.

A variety of incentives are already in place for ICCT and other pollution control equipment at the state level. These are summarized in Tables 1 and 2.

Government participation of this type in the ICCT deployment process is not intended to subsidize the private sector. Rather, it is to forge national public-private cooperation to share costs and risks during the commercial maturation of specific, privately developed technologies whose widespread application is in the public interest. Involvement is premised on obtaining benefits for the public that are not priced in the marketplace and, therefore, are not part of private decision making.

Further, government participation should be greatest where the risk is greatest—in the early stages of deployment—tapering off as commercial maturity is approached and risks shrink. This participation is consistent with the ongoing DOE-cosponsored ICCT Demonstration Initiative, and is expected to involve less than 5 percent of the total anticipated ICCT market over the remainder of this century (see p. 18). Government support in ICCT development over the past two decades has been important in bringing these technologies to the point at which they are ready for deployment. However, without substantive and timely government support during the deployment effort, ICCT commercialization will either not take place or be seriously delayed. There are two primary reasons for this:

- The required deployment effort involves technical, commercial, environmental, and regulatory risks too large for individual companies or industries to accept alone while still meeting obligations to ratepayers, shareholders, investors, or other stakeholders. Several factors accentuate this problem. Energy R&D is conducted in an unusually volatile market because the price of the benchmark fuel, oil, is set not only by supply and demand, but also by cartel and geopolitical factors. In addition, an innovating firm is not likely to capture even a majority of the economic benefits of its technical knowledge, and policy uncertainties increase market risk including premature product obsolescence.
- ICCT deployment must be accelerated to have proven, environmentally sound and cost-effective technologies commercially available over the next decade. If ICCTs are not available, the electric utility industry will be limited to existing technology, coal switching, or shifts to more risky/expensive fuels to accommodate

TABLE 1

Clean Coal Development Incentives by State

	Allows R&D Costs in Ratebase	Allows Pollution Control Equipment In Ratebase	Recognizes R&D Expenses For Tax Purposes	Rate Incentives Specifically For ICCT
Alabama		•		
Alaska				
Arizona	•	•		
Arkansas	•	•		
California	•	•	•[1]	
Colorado	•	•		
Connecticut		•		
Delaware	•	•		
Florida	•	•		•[5]
Georgia	•	•		
Hawaii		•		
Idaho		•		
Illinois	•	•		
Indiana	•	•		•[6]
Iowa		•	•[1]	
Kansas	•	•		
Kentucky	•	•		
Louisiana	•	•		
Maine	•	•		
Maryland	•	•	•[2]	
Massachusetts		•		
Michigan		•		
Minnesota		•		
Mississippi	•	•		
Missouri	•	•		
Montana		•		
Nebraska	•	•		
Nevada	•	•		
New Hampshire	•	•		
New Jersey	•	•	•[2]	
New Mexico	•	•		
New York	•	•	•[2]	
North Carolina		•		
North Dakota		•		
Ohio		•		•
Oklahoma	•	•		
Oregon	•	•		
Pennsylvania	•	•		
Rhode Island		•	•[3]	
South Carolina		•		
South Dakota	•	•		
Tennessee				
Texas		•		
Utah		•		
Vermont	•	•	•[2]	
Virginia		•		
Washington		•		
West Virginia		•	•[4]	
Wisconsin		•	•[1]	
Wyoming		•		

(1) Income Tax
(2) Sales and Use Tax
(3) Favorable Depreciation
(4) Credit Against Severance and Franchise Tax
(5) Discretionary
(6) Approval Pending

SOURCE: Innovative Control Technology Advisory Panel

TABLE 2

State Tax Credits, Exemptions, and/or Reductions for Pollution Control Equipment

	Income	Sales/ Use	Property	Ad Valorem	Accelerated Depreciation
Alabama	•	•		•	
Alaska					
Arizona					•
Arkansas		•			
California					•
Colorado					
Connecticut	•	•	•		
Delaware					
Florida			•		
Georgia		•	•		•
Hawaii		•	•		
Idaho		•	•		
Illinois		•	•		
Indiana		•	•		
Iowa			•		
Kansas					
Kentucky		•	•		
Louisiana					
Maine		•	•		
Maryland		•			
Massachusetts	•		•		
Michigan		•	•		
Minnesota			•		
Mississippi					•
Missouri		•			
Montana			•		
Nebraska		•			
Nevada					
New Hampshire			•		
New Jersey			•		
New Mexico					
New York			•	•	
North Carolina		•	•		•
North Dakota					
Ohio	•	•	•		
Oklahoma	•				
Oregon	•				
Pennsylvania		•			
Rhode Island		•	•		•
South Carolina			•		
South Dakota					
Tennessee		•	•		
Texas					
Utah					
Vermont			•		
Virginia		•	•		
Washington					
West Virginia	•				
Wisconsin					•
Wyoming			•		

SOURCE: Innovative Control Technology Advisory Panel anticipated growth in electricity demand and to replace/refurbish a sizeable number of its aging power plants.

Arguments for Goverment Participation

Several arguments support increased and stable government involvement in deployment of ICCT. They include:

- Environmental controls are required by government actions. Without compensating government actions such as those recommended in this report, coal may not remain competitive as a national resource, thereby depriving the market of access to the full benefits of broad coal utilization and a full set of energy options. Support for retrofit ICCT deployment would compensate for this market intervention and give industry positive, dynamic incentives to implement new environment-saving coal technologies.
- The burden of maintaining national energy security over the coming decades is likely to fall to coal. New/repowering ICCTs in particular will be necessary to protect the economic attractiveness of coal in the face of increasing environmental requirements, and thus make coal a more attractive energy option for all segments of society. Therefore, government support for deployment contributes to the national policy goal of reduced dependence on foreign oil and long-term energy security.
- Increased coal utilization can make an important contribution to international competitiveness by reducing both U.S. energy costs and the foreign trade deficit. For example, the United States spends 10 percent of its GNP on petroleum-based energy costs, while Japan spends only 4 percent. This represents a difference of $200 billion/yr not available for investment elsewhere in the economy. Further, oil imports accounted for $44 billion (26 percent) of the nation's trade deficit in 1987.
- The historic U.S. technological leadership in coal utilization technology is rapidly being lost as a result of increased foreign competition and temporarily depressed domestic markets. This is particularly true for combustion and environmental control technology.
- The market battle is primarily being lost in the cost-intensive demonstration/deployment stages of development where foreign sources, as a result of superior government cooperation and support, are able to better shoulder the risks and liabilities associated with the commercial introduction of new technology. This is especially disturbing to private industry which has invested over $1 billion in the past decade to bring the array of ICCTs to the point of deployment.
- The regulated electric utility industry, which is far and away the primary domestic user of coal, faces many disincentives to applying innovative technology. This stems primarily from the fact that the regulatory process places the burden of risk on the stockholder without commensurate opportunity for profit, or even assurance that the risk will be shared among other beneficiaries of successful implementation. This problem is particularly acute for retrofit and new/repowering ICCTs where rigid environmental and regulatory requirements further emphasize guaranteed performance of existing technology at least cost rather than innovative improvement.
- Public-private risk sharing partnerships are prevalent within the world's industrial nations, and are an important factor contributing to the competitiveness of products from these nations in international markets. These partnerships have eroded U.S. leadership in many arenas, including coal utilization technology. Government support for ICCT deployment would provide a counterbalance for U.S. technology in competition with foreign public-private consortia, and would thus improve the nation's export opportunities.

Responses to Arguments Against Government Participation

Arguments against government participation in accelerating ICCT deployment typically stem from several misconceptions. These include:

- Argument: Accelerated ICCT deployment will give coal an unfair competitive advantage in the energy market.

  Response: On the contrary, the objective is to allow coal, as the primary national energy resource, to remain competitive in the energy market while meeting environmental constraints imposed by society. Accelerated deployment is intended to match the accelerated pace of these legislative and related environmental activities so that coal remains a viable market choice.

- Argument: Government action to share private sector risks or costs will distort the energy market.

  Response: This argument incorrectly suggests that the deployment process is endless rather than applying only to the limited number of installations necessary to achieve confident commercial application for technologies

The Need for Broad Public Support of ICCT

Public opinion is a factor of major importance in deciding which energy options the nation pursues. Negative public perceptions of health and safety issues relating to nuclear power, for example, have been largely responsible for licensing and siting difficulties that have stalled the widespread application of nuclear technology.

Public perceptions will have an equally powerful influence on whether ICCT deployment can be accomplished in the existing window of opportunity. Whether that perception is favorable will depend on the extent to which the public receives clear, accurate information that explains how ICCT will serve the public need for secure, abundant, reasonably priced, environmentally benign energy.

The immediate goals of a public communication program are to build support to obtain: sufficient time for ICCT deployment; continued federal and state involvement in ICCT demonstration and deployment; state and local regulatory support for ICCT deployment; and private sector participation in ICCT projects.

A public communication program designed for this purpose must include at least four elements.

1. **It must emphasize the environmental as well as the strategic and economic advantages of ICCT.** The public's desire for a clean environment is a force which cannot be underestimated. Outmoded images associated with coal use—belching smokestacks and miners' faces covered with coal dust—have lost some of their strength due to improved worker safety practices and air pollution control. Nevertheless, ICCT is not likely to find public support unless coal's image as dirty fuel to both mine and burn is supplanted by a new public vision of coal as clean and high-tech.

   The public perception of coal's impact on a broad range of environmental issues must be recognized and addressed. If the public can be shown that these impacts can be controlled at less cost through ICCT, then "crisis" induced retrofit policies may be avoided. The public must be convinced of industry's commitment to decreasing emissions.

   Because mainstream environmental groups have a relatively high degree of public credibility, their support for ICCT will be crucial to obtaining public support. The support of environmental organizations, which have developed significant lobbying capability, will also influence Congressional, state legislative, and local policy debate.

2. **It must comprehensibly communicate the results of ICCT demonstrations as concrete evidence of the economic, technical, and environmental benefits of these technologies.** Hard data need to be made broadly available and packaged in a way that clarifies rather than obfuscates the criteria involved in choosing one technological option over another. Skeptics must be convinced of the validity of an ICCT investment strategy and the integrity of financial evaluation of ICCT projects and be made aware of the extent of private sector investment in these projects.

3. **It must originate from a representative group of stakeholders from the public and private sectors who are committed to a long-term, cooperative effort to build public consensus based on understanding of, and support for, these technologies.** Such a broad-based group could conceivably be brought together under the aegis of the Secretary of Energy. It would include electric utilities, technology developers, coal producers, industrial coal users, and representatives from state governments with ICCT programs in place.

4. **It must be backed up by a consistent federal energy policy that firmly establishes ICCT as one of its key**

developed and selected by the private sector. The objective is not industrywide subsidization but limited risk sharing to accelerate commercial maturation. This will encourage, not restrict, choice in the market.

- Argument: Action by government to absorb a portion of cost or risk means that risk will not be taken by private sector firms.

  Response: This argument ignores the real world in which ICCT deployment must take place. For example:

  - The majority of ICCT users will be in regulated industries lacking profit incentive commensurate with the risks of commercially introducing emission control technology whose primary economic beneficiary will be the consumer/ratepayer.
  - The regulated utilities and their ratepayers have borne a large portion of the development burden for ICCT technology. Adequate mechanisms are either not available, or are not being applied, in the current regulatory climate to assure commercialization. Thus, the economic benefits of ICCT to the consumer/ratepayer will be inhibited.
  - Foreign manufacturers are moving into the market, as discussed above, with private/public collaboration designed to reduce commercialization risks to those foreign manufacturers relative to their U.S. counterparts.
  - Government risk sharing in ICCT deployment is expected to involve less than 5 percent of the potential domestic market over the remainder of the century, and therefore will not provide a competitive advantage discouraging investment, risk taking, or market choice across the industry.

- Argument: Government participation in the acceleration of ICCT deployment means just financial subsidies.

  Response: This argument ignores the opportunities that both federal and state governments have to remove both financial and regulatory disincentives to ICCT investments, disincentives such as those pointed out by the President's Task Force on

elements. Working through Congressional subcommittees and interagency liaison groups, the Department of Energy can use its influence to sustain the clean coal technology thrust in the face of arbitrary changes in direction and funding levels, whether by Congressional mandate or changes in laws and regulations.

Key Audiences

A public communication program needs to focus on three major groups:

- Decision makers. At the federal level these include members of Congress and staffs of key agencies such as the Department of Energy,Environmental Protection Agency, Office of Management and Budget, Department of Interior, and Federal Energy Regulatory Commission. At the state level, they include governors, state legislators, public utility commissioners, and state environmental officials. At the local and regional levels, they comprise a variety of officials who decide on facility siting and permitting issues for specific projects. In the private sector, industrial managers and directors who select, purchase, and operate coal utilization and environmental control facilities are particularly important.
- Opinion makers. This group encompasses environmental organizations,media, the financial community, labor organizations, consumer groups, trade organizations, technical and professional societies, civic groups, and educators.
- The general public.

Key Messages

Points to be emphasized would depend on the audience being addressed, but in general key messages would be:

- Coal is the nation's most abundant fossil energy resource and the only one which could provide domestic self sufficiency in the foreseeable future.
- In the interest of security and economic health, the clean, efficient use of coal needs to be the cornerstone of national, state, and local energy policy.
- ICCT can control air, groundwater, and toxic solid pollutants more cost-effectively than can alternative methods or technologies for coal-based power production.
- ICCT is a responsible and lasting way to improve the environment while ensuring an abundant, secure, and economic source of energy.
- Advanced coal-conversion technology using ICCT building blocks is the means for the United States to become a winner in the global market for innovative technology and in the solution of a major world resource issue.

Implementation Program

An implementation program should take advantage of existing forums for advancing the case for ICCT and should create additional ones by means of speeches, seminars, school programs, and media campaigns aimed at industry and trade as well as public media. Particularly useful efforts could come from the private sector. Some features of a privately funded program might be: a proactive media resource center on clean coal technology with media kits and an article placement service; a clean coal advocates speakers bureau; and a Washington forum as a national event in early 1989 that would stimulate Congressional and media interest in the benefits of ICCT.

Regulatory Reform. The argument also does not distinguish between the two fundamentally different categories of ICCT technology and the corresponding government roles—specifically, new plant and repowering systems that potentially improve the productivity and economics of coal use in contrast to retrofit emissions control options intended to respond to environmental policies affecting existing plants. Some of the former are being deployed with minimal government involvement, while the latter may require much greater government encouragement since the primary beneficiary is the electricity consumer/ratepayer, not the regulated utility bearing the risk. There will be no market for retrofits in the absence of new statutory or regulatory requirements.

- Argument: Immediate environmental legislation will provide a sufficient market incentive for ICCT commercial application.

  Response: The nation's expensive experience with legislation forcing application of flue gas scrubbers underscores the fallacy of this argument. Such requirements tend to freeze technology and inhibit further development. Under such circumstances the cost and productivity savings achievable through ICCT would be largely lost to the nation. Environmental regulations must provide a compliance schedule consistent with the time frame required for development, demonstration, deployment, and broad commercial application.

- Argument: Government participation in the acceleration of ICCT deployment should be limited to the state level.

  Response: Although state governments are an important partner in the deployment effort, such a position ignores both the national importance of the initiative and the fact that national policies related to environmental requirements, economic stability, energy security, and international competitiveness have accelerated the need for such technology. Federal government participation becomes an important element of the equitable risk sharing, collaborative effort necessary to satisfy these national policy objectives.

Chapter II

ICCT Deployment: Scope and Constraints

The need for a well-thought-out, comprehensive ICCT deployment effort is based on commercial realities. In order for a new technology to be regarded as commercially available, it must have acquired sufficient testing and operating experience at large scale to have established its technical feasibility and its economic competitiveness in the marketplace with other commercially available options. Also, it must be commercially offered with appropriate performance guarantees by vendors.

During deployment, performance and reliability risks of the new technology are defined, quantified, and resolved through operation and evaluation of a series of successive commercially sized demonstration units selected and applied by the ultimate user. Allowances for uncertainty, such as design margins and equipment redundancy, are systematically reduced or eliminated as operational confidence and reliability are established, thereby reducing capital and operating costs accordingly.

The Proposed Scope of ICCT Deployment

The scope of the deployment effort required to confidently prove ICCTs typically involves technical, commercial, environmental, and regulatory risks too large for individual companies or industries to accept alone while still meeting obligations to ratepayers, shareholders, investors, or other stakeholders.

No single technology covers all market segments in a cost-effective manner. Therefore, deployment of a number of promising ICCT options is necessary. Moreover, realization of commercial potential requires that there be multiple demonstrations of each technology. This need is especially critical in the electric utility industry where reliability is of paramount importance. Here, complementary demonstrations addressing the range of designs, fuels, and operating variables faced by the user will be necessary to achieve confident and cost-competitive commercial application.

Figure 1 illustrates this as a matrix of technology categories versus major demonstration needs (illustrative, not all-inclusive). The technology categories shown on the figure fall into three major groupings: fuel upgrading, SO_2 and NO_x emissions control, and advanced combustion and gasification. These technologies were described in some detail in the June 1986 National Coal Council report, *Clean Coal Technology*.

The demonstration needs shown in the figure fall into four major groupings: sector, application, fuel, and design issues.

