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Clean Coal Technology Demonstration Program

Annual Report to Congress

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EXECUTIVE SUMMARY

On December 22, 1987, Public Law No. 100-202, "An Act Making Appropriations for the Department of the Interior and Related Agencies for the Fiscal Year Ending September 30, 1988, and for Other Purposes," was signed into law. Included in this act were provisions to fund cost-shared, innovative clean coal technology projects to demonstrate emerging clean coal technologies that are capable of retrofitting or repowering existing facilities. Coupled with the President's announcement on March 18, 1987, regarding the Nation's ability to break the linkage between the increased use of coal, the most abundant energy resource in the United States, and concern over environmental disorders such as acid rain, this act will have a major impact on the Department of Energy (DOE) Clean Coal Technology Demonstration Program.

On March 18, 1987, the President announced three significant new actions:

- A strategy for demonstrating, in partnership with industry, a new generation of coal-burning technologies: clean, highly efficient concepts that can restore the energy strength of America without compromising its environmental goals
- A strategy for deploying these new technological options by removing regulatory obstacles, rather than providing market subsidies
- A strategy for public input and participation in shaping and overseeing these important national initiatives.

Along with previous Presidential support for the National Acid Precipitation Assessment Program, these actions will expand the Nation's efforts in combating acid rain problems, as well as expand our options for developing new pollution control technologies and improved power generating processes, each operating more cleanly and more economically than today's aging hardware.

The Clean Coal Technology Demonstration Program is a $5-billion national commitment to be shared equally by the Government and the private sector. The twin approach of scientific study and technology development will ensure that the United States acts responsibly in shaping its energy and environmental future.

Previous clean coal technology efforts initiated by the Congress resulted in the passage on December 19, 1985, of Public Law No. 99-190, "An Act Making Appropriations for the Department of the Interior and Related Agencies for the Fiscal Year Ending September 30, 1986, and for Other Purposes." Included in this act were provisions for funds to conduct cost-shared, clean coal technology projects for constructing and operating facilities demonstrating the feasibility of future clean coal commercial applications. These demonstration projects comprise the Clean Coal Technology-I (CCT-I) Program.

As a result of the funding provided by Public Law No. 99-190, DOE selected nine projects for cooperative agreement negotiations. At this time, seven cooperative agreements have been executed. Two industrial participants withdrew their proposals from further consideration. Four replacement projects were selected by DOE on October 7, 1987. Fact-finding activities are currently under way on these four proposals. Detailed information on each of the currently selected 11 projects for CCT-I is provided in this report. Included are significant features of projects, process descriptions, key milestones, and the status of progress for each project.

For the follow-on Innovative Clean Coal Technology Program (ICCT), the Program Opportunity Notice is expected to be issued in February 1988 with proposals due by late May 1988. The selection of projects for the ICCT program is expected by fall 1988.

The Clean Air Act as amended in 1970 and 1977 has resulted in improving the quality of the Nation's air during the past decade. Sulfur oxide (SO_x) emissions have declined dramatically. Nationwide, coal-fired powerplants reduced SO_x emissions by 11.4 percent from their peak in 1977 even though coal consumption rose steadily. From 1973 to 1985, the use of coal by U.S. electric utilities increased by 78 percent, from 389 million tons per year to 693 million tons per year. Reductions in sulfur emissions from coal-fired powerplants in the environmentally sensitive Northeast have been more dramatic, dropping by 19 percent from 1975 to 1985, even as coal consumption in this region increased by 23 percent.

The environmental progress required by the Clean Air Act has not been achieved without cost, however. Since the act was passed 18 years ago, U.S. industry has spent over $225 billion to control air emissions. A major portion has been spent by the electric utility industry to generate power cleanly from coal. From 1975 to 1985, the Nation's utilities have spent $60 billion for SO_x capture. The Environmental Protection Agency estimates that the electric industry alone spends about $10 billion annually for air pollution controls.

To date, these expenditures have been made on the only three available options for controlling SO_x:

- Flue gas scrubbing
- Coal cleaning
- Coal switching

Current technologies can achieve the pollution control requirements of the Clean Air Act, albeit with some trade-offs. For example, flue gas desulfurization (scrubbers) can remove 90 percent of the sulfur pollutants from the combustion gases of coal. But scrubbers are very costly and have virtually no effect on nitrogen oxide (NO_x) emissions. Scrubbers also consume a portion of the powerplant's energy, thereby reducing efficiency and raising the cost of electricity. In addition, they produce massive amounts of waste that are difficult to handle and are environmentally damaging if not disposed of properly.

Conventional coal cleaning has a limited ability to remove sulfur impurities, typically only 10 percent to 30 percent of the total sulfur in coal, and therefore cannot achieve the more stringent Clean Air Act standards by itself. Coal switching cannot be used to meet new standards and, even if applied to existing

plants, often results in diminished boiler performance and increased costs (because low-sulfur coal is typically more expensive than high-sulfur coal).

The Clean Coal Technology Demonstration Program can dramatically change how the Nation utilizes its vast coal resource base. By doing so, the program will contribute significantly to the long-term energy security of the United States in a manner compatible with environmental objectives.

The program is not a research and development effort. Rather, it is a cost-sharing effort with industry to select improved coal-based technologies that have been proven to work at smaller scales and move them into large-scale demonstration, where their market viability and commercial-scale performance can be assessed. Candidate projects are selected for direct financial assistance for a specific period of design, construction, and operation. The private sponsor, who must contribute at least half the costs of the demonstration effort, is then responsible for commercialization of the technology.

The clean coal technology initiative sets into motion a national commitment to meet the demands of a rapidly changing power industry. It also opens new opportunities for coal to penetrate industrial, commercial, residential, and transportation markets previously dominated by petroleum-based fuels.

The successful outcome of the 5-year Clean Coal Technology Demonstration Program would result in a new suite of advanced, clean-burning coal technologies including:

- More effective precombustion coal cleaning processes
- New combustion techniques that remove sulfur and nitrogen pollutants inside the coal furnace
- Improved scrubber systems capable of removing sulfur and nitrogen pollutants without producing the wet sludges of today's technology
- Advanced energy concepts that produce clean-burning fuels, such as coal-based liquid products or combustible gases from unminable coal seams
- Highly efficient, more environmentally benign, coal-based combined-cycle powerplants that can be fabricated easily and quickly in a wide range of modular sizes.

The common theme of the program is using domestic coal more efficiently while protecting the environment. Clean coal technologies offer the opportunity to produce usable energy at costs much lower than today's technologies. Several of the concepts have the added advantage of boosting an existing powerplant's electrical output, possibly forestalling expensive investments in new power-generating capacity. In addition, the program has the potential to improve the international competitiveness of U.S. technologies and to increase U.S. coal exports.

1.0 OVERVIEW OF THE PROGRAM

1.1 Role of the Program

The Clean Coal Technology Demonstration Program is a technology development program jointly funded by Government and industry. It will take the best and most promising of the advanced coal-based processing and emissions control technologies and over the next decade move them from the proof-of-concept stage into the commercial marketplace through demonstration. These demonstrations will be at a scale large enough to generate all data (from design, construction, and operation) necessary for the private sector to judge their commercial potential and to make informed commercial decisions. In this manner, the program serves as a bridge between research and development and the marketplace.

The activities of the program respond directly to the strategic importance recognized for coal both in the U.S. economy and in the international marketplace. This importance is emphasized by the fact that more than one-quarter of the world's total supply of recoverable coal lies in massive deposits beneath 38 of the 50 States.

Optimizing the potential of these resources for application in each of the many impacted sectors of the U.S. economy depends on how successful the program has been in generating options for the increased use of coal in an environmentally responsive manner. When grouped together, these options or applications establish the role of the clean coal program as being:

- A cornerstone of the U.S. acid rain strategy
- An effective strategy for achieving long-range goals in power production
- The passport to energy security
- The competitive edge in the international marketplace.

1.1.1 A Cornerstone of the U.S. Acid Rain Strategy

In January 1986, Special Envoys Drew Lewis of the United States and William Davis of Canada presented the findings of a study commissioned jointly a year earlier by the President of the United States and the Prime Minister of Canada. Beyond their recognition of the international nature of acid rain, the Special Envoys made three key recommendations:

1. The initiation of a 5-year, $5-billion program in the United States for commercial demonstration of innovative clean coal technologies

2. A commitment to ongoing cooperative activities, including bilateral consultations and information exchange

3. A greater emphasis on carrying out research essential to resolving transboundary acid rain issues.

The U.S. technology demonstration program was a key aspect of the report's recommendations. By proposing that the U.S. Government share the costs of a $5-billion demonstration program with industry, the Special Envoys believed that the commercial availability of more cost-effective control technologies would be accelerated. According to the report, "If the menu of control options were expanded, and if the new options were significantly cheaper, yet highly efficient, it would be easier to formulate an acid rain control plan that would have broader public appeal."

Because this technology demonstration program would be meant as part of a long-term response to the transboundary acid rain problem, the Special Envoys recommended that prospective projects should be evaluated according to several specific criteria:

- The Federal Government should cofund projects that have the potential for the largest emission reductions, measured as a percentage of sulfur or nitrogen oxides removed.

- Among projects with similar potential, U.S. Government funding should go to those that reduce emissions at the cheapest cost per ton.

- More consideration should be given to projects that demonstrate retrofit technologies applicable to the largest number of existing sources, especially existing sources that, because of their size and location, contribute to transboundary air pollution.

- Special consideration should be given to technologies that can be applied to facilities currently dependent on the use of high-sulfur coal.

In March 1986, the President endorsed the Special Envoys' recommendations. Simultaneously, the Department of Energy (DOE) was carrying out a congressionally directed competition to select an initial set of clean coal demonstration projects. The President's endorsement of the Special Envoys' report set into motion a year-long effort within DOE to develop an expanded clean coal technology program that would build on the initial congressional effort, reflect ongoing State and privately initiated efforts, and be fashioned, as fully as practicable, from the guidelines recommended by the Special Envoys.

The President commissioned an expanded program consisting of three major steps. These steps included:

- Seeking the full amount of the U.S. Government's share of the funding recommended by the Special Envoys--$2.5 billion--for demonstrating innovative control technology over a 5-year period. Five hundred million dollars would be requested for the fiscal years 1988 and 1989 to fund innovative emissions control projects. Industry would be encouraged to invest an equal or greater amount over this period.

- Directing the Secretary of Energy to establish an advisory panel. This panel, which would include participation by State governments and by the Government of Canada, would advise the Secretary of Energy on funding and criteria for selecting innovative control technology projects. As fully as practicable, projects would be selected by using the criteria recommended by the Special Envoys.

- Requesting the Vice President to have the Presidential Task Force on Regulatory Relief review Federal and State economic and regulatory programs to identify opportunities for addressing environmental concerns under existing laws. The Task Force would examine incentives and disincentives to the deployment of new emissions control technologies and other cost-effective, innovative emissions reduction measures now inhibited by various Federal, State, and local regulations.

1.1.2 An Effective Strategy for Long-Range Goals in Power Production

The convergence of two trends, aging powerplants and increasing power demand, is occurring at the same time environmental requirements for new powerplants are becoming increasingly stringent. Since the passage of the Clean Air Act, Prevention of Signification Deterioration (PSD) regulations have significantly increased the permitting time for major new sources of emissions. In addition, the Clean Air Act amendments of 1977 introduced nonattainment area requirements for new sources requiring, in many cases, emission levels for individual plants that are more stringent than national emission standards.