- **The industry sector (utility or nonutility)** into which the potential user falls affects his perspectives on all of the major risk components—technical, market, regulatory and environmental. In general, firms in the nonutility sector have more ability and incentive to take calculated technical and financial risks than regulated utilities. This point is illustrated by the fact that 109 atmospheric fluidized-bed combustion (AFBC) units are now generating power or are on order in the nonutility sector in North America, versus 11 in the utility sector. (The relatively smaller size of nonutility units is also relevant.)
- **The application (retrofit versus new/repowering)** for which the ICCT is needed by the user determines which technologies are applicable as well as what the major design criteria and constraints will be. The nature of the existing site and facilities, plus a set of new environmental permit requirements, will dictate a narrow band of performance and technology options in the case of a retrofit project. A repowering project also must adapt to an existing facility, but with more latitude to invest in modernizing the plant while simultaneously improving its environmental performance, productivity, fuel flexibility, and output. Even greater flexibility generally exists for a new plant application, although the specific user requirement will still determine the technology selected.
- **Fuel choices** that are competitively available

FIGURE 1 Clean Coal Technology Demonstration Needs and Status*

Technology Category	Sector: Utility	Sector: Non-utility	Application: Retrofit	Application: New/ Repower	Fuel: High-S Bit. Coal	Fuel: Low-S Bit. Coal	Fuel: Low Rank Coal	Design Issues: Boiler Design	Design Issues: Process Design	Design Issues: Scale	Demonstrations U.S.: Operating	Demonstrations U.S.: Pre-operational	Demonstrations Foreign: Operating	Demonstrations Foreign: Pre-operational
■ Fuel Upgrading														
1. Coal Cleaning and Upgrading	▒ ●	▒ ●	▒ ●	▒ ●	▒ ●	▒	▒		▒ ●	▒	0	1	4	4
2. Coal Liquefaction	▒	▒ ●	▒	▒ ●	▒ ●	▒	▒		▒ ●	▒	0	2	2	0
■ SO_2 and NO_x Emissions Control														
3. Advanced Flue Gas Desulfurization	▒ ●		▒ ●	▒ ●	▒ ●	▒ ●	▒ ●		▒ ●	▒	1	3	7	3
4. Sorbent Injection**	▒ ●		▒ ●		▒ ●	▒ ●	▒ ●	▒ ●	▒ ●	▒	3	4	8	5
5. Low NO_x Combustion**	▒ ●	▒	▒ ●	▒	▒ ●	▒ ●	▒	▒ ●	▒ ●		5	6	5	2
6. Post Combustion NO_x Control	▒ ●		▒ ●	▒ ●	▒ ●		▒ ●	▒ ●	▒	▒	0	2	6	5
7. Combined SO_2/NO_x Control	▒ ●	▒ ●	▒ ●	▒ ●	▒ ●	▒ ●	▒	▒ ●	▒ ●	▒	0	2	3	6
■ Advanced Combustion and Gasification														
8. Atmospheric Fluid Bed Combustion	▒ ●			▒ ●	▒ ●	▒ ●	▒ ●		▒ ●	▒	9	4	10	2
9. Pressurized Fluid Bed Combustion	▒ ●	▒		▒ ●	▒ ●	▒	▒		▒ ●	▒ ●	0	2	0	5
10. Slagging Combustion	▒ ●	▒ ●	▒ ●	▒ ●	▒ ●	▒ ●	▒	▒ ●	▒ ●	▒	1	2	0	0
11. Integrated Gasification Combined Cycle	▒ ●	▒ ●		▒ ●	▒ ●	▒ ●	▒ ●		▒ ●	▒	3	4	3	1
■ Other											0	6	1	2
Total Demonstrations**											22	38	49	35
Total Projects**											20	36	47	35

▒ Demonstration needed ● Relevant U.S. demonstration

* Appendix C lists U.S. projects and selected foreign demonstrations.

** Six projects are demonstrating both sorbent injection and low NO_x combustion technologies. Therefore, they are double-counted except in the "Total Projects" line.

BASIS: Innovative Control Technology Advisory Panel and Electric Power Research Institute

to the user are dictated by geography and the transportation infrastructure. Today's mature coal combustion technology is fuel-specific: a plant designed for a specific high-sulfur bituminous coal looks and operates differently from a plant designed for a low-sulfur bituminous coal, and both are different from a plant designed for a low-rank coal. The fuel flexibility of the advanced combustion and gasification technologies is one of their major advantages. However, commercial-scale operating experience is the only way to validate this flexibility and confidently map the envelope of applicability for each technology to the range of fuels available.

- **Design issues** include such items as the type of boiler to which a retrofit SO_2 or NO_x control system is to be applied; the competing versions of a technology, such as circulating versus bubbling AFBC, or entrained versus fluidized gasifiers; and the engineering issues involved in scaling up a technology such as AFBC from 20 MW, to 200 MW, to 400 MW, etc. A complete list of such design issues (or technical options and risk factors) would be a long one, but these three examples illustrate the point that one demonstration—even at full scale, including a comprehensive test program, and achieving all of its technical objectives—is insufficient to address the commercialization issues facing the coal-using industry at large.

Analysis of these risk and applicability issues as they relate to moving down the "technology learning curve" (see Figure 3, page 20) leads to the conclusion that a deployment program consisting of 65 to 85 ICCT demonstration projects would cover the highest priority needs of the coal-using industries and allow the successfully demonstrated ICCTs to begin competing in the commercial arena. This number of projects is determined by the fact that between three and 10 projects will be needed per technology category, depending on the nature and number of risks associated with each technology.

The "risk costs" (see page 19) of ICCT deployment appear to be manageable within the framework of the $2.5 billion DOE-cost-shared ICCT Demonstration Initiative. If a "typical" project averaged 100 MW in size, for example, the total cost-shared program would involve no more than 5 percent of the potential market for ICCT between now and the year 2000—a level consistent with national joint ventures under way by both Japan and West Germany to accelerate the commercial availability of advanced coal technology in those countries and abroad.

Implicit in this scenario is the assumption that industry and DOE would collectively plan and select the "right" portfolio of demonstration projects. The plan and the selections would be based on technical and market insight rather than political factors. Key ingredients in the success of such a joint government/industry program would be consistent and persistent DOE leadership to protect the program's technical integrity, and active, functioning advisory bodies such as ICTAP and ERAB which would bring the collective industry and public perspectives to bear in a focused manner.

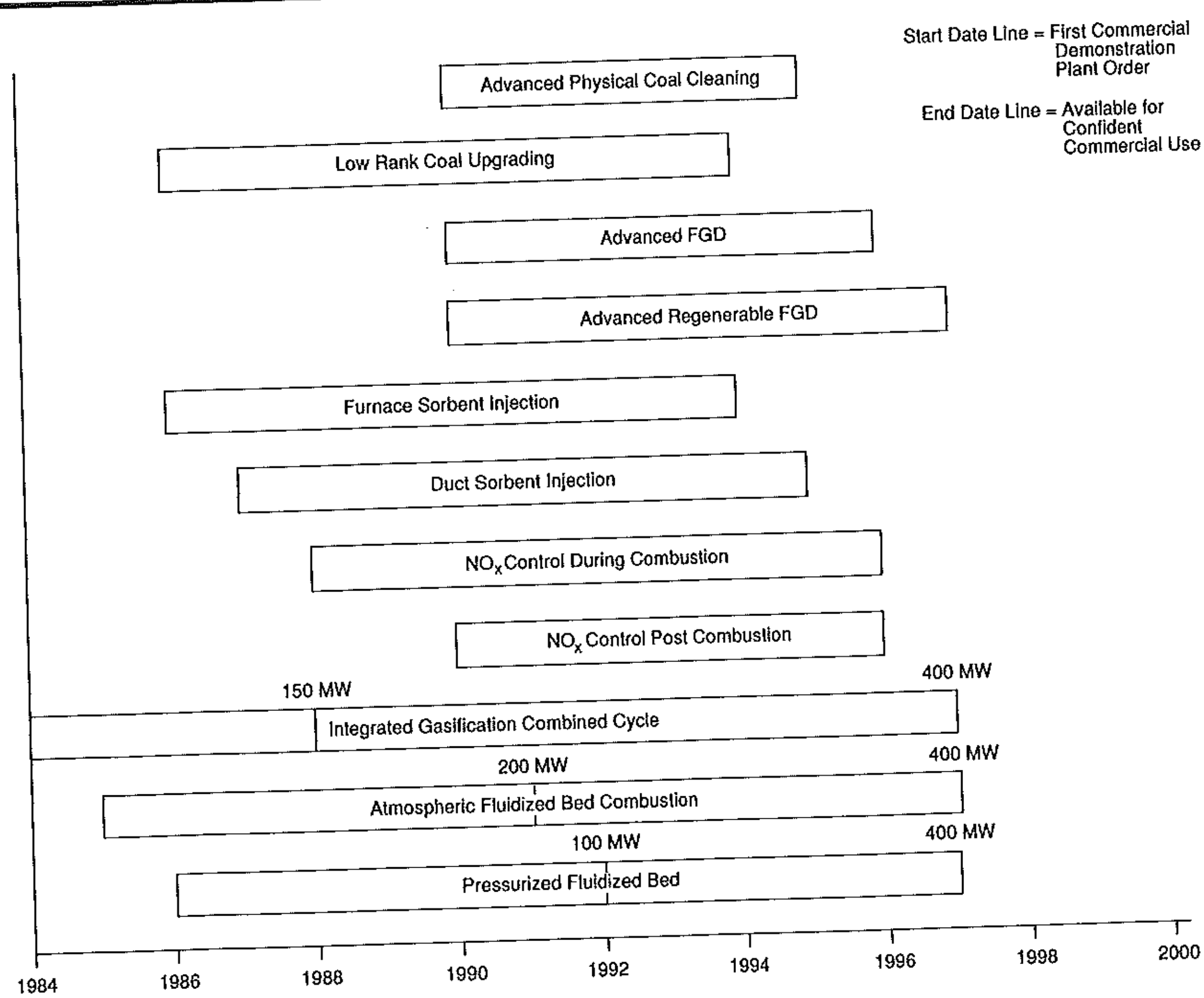
Assuming no delays in implementation of the DOE-cosponsored ICCT Demonstration Initiative, Figure 2 indicates that commercial maturity could be achieved prior to the year 2000. At that point, the various technologies will have demonstrated their commercial potential across the envelope of application and be ready to compete on their economic merits in the marketplace. Full utilization will potentially involve a market of more than 140,000 MW of existing coal capacity plus an additional 170,000 MW of new and repowering capacity over the next 20 years.

The magnitude of the market for ICCT must be considered in terms of the additional time necessary to achieve commercial equilibrium—a process which can be expected to take at least an additional five to 10 years beyond the commercial maturity dates shown on Figure 2.

Financial Constraints

Incremental costs associated with mounting a deployment effort are defined by the concept of "risk cost," the net difference in capital cost and O&M and other costs between the first commercial unit and the Nth (mature) unit of a given technology. This cost increment is shown in Figure 3, a depiction of the characteristic learning curve associated with

FIGURE 2 Estimated Deployment Time Period for ICCTs



BASIS: Clean Coal Technology Coalition and Electric Power Research Institute the development and commercial deployment of new technology. It is at the "first commercial service" step shown on this figure that the size and cost of the facility necessary to ensure reliable operation are the greatest. As the learning curve continues, each succeeding installation entails less risk and therefore less engineering margin and redundancy until full commercial maturity is reached.

The risk cost for ICCT represents a significant barrier to technology developers/suppliers and users—acting alone or together. This is especially true today for developers/suppliers because the markets for these emerging technologies do not yet fully exist—indeed the market for currently available environmental control equipment is depressed. As a result, private developers/suppliers will either wait for the market to develop or—as in the ongoing DOE ICCT demonstration program—receive government assistance to reduce the risk of technology development in anticipation of a future market. If a developer/supplier were to wait for the market to develop, the ICCT options would not be confidently available when users need new capacity.

Despite the risks and uncertainties associated with a deployment effort of the size envisioned, the electric utility industry has assumed increasing leadership for the development of ICCTs. Today, the utility industry is one of the nation's most technologically intensive industries, with a steadily growing commitment to research, development, and demonstration. Both independently and through EPRI, the industry has already spent more than $1 billion moving ICCTs forward to commercial maturity.

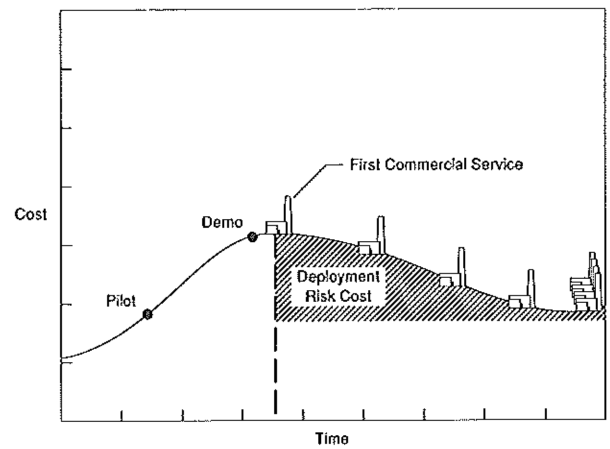
Regulatory Constraints

Regulatory constraints—existing and potential—represent another impediment to more aggressive private sector effort to deploy ICCTs. This is particularly true for the regulated utility industry, the primary domestic user of coal technology. Therefore, to complement government risk sharing of ICCT demonstration projects, regulatory changes to remove constraints and provide incentives to investment in ICCT are required.

In the electric utility industry, the regulatory process tends to place the burden of risk on the shareholder without commensurate opportunity for profit, or even assurance that the risk will be shared among other beneficiaries of successful implementation of new technology. This problem is particularly acute for innovative emissions control technologies where rigid environmental regulatory requirements further emphasize guaranteed performance of technology at least cost, rather than fundamental performance improvement through innovation.

Since ICCT deployment in most instances will involve costs for facilities that exceed those normally incurred in plants providing the same electrical capacity, a utility must be provided some type of assured rate base treatment for appropriate ICCT deployment projects.

FIGURE 3 Technology Learning Curve



SOURCE: Electric Power Research Institute

Problems may also arise due to the split in regulation of wholesale and retail rates between the Federal Energy Regulatory Commission (FERC) and the state Public Utility Commissions (PUCs). When a state PUC or FERC provides for appropriate rate base treatment of the extra costs of ICCT facilities, but the other does not, one group of ratepayers is treated inequitably. If ICCT facilities are appropriate, then all of the ratepayers served by the utility should help support the effort.

Electric utilities face the additional significant risk of being judged by their regulatory commissions to have acted imprudently were they to make expenditures to retrofit or repower an existing generating facility with a clean coal technology designed in whole or in part to reduce emissions. Such action by a utility, while perhaps beneficial to the environment, may not be a required action, in which case a regulatory body may disallow some or all of the costs involved. This judgment by a regulatory commission could be made long after substantial commitments and expenditures have been made. The potential for retrospective prudence review of projects involving advanced technologies acts to discourage utilities from any such commitments.

For the investor-owned utility, the shareholders and creditors assume these financial risks unless these costs can be recovered from the ratepayer. On the other hand, rural electric cooperatives are normally owned by their users and may be customers of other utilities as well as important users of coal for electric power generation. They can be regulated by state PUCs and/or FERC. In some jurisdictions, these cooperatives need the approval of both the state PUC and FERC to recover deployment expenditures.

Municipal utilities are essentially self-regulating and purchase power wholesale under rates established by FERC. The municipal must recover deployment costs from its customers. Finally, the independent power producer or cogenerator must recover any deployment costs as part of its negotiated selling price of power, generally at an avoided cost of power generated by proven technologies.

The potential for new, more stringent environmental controls represents a large uncertainty and constraint on ICCT deployment given the as yet unproven commercial status of most of these technologies. Consequently, in the event new controls were mandated, private sector financial resources that would have been available for further ICCT deployment would likely be diverted to install existing commercial emission controls, switch to lower-sulfur compliance coal or other fuel resources, or retire facilities. The effect would be to reduce ICCT funding to insignificant levels and lock in today's emission control state of the art, as is now happening in West Germany following promulgation in 1984 of strict emissions standards which require compliance by individual plants within six years.

West Germany's investment in existing control technology has been an important factor in the rise of electricity costs in that country. These costs are now by far the highest in Western Europe (as indicated in Appendix D, Figure D-8), and are expected to remain inflated through the completion of this investment program. Acceptance of a more technically flexible compliance program which would have taken advantage of the rapid improvements occurring in environmental control and coal utilization technology could have substantially moderated this cost impact.

Perhaps the best example of the negative impacts of forced, premature deployment of environmental control technology is the national experience with flue gas desulfurization technology in the 1970s.

Given the possibility of more stringent near-term environmental controls, utilities are now confronted with the question of whether it is prudent to embark on a program for the installation of new clean coal technologies to reduce emissions and meet new load (or to retrofit or repower existing units), or to wait for definitive action. Should a utility proceed with installation of a retrofit technology that achieves less than NSPS levels of emissions control, and then a new control program be enacted, the utility's investment might prove to be insufficient as a means for compliance and, therefore, be lost. Without some form of safe harbor/cost recovery protection, it is unlikely that utilities would undertake clean coal technology projects which achieve less than NSPS levels of control.

The Costs of Brute Force

The history of lime/limestone flue gas desulfurization (FGD) scrubbing technology in the United States provides a valuable but very expensive lesson on the price of exchanging "technology forcing" legislation and regulation for a cooperative development and deployment effort.

Contrary to sound development practice, FGD scrubber technology bypassed stepwise process development and was prematurely deployed at commercial scale as a result of legislative and regulatory requirements. The difficulties of deploying this partially developed technology were compounded by an adversarial atmosphere where the emphasis was on least first cost without adequate understanding of, or insurance against, the performance and reliability risks involved.

As a result, this "brute force" approach to development and deployment has involved over 50,000 MW of electric generating capacity at a total cost to the utility industry and ratepayer of over $20 billion (in 1988 dollars) in capital, operating, and lost generating capacity costs during the past 15 years. Only now is the technology approaching acceptable reliability, although at an excessive cost for operational risk protection and redundancy which still requires substantial development attention as reflected in proposals to Phase 2 of the DOE ICCT Demonstration Initiative.

Had FGD scrubber technology been developed and deployed in a more rational and cooperative manner by investing $1–2 billion in technical demonstrations involving no more than 2000 MW of capacity, the total cost to scrub the 50,000 MW could have been substantially reduced with no delay in reducing SO_2 emissions. In addition, the legacy of poorly performing or obsolete commercial scrubber installations and the resulting ill will on the part of the user could have been avoided.

Chapter III

ICCT Implications for Environmental Control and Energy Costs

ICCTs offer a number of potential advantages not attainable with existing coal-fired generating technologies and environmental controls. Primary among these is the potential to reduce the costs associated with emissions control on existing coal combustion facilities, and to achieve greater and more sustainable reductions in emissions from new/repowered facilities.

Improvement in the productivity/cost-effectiveness of coal use is the primary goal of both coal producers and users. New and repowering ICCTs such as fluidized-bed combustion (FBC) and coal gasification are especially attractive options for cost control and environmental protection. Environmental interests, on the other hand, emphasize further immediate reductions in SO_2 and NO_x, and thus tend to focus on retrofit options for controlling these two pollutants in mandated application to existing plants.