Today's technology will have difficulty responding to the rapidly changing requirements being placed on powerplants. New power options must be capable of meeting stringent siting and environmental demands without sacrificing productivity. The importance of new, more economical environmental control technologies is underscored by the fact that approximately 40 percent of the capital investment and 30 percent of the total cost of power for new, conventional, coal-fired powerplants are related to environmental controls.

The powerplant of the future must not only be clean and economical but also be capable of being rapidly constructed, preferably in modular fashion, with a high degree of performance efficiency over a range of unit sizes. Future environmental control options must be less sensitive to fuel type and retain acceptable economies over a wide range of boiler sizes and types.

Present-day commercial technology cannot meet these objectives in many situations. In fact, conventional commercial technology--both for power production and pollution control--is nearing the end of its development potential. Therefore, the next 5 to 10 years will be critical to the development of new energy options that meet America's energy, economic, and environmental goals.

The successful outcome of the clean coal technology program will be a new suite of advanced, environmentally improved, coal-burning technologies that include:

- More effective precombustion coal cleaning processes

- New combustion techniques that remove sulfur impurities and minimize nitrogen pollutants inside the coal furnace

- Improved scrubber systems capable of removing sulfur and/or nitrogen pollutants without producing the wet sludge of today's technology

- Advanced energy concepts that produce clean-burning fuels, such as coal-based liquid products or combustible gases from unminable coal seams

- Highly efficient, environmentally responsive, coal-based combined-cycle powerplants that can be easily and quickly fabricated in a wide range of modular sizes.

A common thread running through each of these advanced coal concepts is the ability to use domestic coal more efficiently while better protecting the environment. Several of these concepts have the added advantage of boosting an existing powerplant's electrical output, possibly forestalling expensive investments in new power generating capacity.

Together, they can bring the Nation to the threshold of technological opportunities that could significantly reduce, or perhaps eliminate, the threat of acid rain damage in the future, while at the same time create the capabilities to solve the anticipated problems expected to confront the Nation in its long-range efforts to meet requirements for increased power production capacity.

1.1.3 The Passport to Energy Security

Coal's abundance makes it one of the Nation's most important strategic resources in building a more secure energy future. (Coal comprises 80 percent of the known U.S. fossil fuel resources.) Coal can be one of the country's most useful energy sources well into the 21st century and beyond. With current prices and technology, U.S. recoverable reserves of coal could supply the Nation's coal consumption at current rates for nearly 300 years.

Although the United States is endowed with vast quantities of coal, it must be recognized that coal is a demand-constrained commodity. The characteristics of coal tend to inhibit its greater use as a fuel. While lower coal prices would promote some increase in consumption, more substantial demand increases are hindered currently by various technical, regulatory, and environmental obstacles. If coal is to reach its full potential, economically competitive, advanced coal-using systems must be developed; these systems must be sensitive to diverse energy markets and site-specific factors as well as stringent environmental requirements.

The expanding state of innovative clean coal technologies being developed will provide substantially improved options that are preferable to today's choices. The continued development and deployment of these clean coal technologies will reduce the technical obstacles, while the initiative to review and modify regulatory barriers offers the potential to create incentives for investment in new, upgraded, environmentally responsive, clean-coal-using facilities. Both activities are essential components of the Clean Coal Technology Demonstration Program. Thus, successful accomplishment of the goals of the clean coal program, a public and private sector partnership, will make coal an environmentally attractive fuel and an alternate source of energy residing within and controlled by the United States.

1.1.4 The Competitive Edge in the International Marketplace

New technology is a major factor in making the coal export package attractive. The technologies coming out of the Clean Coal Technology Demonstration Program may provide the single most important advantage that the United States could have in the global race for new technologies and new energy supplies. If this program is successful, the United States will have in place by the mid-1990's a full complement of demonstration facilities--each a showcase for a new clean coal concept: new combustors, new scrubbing concepts, new coal cleaning devices, and new power generating options, all using U.S. coals.

The ability to show a prospective overseas customer an actual operating facility running on U.S. coal, rather than just a drawing-board concept or an engineering prototype, is expected to be a very persuasive inducement. It easily could be the advantage that will sway overseas consumers to buy an American package of coal and the proven technology to burn it cleanly and effectively. This opportunity is consistent with and recognizes the increasing demand for safe, effective technology that does not impose further burdens on environmental quality. These clean coal technologies also will satisfy the demand for lower cost, more highly efficient energy concepts that will not reverse the recent gains in economic growth by imposing new costs on consumers.

The marketing advantage of clean coal technology in supplying these equipment demands is clear when it is recognized that most of the technology on the market is vintage 1940. Most of it could not stand up against the efficiency or cleanliness of modern fluidized-bed boilers or other advanced combustion or conversion concepts.

Hardware and power generating concepts--from combustors to gas cleanup; to advanced sensors, instrumentation, and diagnostics; to repowering technologies such as pressurized fluidized-beds and gasification combined cycles--can be an effective marketing tool when included with the coal itself. This linkage can be a most effective marketing edge and provides essential options to foreign utilities to address problems similar to those expected by the U.S. power industry. Unless resolved, these problems will adversely impact the industry's ability to meet increased demands in an environmentally acceptable manner. The future of coal as an acceptable and perhaps desired energy option lies in the development and subsequent use of these clean coal technologies.

1.2 The Technologies

The term "clean coal technology," as used by DOE's Office of Fossil Energy, refers to advanced coal-based systems that offer significant potential for power generation and pollution control as well as for other uses.

For power generation, clean coal technologies can improve performance and thermal efficiency and thus dramatically improve the economics of operation. They can be used to minimize the system's environmental impact, and many can be added to the utility in modular fashion to permit the utility to match supply and demand requirements more closely. They can be designed to use a variety of coals, and they can be used to repower existing coal-fired boilers to extend plant life, increase the plant's power output, and at the same time greatly reduce emissions. The clean coal technologies used to address some of the current as well as projected problems in power generating systems include fluidized-bed combustion, integrated gasification combined-cycle systems, fuel cells, direct coal-fired turbines, and magnetohydrodynamics.

For pollution control, clean coal technologies can be used to reduce the amounts of sulfur oxides (SO_x), nitrogen oxides (NO_x), and other pollutants discharged from coal burning systems. These technologies can be used for meeting New Source Performance Standards (NSPS) for new boilers more economically than conventional control equipment. Clean coal technologies also are potentially low-cost retrofit devices for meeting State or local environmental requirements for existing units.

For other uses, clean coal technologies can include coal conversion processes that have the capability to produce liquid and gaseous fuels for the industrial, commercial, residential, and transportation sectors. These technologies include coal gasification, coal liquefaction, *in-situ* gasification, and coal/oil coprocessing. They have the potential to increase energy efficiencies over currently available technologies as well as increase the use of domestic coal reserves.

Clean coal technologies offer the opportunity to produce usable energy at costs much lower than current state-of-the-art systems. From an environmental standpoint, clean coal technologies open the door to a future of sustained reductions in the acid rain precursors SO_x and NO_x.

The majority of the innovative clean coal technologies in this program are generally grouped into one of three categories: (1) retrofit technologies that can be used on existing plants to reduce emissions, (2) repowering technologies that replace a significant portion of the original plant and increase the power output of the facility, and (3) conversion technologies that have applicability in the industrial, commercial, transportation, and residential markets by utilizing coal conversion processes that produce liquid and gaseous fuels.

1.2.1 Retrofit Technologies

As shown in Exhibit 1-1, retrofit technologies include concepts such as advanced coal cleaning, limestone injection multistage burners (LIMB), slagging combustors, gas reburning, in-duct sorbent injection, coal-water mixtures, and advanced flue gas cleanup. These technologies, used separately or in combinations, can control both SO_x and NO_x. Although some may be less able to reduce sulfur emissions than conventional flue gas scrubbing, these retrofit technologies can reduce levels sufficiently to meet possible future environmental requirements for existing plants.

Of increasing interest is the ability of many retrofit technologies to be operated as combined systems. Benefits of such operation can include greater reductions in SO_x and NO_x emissions as well as costs. For example, coal cleaning combined with duct injection and combustion modification can significantly reduce both pollutants. By combining coal cleaning and duct injection, the overall cost of reducing SO_x emissions can be cut for many coals.

The relative benefits of combined systems mainly depend on the sulfur content of the coal and the efficiency of sorbent utilization in the control system. For example, because furnace sorbent injection has a comparatively low sorbent utilization rate, the economics of pollutant reduction are significantly improved when the coal is cleaned first to reduce its sulfur content. Further, using physically cleaned coal in LIMB technology to remove 85 percent to 90 percent of the SO_x is more cost effective than burning run-of-mine coal in a plant equipped with a wet limestone flue gas desulfurization (FGD) system.

Exhibit 1-1.

Retrofit Technologies

Pre-Combustion Cleaning	Combustion Modification	Post-Combusiton
Physical • Fine Grinding (micronization) • Advanced Froth Flotation • Heavy Media Cyclones • Micronization w/Limestone • Microbubble Flotation	**Combustor/Burner Types** • Slagging Combustors • Rotary Cascading Bed Combustors • Entrained Combustors • Limestone Injection Multistage Burners • Gas Reburning	**In-Duct Injection** • Sorbent Injection • Catalytic Reduction
Physiochemical • Molten Caustic Leaching • Organic Solvent	**Fuel Types** • Coal-Water Slurries • Coal-Gas Co-Firing • Coal-Water-Gas Co-Firing	**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
Microbial • Bioleaching		**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

Thus, either by themselves or in combination, the advanced technologies have the potential to meet the wide variety of site-specific needs of individual utilities. This includes meeting NSPS and other requirements such as those of State Implementation Plans.

Most of the retrofit technologies are designed to control emissions only. When NSPS were enacted in 1977, the U.S. Congress anticipated a routine replacement of old and less stringently regulated equipment with new boilers having pollution controls. However, because of regulatory uncertainties, a demand for electricity lower than expected, and the high capital costs of new power generating equipment, electric utility companies are opting to extend boiler life. As a result, the anticipated routine replacement of old, uncontrolled facilities with new and less polluting plants is being delayed.

If new pollution control regulations now being considered are established and the further control of emissions from these older boilers is mandated, the utility industry will be forced to make immediate decisions on control equipment. Utilities would have to choose from today's control options--flue gas scrubbers, coal cleaning, and coal switching. Development of advanced control systems would be delayed. The long-range impact of this delay would be increased power

costs and less than optimal efficiency in the removal of pollutants. Moreover, the maximum reduction in pollutants would be considerably less than could be achieved with the advanced control systems.

1.2.2 Repowering Technologies

Repowering consists of modifying aging coal-fired electric powerplants with a new generation of environmentally improved, highly efficient coal utilization technologies. As shown in Exhibit 1-2, this group of clean coal technologies includes concepts such as fluidized-bed combustion, gasification combined cycles as well as advanced options such as magnetohydrodynamics, gasification with fuel cells, and direct coal-fired turbines.

A repowered coal-fired plant would retain much of its existing solids handling equipment and virtually all of its steam cycle, electrical generating, and power conditioning hardware. Thus, repowering also can be considered part of a life extension program.

From an environmental standpoint, repowering opens the door to a future of sustained deep reductions in nationwide emissions of SO_2, one of the chief pollutants thought to contribute to acid rain. Repowering concepts are among the cleanest of coal burning options. Fluidized-bed combustors can eliminate 90 percent to 95 percent of the potential sulfur pollutants during the combustion process itself, eliminating the need for postcombustion sulfur controls. Combined-cycle coal gasification systems can remove more than 99 percent of sulfur emissions from coal-derived gases.