Figure 4 approximates the impact of alternative emission reduction scenarios on future SO_2 and NO_x emissions. The key difference between the two is that NO_x emissions are unlikely to decline unless ICCT is implemented.

The base case for electric utilities using existing environmental control technology is represented by the bold solid lines in the figure. Key assumptions include:

- 2.1 percent average demand growth rate (North American Electric Reliability Council, 1986) and 20 percent reserve margin after 1996
- 60 GW of new gas-fired turbine, combined-cycle, and cogeneration capacity by 2000
- No nuclear additions after 1996
- 60-year fossil plant life
- 40-year nuclear plant life
- No change in fuel sulfur content or control requirements (e.g., 90 percent removal for new coal units with FGD)

Under these anticipated conditions, SO_2 emissions are expected to continue to decline. Even increasing demand growth to 3 percent does not change the basic conclusion that SO_2 emissions will not rise above 1980 levels over at least the next 20 years.

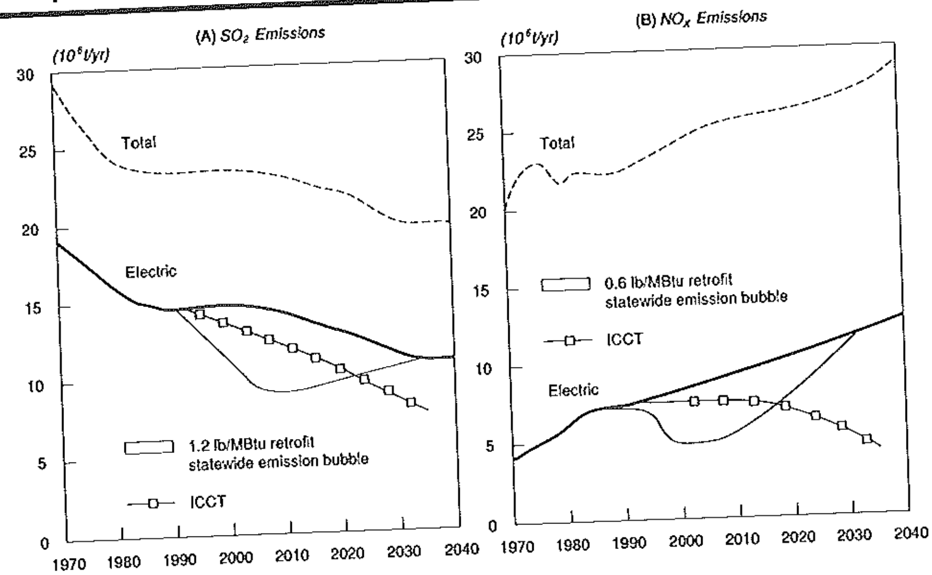
The variable which has the greatest impact on the base case SO_2 projection is fuel sulfur content. It is important to note in this regard that current and projected electric utility SO_2 emission rates remain about 25 percent below the State Implementation Program (SIP) requirements.

The lines superimposed with boxes in Figure 4 A and B conservatively represent the potential impact of ICCT application to new and repowered generating capacity only. This reflects the inherently greater control efficiency of these technologies—based on equal market shares of AFBC, pressurized fluidized-bed combustion (PFBC), integrated-gasification-combined-cycle (IGCC), and pulverized coal with advanced FGD—relative to current technology. This scenario can achieve and, most importantly, sustain a level of emission reduction exceeding that of typical retrofit emission control legislation now being proposed.

In the event that immediate requirements for a retrofit 1.2 lb/MBtu SO_2 statewide emission bubble were imposed by proposed acid rain legislation, the impact would be approximately as indicated by the shaded area on Figure 4A. This requirement would provide an initially larger SO_2 reduction but, because of the cost implications discussed below, the advantage would diminish and ultimately be lost. Any emission control strategy which does not sustain its reduction well beyond that achievable through this retrofit approach is unlikely to demonstrate long-term resolution of the environmental issues for which it is designed.

The comparative cost implications are shown in Figure 5. Legislatively imposed retrofit emission control scenarios relying on existing technology (shaded area) would be as much as $10 billion/yr more than the current cost to meet NSPS/SIPs. Such restrictive emission control legislation and the attendant diversion of resources would act as a powerful deterrent to commercial application of emerging

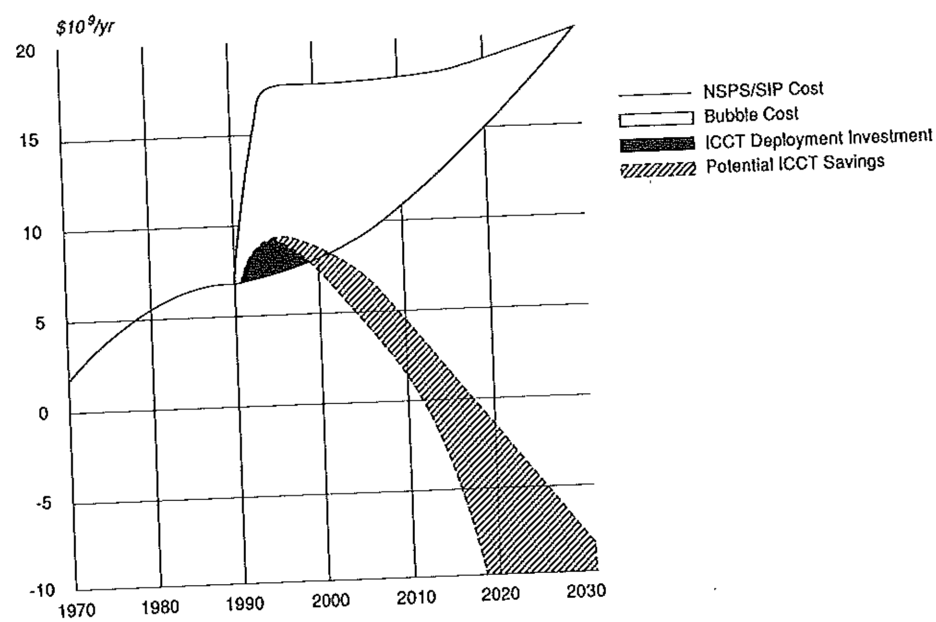
FIGURE 4 ICCT Impact Upon Projected Annual SO_2 and NO_x Emissions



- Total: Total U.S. emissions trend.
- Electric: Electric power emissions based on 2.1% per year demand growth, 20% reserve margin after 1996, 60GW of new gas-fired capacity by 2000, no nuclear additions after 1996, 60-year fossil plant life, 40-year nuclear plant life, and no change in fuel sulfur content or control requirements (baseline).
- New ICCT Plants: Emission trend resulting if power plants utilize innovative clean coal technology. The rate of market penetration is strongly influenced by deployment incentives.
- Bubble: Emission trend resulting from a statewide emission control bubble.

SOURCE: NAPAP and Electric Power Research Institute

FIGURE 5 Annual Utility Emission Control Cost (1986$)



SOURCE: Edison Electric Institute and Electric Power Research Institute

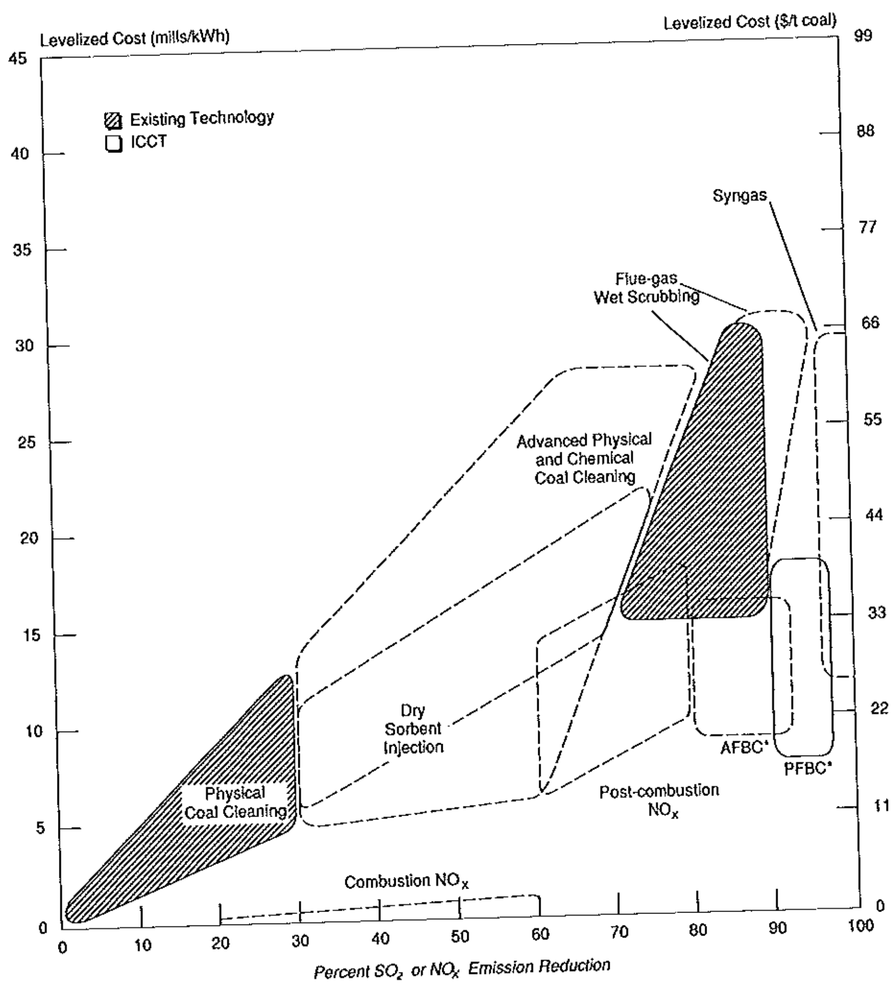
ICCTs to new and repowered plants, tending to freeze existing control technology.

In contrast, costs with ICCT would initially be higher than current NSPS/SIP costs during the deployment phase, but would rapidly begin to decline. By the year 2010, potential savings with ICCTs relative to current practice (NSPS/SIP) could be over $5 billion/yr. In 2030, these potential savings could approach $30 billion/yr based on broad application to U.S. coal-fired electricity generating capacity. These net savings result from the ability of ICCTs on new and repowered plants to integrate and simplify emissions control, thus reducing the major operating cost elements in power generation relative to current technology.

However, if science or public policy requires that existing coal-burning sources also be controlled further, then—for the same level of reduction—a retrofit control strategy whose timing and requirements encourage the cost-effective use of ICCTs is expected to be about 40 percent less expensive than a strategy restricted to current control technology. In achieving a 10 million ton-per-year reduction in SO_2, for example, such a retrofit strategy could save the nation about $3 billion/yr.

Figure 6 compares the levelized cost windows to attain various degrees of SO_2 or NO_x reduction using existing technology and retrofit and new/repowering ICCT options. For retrofit ICCTs whose sole function is environmental control, levelized costs reflect total capital and operating cost. For new/repowering ICCTs, such as AFBC, PFBC, and IGCC—generating technologies with inherent environmental control capabilities—the levelized cost shown reflects only that portion of total process cost directed to environmental control (15–25 percent). As the figure reflects, ICCTs accomplish higher levels of emissions reductions at costs comparable to those of existing technology, or comparable emissions reductions at significantly lower costs.

FIGURE 6 Cost-effectiveness of Clean Coal Options Versus Existing Technology



* Reflects only that portion of total process cost directed to environmental control (15-25 percent)

SOURCE: Electric Power Research Institute

ICCTs and Global Warming

Concern with global warming and the "greenhouse effect" is gaining international attention. Certain atmospheric gases function as a "greenhouse" in allowing solar energy to reach the earth but absorbing surface heat which otherwise would radiate into space. The theory of climate change is not yet able to provide a sure answer to the importance of the enhanced greenhouse effect. More research is needed on atmospheric physics and on modeling the atmospheric-ocean system. Nor can observations over the past century confidently separate climate fluctuations from long-term trends.

Nevertheless, there is growing concern that increased concentrations of so-called "greenhouse gases"—carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and chlorofluorocarbons (CFC's)—are likely, sooner or later, to cause global warming with the increase lowest at the equator and highest in polar regions. CO_2 and N_2O, in turn, are both produced during fossil fuel combustion.

Prior to the industrial revolution, atmospheric CO_2 concentration was 295 ppm. This concentration had reached 335 ppm by 1980 and extrapolations suggest it might double sometime during the next century. This doubling may, in turn, lead to a 1.5°–4.5°C increase in the global average temperature. However, it must be emphasized that these estimates are based on computer models of the climate, a very complex and not completely understood system that is controlled and regulated by solar energy, clouds, the oceans, the evaporation and precipitation cycle, as well as greenhouse gases. The impact of various climate-controlling factors on surface temperature is illustrated in Figure 1. Note that the greenhouse-induced warming is offset by other atmospheric changes, including an increase in atmospheric aerosols, increases in cloud cover, and increases in land albedo.

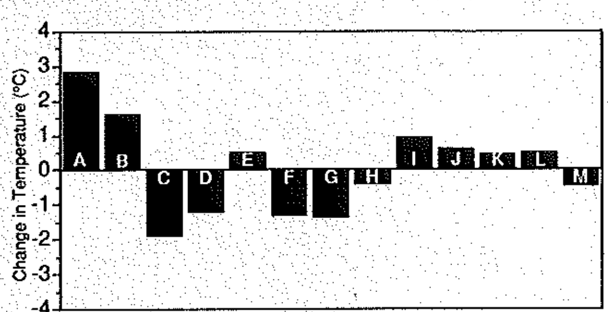
The difficulty of confidently integrating these factors highlights the many uncertainties about the greenhouse effect, especially the timing of the warming trend and the ability of the oceans and the atmosphere to absorb CO_2. Compared to other environmental issues, the greenhouse effect is distinct in that it is first a global issue ultimately affected by, and affecting, every nation and, second, any consistent climate change pattern may not be seen for decades.

As a result, policy responses proposed to date include both mitigation and adjustment, since there is a chance that naturally occurring or anthropogenic factors will not fully counter the effects of increasing atmospheric carbon concentration. Given the uncertainties and importance of this emerging environmental issue, it is essential that coal users and producers participate actively in the scientific, technology, and policy development process at both the national and international level. Of particular importance is the need for direct measurement of the earth's energy balance as a rational foundation for policy development.

Combustion of fossil fuels in the United States today accounts for about 26 percent of global man-made CO_2 emissions. Electric power generation, transportation, and other industrial uses of fossil fuels produce about 35, 30, and 24 percent, respectively, of the U.S. total, with about 11 percent coming from fossil fuel use in homes and businesses. Coal combustion by all sectors in the United States accounts for about a quarter of national CO_2 emissions, or approximately 7 percent of global emissions.

The declining contribution of the United States to man-made global CO_2 emissions is summarized in Table 1. This also indicates the rapidly growing role of the lesser developed countries (LDC), primarily in the southern hemisphere, and their resulting importance in any strategic CO_2 mitigation strategy.

FIGURE 1 Potential Radiative Perturbations of Climate



Legend

	Factor	Assumed Change
A.	CO_2	Increase from 300 to 600 ppm
B.	Solar Luminosity	Increase by 1%
C.	Stratospheric Aerosols H_2SO_4	Increase in optical depth of 0.02
D.	Tropospheric Aerosols H_2SO_4	Increase in optical depth of 0.1
E.	Tropospheric Aerosols, Soot	Increase in optical depth of 0.02
F.	Land Albedo	Increase of 0.05
G.	Low Clouds	Increase 2% of globe
H.	Middle Clouds	Increase 2% of globe
I.	High Clouds	Increase 2% of globe
J.	N_2O	Increase from 0.28 to 0.56 ppm
K.	CH_4	Increase from 1.6 to 3.2 ppm
L.	CCl_2F_2 & CCl_3F	Increase from 0 to 2 ppb each
M.	O_3	Decrease of 25%

SOURCE: World Meteorological Organization

TABLE 1

Percentage Contribution to Global Man-Made CO_2 Emissions

	YEAR		Estimate	
	1950	1985	2020	2060
U.S.	42	26	18	10
ODC*	48	54	32	20
LDC*	10	20	50	70

* ODC = Other Developed Countries
LDC = Lesser Developed Countries

Estimates of global man-made emissions of nitrous oxide (N_2O) are more uncertain. Fossil fuel combustion has been estimated to account for about 50 percent of man-made N_2O emissions. However, recent research indicates that these earlier measurements are inaccurate (the earlier techniques produced extra N_2O within the sampling equipment), and that, in fact, N_2O emissions from power plants are very low compared to emissions of the gas from other sources.

CO_2 scrubbing from fossil generating plants is not only very costly (as much as doubling the power generation cost), but seldom offers the possibility of either reuse or permanent sequestering of CO_2. It also requires some 15 percent of the power plant capacity. Even if successful, the resulting cost would be about $100 billion for each percent reduction in global CO_2 production. Shifting to natural gas, or renewable technologies as a strategy to reduce CO_2 emissions has limited global potential, facing both technical and economic barriers. The most feasible approach to controlling CO_2 emissions worldwide, therefore, is expected to be more efficient conversion and use of fossil fuels, in particular with ICCT, a revitalization of nuclear power, and forest renewal to absorb CO_2.

The relative emission rates of alternative fossil fuel utilization technologies are summarized in Table 2.

Thus, to the extent ICCTs provide increased efficiency in the conversion of coal to usable energy, they will have a beneficial global impact on CO_2 and N_2O generation. This is particularly true for new and repowering ICCTs, like PFBC and IGCC. To a lesser extent it is also true for ICCTs which improve the efficiency of add-on emission controls and reduce their energy demand compared to wet flue gas SO_2 scrubbing technology available today. In the event that greenhouse warming is substantiated and reducing CO_2 growth becomes a policy imperative, this will provide a powerful additional argument in favor of more rapid development and global deployment of ICCTs for coal use. The resulting reduction in global man-made CO_2 production by 2030 with ICCT is expected to be in the range of 10 to 20 percent, depending on the technology and extent of global application.