Repowering of a power generation facility would improve its emissions control capability, boost energy production efficiency, and enhance the cost-effectiveness of operation.

Exhibit 1-2.

Repowering Technologies

Fluidized Bed Combustion	Gasification-Based	Advanced Options
Atmospheric • Circulating Bed • Bubbling Bed	**Gasifier Types** • Fixed Bed • Fluid Bed • Entrained Flow • Rotary Kiln-type	**Gasification w/Fuel Cell** **Magnetohydrodynamics** **Direct Coal-Fired Turbines**
Pressurized • Circulating Bed • Bubbling Bed	**Gas Cleanup systems** • Conventional "Cool" Gas Cleanup • Zinc Ferrite Hot Gas Cleanup • Ceramic Filter Cleanup • In-situ Desulfurization	
Hybrid Designs • Bubbling-Circulating Bed • Coal Pyrolyzer/Fluid Bed		

1.2.3 Conversion Technologies

Coal conversion technologies have the capability to produce liquid and gaseous fuels from coal for use in industrial, commercial, residential, and transportation sectors. Examples of coal conversion technologies are listed in Exhibit 1-3. Surface and underground coal gasification can produce clean fuels and chemical products for use in industrial or utility applications, or as substitute natural gas. Coal liquefaction technologies rely on pyrolysis and direct and indirect liquefaction to convert coal into liquid products. Coal-based alternative fuels also include coal-liquid mixtures, coal-sorbent mixtures, and preprocessed coal.

Exhibit 1-3.

Conversion Technologies

- Mild Gasification
- Gasification with Once-Through Methanol Production
- Underground Coal Gasification
- Gasification in Indirect Liquefaction
- Liquefaction
- Coal/Oil Coprocessing

1.3 The Program

In conjunction with the private sector, DOE is conducting cost-shared projects to demonstrate the feasibility of future commercial applications of a new generation of clean coal technologies. These projects include the design, construction, and operation of the demonstration facilities. Their purpose is to provide sufficient technical, economic, environmental, health, safety, and operational information to enable the private sector to make rational commercialization decisions. The program currently consists of two major parts: (1) Clean Coal Technology I (CCT-I) Demonstrations and (2) Innovative Clean Coal Technology (ICCT) Demonstrations. CCT-I is discussed in Section 2, and ICCT in Section 3 of this report.

Through the Clean Coal Technology Demonstration Program, DOE is conducting the following activities:

- Soliciting expressions of interest from industry for emerging clean coal technology projects
- Soliciting, selecting, and negotiating Government-industry cost-shared projects, as funds are made available from Congress
- Assuring that the projects provide useful technical, environmental, operational, performance, and economic data to reduce the uncertainties of subsequent commercial scale deployment of the technology
- Developing a combined technical, engineering, and environmental knowledge base from which to make sound policy decisions relating to future clean coal technology initiatives and environmental issues and to provide the public with the information it needs to form a national consensus on the control of pollutants that may contribute to the formation of acid rain
- Providing an adequate technology transfer mechanism to assure that the private sector has the necessary access to the data on clean coal technologies
- Improving the regulatory and institutional climate to encourage deployment of demonstrated clean coal technologies into the marketplace at a pace consistent with free market decisions
- Fostering an understanding of the Clean Coal Technology Demonstration Program and its projects and the benefits to be derived from the demonstration and subsequent deployment of these projects, working with other Federal agencies, States, and international and private organizations.

1.4 Significant Accomplishments

The activities completed in the program as of December 31, 1987, can be grouped into five major areas. The completion of each group of activities is a significant accomplishment of the program. These accomplishments, including key activities and completion dates, follow:

1. **Established industrial interest in a clean coal technology program by initiating, managing, and evaluating an informational solicitation (i.e., the Section 321 activities).**

   DOE published a program announcement in the *Federal Register*, as requested in Public Law No. 98-473. Through this announcement, DOE sought expressions of interest and informational proposals for CCT demonstration projects. Two reports on the technologies and expressions of interest were submitted to the Congress. Key actions and completion dates are:

Public Law No. 98-473 signed	Oct. 12, 1984
Program announcement published in *Federal Register*	Nov. 27, 1984
Report to Congress issued	May 1, 1985
Supplemental report to Congress issued	Sept. 6, 1985

2. **Completed a competitive procurement activity and selected projects for the clean coal technology program.**

Pursuant to Public Law No. 99-190, DOE published its intent to release a Program Opportunity Notice (PON) for CCT demonstration projects. A draft PON was issued for public comment, followed by the final PON and a preproposal conference. Nine projects were selected initially. Subsequently, two of the nine projects were withdrawn by the proposers, and four replacement projects were selected and are being negotiated.

A report on proposals received in response to the PON and a report on the relationships between the projects selected and the recommendations of the Special Envoys on Acid Rain were published and sent to Congress.

Public Law No. 99-190 signed	Dec. 19, 1985
PON announcement published in *Federal Register*	Jan. 27, 1986
Draft PON issued for public comment	Jan. 30, 1986
Final PON issued	Feb. 17, 1986
Amendment to final PON issued	Feb. 24, 1986
Preproposal conference held	March 6, 1986
Public abstracts of proposals released	April 21, 1986
Source selection official's selection statement issued	July 25, 1986
Comprehensive report on solicitation issued	Aug. 21, 1986
Report to Congress on "Relationship/Acid Rain" issued	Oct. 24, 1986
DOE announced four replacement projects	Oct. 7, 1987

3. **Completed negotiations of seven cooperative agreements and initiated negotiations on four additional projects.**

Cooperative agreements were negotiated with seven industrial participants. Subsequent to the signing of the agreements by the industrial participants, comprehensive reports on each project were sent to the Congress for review. Upon completion of the congressional review requirement, DOE executed these agreements. Negotiations were initiated with the potential industrial participants who proposed the four replacement projects.

Three projects have proceeded into Phase II (construction), and one project is in Phase III (operation). Four projects have completed the NEPA process.

Accomplishments for each CCT-I project are shown in Exhibit 1-4.

4. **Reconfirmed industrial interest in an expanded clean coal technology demonstration by initiating, managing, and evaluating a second informational solicitation.**

Pursuant to Public Law Nos. 99-500 and 99-591, DOE issued a program announcement for statements of interest and informational proposals on "Emerging Clean Coal Technologies Capable of Retrofitting, Repowering, and Modernizing Existing Facilities." Following the receipt of 139 responses, two summary reports were published and sent to Congress.

Public Law No. 99-500 signed	Oct. 18, 1986
Public Law No. 99-591 signed	Oct. 30, 1986
Program announcement published in *Federal Register*	Nov. 12, 1986
DOE news release and public abstracts issued	Jan. 16, 1987
Summary report to Congress issued	March 6, 1987
Second report to Congress issued	May 12, 1987

Exhibit 1-4.
CCT-I Project Accomplishments

	Project Selected	Kick-Off Meeting for Fact-Finding Process Held	Comprehensive Report to Congress Issued	Cooperative Agreement Executed	Continuation into Phase II (Construction and Start-Up) Approved	Continuation into Phase III (Operation, Data Collection, Reporting, and Disposition) Approved
Tidd PFBC Demonstration Project (Ohio Power Company)	7/24/86	8/22/86	2/11/87	3/20/87	12/9/87	
LIMB Demonstration Project Extension (The Babcock & Wilcox Company)	7/24/86	9/11/86	5/11/87	6/25/87	Phase IIB 8/26/87	
Advanced Cyclone Combustor Demonstration Project (Coal Tech Corporation)	7/24/86	9/3/86	2/11/87	3/20/87	7/2/87	11/23/87
Gas Reburning/Sorbent Injection Demonstration Project (Energy & Environmental Research Corp.)	7/24/86	9/23/86	6/5/87	7/14/87		
Underground Coal Gasification Demonstration Project (Energy International, Inc.)	7/24/86	8/20/86	11/9/87	12/23/87		
The Appalachian IGCC Demonstration Project (The M. W. Kellogg Company/ Bechtel Development Company)	7/24/86	8/19/86	12/22/87			
Prototype Coal/Oil Coprocessing Project (Ohio Ontario Clean Fuels, Inc.)	7/24/86	9/19/86	10/30/87	12/15/87		
Nucla CFB Demonstration Project (Colorado-Ute Electric Association, Inc.)	10/7/87	11/10/87				
Clean Energy IGCC Demonstration Project (Consolidation Coal Co./Foster Wheeler Power Systems, Inc.)	10/7/87	11/5/87				
Advanced Slagging Coal Combustor Utility Demonstration Project (TRW, Inc.)	10/7/87	11/24/87				
COREX Ironmaking Demonstration Project (Minnesota Dept. of Natural Resources)	10/7/87	11/3/87				

5. **Gathered public opinion about the clean coal technology program for use in preparing a solicitation for a second request for projects suitable for retrofitting and repowering.**

In anticipation of a PON for the ICCT demonstration projects, DOE announced and convened four public meetings to gather views and comments on what the second solicitation should contain and how it should be implemented. These meetings were held in New Mexico, Missouri, Pennsylvania, and Washington, DC. A background informational report and a summary of proceedings were published by DOE.

President announces new $2.5-billion, Government-funded acid rain initiative	March 18, 1987
Secretary of Energy describes implementation of the President's expanded CCT program	March 23, 1987
Public meetings held to obtain comments on planned ICCT solicitation	
Albuquerque, NM	Aug. 13, 1987
St. Louis, MO	Sept. 3, 1987
Pittsburgh, PA	Sept. 10, 1987
Washington, DC	Sept. 22, 1987
Summary proceedings for ICCT public meetings issued	Dec. 1, 1987
Public Law No. 100-202 signed	Dec. 22, 1987
Draft PON planned to be issued for public comment	Jan. 28, 1988
Public comments on draft PON scheduled to be received	Feb. 5, 1988
Final PON planned to be issued	Feb. 22, 1988
Proposals to be submitted	May 23, 1988

6. **Established the Innovative Control Technology Advisory Panel (ICTAP) and obtained recommendations.**

The ICTAP was established to provide advice and recommendations to the Secretary of Energy concerning innovative control technologies that will broaden cost-effective and efficient options for controlling precursor emissions associated with acid rain.

President established ICTAP	March 18, 1987
ICTAP charter established	April 27, 1987
ICTAP established by Secretary of Energy	June 9, 1987
Initial meeting held	Sept. 30, 1987
First report issued	Dec. 1987
1988 meetings planned to be held	Feb. 25, 1988
	July 13, 1988
	Oct. 19, 1988

2.0 CLEAN COAL TECHNOLOGY-I DEMONSTRATIONS

2.1 Background

The Clean Coal Technology-I Program (CCT-I) had its genesis in August 1984 when work commenced on the original solicitation for informational proposals and statements of interest. That "Section 321" Program Announcement, as it became known from the implementing section of Public Law No. 98-473, was published in the *Federal Register* on November 27, 1984. This first foray into surveying the private sector for eligible demonstration projects resulted in 175 responses distributed among 13 technology categories and worth over $8 billion in total. The results of this solicitation were summarized in two reports: *Report to Congress on Emerging Clean Coal Technologies* issued in May 1985 and *Supplemental Report to Congress on Emerging Clean Coal Technologies* issued in August 1985.

Congress reacted to this private-sector response by implementing the first funded CCT activity on December 19, 1985, and enacting Public Law No. 99-190 which provided about $400 million for a cost-shared financial assistance solicitation. The final Program Opportunity Notice, issued on February 17, 1986, produced 51 proposals for CCT-I demonstration projects, with private sector cost sharing in each instance of at least 50 percent. The results were summarized in the Comprehensive Report on Proposals Received in Response to the Clean Coal Technology Program Opportunity Notice issued in August 1986.

2.2 Project Selection

The first nine projects were selected for the CCT-I Program in July 1986. Fact-finding and negotiations activity with each industrial participant began immediately after selection and continued through June 1987.

In July 1987, DOE established a fixed timetable for completing negotiations on the projects initially selected to be in the Clean Coal Technology activity. By the date designated, September 30, 1987, DOE had signed Joint Government/Industry Clean Coal Technology Cooperative Agreements with four of the nine proposers: American Electric Power Service Corporation, acting on behalf of the Ohio Power Company; The Babcock & Wilcox Company; Coal Tech Corporation; and Energy and Environmental Research Corporation. Three other industrial participants, i.e., The M.W. Kellogg Company/Bechtel Development Company, Energy International, Inc., and Ohio Ontario Clean Fuels, Inc., had agreed to cooperative agreements that DOE planned to execute upon successful completion of the congressional review process. The other two industrial participants, i.e., General Electric Company and Weirton Steel Corporation, withdrew their proposals from

further consideration. As a result of the withdrawal of these two proposers, the funds made available were used to select additional projects from the list of alternates identified in the July 25, 1986, Clean Coal Technology Selection Statement.

In October 1987, DOE named 4 clean coal technology projects from the alternate list as replacements. Provided negotiations are successful, the number of projects will increase to 11. Exhibit 2-1 lists these 11 projects which now comprise CCT-I.

Activities in progress on the CCT-I projects range from initial fact-finding for those most recently selected to various stages of construction or operation:

- In the case of the pressurized fluidized-bed combustion combined-cycle project proposed by American Electric Power Service Corporation (on behalf of the Ohio Power Company), onsite activities have been initiated and significant progress has been made in the construction of the pressure vessel.

- Operational testing on the LIMB project being conducted by the Babcock and Wilcox Company at Ohio Edison's Edgewater Station has been started. The DOE cofunding for this project is being used to extend the EPA-funded demonstration of the LIMB process by using three additional coals and four additional sorbents. This project also will include a demonstration of the Coolside process in which sorbent and water are injected into the flue gas downstream of the boiler. Design work is well advanced on the equipment to be installed during a major plant turnaround scheduled for late-1989.

- In the gas reburning/sorbent injection project to be performed at three sites in Illinois (i.e., Bartonville, Hennepin, and Springfield), Energy and Environmental Research Corporation has made significant progress in the design and permitting tasks.

- In the advanced cyclone combustor effort being performed by Coal Tech Corporation, the construction and installation of the demonstration burner is nearing completion and the request for permission to move into Phase III, operational testing, has been approved by DOE.

Each of the 11 projects is summarized at the end of Section 2. Work on the 11 projects of the CCT-I activity will proceed concurrently with the efforts now under way to initiate the ICCT effort.

2.3 Financial Aspects and Outlook

2.3.1 Cost Sharing

Public Law No. 99-190, "An Act Making Appropriations for the Department of the Interior and Related Agencies for the Fiscal Year Ending September 30, 1986, and for Other Purposes," introduced and defined cost sharing as it was to be implemented in the clean coal projects. Included in the requirement and definition were the following concepts:

- The Secretary of Energy may not finance more than 50 percent of the total costs of a project as estimated by the Secretary as of the date of award of financial assistance.

Exhibit 2-1.
CCT-I Projects

Project and Industrial Participant	Project Location	Technology
Tidd PFBC Demonstration Project (Ohio Power Company)	*Brilliant, OH*	*Pressurized Fluidized-Bed Combustion Combined-Cycle Utility Retrofit, 70 MW_e*
LIMB Demonstration Project Extension (The Babcock & Wilcox Company)	Lorain, OH	Extended Test of Limestone Injection Multistage Burner Plus Sorbent Duct Injection, 105 MW_e
Advanced Cyclone Combustor Demonstration Project (Coal Tech Corporation)	Williamsport, PA	Slagging Combustor and Sorbent Injection into Combustor, 1,000 Tons/Day
Gas Reburning/Sorbent Injection Demonstration Project (Energy and Environmental Research Corporation)	Bartonville, Hennepin, and Springfield, IL	Gas Reburning and Sorbent Injection Retrofit into Three Utility Boilers, 117 MW_e, 80 MW_e, 40 MW_e
Underground Coal Gasification Demonstration Project (Energy International, Inc.)	Rawlins, WY	Steeply Dipping Bed Underground Coal Gasification Integrated with Ammonia/Urea Plant, 500-1,000 Tons of Coal/Day
The Appalachian IGCC Demonstration Project (The M. W. Kellogg Company/Bechtel Development Company)	Quemahoning Industrial Park, Somerset County, PA	Fluidized-Bed Gasification with Hot Gas Cleanup Integrated Combined-Cycle Demonstration Plant, 60 MW_e
Prototype Commercial Coal/Oil Coprocessing Project (Ohio Ontario Clean Fuels, Inc.)	Warren, OH	Coal-Oil Coprocessing Liquefaction (Process 800 TPD Coal, Plus Residual Oil to Yield 11,750 BPD Clean Distillate Liquid)
Nucla CFB Demonstration Project* (Colorado-Ute Electric Association, Inc.)	Nucla, CO	Circulating Fluidized-Bed Combustion, Utility Retrofit, 110 MW_e
Clean Energy IGCC Demonstration Project* (Consolidation Coal Company/Foster Wheeler Power Systems, Inc.)	WV	Integrated Combined-Cycle Power System for Coproduction of Power and Steam
Advanced Slagging Coal Combustor Utility Demonstration Project* (TRW, Inc.)	Stoney Point, NY Cleveland, OH	Advanced Slagging Coal Combustor with NO_x and SO_x Control
COREX Ironmaking Demonstration Project* (Minnesota Department of Natural Resources)	Mt. Iron, MN	Production of Iron Using New Melter/Gasifier Concept

* Projects currently in the fact-finding process.

- Cost sharing by the project sponsors is required in each of the design, construction, and operation phases.

- Financial assistance for costs in excess of those estimated at the date of award may not be provided in excess of the proportion of costs borne by the Government in the original agreement and only up to 25 percent of the original financial assistance.

In addition, further definition was given of funds that may be available to the participant but could not be considered as cost sharing for the purposes of this appropriation. These included:

- Revenues or royalties from the prospective operation of the projects beyond the time considered in the award

- Proceeds from the prospective sale of the assets of the project

- Revenues or royalties from replication of the technology in future projects or plants

- Other appropriated Federal funds

- Existing facilities, equipment, and supplies or previously expended research or development funds, except as amortized, depreciated, or expended in normal business practices.

By contrast to the initial reception given to this concept of cost sharing and its stringent definitions and/or limitations, the industrial participants have responded in a manner that fully implements the intent as well as the letter of the law regarding cost sharing.

In the seven negotiated agreements, the cost-sharing ratio is 70 percent by the industrial participants and 30 percent by the Government, as shown in Exhibit 2-2. This funding ratio represents a commitment of $529.8 million by the industrial sector and $227.5 million by the Government. (It should be noted that the participants will repay the Government its contribution through recoupment provisions contained in the agreements.) Thus, the near-term investment of $227.5 million by the Government is stimulating over $750 million of development efforts.

Assuming the cooperative agreements for the remaining four CCT-I projects now in fact-finding are executed, this will fully commit the remainder of the Federal funds appropriated for CCT-I. When this has been accomplished, it is estimated that the funding ratio for CCT-I will be about 32 percent Government and 68 percent private industry, as shown in Exhibit 2-3. The Government will have leveraged its investment of $387.2 million to initiate and sustain over $1.2 billion of development support for the demonstration of clean coal technologies.

2.3.2 Obligations and Costs

Public Law No. 99-190 made available about $400 million to conduct cost-shared clean coal technology projects to demonstrate the feasibility of future commercial application. The funds will remain available until expended. Of the total, $100 million became available immediately, an additional $150 million became available beginning October 1, 1986, and another $150 million

Exhibit 2-2.

Cost Sharing for Projects with Negotiated Cooperative Agreements (Millions)

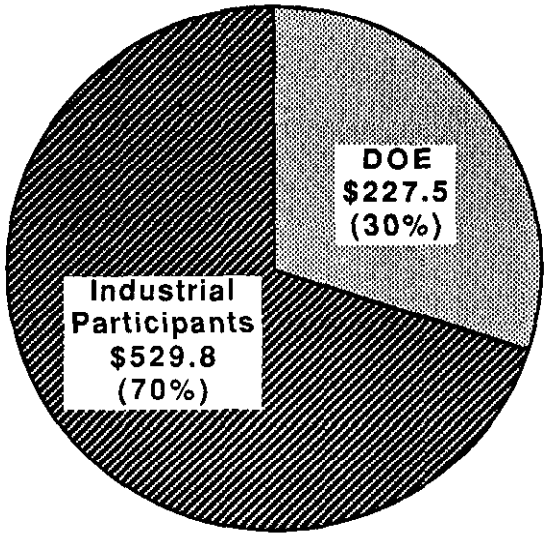
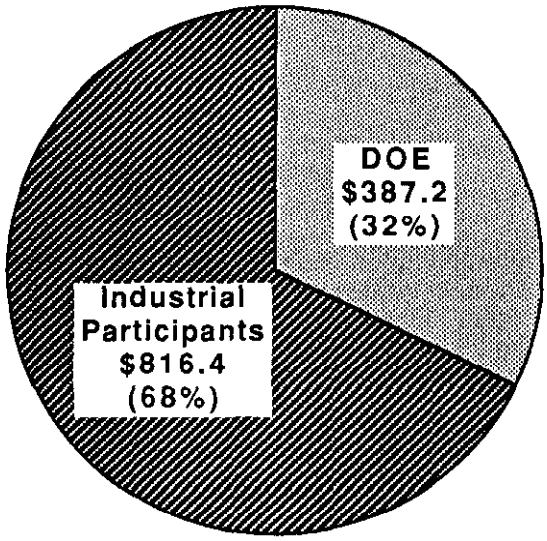


Exhibit 2-3.

Estimated Cost Sharing for All Projects, Including Those in Negotiations (Millions)



became available beginning October 1, 1987. These amounts were subsequently reduced slightly to satisfy the requirements of the Gramm-Rudman-Hollings Act, and $387.2 million is available to support the projects selected, as shown in Exhibit 2-4.

Of this total amount available for projects, $227.5 million has been committed in the seven cooperative agreements negotiated as of December 31, 1987. The distribution of these funds to the various projects, with the amount of cost sharing from industry, is shown in Exhibit 2-5.