The combination of urban ozone nonattainment and global warming issues is also likely to place considerable pressure on relatively inefficient and uncontrollable internal combustion engines for ground transport. An alternative may be electric vehicles utilizing off-peak power from higher efficiency electric generating stations utilizing ICCTs. This could reduce man-made global CO_2 emissions by an additional 10 percent.

TABLE 2

Estimated Emission of Carbon Dioxide (lb/kWh generated*)

PC Plant with SO_2 Scrubber or AFBC Plant	2.1
PFBC Plant	1.9
IGCC Plant	1.9
Oil—Steam Plant	1.6
Coal Gasification—Molten Carbonate Fuel Cell	1.5
Natural Gas—Modern Gas Turbine	1.3

* Using EPRI Technical Assessment Guide (TAG™) Assumptions

Chapter IV

ICCT Implications for Coal Utilization and U.S. Trade and Competitiveness

Rapid deployment and commercialization of ICCTs over the next decade represent an opportunity for the nation to protect existing coal markets and to expand coal utilization in both existing and new energy applications.

New and repowering ICCTs will act to expand coal markets. Retrofit ICCTs will act to protect existing coal markets by offering improved environmental control at a cost lower than existing technology. Retrofit controls are important in the event science or public policy demands greater levels of control from the existing base of operating power plants before more advanced new/repowering ICCTs are commercially available. Moreover, cost-effective retrofit ICCTs could make continued use of high-sulfur coal attractive to utilities that might otherwise be considering fuel switching or early retirement of high-emitting plants.

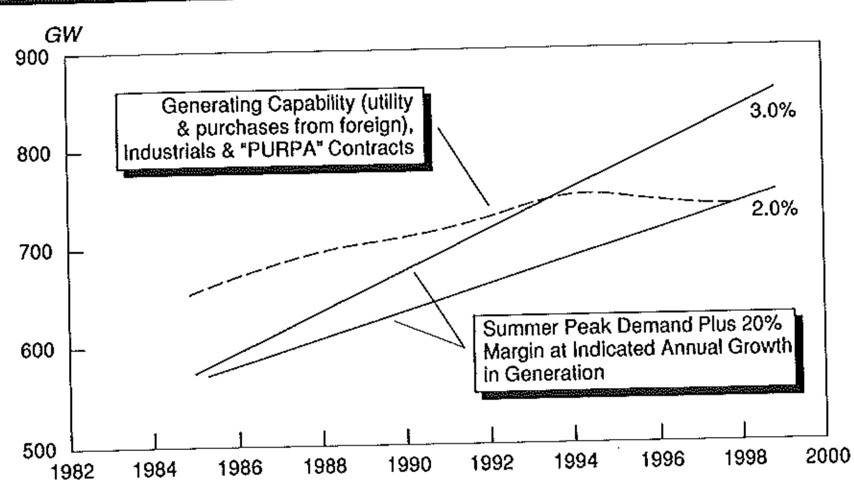
Utility Markets

The largest market for both retrofit and new/repowering ICCTs is the electric utility industry which utilizes about 85 percent of the nation's coal production to generate over one-half the nation's electricity. While total U.S. energy consumption has remained constant since 1973, GNP has increased by 39 percent and electricity sales have risen by 45 percent. This trend toward increased use of electricity as a power source is encouraged by the fact that over this same period since 1973 electricity prices have risen 14 percent compared to a 37 percent increase in heating oil prices and a 68 percent increase in natural gas prices.

The urgency for ICCT deployment and commercial availability is underscored by the approaching challenge to the nation's electricity supply capability, as reflected in Figure 7. These projections assume that growth in electricity use will continue to pace or exceed economic growth. Indeed, without secure, coal-based electricity generating capacity, the no-growth issue may become a self-fulfilling prophecy with its attendant economic and social difficulties for the nation.

Based on an anticipated 2 percent average rate of

FIGURE 7 National Electric Demand Versus Generating Capability



SOURCE: Based on North American Electric Reliability Council growth in U.S. electricity demand, current forecasts are that between 1995 and 2010 at least 170,000 MW of new coal-fired generating capacity will be required. Essentially all of this capacity should be able to use ICCT, if ICCT deployment proceeds without delay. Implicit in this projection are major improvements in energy conservation plus improved productivity from existing power plants. If these improvements do not occur, then the need for new generating capability will be even greater. The risk of underestimating generating capacity needs is underscored by the fact that since 1982 electric load growth has averaged 3.2 percent/yr. Continuation of this trend would increase the above forecast accordingly.

Beyond the need to meet increasing electricity demand, over 50,000 MW of existing coal-fired capacity will exceed 40 years of age by the year 2000. Most of these units are less than 300 MW in size and thus provide relatively low technical risk for early commercial application for ICCTs. An additional

The Potential For Repowering

Repowering provides an attractive option for partially meeting electricity demand growth, recovering lost capacity, extending operating life, improving productivity and, concurrently, reducing emissions—all at substantially lower capital cost and cost of electricity. Depending on site-specific conditions, the capacity increase may range from 10 percent to more than 150 percent.

Several factors combine to make repowering an attractive option today. They include:

- Demand for electricity is growing at a slower pace today than historically, justifying the addition of capacity in small increments.
- No coal plant technology currently on the market offers cost and efficiency improvements sufficient to make it an attractive replacement for capacity now in place.
- Greater competition in the utility industry has increased attention to cost control, and repowering is generally less costly than plant replacement.

Several emerging ICCTs effectively lend themselves to repowering applications: AFBC, PFBC, and IGCC. AFBC is showing the greatest near-term potential for repowering with over 1000 MW of existing coal-fired generating capacity already being converted to this technology.

Technically, all fossil plants (coal, oil, gas) are potential candidates for repowering. However, a number of factors will determine the relative attractiveness of this option for a specific utility and power plant. First and foremost is the need for capacity. Beyond this, the capital cost, degree of repowering difficulty, remaining plant life, and environmental requirements affecting each specific installation must be taken into account.

Current preliminary estimates suggest that some 237 units totaling 33,000 MW and emitting about 2.6 million tons/yr of SO_2 and 726,000 tons/yr of NO_x would be likely candidates in the next decade for repowering based on energy needs, age, size, and technical risk. These units are located in 32 states.

This initial commitment would be expected to grow as capacity needs increase, additional generating units are renovated, and confidence in the use of ICCT for repowering is gained from the initial installations. As a result, by 2010 as much as 175,000 MW of existing coal capacity and 75,000 MW of existing oil and gas capacity may be candidates for repowering. Based on an average repowered capacity rate of 125 percent of this base, over 60,000 MW of the forecasted 170,000 MW of required new capacity may be provided by repowering during this time period.

Although this summary suggests an important role for repowering, a more thorough objective analysis is needed to fully understand its potential. Weaknesses in existing studies of the potential market for repowering existing units include:

- Insufficient attention to oil- and gas-fired units
- Insufficient attention to smaller units at existing sites which may present options for expanding capacity at lower cost and with less opposition than at new sites
- Focusing on coal as the likely fuel for repowering when competitive, commercially available technologies using natural gas or oil may be available
- Contradiction and uncertainty about supply security and price risks associated with natural gas
- Insufficient attention to regulatory and other factors that must and will be taken into account by utilities when making choices about repowering and other options

90,000 MW will be added to this over-40 coal-fired population in the first decade of the next century.

The size of the retrofit utility market depends on whether new, more stringent environmental controls are required over the next decade, the phase-in period for these controls, and the degree of flexibility utilities will be allowed in responding. Based on North American Electric Reliability Council (NERC) data, if SO_2 emissions limits were set at 2.5 lb/MBtu, for example, some 400 electric generating units representing 90,000 MW concentrated in a ten-state area in the middle eastern United States would be required to reduce emissions by an average of 40 percent. If limits were set at 1.2 lb/MBtu, over 700 units spread across 32 states in the eastern half of the nation and representing 160,000 MW would need to reduce SO_2 emissions an average of 60 percent.

The three most likely compliance alternatives other than commercially available ICCTs include plant retirement, fuel switching (principally to lower-sulfur coal, oil, or natural gas), or installation of currently available environmental controls (principally wet FGD scrubbers for SO_2 control and combustion controls for NO_x emissions reductions).

The inherent advantages and, at least short term, availability of natural gas, make it both politically and economically attractive today for industrial and utility peaking-duty applications. It is clean burning and requires relatively low capital and operating costs. Additionally, in recent years there has been a substantial reduction in federal restrictions on the construction of new gas-fired facilities. The result may be installation of up to 60,000 MW of relatively low risk new gas turbine peaking and combined-cycle capacity by the turn of the century. Demand for natural gas is below former levels, and advocates suggest that if gas prices rise above the economic break-even point (approximately $4–5 per thousand cubic feet [mcf]) utilities using combined-cycle operation would be able to convert their gas-fired turbines and combined-cycle systems to coal-derived synthetic gas.

However, uncertainty over future prices and availability discourages more widespread use of natural gas in place of coal to reduce emissions. For example, average costs of natural gas to electric utilities increased from $0.30 per mcf in 1973 to a peak of $3.70 per mcf in 1984. Current costs are about $2.30 per mcf. Sources of concern to those considering a major, long-term commitment to natural gas include:

- The interruption of natural gas supplies to many users in 1978
- The risk that government policies which discouraged natural gas use in the late 1970s will re-emerge
- The reduction in the number of drilling rigs at work now compared to the peaks reached in 1981 and 1982
- The decline in U.S. reserve-to-production ratios in recent years
- Higher prices paid for spot gas purchases during the winter of 1987–1988
- Estimates that natural gas demand reached or nearly reached the limits of deliverability during some parts of January and February 1988
- Significantly increased demand for gas resulting from plans by many cogenerators and other potential gas users to build gas-fired facilities, as well as the potential for the use of gas as a short-term emission control expedient
- Deliverability figures that may not be reliable since maximum output has not been tested in the marketplace in more than seven years

On the other hand, recent government and gas industry reports suggest that abundant domestic gas reserves and resources will remain available at costs below $3 per mcf for many years. This forecast is based on adding unconventional resources (such as low-permeability formations and coal-bed methane), expectations of the yield from more intense development of existing fields, as well as undiscovered resources. Other reasons for optimism among those considering the natural gas option include:

- The natural gas supply interruptions that occurred in some areas in 1978 were due primarily to regulatory constraints (regulation of wellhead prices of gas sold in interstate markets), not gas supply shortages.
- Reductions in federal regulation of natural gas wellhead prices and changes in gas pipeline regulation will have a lasting and favorable effect on gas availability and price competitiveness.
- Substantial gas supplies available from other countries, particularly Canada and potentially Mexico, will add to supplies. Liquefied natural gas from Algeria, Indonesia, and possibly the Middle East, would be available at market prices well below $5 per mcf.

Despite this, however, significant uncertainty and risk remain. The dynamics of industry activities will determine what gas supplies and prices will actually be at various points in time. In addition, transport of large quantities of new gas supplies from producing to consuming regions would be a constraint that would be difficult to resolve, both because of pipeline right-of-way and permitting issues, and because of financial disincentives created by recent FERC rulings.

Based on DOE EIA data, use of natural gas as a retrofit environmental compliance option to meet proposed regulations will likely remain a limited option. For example, use as the principal compliance option, assuming the ability to deliver it to the necessary locations, would require a quadrupling of electric utility gas use by the turn of the century (from its current level of 2.7 to some 12 trillion cubic feet/yr). This, in turn, would represent a 50 percent increase in U.S. natural gas consumption and a corresponding 50 percent decrease in coal consumption. A more feasible forecast suggests a doubling to about 6 trillion cubic feet/yr by 2010 for electric generation. This assumes a 2010 wellhead gas price of \$4.50 per mcf, oil cost to refiners of \$37.50 per barrel, and coal cost at the minemouth of \$34.70 ton.

As regards the coal switching option, Figure 8 shows the related but opposite "demand curves" for coal switching and flue gas scrubbing. These curves plot the break-even costs for compliance with a hypothetical stringent SO_2 reduction requirement, using the commercially available options of switching to lower-sulfur coal or installing a flue gas scrubber. The striking feature of the curves is the hypersensitivity of the scrubbing-switching balance to small changes in coal price. A \$5/ton increase in coal cost would be expected to reduce the amount of coal switching by about 80 million tons, and would increase the amount of scrubbing capacity installed by 17,000 MW.

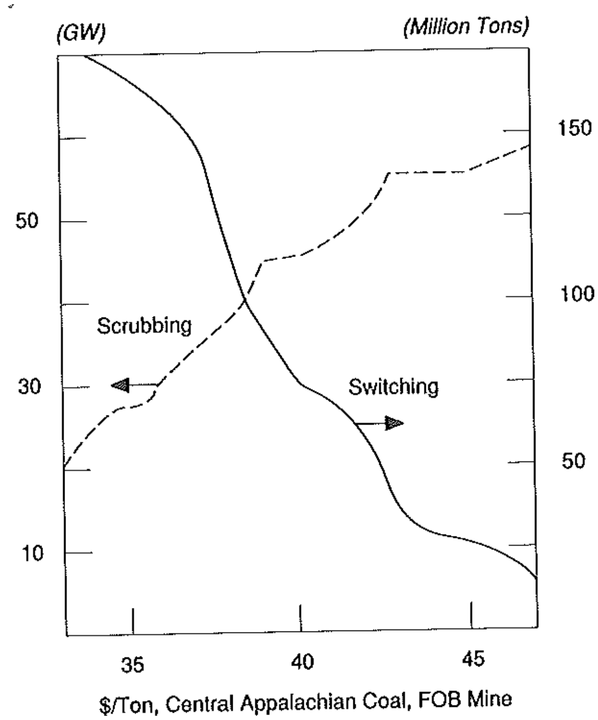
Even without considering ICCT, widespread installation of existing FGD technology would likely be the dominant compliance strategy, accounting for two-thirds to three-fourths of SO_2 reductions under a high SO_2 reduction scenario (10 million tons/yr). The more cost-effective options available with ICCT would tend to further preserve existing coal markets as coal users adapted to new emission regulations. Thus, ICCT would buffer the potential rise of low-sulfur coal prices and mitigate the losses in Appalachian and Midwest high-sulfur coal production.

Industrial Markets

As shown in Figure 9, coal accounts for less than 16 percent of the U.S. industrial fuel market today, with oil and natural gas each commanding over 40 percent. Thus, the potential market for coal in this sector is substantial if relative fuel prices shift in coal's favor over time. Application of ICCTs could be an important factor facilitating this shift and allowing coal to compete with oil and gas in the face of increasingly stringent environmental requirements.

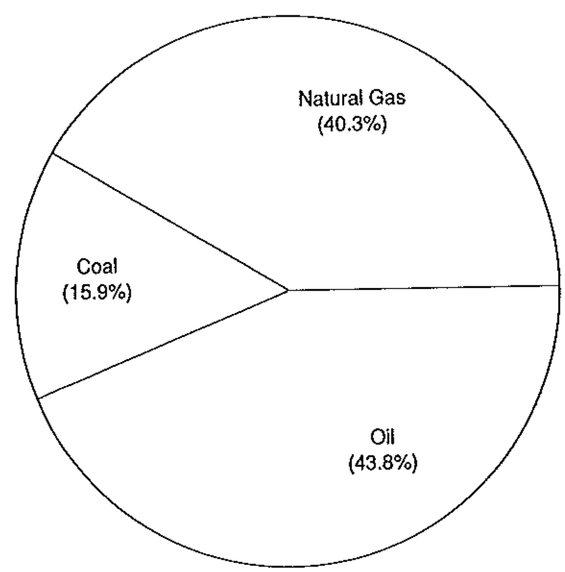
At present, over 1360 process steam-producing coal-fired boilers are in use by industry in the United

FIGURE 8 Effects of Coal Price on Demand Curves for Coal Switching and Wet Flue Gas Scrubbing



SOURCE: EPRI *Coal Markets and Utilities Compliance Decisions*, September 1987

FIGURE 9 Industrial Use of Fuels



SOURCE: NCC Study, *Use of Coal in the Industrial, Commercial, Residential, and Transportation Sectors*

States. Direct coal firing in the form of FBC appears to be the most attractive ICCT option both for existing and new industrial coal applications. Indeed, over 100 process and small-power FBC boilers with a total capacity of 17 million lbs/hr steam are currently operating or on order.

Strategic Coal Market Opportunities

ICCTs also present the opportunity to expand coal use beyond conventional coal applications. These include using coal liquefaction and gasification ICCTs to back out petroleum in the industrial, residential, commercial, and transportation sectors. As discussed in a separate NCC study, *Use of Coal in the Industrial, Commercial, Residential, and Transportation Sectors*, for example, if coal could back out 25 percent of the oil used in light industry, businesses, and residential units in the Northeast region alone, the United States could reduce oil imports by 45 million barrels/yr and increase coal production by 11 million tons/yr.

In industry, synthetic gas produced by coal gasification (syngas) has great potential as a building block for fuels and chemical feedstocks, and may well bring about an emergence of chemical-from-coal technologies. Syngas is a generic name for mixtures of carbon monoxide and hydrogen, and is a key intermediate product in the production of several important chemicals, including ammonia, hydrogen, methanol, and oxoalcohols. Syngas is also the fuel that is burned in combustion turbines to produce electricity in IGCC plants. Natural gas is the primary raw material used today in chemical plants for syngas production, but coal is used in one major U.S. project (Eastman Kodak Company, Kingsport, Tennessee) producing acetic anhydride, and in one project in Japan (Ube Chemicals) producing ammonia.

Based on these technologies, and with dynamic implications for coal markets, lies the prospect—already a technical possibility—of coal plants that can convert all components of raw coal into useful products, including but not limited to power. Thus, a fully integrated "coal refinery" could be adapted to any local coal, or other fossil fuel and resource base, and be able to produce a mixture of electricity, heat, fuels, and marketable products for the local economy. Realizing such a plant is dependent on successful deployment of a variety of ICCT building blocks.

In the coal refinery, FBC boilers, coal conversion facilities, fuel cells, and a variety of by-product recovery technologies would be linked by electronic diagnostic and control systems. Syngas would be used as fuel for electricity generation and to produce chemicals. Coal ash could find use in highways and railroads, cement and concrete, and as a source of high-value trace metals. And the enhanced CO_2 recovery capability of the concentrated gas stream and fuel cells in such coal refineries could make a significant contribution to decreasing emissions of this "greenhouse" gas. Table 3 shows the potential increase in U.S. coal use if the opportunities in both the industrial fuel and chemicals markets are realized.