Although Federal funds in the amount representing the Government's cost share are fully committed to each project upon the signing of the cooperative agreement, these funds are controlled by the Assistant Secretary for Fossil Energy. The Assistant Secretary approves the subsequent obligation of funds to the industrial participant (i.e., makes funds available to cover allowable costs) in accordance with procedures outlined in the negotiated cooperative agreements. These procedures, which were generally defined in the solicitation's Appendix B, "Model Cooperative Agreement," Article II (C)(2), "Determination to Proceed with Subsequent Phases," are as follows:

> Budget periods will be established to coincide with the project phases. Consistent with Public Law No. 99-190, DOE will obligate sufficient funds to cover its share of the cost for each budget period. To continue work beyond the current project phase, the participant shall submit a project evaluation report and a continuation application to the DOE Contracting Officer at least 60 days prior to the end of the current budget period. As a minimum, the continuation application shall contain the following:
>
> - A detailed report of technical progress
> - A detailed description of the participant's plans for the conduct of the subsequent phase
> - The detailed budget for the subsequent phase.
>
> DOE will approve or disapprove the continuation application 30 days prior to the end of the current budget period. DOE will approve the continuation application provided the criteria in the approved Project Evaluation Plan . . . are met and appropriated funds are available for the project. In determining whether the criteria have been met, DOE will consider the Participant's Project Evaluation Report and other available information. In the event the DOE does not approve the continuation application, DOE shall bear no costs of the project in excess of the maximum DOE obligation through the current budget period.

The application of the "budget period" concept to the schedules and milestones currently planned for each of the seven projects has resulted in a projection of the yearly obligation as well as a projection of expected annual costs. The projected obligations are shown in Exhibit 2-6, and the associated cost projections are shown in Exhibit 2-7.

The totals for each yearly period can be expected to change, and more years (i.e., 1994, 1995, etc.) may be included as cooperative agreements are reached on the four projects in fact-finding as of December 31, 1987.

Exhibit 2-4.

CCT-I Program Budget ($1000)

	Operating Expenses	SBIR* Program	Technology Projects	Total
FY 1986	1,491	1,224	96,685	99,400
FY 1987	1,988	1,839	145,273	149,100
FY 1988	1,988	1,839	145,273	149,100
Totals	$5,467	$4,902		$397,600
Available for Selected Projects			$387,231	

*Small Business Innovated Research

Exhibit 2-5.

Cost Sharing for CCT-I Projects with Negotiated Cooperative Agreements

Project	Industry	DOE	Total
Tidd PFBC Demonstration Project	$107,300,000	$60,200,000	$167,500,000
LIMB Demonstration Project Extension	$11,807,914	$7,597,026	$19,404,940
Advanced Cyclone Combustor Demonstration Project	$392,992	$392,992	$785,984
Gas Reburning/Sorbent Injection Demonstration Project	$15,000,000	$14,998,253	$29,998,253
Underground Coal Gasification Demonstration Project	$58,323,092	$11,792,362	$70,115,454
The Appalachian IGCC Demonstration Project	$156,308,500	$87,528,500	$243,837,000
Prototype Commercial Coal/Oil Coprocessing Project	$180,674,805	$45,000,000	$225,674,805
TOTAL	$529,807,303	$227,509,133	$757,316,436

Exhibit 2-6.

Projected Yearly Obligations for Projects with Negotiated Cooperative Agreements

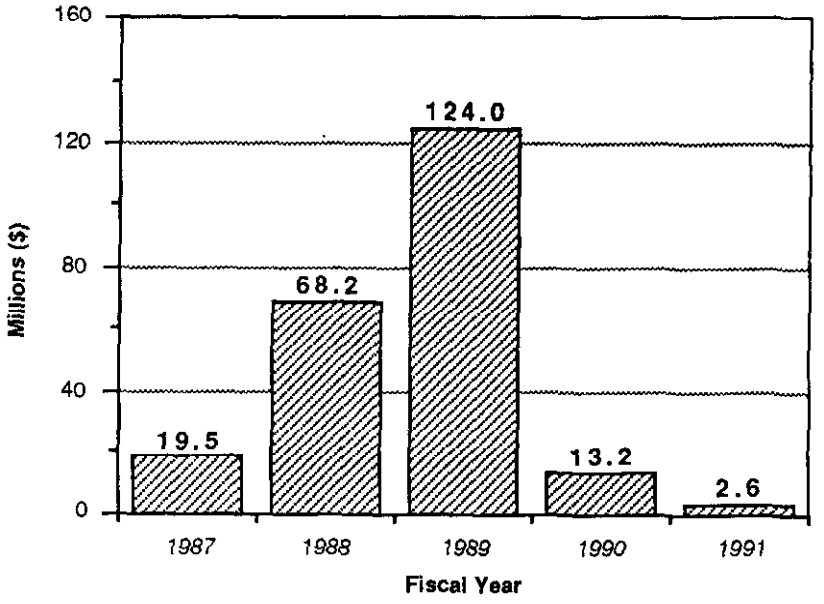
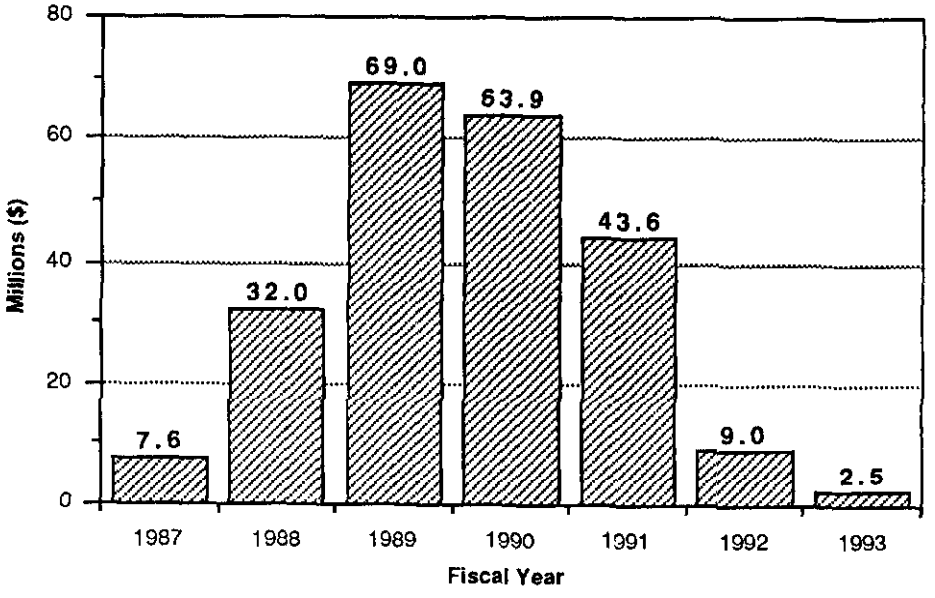


Exhibit 2-7.

Projected Annual Costs for Projects with Negotiated Cooperative Agreements



2.3.3 Recovery of Investment (Recoupment)

The requirement for recovery of the Government's investment in each project, termed "recoupment," is stated in the Program Opportunity Notice for CCT-I:

> It is the policy of DOE to recover an amount up to the Government's contribution to the Project. Successful offerors will be required to submit a plan outlining a proposed schedule for recovering the Government's contribution. The recovery will be derived from the sum of the following potential revenue sources:
>
> 1. Operations of the demonstration project beyond the operating phase of the Cooperative Agreement. The net revenue from the operation (after operating costs) will be shared in proportion to the overall cost-share for the project.
>
> 2. The commercial sale, lease, manufacture, licensing, or use of the technology demonstrated under the Clean Coal Technology Program.
>
> The decision of whether to dispose of the facility at the end of the cost-shared project, or whether to continue operating the facility at the proposer's expense, is solely the responsibility of the proposer and must be included as part of the proposal . . . . Proceeds from the sale of project assets will be shared in proportion with the overall cost-share for the duration of the project.

Complying with this requirement and defining the associated plan were among the major activities that required a considerable effort during the negotiation of each cooperative agreement. A number of complications were encountered and overcome; these included interpretation of some requirements, the presence of third parties in the financial arrangements, and what some industrial participants believed was a conflict between the Government's perceived role in technology commercialization and its policy to recover funds it contributed.

The issues encountered in negotiating these agreements were found to be considerably more complex when the industrial participant was a regulated utility whose financial commitments, performance responsibilities, flexibility, etc., are carefully controlled by law or when the technology being developed is controlled by a third party. Similar difficulties were encountered when the negotiations involved an industrial participant who was not the entity profiting from the commercialization of the technology or was only one of several participants, each with different aims or objectives and expectations.

Seven recoupment plans have been negotiated as of December 31, 1987. The results of these negotiations have shown that the concept of recoupment is achievable and desirable as a requirement of the cooperative agreement. This desire by the Government to gain return of its cost share (from profits made by the industrial participant and/or partners) has placed the agreements and the projects on a more businesslike basis and has indeed tested the intent of the industrial participant.

2.4 Status of Individual Projects

Summaries of the 11 projects selected follow. Each project summary provides key project data, a description, and a brief status report. Process diagrams and milestone schedules are also included.

CCT-I Project Summaries

To prevent the release of project specific, proprietary information, the diagrams contained in this section of the report are presented only as illustrative of the concepts involved.

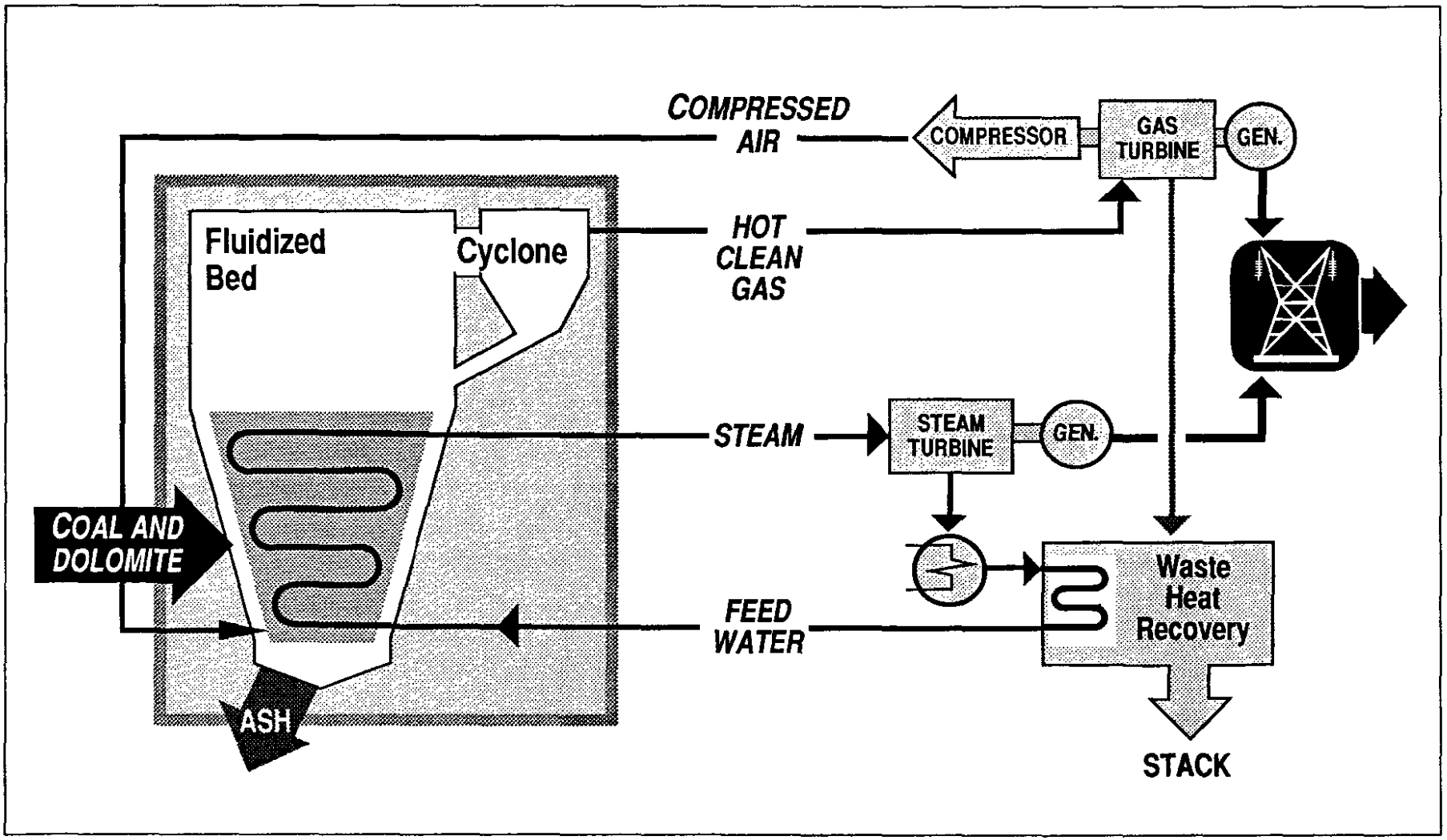
Tidd PFBC Demonstration Project

Ohio Power Company

Tidd PFBC Demonstration Project

OHIO POWER COMPANY

PROCESS FLOW DIAGRAM



Project: Tidd PFBC Demonstration Project

Industrial Participant: Ohio Power Company

Cofunder: State of Ohio

Process: Pressurized fluidized-bed combustion

Location: Brilliant, Jefferson County, OH

Coal Feed Characteristics: Ohio high-sulfur bituminous

Plant Capacity/Production: 70 MW_e

Feed Rate: 660 tons of coal per day

Estimated Total Cost:	$167,500,000
DOE:	$60,200,000
Industrial Participant:	$107,300,000

Project Objectives:

To build and operate a 70-MW_e PFBC combined-cycle powerplant demonstrating that this new coal-burning technology will permit the burning of high-sulfur coal to produce electricity in a more economical and efficient way than is commercially available, while meeting or exceeding stringent U.S. environmental standards.

Process Description:

Pressurized fluidized-bed combustion (PFBC) is a clean coal technology that can burn high sulfur coal in an environmentally superior manner; that is, the emissions of SO_x and NO_x are held within current environmental limits. Unlike conventional technologies, combined-cycle PFBC provides for increased electric generation efficiency through a combined gas and steam cycle.

In the PFBC process, crushed coal and a sorbent (dolomite or limestone) are continuously fed into a pressurized vessel in which air, fed from the bottom, maintains the coal and sorbent in a highly turbulent suspended state, called fluidization. During the combustion process, the SO_2 formed is absorbed by the dolomite ($CaCO_3$ $MgCO_3$) to form an inert magnesium oxide calcium sulfate (MgO $CaSO_4$) complex.

The MgO $CaSO_4$ complex, a dry, granular byproduct when removed from the fluidized bed, can be managed more easily than the sludget from a wet flue gas desulfurization system. The PFBC process has been demonstrated through extensive pilot plant testing to remove over 90 percent of the sulfur from 4-percent sulfur coal at a Ca/S molar ratio of 1.6. Similar reactions take place when limestone is used as the sorbent.

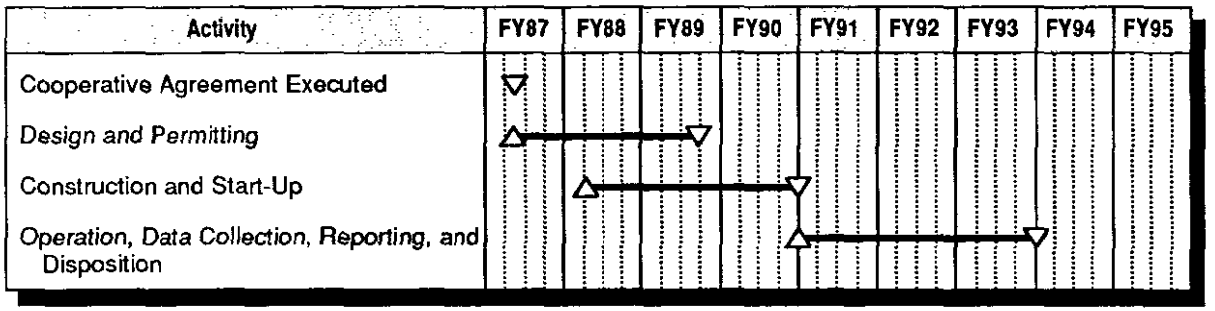
Combustion occurs in a fluidized bed at a relatively low temperature of 1,580 ^{o}F (860 ^{o}C). This temperature is below the ash fusion temperature of most coals, thus eliminating slag formation as well as reducing process sensitivity to coal type. Furthermore, the low combustion temperature restricts the formation of NO_x to less than that from a conventional pulverized coal-fired plant.

High pressure in the PFBC process permits a deep bed and allows high residence times, ensuring high combustion efficiency and good sorbent utilization. The deep bed also permits submerging all boiler tubes in the bed, thus taking maximum advantage of the high heat transfer coefficient, leading to a very compact boiler design. The overall heat-transfer rates in submerged boiler tubes are about 4 to 5 times higher than in a convective environment. The steam produced within these tubes drives a steam turbine generator to produce the bulk of the plant's electric power.

High pressure in the process also permits hot gases from the combustor, after cleaning, to operate a gas turbine-generator. Gases from the combustor pass through high efficiency cyclones to remove approximately 99 percent of the solids in the gas stream before entering the gas turbine. The flue gas from the gas turbine exhausts through an economizer, an electrostatic precipitator, and a stack.

Key Milestone Dates:

DOE selected project	7/24/86
Comprehensive report to Congress issued	2/11/87
DOE signed cooperative agreement	3/20/87
Air Permit to Install received from Ohio EPA	5/28/87
Continuation into Phase II approved	12/9/87
Ash Disposal Permit to use existing Cardinal fly-ash pond expected	1/88
Complete construction	10/90
Begin operation	10/90
Complete project	10/93



Project Status:

The Ohio Power Company's request for the continuation of this project from Phase I (engineering and permitting) into Phase II (procurement, construction, and start-up) was approved on December 9, 1987, by DOE. Overall, the project is running smoothly and remains on schedule and within budget.

Financially, both Phases I and II show a negative variance to date. It is anticipated that these moneys will be expended in this and the coming fiscal year for some delayed activities. Also, in accord with the cooperative agreement, moneys associated with a negative variance will be rolled over into subsequent phases. The total DOE contribution is capped at $60.2 million based on a total project cost of $167.5 million (35.9 percent). The total DOE obligation of funds for Phases I and II is now $54 million and is in accordance with the cooperative agreement.

Fabrication of the pressure vessel is progressing ahead of schedule. It is to be shipped by barge to the Tidd site in April 1989.

Testing of a prototype of the CT-35P gas turbine to be used by this project began on December 22, 1987, and is scheduled to continue for approximately 8 months. The gas turbine for the Tidd project is scheduled for delivery in late 1989.

Formal ground breaking at the Tidd site is scheduled for early April 1988. It is anticipated that the main construction contract will be let by the end of March 1988.

The ash-disposal permit has been received from the Ohio EPA and calls for the disposal of the ash from the project in the existing Cardinal plant fly-ash pond. An air permit has been issued to the Ohio Power Company by the Ohio EPA.

Problems/Potential Problems:

None.

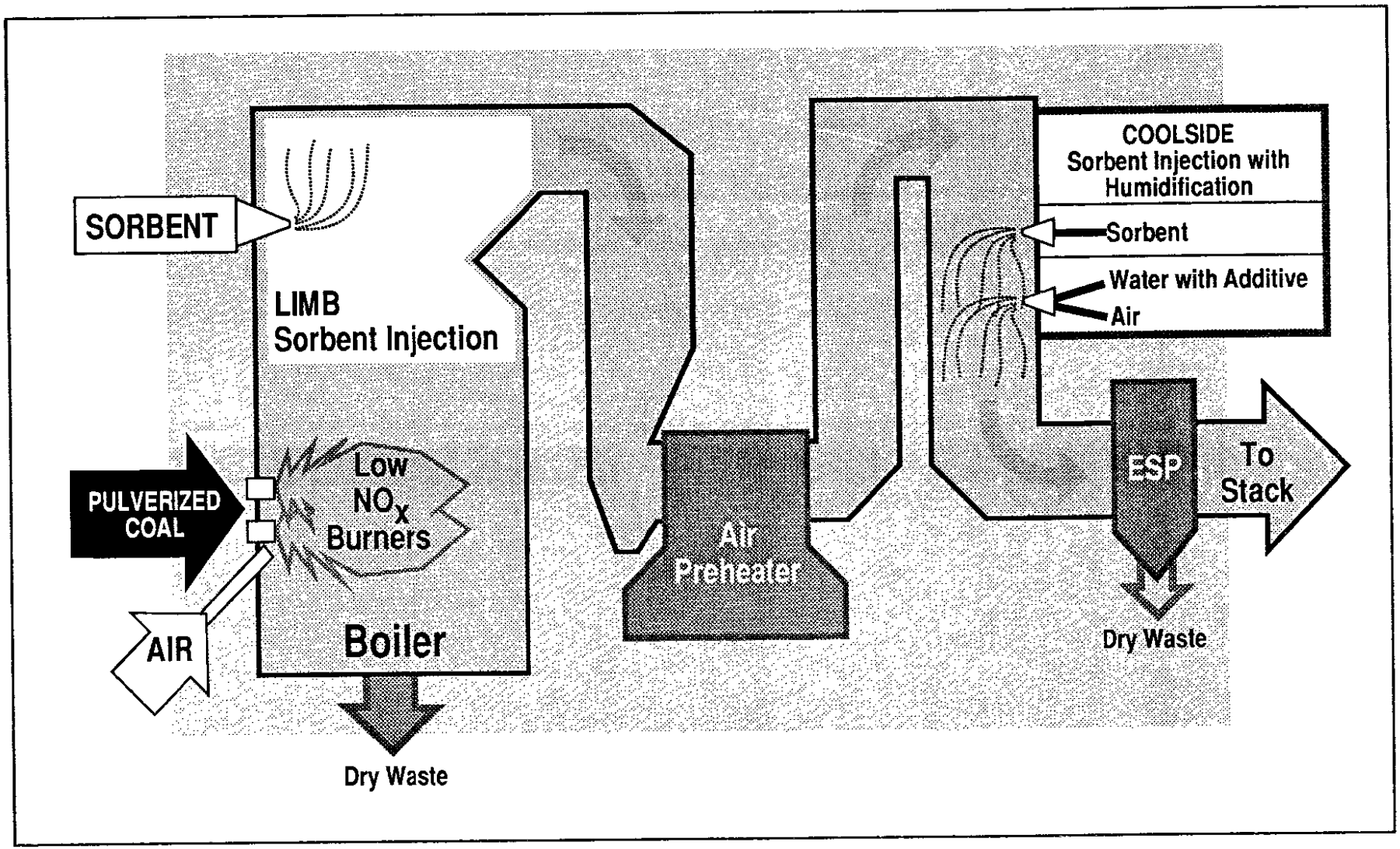
LIMB
Demonstration Project Extension

The Babcock & Wilcox Company

LIMB Demonstration Project Extension

THE BABCOCK & WILCOX COMPANY

PROCESS FLOW DIAGRAM



Project: LIMB Demonstration Project Extension

Industrial Participant: The Babcock & Wilcox Company

Cofunders: State of Ohio
The Babcock & Wilcox Company
Consolidation Coal Company

Process: Flue gas cleanup--LIMB and Coolside duct injection

Location: Lorain, Lorain County, OH (Ohio Edison's Edgewater Plant)

Coal Feed Characteristics: Medium- and high-sulfur bituminous

Plant Capacity/Production: 105 MW_e

Estimated Total Cost:	$19,404,940
DOE:	$7,597,026
Industrial Participant:	$11,807,914

Project Objectives:

To test a variety of coals and sorbents to demonstrate the limestone injection multistage burner (LIMB) process as a retrofit system for simultaneous control of sulfur and nitrogen oxides in the combustion process. Project goals for LIMB are to demonstrate up to 60-percent NO_x and SO_x reductions. Additionally, using the Coolside duct injection (Coolside) process, a base of sorbent and one coal will be tested to demonstrate in-duct sorbent injection, upstream of the humidifier and precipitator, to show SO_x removals of up to 80 percent.