TABLE 3

Potential U.S. Industrial Coal Use

Type of Use	Present Use	Minimum Potential Use (10^6 tons)
Fuel	9.1	91
Methanol	0.3	4–5
Oxoalcohols	-	4
Ammonia	-	27
Sugar Refinery	-	3–4
Cement Kilns	-	2–3
	9–10	131–134

SOURCE: NCC Study, *Use of Coal in the Industrial, Commercial, Residential, and Transportation Sectors*

U.S. Trade and Competitiveness

The primary implication of aggressive ICCT deployment and commercialization for U.S. trade and competitiveness will be the potential for technology export and renewed U.S. technological leadership in a growing world market for coal utilization technology.

ICCT deployment may prove essential to protecting and expanding the U.S. share of the world export coal market as more stringent environmental requirements are introduced. In the absence of ICCT, these new requirements may favor lower-sulfur content foreign coal sources. The implications for this market are discussed in more detail in "Improving International Competitiveness of U.S. Coal and Coal Technologies," a separate NCC study published in June 1987.

Rapid development of ICCTs will position the United States to become a major player in a worldwide clean coal technology market valued at $50 billion/yr by 2000, and $70 billion/yr by 2010. Table 4 projects this market by technology application.

The potential for world leadership in ICCT represents a major opportunity for the United States. The single most important economic problem for the country today is how to respond effectively to increased competition in the global marketplace. The past two decades have seen the United States lose competitive ground to countries employing public-

TABLE 4

Potential Annual Electricity Generation Market for ICCT (1987$)

	2000		2010	
	GW	$10^9$$	GW	$10^9$$
United States				
New and Repowered Generation	15	12	24	19
Emission Control	30	9	10	3
Rest of the World (Soviet Bloc Nations Excluded)				
New and Repowered Generation	25	20	45	36
Emission Control	35	10	60	15

BASIS: World Coal Study, *Coal—Bridge to the Future*, 1980

private partnerships to build "arsenals of innovation" to ensure their dominance in a particular technological arena. Advanced coal technologies offer the United States the opportunity to apply this strategy to the burgeoning world coal and coal conversion markets. The DOE ICCT Demonstration Initiative is an important prototype in this regard.

Important national security interests are also served by promoting selection of the coal option in developing countries. The United States, as one of the largest markets for, and developers of, ICCT, can offer developing country customers state-of-the-art technology to meet their power generation needs in a manner which protects an increasingly integrated global environment and economy.

Until the past decade, the large majority of coal-fired power plants in the free and developing world relied on technology provided by, or licensed from, U.S. developers and manufacturers. However, this leadership is increasingly being challenged. For example:

- Japan and Germany have gained parity with the United States in wet FGD technology and are likely to become primary suppliers of state-of-the-art FGD systems in the 1990s—not only to the rest of the world, but to the United States itself.
- Japan has become a world leader today in the development of both combustion and post-combustion NO_x control technology; increasingly, NO_x control technology for existing coal-fired plants worldwide is being supplied by, or licensed from, Japan.
- Although the United States remains an important participant in the development of AFBC, the majority of the large industrial and utility AFBC plants now operating or under construction in the United States use technology supplied or licensed by European sources. In PFBC technology, nearly all U.S. efforts have been superseded by Europe, which is the only commercial source of PFBC technology today. Sweden, through a licensing agreement and joint venture with Babcock & Wilcox, will supply the first demonstration of PFBC technology under the U.S. Clean Coal Demonstration Initiative.

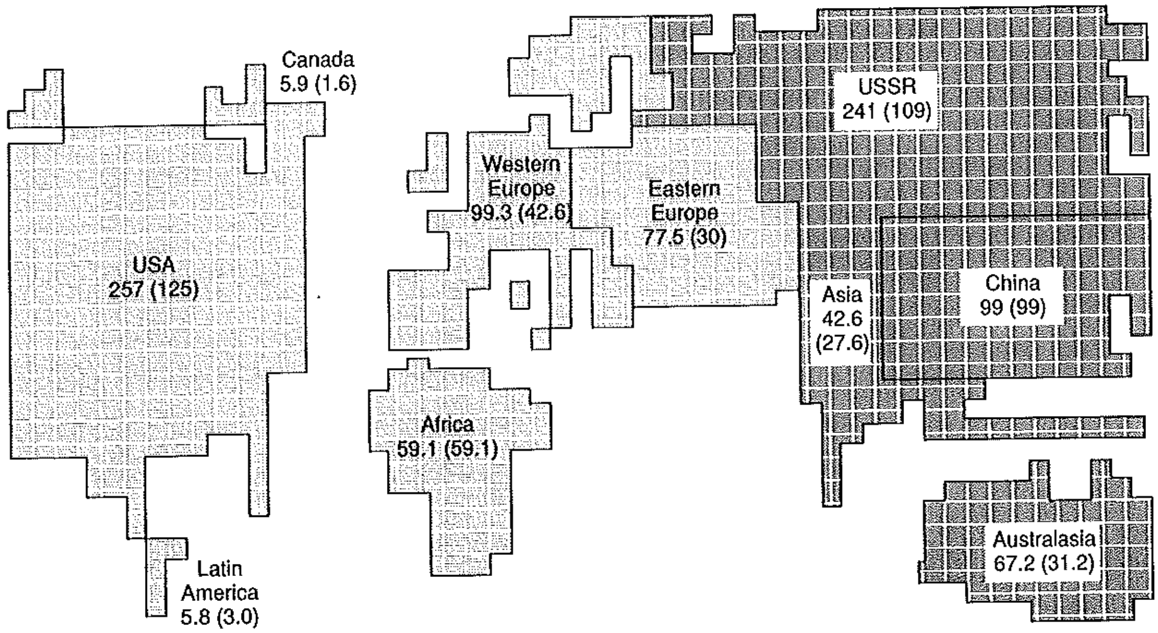
In contrast, an ICCT in which the United States has a lead is coal gasification. Much of the commercial-scale development of this technology today is being done in the United States by Texaco, Dow, Shell, and KRW, for example.

The opportunity to export technology that cleanly and efficiently converts coal to energy and other useful products is based on the increase in world coal use and the related demand for electricity that has already begun and is expected to continue well into the twenty-first century. However, protectionist trade policies, business practices, and government involvement in commercial transactions are significant facts of life in most foreign countries and can restrict the competitiveness of American companies attempting to sell coal and/or ICCT abroad.

Economically recoverable coal reserves are very large and more evenly distributed among the world's nations than any other fossil fuel. Currently estimated totals are shown in Figure 10. As a result of this abundance, coal is expected to supply between one-half and two-thirds of the additional energy needed by the world over the next 20 to 30 years. Figure 10 also indicates that two of the United States' largest geopolitical competitors—the USSR and China—are its closest competitors in terms of coal assets as well. As discussed in Appendix D, global coal use is expected to surpass petroleum use during the first decade of the next century and may continue to grow for at least the next 50 years. World coal trade has increased by 91 percent in the twelve years between 1973 and 1985, due to the increased demand for steam coal used in electricity generation. Growth on the order of 3 percent/yr through the year 2000 is projected.

FIGURE 10 World Coal Reserves at End of 1985

Billion Tons (bracketed figures are share of total represented by bituminous coal and anthracite)



SOURCE: British Petroleum Statistical Review of World Energy, 1986

The largest portion of increased coal use will also likely be for the generation of electrical energy. In a United Nations study of 50 countries representing 95 percent of presently installed thermal capacity (excluding the United States, Canada, and USSR), 160,000 MW of new coal-fired capacity is expected to be added over the next ten years. About 110,000 MW of this total is expected to occur in the Asia/Pacific region, where economic development of developing countries will require very large increases in electrification.

The extent to which the market uses ICCT will be determined in large part by the emphasis given to environmental control by the world's nations. Environmental laws and regulations are already in place in most countries, and there is a growing trend in the industrial nations toward a more rigorous enforcement of environmental laws. The United States and, more recently, West Germany and Japan are the standard setters for environmental quality control. However, acidic deposition issues and improved understanding of atmospheric transport patterns of SO_2 and NO_x across international boundaries are leading other European countries to improve air quality.

In less developed countries (LDCs), the driving force for ICCT application will be more an interest in realizing the full energy potential of indigenous coal resources than in environmental control per se. Environmental control will have to be cost-effectively integrated in the LDCs if the world's environment is to be protected. Moreover, given economic constraints in these countries, potential suppliers of ICCT may well need to offer financing assistance to facilitate application.

If even half of the world's expected expansion in coal utilization for power generation used U.S.-manufactured equipment, the value to the United States by the year 2010 would be about $35 billion/yr (as reflected in Table 4). The environmental benefits to "spaceship earth" of using ICCT instead of existing coal technologies to support the projected worldwide expansion in coal use would be profound.

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Appendix A

Definitions

A clean coal technology (CCT) is any existing technology (including process modification and software) which, when applied prior to, during, or after coal combustion would, by itself or in conjunction with other clean coal technologies, either enable a new plant to meet or exceed standards for environmental protection, or reduce pollutant emissions (solid, liquid or gaseous) from an existing plant to improve environmental performance.

An innovative clean coal technology (ICCT) is a developmental clean coal technology, or technology modification, which has the potential to reduce costs intrinsic to existing commercial technology. These intrinsic costs are limits which cannot be reduced without innovation. An ICCT, therefore, requires further research, development, demonstration, and deployment before it can be considered commercially applicable. This definition encompasses both new types of technology and significant improvements to existing, commercially available technologies.

Retrofitting is the process of adding environmental control equipment to a coal-using facility originally designed to perform without such equipment. Doing so today may require altering plant operating characteristics, although research and development in retrofit emissions controls continues to develop methods for minimizing these effects. Even with the most advanced retrofit technology, operating add-on environmental control equipment requires a portion of the plant's overall energy output and increases capital and operating costs.

Repowering is the process of modifying or replacing the structure and operating characteristics of an existing generating unit in order to increase its capacity and efficiency. Repowering can increase generating capacity from 10 percent to 150 percent depending on the scope of renovation. Even with its potentially high, site-specific equipment acquisition and installation costs, repowering may still be more cost-effective than retiring older units and replacing them with new plants. Repowering offers the opportunity to efficiently and reliably integrate emissions control and power generation processes.

Demonstration is the process in which newly developed technology designed for the first time to utilize commercial types and sizes of equipment is constructed and operated continuously to establish commercial plant design bases. Demonstration plants typically have higher design margins and levels of redundancy than facilities using commercially mature technology, as necessary to assure reliable operation.

Deployment is the process through which a new technology achieves commercial maturity. It involves defining, quantifying, and resolving the performance and reliability risks associated with new technology through a series of increasingly cost-competitive installations reflecting the envelope of expected commercial application and range of designs and suppliers. Design margins and equipment redundancy are systematically reduced as operational confidence and reliability are established.

Commercial availability is characterized by three key elements: demonstrated technical feasibility, demonstrated competitive cost and reliability, and existence of a qualified supplier for the technology. If any of these conditions is absent, a technology cannot be considered a realistic commercial option.

Appendix B

ICCT Descriptions

Tables B-1 and B-2 summarize the wide range of ICCTs being considered by the DOE. Some of these options are currently in the very early stages of R&D; others are already being commercially demonstrated.

No one of these options will satisfy the widely varying conditions of existing coal-fired utility and industrial power plants. As a group, however, they can reduce the cost and productivity limitations being experienced today as a result of emission control requirements on coal. *Clean Coal Technology*, a report published by the National Coal Council in June 1986, further describes the more developed options and their application to a range of specific projected scenarios for the major coal-use sectors.

An important distinction between retrofit and new/repowering ICCTs is that new/repowering options have the potential to reduce the absolute cost and increase the productivity of power generation, while retrofit options can only limit the cost increase which would otherwise be imposed by more expensive retrofit controls. At the same time, however, these options have in common several advantages relative to existing technologies. These advantages include:

- Better integration of emissions control with the coal-based power generation process, thus reducing the complexity and quantity of required equipment while better addressing the range of environmental issues affecting coal
- Simplified process design leading to improved reliability and construction modularity
- Improved flexibility to target the wide range of site-specific requirements associated with variability in coal type, plant design, and operating characteristics
- Production of by-products which are more easily managed and potentially marketable

TABLE B-1

New/Repowering ICCTs

Fluidized-Bed Combustion	Gasification-Based	Advanced Options
Atmospheric • Circulating Bed • Bubbling Bed **Pressurized** • Circulating Bed • Bubbling Bed **Hybrid Designs** • Bubbling-Circulating Bed • Coal Pyrolyzer/Fluid Bed	**Gasifier Types** • Fixed Bed • Fluid • Entrained Flow • Rotary Kiln-Type **Combinations** • Gasification w/Pyrolyzation • Gasification w/Once-Through Methanol Production **Gas Cleanup Systems** • Conventional "Cool" Gas Cleanup • Zinc Ferrite Hot Gas Cleanup • Ceramic Filter Cleanup • In Situ Desulfurization	**Gasification w/Fuel Cell** **Magnetohydrodynamics** **Direct Coal-Fired Turbines**

SOURCE: U.S. Department of Energy

TABLE B-2

Retrofit ICCTs

Pre-Combustion Cleaning	Combustion Modification	Post-Combustion
Physical • Fine Grinding (Micronization) • Advanced Froth Flotation • Heavy Media Cyclones • Micronization w/Limestone • Microbubble Flotation **Physiochemical** • Molten Caustic Leaching • Organic Solvent **Microbial** • Bioleaching	**Combustor/Burner Types** • Slagging Combustors • Rotary Cascading Bed Combustors • Entrained Combustors • Limestone Injection Multistage Burners • Gas Reburning **Fuel Types** • Coal-Water Slurries • Coal-Gas Co-Firing • Coal-Water-Gas Co-Firing	**In-Duct Injection** • Sorbent Injection • Catalytic Reduction **Post-Combustion Devices** • Vanadium Pentoxide Afterburners • Ternary Boiler w/Pollutant Capture • Furnace Injection w/Water Activation Reactor • Post-Combustion Oxidation w/Fluid Bed Lime Reactor • Fluid Bed Absorption **Advanced Scrubbers/FGD Devices** • Spray Dryers • Regenerable Scrubbers • Dual Alkali Scrubbers • Electron Beam Scrubbers • Ion Exchange Membrane FGD • Magnesium Enhancements • NO_x Specific Scrubbers • Electrode Precharger Enhancements to Precipitators • High-Temperature Baghouses

SOURCE: U.S. Department of Energy

Selection of ICCTs for specific applications will depend on a number of variables including control requirements, cost, and functional criteria such as plant design and space limitations.

Functional criteria can be particularly important constraints when considering retrofit to existing plants. Unlike new plants, where the boiler and emissions controls can be designed as an integrated unit, retrofit requires adaptation to a plant not designed for such modification. Nevertheless, retrofit controls can become particularly valuable in the event emissions control on existing high-sulfur coal plants is required. The potential for 40 to 70 percent SO_2 and NO_x reduction is attractive under these circumstances. The value of retrofit ICCTs results not only from lower capital costs compared to existing controls, but also from reduced process complexity which simplifies their integration with existing plants.

New/repowering coal utilization technologies such as AFBC, PFBC, and IGCC systems have the potential to be more effective both in terms of environmental control capability and cost. These technologies combine, to varying degrees, emissions control within the combustion or conversion process. Their potential is both greater emissions control efficiency and improved generation productivity—the two conditions necessary to resolve the conflict between coal use and the environment.

The potential of new/repowering ICCTs to improve rather than reduce productivity means that these options can make more effective use of national resources than additions of emission control to existing coal-fired capacity. However, two key questions must be resolved before large-scale application of these options can occur: Proof of their long-term reliability under utility operating conditions, and determination of the range of conditions within which they are the most economically attractive.

Appendix C

Inventory of ICCT Demonstration Projects

Following is an inventory of clean coal technology demonstration projects compiled by the Innovative Control Technology Advisory Panel (ICTAP). Two screens were used to determine which projects would be included:

1. Only projects which are considered commercial demonstrations are listed. Thus, projects which are at the pilot stage or smaller scale research phase are not included.
2. Projects which are strictly commercial in nature are not included, i.e., those with normal contractual terms and conditions such as guarantees and without Government subsidy are excluded.

The inventory is, thus, representative of those projects worldwide which meet the criteria of the DOE cost-shared demonstration program as currently constituted.

PROJECT	TECHNOLOGY	SITE	SIZE	STARTUP
DEPARTMENT OF ENERGY CLEAN COAL PROJECTS				
American Electric Power Service Corp./ Philip Sporn Plant PFBC Repowering Project	PFBC	New Haven, WV	330 MWe	10/95
American Electric Power Service Corp./ Tidd PFBC Demonstration Project	PFBC	Brilliant, OH	70 MWe	10/90
Babcock & Wilcox/ Demonstration of the SOx-NOx-ROx Box Post-Combustion Flue Gas Cleanup Process	Combined SO_2/NO_x	Dilles Bottom, OH	5 MWe	02/01/89
Babcock & Wilcox/ LIMB Demonstration Project	Sorbent Injection Low NO_x Combustion	Lorain, OH	104 MWe	08/26/87
Babcock & Wilcox/ Coal Reburning For Cyclone Boiler NO_x Control	Low NO_x Combustion	Cassville, WI	100 MWe	06/91
Bethlehem Steel Corp./ Innovative Coke Oven Gas Cleaning	Other	Baltimore, MD	5,700 tph (coal)	07/91
Coal Tech Corp./ Cyclone Combustor With Integral Sulfur, Nitrogen, and Ash Control	Slagging Combustion	Williamsport, PA	30 MMBtu/hr	11/87
Colorado-Ute Electric Assoc. Inc./ Nucla CFB Demonstration Program	AFBC	Nucla, CO	110 MWe	87
Combustion Engineering/ Innovative Clean Coal Gasification Repowering Project	IGCC	Springfield, IL	65 MWe	01/93
Combustion Engineering/ Post-Combustion Dry Sorbent Injection Technology Demonstration	Sorbent Injection	Yorktown, VA	180 MWe	92
Combustion Engineering and Snamprogetti/WSA-SNO_x Technology For Catalytically Reducing SO_2 and NO_x From Flue Gas	Combined SO_2/NO_x	Niles, OH	35 MWe	03/91
Energy & Environmental Research Corp./ Reburning Sorbent Injection in Utility Boilers	Sorbent Injection Low NO_x Combustion	Springfield, IL Hennepin, IL Bartonville, IL	80 MWe	12/89
Energy International Inc./ Underground Coal Gasification Integrated With Ammonia Production	Other	Rawlins, WY	400 tpd (ammonia)	11/89
Foster Wheeler and Consol/ IGCC Project	IGCC	WV	600 tpd	pre-operational
Minnesota Department of Natural Resources/ Corex Project	Other	TBD	330,000 tpy (pig iron)	07/92

M. W. Kellogg Company/ Fluidized Bed Integrated Combined Cycle With Hot Gas Cleanup	IGCC	Cairnbrook, PA	63.5 MWe	04/91
Ohio Ontario Clean Fuels, Inc./ Coal-Oil Coprocessing	Coal Liquefaction	Warren, OH	800 tpd 8,675 bpd	12/91
Otisca Industries/ Production of Compliance OTISCA Fuel and Combustion In Utility Boilers	Coal Cleaning	Syracuse, NY Jamesville, NY Oneida, NY	40,000 tpy	01/90
Passamaquoddy Tribe/ Innovative Scrubbing System for Coal-Burning Cement Kilns	Other	Thomaston, ME	11 tph (coal)	01/90
Pure Air/ Advanced On-Site FGD Process	Advanced FGD	Gary, IN	4x123 MWe	09/91
Southern Company Services/ Advanced T-Fired Combustion for Reduced NO_x	Low NO_x Combustion	Panama City, FL	180 MWe	03/90
Southern Company Services/ Advanced Wall-Fired Combustion for Reduced NO_x	Low NO_x Combustion	Rome, GA	500 MWe	03/90
Southern Company Services/ Demonstration of the Chiyoda Thoroughbred-121 FGD Process	Advanced FGD	Atlanta, GA	100 MWe	01/92
Southern Company Services/ Selective Catalytic Reduction Technology For Control of NO_x	Post Combustion NO_x	Pensacola, FL	3x2.5 MWe	05/91
Southwestern Public Service Company/ Circulating Fluidized Bed Repowering Project	AFBC	Amarillo, TX	256 MWe	08/92
TransAlta Resources/ Low NO_x-SO_2 Burner Retrofit For Utility Cyclone Boilers	Slagging Combustion	Marion, IL	33 MWe	04/90
TRW, Inc./ Advanced Slagging Coal Combustor	Slagging Combustion	Stony Point, NY	69 MWe	03/90
DEPARTMENT OF TREASURY PROJECTS (formerly financed by U.S. Synthetic Fuels Corp.)				
Dow Chemical/ Dow Syngas Coal Gasification Combined Cycle	IGCC	Plaquemine, LA	115 MWe	82 proto 86
Cool Water Gasification Combined Cycle	IGCC	Daggett, CA	100 MWe	07/79
PRIVATELY FINANCED PROJECTS INVOLVING ELECTRIC POWER RESEARCH INSTITUTE				
Northern States Power/ Fluidized Bed Combustion Unit Conversion (Black Dog Unit #2)	AFBC	Burnsville, MN	125 MWe	07/86 04/87 update
Richmond Power & Light - EER/ T-Fired LIMB	Sorbent Injection Low NO_x Combustion	Richmond, IN	60 MWe	operational
EPRI/Kansas Power and Light/ Low NO_x Burner Retrofit/ T-Fired Boiler	Low NO_x Combustion	Lawrence, KS	350 MWe	07/87
EPRI/ Penelec/ NYSEG/ Low NO_x Burner Retrofit/ Wall-Fired Boiler	Low NO_x Combustion	Homer City, PA	600 MWe	11/88
EPRI/ EPA/ GRI/ Ohio Edison/ Gas Reburn Retrofit/ Cyclone Boiler	Low NO_x Combustion	Niles, OH	110 MWe	08/89
Shell Oil Coal Gasification Demonstration Plant	IGCC	Deer Park, TX	250 tpd	87
STATE-FINANCED CLEAN COAL DEMONSTRATION PLANTS				
Anderson Clayton Foods Company/ Dual Fluidized Bed Boiler Retrofit	AFBC	Jacksonville, IL	85,000 lb/hr (stm)	07/86
Archer-Daniels-Midland/ Circulating Fluid Bed Cogenerators	AFBC	Decatur, IL	108 MWe	86
Babcock & Wilcox/ Post Combustion SO_2 Control	Sorbent Injection	Jefferson, OH		operational
Columbia Gas System Corp./ Catalytic Reduction Process for Coal Flue Gas	Post Combustion NO_x	Columbus, OH		pre-operational
Hudepohl Brewery Power House/ Industrial Rotary Cascading Bed Boiler	Other	Cincinnati, OH		pre-operational
Scio Pottery Company/ Industrial Cogeneration	Other	Scio, OH		pre-operational
University of Illinois/ Wet FGD System	Advanced FGD	Champaign, IL	40 MWe	87
TENNESSEE VALLEY AUTHORITY PROJECTS				
AFBC Demonstration Project	AFBC	Paducah, KY	160 MWe	10/88
AFBC Pilot Plant	AFBC	Paducah, KY	20 MWe	82
Spray Dryer/ Electrostatic Precipitator Pollution Control Device	Advanced FGD	Paducah, KY	10 MWe	91

OTHER PRIVATELY FINANCED PROJECTS				
Air Products and Chemicals, Inc./ Circulating Fluidized Bed Cogeneration Plant	AFBC	Stockton, CA	49 MWe	88
Applied Energy Services/ Thames Project Circulating Fluidized Bed Cogeneration Plant	AFBC	Montville, CT	180 MWe	89
Combustion Engineering and Lurgi Corp./ Circulating Fluidized Bed Cogeneration Plant	AFBC	Reading, PA	25 MWe	pre-operational
Combustion Engineering and Virginia Power/ T-Fired LIMB	Sorbent Injection Low NO_x Combustion	Yorktown, VA	180 MWe	pre-operational
General Motors Corp./Fluidized Bed Cogeneration Unit	AFBC	Pontiac, MI	200,000 lbs/ hr (stm)	operational
Gilberton Power Company/ Anthracite Culm Fired Cogeneration Plant	AFBC	West Mahoney Twnshp, PA	79.5 MWe	operational
New Jersey Energy Associates/ Cogeneration Plant Using Coal Derived Gas	IGCC	Sayerville, NJ		pre-operational
Synfuels Genesis International and Dravo Corp./ Coal Fired Cogeneration Plant	Coal Liquefaction	Colstrip, MT		pre-operational
Texas-New Mexico Power Company/ Circulating Fluidized Bed Boiler	AFBC	TBD	150 MWe	90
AUSTRIA				
Selective Catalytic Reduction	Postcombustion NO_x	Durnrohr	405 MWe 325 MWe	86 86
CANADA				
Wabash Mine/ ARC-COAL Coal-Water Mixture Project	Coal Upgrading	Pointe Noire, QB	3,000 bpd	12/85
Cape Breton Development Corp./ Coal-Water Mixture Project	Coal Upgrading	Chatham, NB	4 tph	complete
Cape Breton Development Corp./ Fluidized Bed Boiler	AFBC	Chatham, NB	210,000 lb/ hr (stm)	86
Ontario Hydro/ LIMB Facility	Sorbent Injection Low NO_x Combustion	Lakeview, OT	300 MWe	complete
Prince Edward Island Air Force Base/ Fluid Bed Boiler	AFBC	Prince Edward Island	80,000 lb/ hr (stm)	83
CANMET/ Coal-Oil Coprocessing	Coal Liquefaction	Alberta	15 tpd	operational
Saskatchewan Power/ T-Fired LIMB	Sorbent Injection Low NO_x Combustion	Regina, Sask	150 MWe	operational
DENMARK				
Flakt Advanced Flue Gas Desulfurization	Advanced FGD	Studsrup	350 MWe	89
Selective Catalytic Reduction	Postcombustion NO_x	Stigsnes	Unknown	85
FEDERAL REPUBLIC OF GERMANY				
Deutsche Babcock/ PFBC	PFBC	Wolfersheim		operational
Rheinische Braunkohlenwerke/ Kraftwerk-Union Gasifier Facility	IGCC	Cologne	55 tph (feed)	09/86
Ruhrkohle AG and Veba Oel AG/ Coal Liquefaction Facility	Coal Liquefaction	Bottrop	250 bpd	81
Steinmuller/ PFBC Facility	PFBC	Aachen	50 MWe	operational
VEW/ IGCC Facility	IGCC	Dortmund	10 tph (feed)	85
Wellman-Lord Advanced Flue Gas Scrubber	Advanced FGD	Buschhaus Offleben	350 MWe 325 MWe	87 87
Lurgi Advanced Flue Gas Scrubber	Advanced FGD	Schwandorf	50 MWe	85
Selective Catalytic Reduction	Postcombustion NO_x	Neckar FWK Buer Heilbronn Knepper	420 MWe 383 MWe 700 MWe 340 MWe	85 85 86 86
Exxon Thermal NO_x Reduction	Postcombustion NO_x	FWK Marl Mainz-Wiesbaden	214 MWt 50 MWe	86 86
NO_xOUT Process	Postcombustion NO_x	Weisweiler	75 MWe	88

Walther Process	Combined SO_x-NO_x	Mannheim Karlsruhe	475 MWe 100 MWe	88 90
Bergbau-Forschung	Combined SO_x-NO_x	Arzberg	130 MWe	87
SHL	Combined SO_x-NO_x	Heyden	740 MWe	87
Steinmüller Process	Sorbent Injection	Weiher Tiefstack Boehringer Ingelheim	138 MWe 180 MWe 65 MWe	82 85 89
	FINLAND			
Tampella Process	Advanced FGD	Inkoo	250 MWe	85
	FRANCE			
Cherchar Injection Demonstration	Sorbent Injection	Gardanne	600 MWe	84
	ITALY			
Aerimpianti and Ansalso/ Cogeneration Bubbling FBC	AFBC	Reggio Emilia	19 MWe 40 MWt	pre-operational
CRTN-ENEL/ RIDOX	Combined SO_2/NO_x	Santa Gilla	2x35 MW	pre-operational
ENEL/ Circulating FBC	AFBC			pre-operational
ENEL/ IGCC	IGCC	Pietrafitta	300 MWe	pre-operational
ENEL/ Pulsating Electrostatic Precipitator	Other	Fusina Marghera	35 MWe	pre-operational
ENEL/ Pulse Generator	Other	Pisa	320 MWe	pre-operational
Eniceche/ Coal Cleaning Facility	Coal Cleaning	Milan	150 M tpy	pre-operational
Enichem-Agricoltura/ Coal-Water Mixture Combustor	Coal Upgrading	Manfredon	15 MWt 22 tph (stm)	pre-operational
Enichem-Anic/ Oil-Coal-Water Mixture Conversion	Coal Upgrading	Milan	200 MWt 300 tph (stm)	pre-operational
Enichem-Anic/ Coal-Water Mixture Production	Coal Upgrading	Porto Torres	0.5 M tpy	pre-operational
Wellman-Lord Advanced Flue Gas Scrubber	Advanced FGD	Sardinia	10 MWe	89
	JAPAN			
Kawasaki Heavy Industries and Mitsui Aluminum/ AFBC Boiler	AFBC	Watamatsu	300,000 lbs/ hr (stm)	83
Babcock Hitachi K.K. and Hitachi/ AFBC Facility	AFBC		50 MWe	87
Nakoso Coal-Water Mixture Project	Coal Upgrading	Nakoso	75 MWe	operational
Japan COM Company/ Coal-Oil Mixture Plant	Coal Upgrading		140 tph	operational
Electric Power Development Corp.	Advanced FGD	Matsushima	100 MWe	84
Hitachi Zosen	Advanced FGD	Hokkaido Electric	15 MWe	87
Electric Power Development Corp.	Postcombustion NO_x	Takehara	250 MWe	81
Active Coke Process	Combined NO_x-SO_x	Matsushima	75 MWe	91
	NETHERLANDS			
Moerdijik/ KEMA/ IGCC Facility	IGCC	TBD	240 MWe	87
GEESI Advanced Flue Gas Scrubber	Advanced FGD	Gelderland	630 MWe	85
Selective Catalytic Reduction	Postcombustion NO_x	Gelderland	150 MWe	86
	REPUBLIC OF SOUTH AFRICA			
ISCOR/ Corex Direct Iron Process	Other		40 tph	88
	SPAIN			
ENDESA/ PFBC Facility	PFBC	Escatron	80 MWe	90
	SWEDEN			
Energlverk's Vartan Power Plant/PFBC Cogeneration Facility	PFBC	Stockholm	131 MWe 217 MWt	89
Flakt Advanced Flue Gas Desulfurization	Advanced FGD	Öresund	55 MWe	83

Appendix D

The National Context for Coal

Coal has the distinction of being the focus of two independent and conflicting policy agendas. On the one hand, its domestic abundance has made it the cornerstone for national energy security; on the other, its environmental implications have encouraged clean air and related federal, state, and local environmental policy that has constrained its use. This conflict over coal was highlighted in the wake of the oil "crisis" of 1973 and has remained a pacing issue in both energy and environmental policy ever since.

Strategic Importance

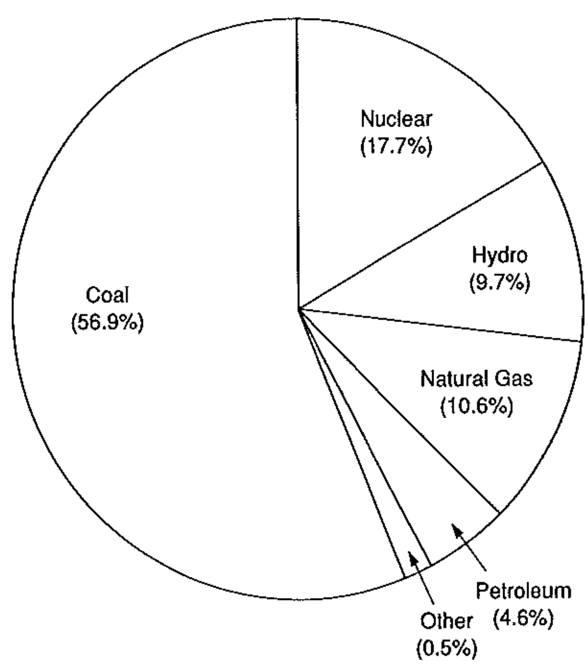
Coal's principal application today is in the electric utility industry, where coal-fired power plants produce more than one-half the electricity generated in the United States using about 85 percent of the nation's coal production. For every ton of coal burned in the industrial market, approximately six and one-half tons are burned in electric utility power plants. Figures D-1 and D-2 show these relationships.

The strategic importance of coal is reflected in the nation's dependence on oil, especially foreign oil. Domestic oil reserves are comparatively small and rapidly dwindling. As shown in Figure D-3, while oil accounts for almost 47 percent of U.S. energy consumption, it represents only 2.7 percent of available fossil fuel reserves. Coal, on the other hand, provides about 26 percent of national consumption and accounts for about 94 percent of available fossil fuel reserves. The United States' continuing dependence on foreign sources of oil supply, and the resulting balance of trade and payment concerns, combined with delays in initiatives to install nuclear capacity, encourage increased use of coal—for steam and electricity generation and, ultimately, for production of fuels and chemical feedstocks.

In addition to coal's advantages as a domestic resource, there is strong competition among thousands of coal suppliers for available markets, indicating that coal use is demand limited, not supply limited. Primary disadvantages and threats to coal's availability, increased application, and price stability include: potential long distances from mines to power plants, with resulting higher transportation costs and exposure to the monopoly powers of transporters; potential strikes by coal miners or transporters; the fact that capital and non-fuel operating costs for coal-fired power plants are typically higher than for oil, gas, or hydro facilities; and various current and potential regulatory constraints, including the potential for new, more stringent environmental standards that could lock in existing environmental control technology options and prevent new, more effective technology from finding its place in the market.

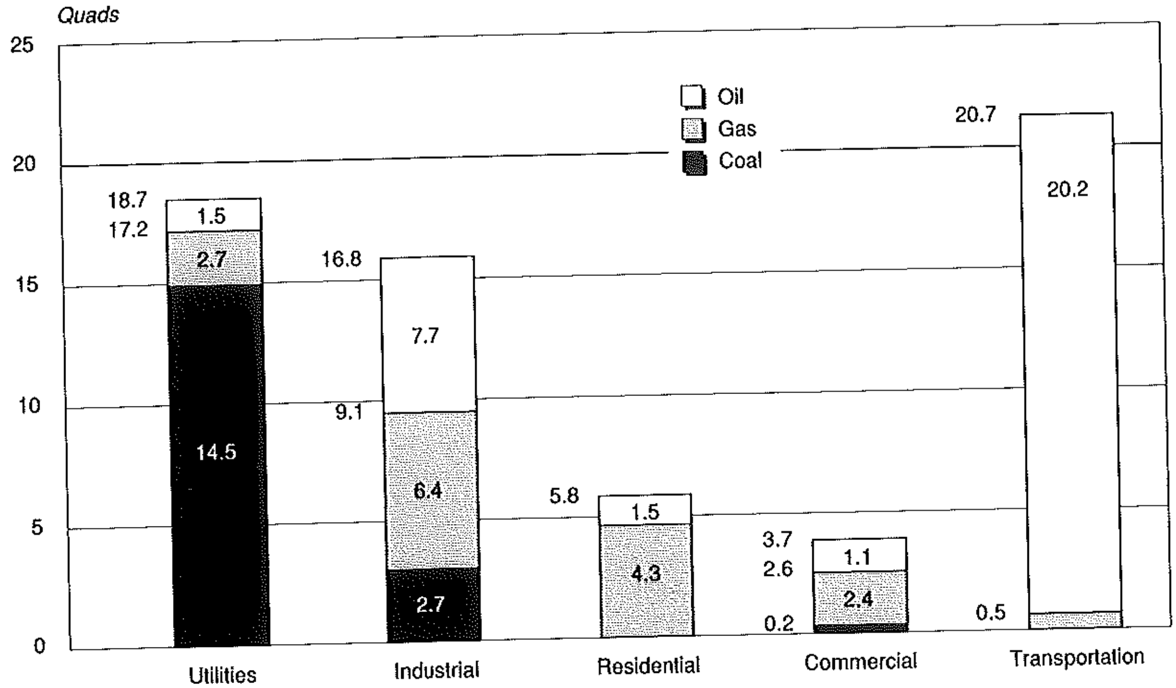
Recent forecasts of demand for fossil fuels by electric utilities to the year 2000, and the range of forecast prices for these fuels, reinforce the increasing importance of coal to utilities and the nation.