This project will be conducted at Ohio Edison's Edgewater Plant in Lorain, OH, on a commercial, 105-MW_e boiler. The present EPA-sponsored project will test only one coal and sorbent combination for the LIMB process. The DOE project will demonstrate the LIMB process with multiple coal and sorbent combinations to show the general applicability of the process using medium- and high-sulfur coal. The DOE project will also demonstrate the Coolside process using high-sulfur coal on a commercial scale. Until now, the Coolside process has been demonstrated only at the 0.1-MW and 1-MW scale.

Process Description:

The LIMB process is expected to reduce SO_x by 50 percent to 60 percent by injecting dry sorbent into the boiler at a point above the burners. The sorbent then travels through the boiler and is removed along with fly ash in the existing particulate removal equipment, either an electrostatic precipitator (ESP) or a baghouse.

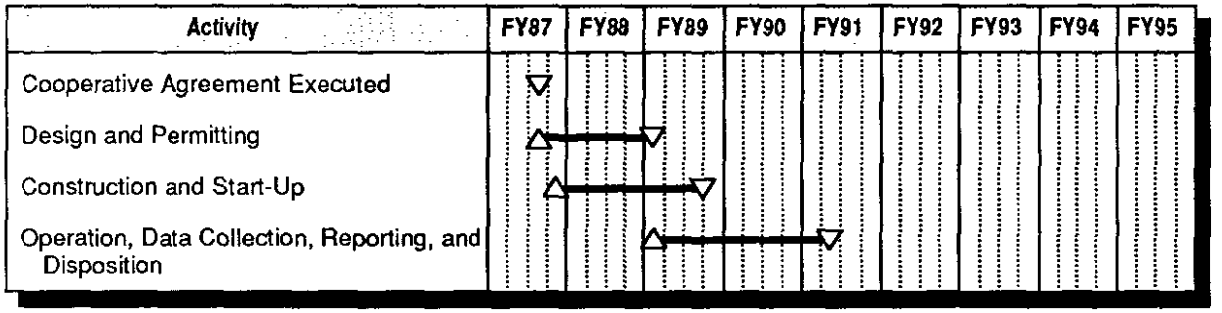
In the Coolside process, dry sorbent is injected into the flue gas after the boiler and before the ESP. The gas is humidified in this process to enhance both ESP performance and SO_x absorption. Also, a chemical additive will be dissolved in the humidification water to improve SO_x absorption. Because of these benefits, it is expected that humidification equipment will be part of most, if not all, commercial Coolside applications. The spent sorbent is also collected with the fly ash as in the LIMB process. Reduction of SO_x by 50 percent to 80 percent is expected.

Both demonstrations will utilize the same low NO_x burners. These burners, which can replace conventional burners, control NO_x by injecting the coal and part of the combustion air simultaneously so that the first of the combustion reactions take place in an oxygen-deficient environment. The balance of the combustion air is introduced in a second stage to complete the combustion process. This staged combustion process has been found to reduce NO_x emissions by 50 percent to 60 percent.

The LIMB and Coolside processes both provide an alternative to conventional wet flue gas desulfurization (FGD) processes. Both are expected to be substantially less expensive than wet FGD, and their space requirements are also substantially less. These factors are very important in retrofit applications.

Key Milestone Dates:

DOE selected project	7/24/86
Comprehensive report to Congress issued	5/11/87
Phases I (design and permitting) and IIA (long-lead procurement) began	5/11/87
Memo-to-File for NEPA requirement signed	6/2/87
DOE signed cooperative agreement	6/25/87
DOE approved B&W continuation into Phase IIB (construction, start-up, and shakedown)	8/26/87
B&W submitted Project Evaluation Plan for Phase IIB	9/26/87
Complete Phase II	7/89
Begin operation	11/88
Complete project	3/91



Project Status:

On June 25, 1987, DOE signed the cooperative agreement. The Babcock & Wilcox Company received approval from DOE to initiate this project starting with Phase I (design and permitting) and Phase IIA (site preparation and long-lead-time item procurement). Phase IIB (Coolside/LIMB construction, start-up, and shakedown) began on August 26, 1987. Installation of the low-NO_x burners, the sorbent injection system, and system modifications have been completed. Installation of the humidification system is scheduled to be completed in May, when shake-down will begin.

The facility is scheduled for high-sulfur coal testing on the EPA test series during July 1988 through January 1989. The DOE 4-month test program for Coolside injection is scheduled to begin in March 1989, followed by a 14-month LIMB test series using three different coals and four sorbents.

B&W has submitted a draft of the Environmental Monitoring Plan Outline to DOE for approval.

Problems/Potential Problems:

The disposal of LIMB and Coolside ash is unresolved. Waste ash characterization is under way so that disposal requirements can be established.

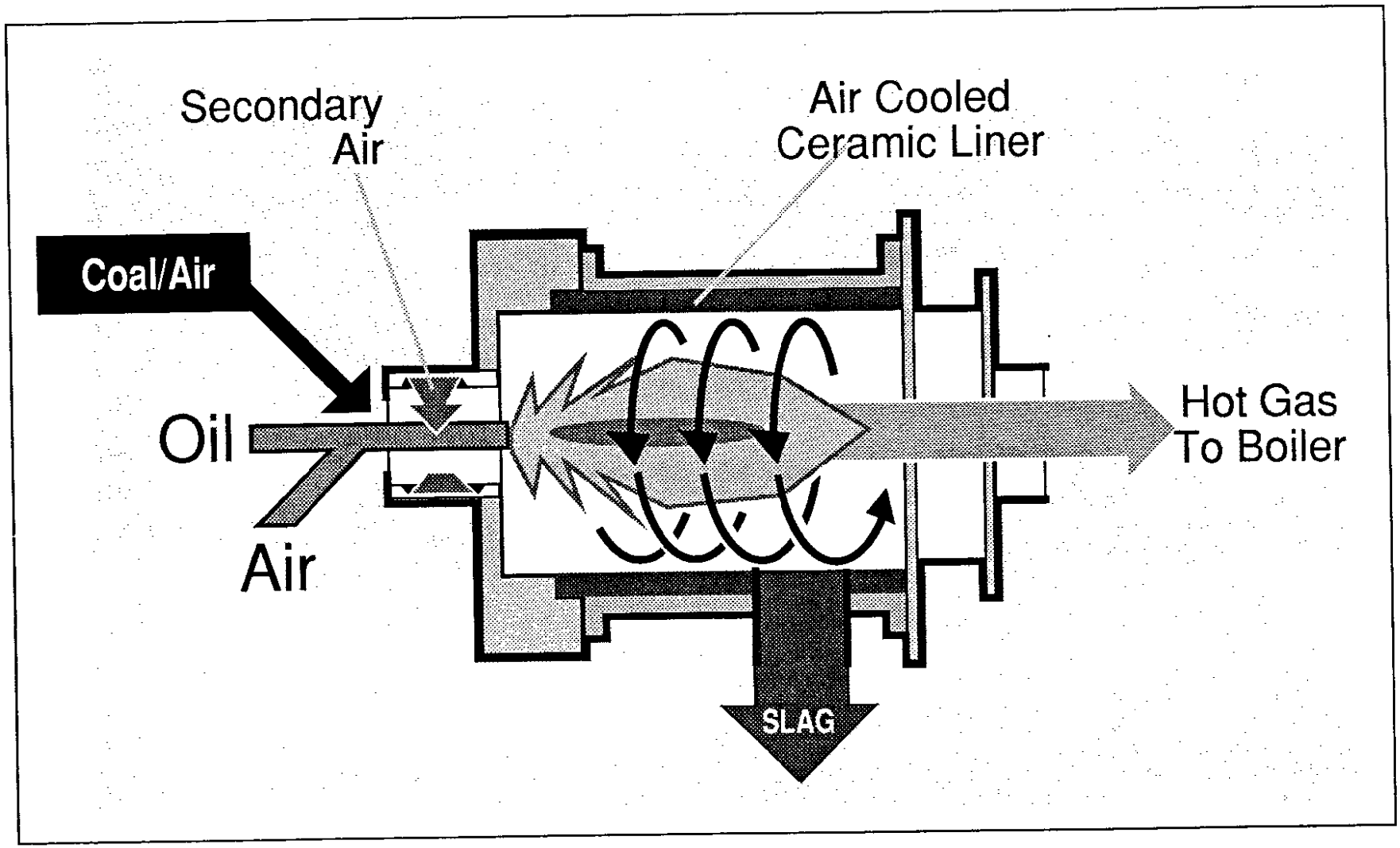
Advanced Cyclone Combustor Demonstration Project

Coal Tech Corporation

Advanced Cyclone Combustor Demonstration Project

COAL TECH CORPORATION

PROCESS FLOW DIAGRAM



Project: Advanced Cyclone Combustor Demonstration Project

Industrial Participant: Coal Tech Corporation

Cofunders:
State of Pennsylvania Energy Development Authority
Pennsylvania Power and Light
Keeler Boiler Manufacturing Company

Process: Advanced air-cooled slagging cyclone combustor with limestone addition for SO_x control

Location: Williamsport, Lycoming County, PA

Coal Feed Characteristics: Pennsylvania bituminous--Freeport seam (2% to 4% sulfur)

Feed Rate: 1 ton of coal per hour

Combustor Size: 30 MMBtu/hour

Production: Steam and/or electricity

Estimated Total Cost:	$785,984
DOE:	$392,992
Industrial Participant:	$392,992

Project Objectives:

To demonstrate an air-cooled cyclone, pulverized coal combustor of an advanced design to show that 90 percent of the coal ash can be retained and rejected, that NO_x emissions can be held to 100 parts per million and that SO_x emissions can be reduced by up to 90 percent. If successful and implemented, boiler slagging and acid rain precursor emissions would be reduced, and additional high-sulfur U.S. coal could be used in an environmentally acceptable manner.