FIGURE D-1 Electricity Generation by Fuel Type (1987)



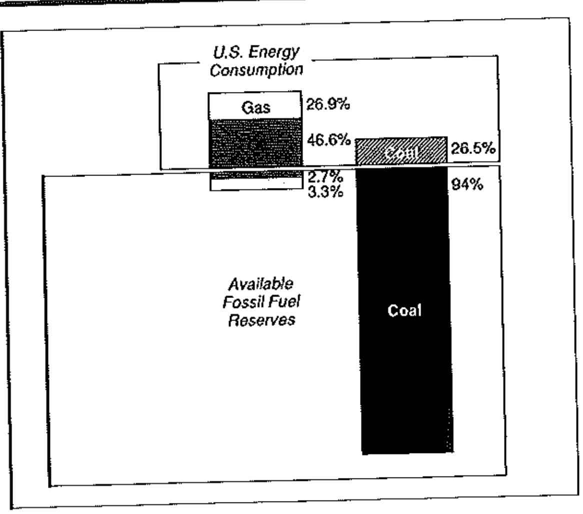
SOURCE: Edison Electric Institute

FIGURE D-2 U.S. Fossil Fuel Consumption by Use Sector (1986)



SOURCE: U.S. DOE Office of Coal Technology, FY 88 Program Plan

FIGURE D-3 The Domestic Energy Imbalance



SOURCE: U.S. DOE Office of Coal Technology, FY 88 Program Plan

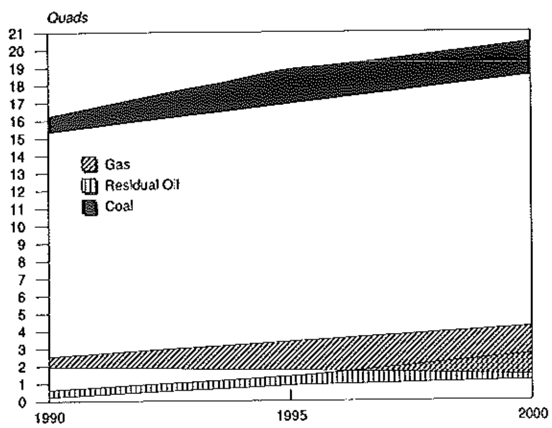
Figure D-4 shows that coal is expected to remain the dominant utility fuel for the remainder of this century and beyond. Figure D-5 shows a range of predicted prices for delivered coal, natural gas, and oil in constant dollar terms at these levels of supply. As can be seen, the range of forecast oil and natural gas prices is high and significantly widens as the forecasting time period extends. Coal prices, on the other hand, are projected to remain appreciably lower in comparison and to be much more stable in the longer term.

Global coal use is expected to surpass petroleum use during the first decade of the next century, and may continue growing rapidly for the next 50 years. This trend is shown in Figure D-6. To accommodate this growth, world coal production will have to more than triple between now and the middle of the next century, and world trade in steam coal will have to grow 10 to 15 times above current levels.

The Impact of Environmental Controls

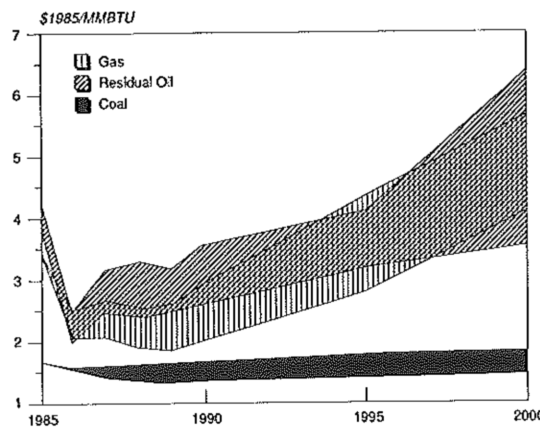
Since the initial application of coal as a boiler fuel for electricity generation, two key trends have characterized coal plant design: increases in efficiency and increases in capacity. Figure D-7 shows that the thermal efficiency of coal-fired steam electric generation went from about 5 percent in the late 1800s to 35–40 percent in the late 1960s. This resulted in an 85 percent reduction in fuel consumption per kW of power produced. During the same period, boiler

FIGURE D-4 Range of Utility Demand Forecasts



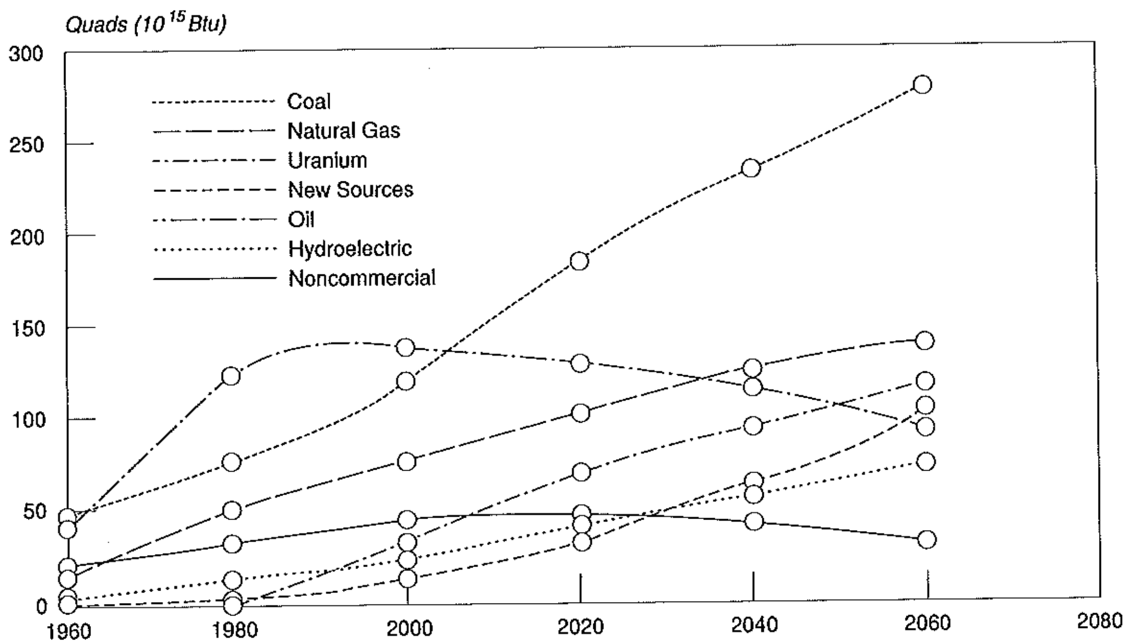
SOURCES: U.S. DOE Energy Information Administration and Electric Power Research Institute

FIGURE D-5 Range of Price Forecasts Delivered to Utilities



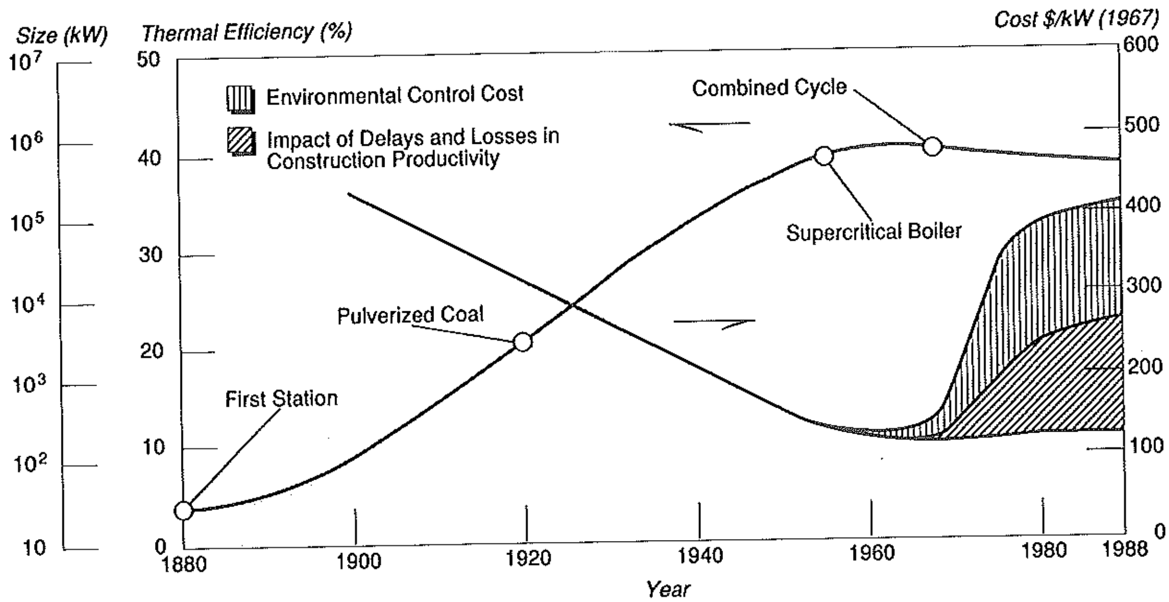
SOURCES: U.S. DOE Energy Information Administration and Electric Power Research Institute

FIGURE D-6 Evolution of World Energy Utilization



SOURCE: World Energy Conference - Conservation Commission, 1986

FIGURE D-7 Coal-fired Power Plant Evolution



SOURCE: Electric Power Research Institute

size increased from 50 kW to 1200 MW. As a result, the cost of new generating capacity dropped from $350/kW in 1920 to $130/kW in 1967 (constant 1967 dollars), and average residential service cost dropped from $0.25/kWh to $0.02/kWh. This pattern of improved efficiency and lower energy costs ended in the late 1960s, suggesting that existing power plants had approached the limits set by thermodynamics, available materials, and economics. Moreover, it coincided with the increasing priority on controlling environmental pollutants.

Today, after three decades of environmental regulation, environmental specifications have become a dominant consideration in design and operation of coal-fired plants, contributing 30 percent or more to capital and operating costs. According to the Department of Commerce Bureau of Economic Analysis, the overall price tag for all U.S. air pollution control now exceeds $29 billion each year. EPA reports that the electric utility industry alone spends about $10 billion annually.

This conflict between new performance demands and old technology has been a key factor pushing the cost of coal-generated electricity higher just at a time when emphasis on coal has been reinforced due to the energy stability and national economic and security risks involved in reliance on imported oil. Indeed, in the United States today it costs three times more in constant dollars to install a kilowatt of coal-fired generating capacity than in 1967, and even more than in 1920. ICCT is essential to controlling this cost escalation.

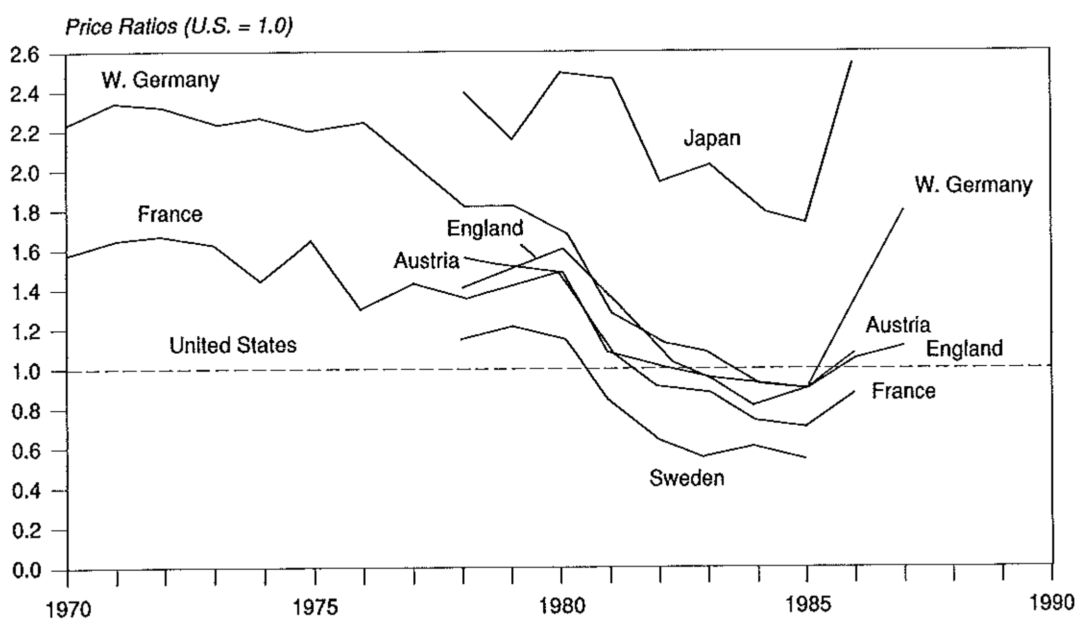
In the past, low electricity costs contributed to U.S. industrial competitiveness abroad. As Figure D-8 shows, during the period between the mid-1970s and 1985 the gaps between United States and foreign electricity costs narrowed or even reversed. Domestic industries thus felt pressure to reduce electricity costs. Less competitive utility electricity prices led industrial customers to self-generate, switch to gas or oil, or move to utility service areas with less expensive electricity, even overseas (e.g., to Australia, as in the case of the aluminum industry). Even with the dramatic turnaround in exchange rates during 1986–87, most of the foreign country/U.S. electricity price ratios shown in Figure D-8 have not returned to their mid-1970s levels.

Figure D-9 shows the increase in electric utility power plant costs attributable to environmental controls since 1900, as well as the percent of pollutants controlled. As the figure illustrates, at the same time compliance with emissions controls has been expensive it has also been effective. For example, SO_2 emissions from coal-fired power plants in the United States decreased by about 18 percent between 1973 and 1986 at the same time as utility coal consumption was increasing by 76 percent. Figure D-10 shows this downward trend in national SO_2 emissions since passage of the Clean Air Act, along with projections of future emissions with continuation of existing environmental standards. Based on current and estimated industry trends, most analysts foresee a continuing decline in SO_2 emissions over at least the next 30 years.

Also shown in Figure D-10 are NO_x emissions which increased until 1977, remained roughly constant until 1979, and then began to decrease slowly. The administration's recent endorsement of the international NO_x protocol is intended to maintain NO_x emissions at or below current levels. In contrast to SO_2, electric utilities contribute only about one-third of national NO_x emissions (one-half is attributable to automobiles). If concerns about acid precipitation and nonattainment of urban ozone air quality standards dictate that emissions of NO_x be further decreased, then ICCT includes options which can more cost-effectively address such requirements.

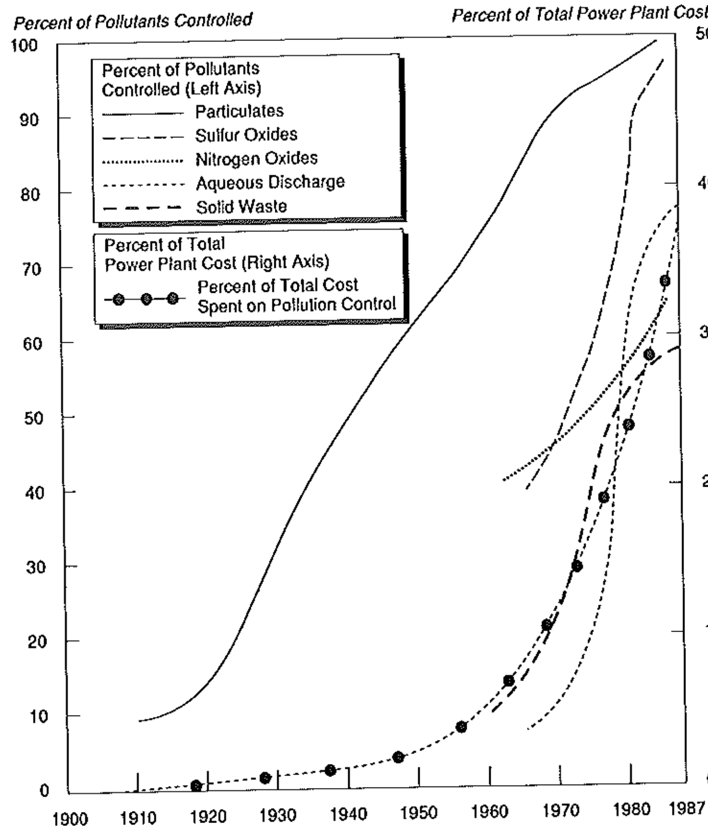
At issue, ultimately, is how best to sustain the progress being made in emission control at a cost that both maintains coal's competitiveness in the energy marketplace and encourages its greater use so as to reduce dependence on more costly, less reliable alternate fuels, and increase domestic productivity and international competitiveness.

FIGURE D-8 Foreign and U.S. Industrial Electricity Price Ratios



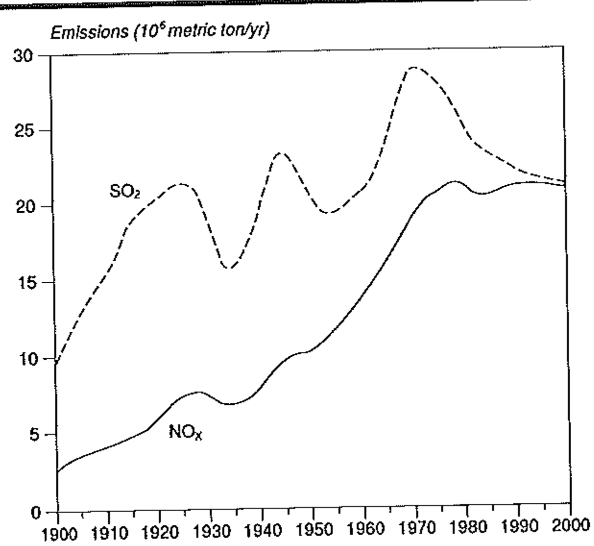
SOURCES: U.S. DOE Energy Information Administration and the International Energy Agency

FIGURE D-9 Percentage of Power Plant Cost Spent on Pollution Control as Percentage of Pollutants Controlled Increases



SOURCE: "Coal-fired Power Plants of the Future," *Scientific American*, September 1987

FIGURE D-10 Trends in U.S. Man-made NO_x and SO_2 Emissions



BASIS: NAPAP, Interim Assessment Report

Appendix E

ICCT Policy Evolution

The evolution of ICCT policy in the United States represents an important backdrop against which to consider the policy decisions of today.

The first coherent recommendations concerning coal use and the environment were made by the Department of Commerce Technical Advisory Board after the oil "crisis" of 1973. The advisory board observed that "not until improved clean fuel technology or improved emission control technology is developed will the maximum utilization of coal be achieved." Further, "protection of the environment is essential, yet it must be balanced by other needs of the Nation. The Panel is of the opinion that some laws, regulations, and Court decisions are unnecessarily restrictive."

The board's recommendations remain relevant today. They included:

- "Establish government policies which provide an economic, regulatory, and environmental climate conducive to the development of coal both with respect to supply and utilization. Such policies must include protection via import limitations against sudden and predatory reductions in international oil prices."
- "Although expansion of all energy sources is required, the maximum effort over the next 15 years must be directed toward a twofold to fourfold increase in coal production and its direct utilization and conversion to synthetics."
- "Modify existing Federal Air Pollution Regulations to permit continued use of high-sulfur fossil fuel as long as health standards are not exceeded."
- "Accelerate Federal R&D and demonstration efforts for improving air pollution control technology."
- "Streamline the environmental impact evaluation and site certification procedures, to greatly reduce the time span presently required for certification."

Recognizing that electric utilities were the primary users of domestic coal production, the board went on to include the following additional recommendations:

- "Provide fast and adequate rate relief"
- "Modify tax measures to increase the internal generation of funds"
- "Adopt a fast 'minimum stop' procedure for Federal and State approvals of plant installations"
- "Insure that environmental regulations for generating stations are justified on a cost/benefit basis"
- "Stabilize environmental regulations"
- "Initiate a joint government and electric utility public information program"

Environmental Policy Development

At the same time these recommendations were being made, environmental policy was evolving that would have major effects on the coal market. This policy was, for the most part, formulated outside the energy policy arena according to its own criteria and constituency, and has since presented significant constraints and resulted in significant compliance costs to coal producers and users. Controls have been highly specific and have not generally included an economic analysis of the tradeoffs between the costs and benefits of environmental protection. In addition, they have usually not emphasized the least-cost ways of minimizing environmental damage.

Federal environmental regulation on a broad scale began with the Clean Air Act of 1970. This act empowered the U.S. EPA to establish ambient air quality standards for "safe" levels of pollution and to introduce, in regions already satisfying ambient air standards, a program for "prevention of significant deterioration." In 1971 the EPA also set rules limiting the emitted amount of sulfur oxides per million Btu of fuel burned in new power plants. These, in turn, compelled the use of low-sulfur fuel or scrubbers to reduce emissions.

In 1977 the Clean Air Act amendments eliminated the economic advantage of using low-sulfur coal by requiring that all new power plants install scrubbers, using the administratively defined "best available control technology" (BACT) and imposing rigid requirements for reduction of emissions without reference to existing levels. These measures, which were widely perceived as intended to preserve markets for high-sulfur coal, have raised the cost of coal-based power considerably more than would be necessary to meet existing standards of environmental protection.

Inconsistent Energy Policy

On the heels of another oil shock, President Carter convened a Commission on Coal whose 1980 Recommendations and Summary Findings again recommended a program of government controls, incentives, and regulations to increase the use of coal and substitute it for imported oil at an accelerated rate. However, as in 1975, the recommendations were not politically or economically sustainable.

For example, the Synthetic Fuels Corporation was created to make loans and grant subsidies for development of synthetic fuel processes and plants. The unexpected availability in the 1980s of petroleum at market clearing costs well below the ability of synthetic products to compete delayed achievement of cost-effective coal conversion technology and thus rendered the organization charged with its introduction both superfluous and a political liability.

Thus, a pattern has emerged: during periods of energy "crisis" when oil supply/cost is threatened, energy policy turns heavily to coal as an abundant fuel resource, a source of synthetic substitutes for oil, a readily available substitute for other forms of energy, and a useful source of geopolitical power to offset the strategic vulnerability of oil dependence. None of these initiatives has been consistently pursued, however, while restrictive regulations have accumulated during the more frequent periods when energy supply is not a politically viable issue.

ICCT Beginnings

During the 1970s, while the federal government was directing its efforts primarily to synthetic fuel technology, the private sector—particularly the electric utility industry and its suppliers—was devoting its more limited resources to the development of an array of ICCT options. Specific attention was given to improved coal cleaning, combustion modifications, gasification, and flue gas cleaning techniques designed to address the productivity and environmental requirements facing power generation.

The primary goal for coal producers and users with this early initiative, and still today, was to capture the advantages ICCT offers to increase the range of available environmental control choices and to reduce costs—thus increasing the profitable markets for coal and/or the final energy products and services it provides.

As a result of this less intensive but generally more consistent private sector effort, an array of promising advanced combustion, coal conversion, and emission control processes successfully completed pilot-scale development and were at the threshold of commercial demonstration. The question was no longer whether coal could be used cleanly, but whether there would be the resources and incentives to achieve prompt commercial application of these ICCTs.

The urgency for a national clean coal technology initiative was underscored during this period by the rapidly escalating cost of environmental control on conventional coal-fired power plants. These costs, plus those associated with the institutional stretch-out of plant construction, had effectively defeated economies of scale and priced new, conventional coal-fired generating capacity out of the market for most utilities. Only a fundamental improvement in coal utilization technology, which had stagnated for nearly 30 years, could effectively respond to these growing constraints on coal-fired power generation and restore economic progress in electricity production.

In November 1984, Congress created a federal clean coal program and authorized a $750 million Clean Coal Technology Reserve in the U.S. Treasury (P.L. 98-473). Congress directed the DOE to solicit "statements of interest in, and proposals for, projects employing emerging clean coal technologies." These projects would be jointly funded by the federal government and private industry. The federal cost share was capped at 50 percent.

By February 1985 DOE had received 159 statements of interest in cost-shared demonstration projects from sponsors in 29 states with a total project value of over $8 billion. These responses covered the full spectrum of ICCT options. Based on this response, Congress in December 1985 provided $400 million from the Clean Coal Technology Reserve Fund over three fiscal years for DOE implementation of selected projects.

In the Shadow of Lewis-Davis

In 1986, Special Envoys Drew Lewis (United States) and William Davis (Canada) in their report entitled *Joint Report of the Special Envoys on Acid Rain* recommended that the United States undertake a five-year, $5 billion program (to be funded equally by the federal government and the private sector) to demonstrate ICCTs. This recommendation was endorsed in March 1986 by President Reagan at the U.S.-Canadian summit meeting.

The administration's endorsement of the Lewis-Davis recommendation represented a major milestone in national coal/environmental policy development. It formally recognized that environmental protection would be better achieved through use of innovative technology than conventional plant modifications which could compromise both productivity and the environment. And, it acknowledged that accelerated commercial deployment of new technology, especially by regulated utilities, will require cost-sharing and other incentives not yet available.

In March 1987 President Reagan announced plans to seek $2.5 billion in federal funding over the next five years, matched by private industry, to expand the ICCT program. The President also announced that his Task Force on Regulatory Relief would examine existing federal and regulatory incentives and disincentives to the deployment of ICCTs, and that ICTAP, a panel made up of state, federal, U.S. industry, and Canadian representatives, would be formed to assist DOE in future selection of ICCT demonstrations.

The stated objectives of the Administration's $2.5 billion ICCT program were to:

- "Expand the suite of technologies available to cost-effectively utilize coal while reducing emissions relative to current technologies"
- "Obtain sufficient technical, economic, environmental, health, safety, and operational information at a scale large enough for the private sector to make rational commercial decisions"
- "Improve the competitiveness of the U.S. in coal utilization and control devices"

The guidelines for this program emphasized that industry would manage the selected projects with DOE acting as a risk sharer, facilitator, and overseer. In addition, the evaluation criteria would be tailored to those identified in the Lewis-Davis report, and the financial provisions would be similar to those used in the initial clean coal demonstration solicitation.

Recommendations have also been made by the President's Task Force on Regulatory Relief and accepted by the President to facilitate ICCT deployment. Affected federal agencies are currently examining the means by which to implement the proposed changes, which include:

- Preferential treatment under the DOE clean coal program for projects in states, that, for ratemaking purposes, treat innovative technologies the same as pollution control projects. Also selection preference should be given to innovative technologies that promise superior cost-effectiveness.
- A FERC five-year demonstration program allowing rate incentives for innovative technologies (coal and noncoal) including:
  - Incentive rates of return on investments
  - 100 percent CWIP in rate base
  - Faster (10–20 yr) amortization of investment costs than is normally allowed for ratemaking purposes
- EPA actions including allowing interpollutant trading, encouraging additional "bubbling" in emission control requirements, and expanding commercial demonstration permits for innovative technologies.

With these government initiatives and proposals, and continued vigorous private sector leadership, ICCT development has moved to the edge of the deployment stage. If aggressive ICCT deployment can be completed over the next decade, there is real hope of resolving the conflict between energy and environmental policy that has stalemated coal utilization. What is required is increased and stable government participation in the effort.

Appendix F

Letter from the Secretary of Energy and the Response of the National Coal Council

THE SECRETARY OF ENERGY
WASHINGTON, D.C.

November 6, 1987

Mr. James G. Randolph
Chairman
National Coal Council
P.O. Box 17370
Arlington, Virginia 22216-7370

Dear Mr. Randolph:

The two reports the National Coal Council (NCC) submitted in June were extremely valuable. Now that they have been completed, this is an appropriate time to request new studies for the NCC to undertake. Particularly, there are two studies I am requesting and which are described in the following items:

1. Clean Coal Technology -- Many reports have been generated recently on the potential impacts of deploying innovative clean coal technologies. Areas addressed in these reports include economic and environmental benefits as well as opportunities to link export of innovative clean coal technologies to U.S. coal export sales. A compilation of these reports is needed. In addition, recognizing the substance of these reports, advice is needed on what actions the Federal Government can take to commercially deploy the technologies once demonstrated so that the Administration's coal-related energy, environmental and competitiveness goals can be achieved.

2. Coal utilization in the light industrial, commercial, residential and transportation sectors -- What are the opportunities for innovative technologies? A study is needed of the impediments to and actions that can be taken to accelerate the penetration of coal or coal-derived fuels into the nonutility sectors. In addition, quantification of the potential impact on energy security resulting from application of coal-based fuels in these sectors would be very useful. The study should span mine mouth to end user and indicate technical and economic impacts of codes and regulations on fuel transport, waste removal and coal or coal-derived fuels utilization.

I believe these studies to be extensions of or complementary to the first six reports: "Coal Conversion," "Interstate Transmission of Electricity," "Clean Coal Technology," "Industrial New Source Performance Standards," "Reserve Data Base," and "Improving International Competitiveness of U.S. Coal and Coal Technologies." I appreciate the Council's efforts in preparing these reports and recognize the quality of analyses and poignancy of recommendations found in the reports. I look forward to receiving resulting reports from the two new studies mentioned above.

Yours truly,

John S. Herrington

THE NATIONAL COAL COUNCIL, INC.
Post Office Box 17370, Arlington, Virginia 22216
(703) 527-1191

November 19, 1987

The Honorable John S. Herrington
The Secretary of Energy
Department of Energy
1000 Independence Avenue, S. W.
Washington, D.C. 20585

Dear Mr. Secretary:

On November 12, the National Coal Council unanimously accepted your request for two additional studies to assist the Department in its formulation of national energy policy.

Dr. Kurt Yeager, Electric Power Research Institute, will chair the work group on clean coal technology. Mr. Joseph Plante, Stone and Webster, will direct the study on coal utilization in the light industrial, commercial, residential, and transportation sectors. The Coal Policy Committee, chaired by Dr. Irving Liebsen, Bechtel Corporation, will provide overall study oversight and coordination to insure proper consideration of all relevant information and data.

The Council will strive to provide comprehensive, yet concise, reports that are objective and balanced in their treatment of information considered in preparation of the reports.

On behalf of the entire Council, I wish to express our appreciation for this opportunity to contribute through these studies our collective experience and insight about pertinent and relevant energy issues.

Sincerely,

James G. Randolph
Chairman

JGR:ph

cc: W. Carr
I. Leibsen
J. McAvoy
J. Plante
K. Yeager

An Advisory Committee to the Secretary of Energy

Appendix G

Listing of Issue Papers Developed By The Work Group

A series of Work Group papers was developed as background for this report. These papers were organized around seven issues bearing on ICCT deployment (subgroup leaders/issue paper authors are listed in parentheses):

- Federal government participation in ICCT deployment (E. Allen Womack, Jr.)
- State regulatory and governmental roles in ICCT deployment (Thomas V. Chema)
- Private sector support for ICCT deployment (John W. Wootten)
- Implications of ICCT deployment for coal utilization (James J. Markowsky)
- Implications of ICCT deployment for environmental protection (Don Carlton)
- Implications of ICCT deployment for U.S. trade and competitiveness (Joseph Farrell)
- Public education and consensus building for ICCT (Edward S. Rubin)

Appendix H

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 idea of a similar advisory group for the coal industry was put forward in 1984 by the White House Conference on Coal. 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 of 1985, Secretary of Energy John Herrington made the Council fully operational. Secretary Herrington's action was based on his conviction that such an industry advisory council could make a vital contribution to America's energy security by providing him with 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 Council is chartered by the Secretary of Energy under the Federal Advisory Committee Act. The purpose of The National Coal Council is solely to advise, inform, and make recommendations to the Secretary of Energy with respect to any matter relating to coal or the coal industry that he may request.

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 the views of any one particular part of the country. It is instead a broad, 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 study. The request is then referred to the Coal Policy Committee which makes a recommendation to the Council. The Council reserves the right to decide whether or not it will consider any matter referred to it.

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. These reports covered New Source Performance Standards for Industrial Boilers, Coal Conversion, Clean Coal Technologies, and Interstate Transmission of Electricity.

In 1987, at the request of the Secretary, the Council completed and presented two additional reports: Coal Reserve Data Base, and International Competitiveness of U.S. Coal and Coal Technologies.

The Council also can determine topics it believes significant for study and then seek the approval of the Secretary to proceed, as in the case of the study of New Source Performance Standards for Industrial Boilers, also completed in 1986.

Members of The National Coal Council are appointed by the Secretary of Energy and represent all segments of coal interests and geographical dispersion. The National Coal Council is headed by a Chairman and Vice Chairman who are elected by the Council. The Council is supported entirely by voluntary contributions from its members.

Appendix I

The National Coal Council Membership Roster 1988

*Mr. John W. Arlidge
Vice President
Resource Planning and Power Dispatch
Nevada Power Company

Mr. Bert Ballengee
Chairman of the Board/CEO
Southwest Public Service Company

Mr. John P. Baugues, Sr.
President
James Spur Coal Company, Inc.

Mr. Daniel Beam
Commercial Fuels, Inc.

Mr. Donald P. Bellum
Executive Vice President
Cyprus Minerals Company

Mr. Thomas J. Belville
President
Belville Mining Company, Inc.

Mr. William W. Berry
Chief Executive Officer
Dominion Resources

Mr. George M. Bigg
President
Simms Fork Associates, Inc.

Mr. Gerald Blackmore
G. Blackmore, Inc.

Ms. Sandra Blackstone
Professor - College of Law
University of Denver

*Mr. Brent W. Blauch
Vice President
Environmental Power Corporation

Mrs. Joan T. Bok
Chairman
New England Electric System

*Mr. Phil A. Bowman
President
R. A. Eberts Company, Inc.

*Mr. Thomas H. Brand, Jr.
President
York Services Corporation

Mr. J. Robert Bray
Executive Director
Virginia Port Authority

Mr. William T. Bright
Chairman of the Board
Land Use Corporation

Dr. Robert W. Brocksen
Executive Director
Living Lakes, Inc.

Mr. Bobby R. Brown
Chairman/CEO
Consolidation Coal Company

*Mr. Thomas Brown
Representative
Eastern Conference Teamsters

Mr. Omer Bunn
President
Southwestern Virginia Coal Corporation

Dr. Donald Carlton
President
Radian Corporation

Mr. William Carr
President
Mining Division
Jim Walter Resources, Inc.

The Honorable Garrey Carruthers
Governor of New Mexico

Mr. William Cavanaugh, III
President/Chief Executive Officer
System Energy Resources, Inc.

Mr. Fred Clayton
President
Shand Mining, Inc.

*Mr. Robert P. Cooper
Vice President
Land Acquisition and Environmental Affairs
Farrell-Cooper Mining Company

*Mr. Joseph W. Craft, III
President
MAPCO Coal, Inc.

* Denotes new member as of April 1988

*Mr. A. W. Dahlberg
President
Georgia Power Company

*The Honorable Eddy Dalton
Virginia State Senator
General Assembly Building

Ms. Barbara Deverick
Administrative Manager
Blueridge Electric Membership Corp.

Mr. Garry Drummond
Chairman of the Board
Drummond Coal Company

Mr. John Dwyer
President
North Dakota Lignite Council

*The Honorable George Evans
Secretary
Kentucky Energy Cabinet

Mr. Jack R. Fairchild
Chairman/CEO
Fairchild International

Mr. Joseph Farrell
Chairman-Coal Group
The Pittston Company

*Mr. Jerry Farrington
Chairman and Chief Executive Officer
Texas Utilities Company, Inc.

Mr. Mason Foertsch
President
Foertsch Construction Company

Mr. Lawrence E. Forgy, Jr.
Attorney at Law
Stohl, Keenan, and Park

***Mr. Joseph A. Frank
President
Centralia Coal Sales Company

Mr. George Fumich, Jr.
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Appendix J

The National Coal Council Coal Policy Committee 1988 and the ICCT Deployment Policy Work Group

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