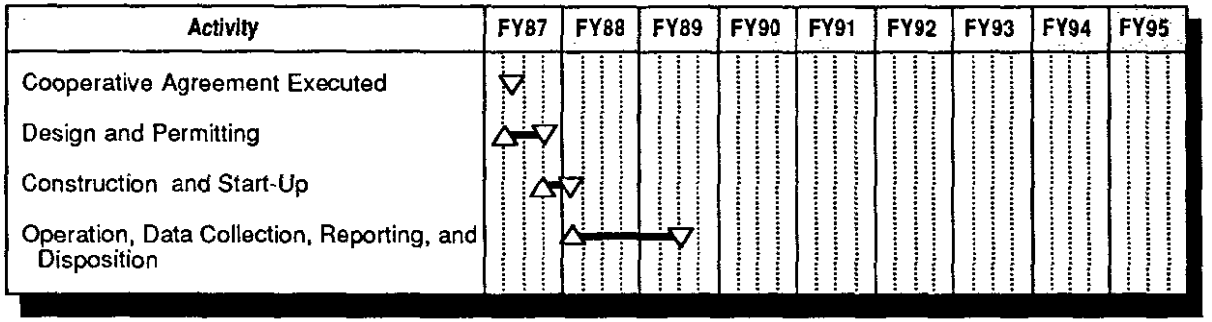
Process Description:

The project demonstrates an advanced horizontal cyclone combustor with integral sulfur, nitrogen, and ash control systems. Air is mixed with fuel in standard burners or combustors that are attached to the outside walls of boilers. The burning mixture is then discharged into the boiler, heating water in the tubes to produce steam. The Coal Tech combustor, which will replace a standard burner, also mounts on the outside wall of the boiler, mixes coal, sorbent (limestone) and air, provides ignition, and removes ash before discharging the hot combustion products to the boiler. The 30-MMBtu-per-hour combustor is approximately 5 feet in diameter and 8 feet long.

Sulfur oxide is controlled by means of limestone injection into the burner. Formation of NO_x is limited by operating the first combustion stage with an oxygen deficiency. Additional oxygen is added to complete combustion after the combustion products leave the combustor. The system is also designed to obtain very high ash removal by cyclonic action in the combustor, resulting in a unit that can be easily retrofitted to gas- and oil-fired units. The simultaneous reduction of three different pollutants makes the performance of this combustor unique.

Key Milestone Dates:

DOE selected project	7/24/86
Comprehensive report to Congress issued	2/11/87
DOE signed cooperative agreement	3/20/87
DOE approved continuation into Phase II (construction and start-up)	7/2/87
DOE approved continuation into Phase III (operation, data collection, reporting, and disposition)	11/23/87
Complete project	4/89



Project Status:

On November 23, 1987, this project became the first CCT-I project to begin Phase III operations. In Phase III, the objective is to conduct parametric studies for 900 hours on 2-percent and 4-percent sulfur pulverized coal.

During Phase II, Coal Tech Corp. successfully completed the retrofit installation of its 30-MMBtu per hour, air-cooled, ceramic-lined, advanced-cyclone coal combustor onto a 23-MMBtu-per-hour industrial boiler, originally designed for oil firing.

During initial testing for Phase III (December 1987 through January 1988), the cyclone combustor is expected to operate for approximately 80 hours. Currently, coal burning is nearing optimal operating conditions; however, equipment adjustments are still being made to increase combustor run time. Preliminary measurements suggest that significant sulfur capture and NO_x reduction is occurring.

Problems/Potential Problems:

Some equipment reliability problems have developed during Phase III operations, thereby causing some delay to testing activities. These problems are being corrected.

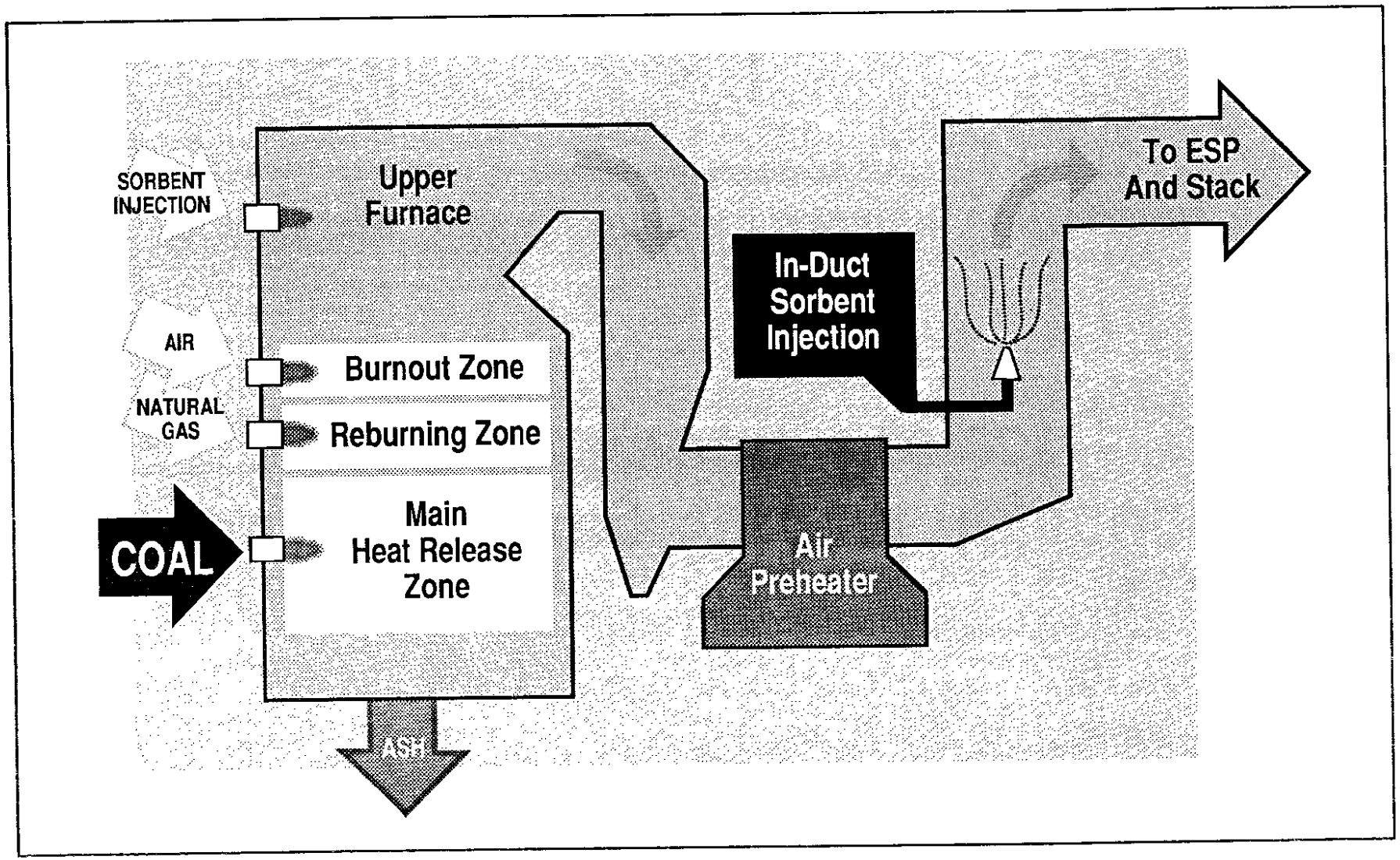
Gas Reburning/Sorbent Injection Demonstration Project

Energy and Environmental Research Corporation

Gas Reburning/Sorbent Injection Demonstration Project

ENERGY AND ENVIRONMENTAL RESEARCH CORPORATION

PROCESS FLOW DIAGRAM



Project: Gas Reburning/Sorbent Injection Demonstration Project

Industrial Participant: Energy and Environmental Research Corporation

Cofunders: State of Illinois
Gas Research Institute

Process: Flue gas cleanup by gas reburning for NO_x control and sorbent injection for SO_x control

Location: Hennepin, Putnam County, IL (Hennepin Station)
Bartonville, Peoria County, IL (Edwards Station)
Springfield, Sangamon County, IL (Lakeside Station)

Coal Feed Characteristics: Illinois and Kentucky bituminous coals (1% to 3.8% sulfur)

Plant Capacity: 80 MW_e, 117 MW_e, 40 MW_e

Estimated Total Cost:	$29,998,253
DOE:	$14,998,253
Industrial Participant:	$15,000,000

Project Objectives:

To conduct three full-scale utility demonstrations to show that the combustion of gas reburning and sorbent injection can reduce NO_x emissions by 60 percent and SO_x emissions by 50 percent from pre-NSPS boilers. If successful, the project will demonstrate a process and equipment that could be easily retrofitted to about 900 U.S. utility boilers (tangentially fired, wall-fired, and cyclone-fired). This project would also make high-sulfur U.S. coals more usable and would reduce SO_x and NO_x emissions.

Process Description:

This project will demonstrate the gas reburning/sorbent injection process (GR/SI) on three different boilers representing three different combustion configurations.

The GR/SI process has been developed to interface with the existing coal combustion systems. The existing burners or combustors are retained when the GR/SI process is installed. Control of NO_x is achieved by burning less coal in the boiler at a carefully controlled air-to-fuel ratio. Natural gas injected downstream of the coal combustion zone compensates for the decreased coal input to the boiler. A portion of the NO_x formed by the coal combustion is converted to nitrogen by the reducing atmospheres caused by the partial combustion of natural gas. Air is then injected downstream of the natural gas injection point to complete this staged combustion process. This procedure reduces NO_x emissions by approximately 60 percent.

Emissions of SO_x are reduced in the GR/SI process by injecting a sorbent into the upper part of the boiler or into the flue gas duct downstream of the boiler. The sorbent (now contained in the fly ash) is removed from the flue gas in an existing ESP or baghouse. The need for flue gas humidification, which enhances both sorbent activity for SO_2 capture and ESP performance, is a site-specific determination. In this project, humidification will be used at two of the three sites, and sorbent injection into the flue gas duct will be tested at the cyclone boiler site. The process will reduce SO_x emissions by approximately 50 percent while burning a blend of high-sulfur coal. The GR/SI process provides an alternative technology to conventional wet FGD processes, while requiring less physical space.

This project will use the following host sites:

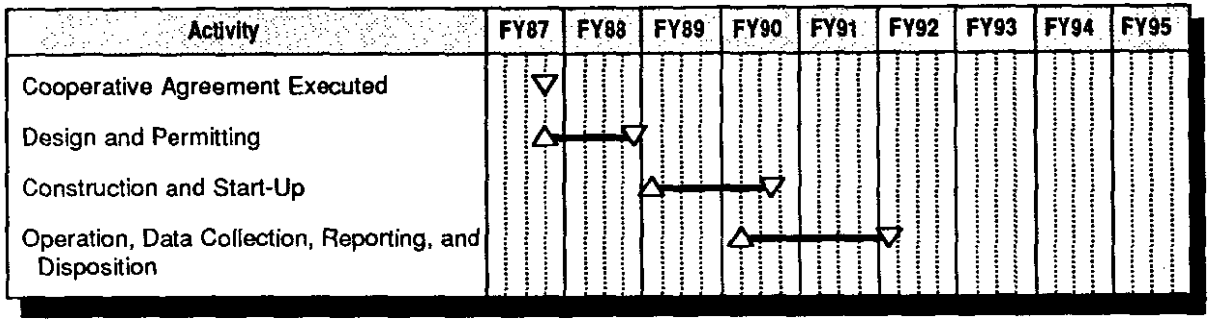
- A tangentially fired, 80-MW_e boiler owned by Illinois Power Company and located near Hennepin, IL. This boiler has burners mounted at the corners and directs the burning coal and air toward points just off the center of the boiler.

- A wall-fired 117-MW_e boiler owned by Central Illinois Central Light Company and located near Bartonville, IL. This boiler has burners that direct the burning air/coal into the furnace in a direction that is perpendicular to the wall in which the burners are mounted.

- A cyclone-fired 40-MW_e boiler owned by City Water Light and Power Company located in Springfield, IL. This boiler has a combustion system that is external to the boiler, and the hot combustion products enter the boiler after the combustion is complete.

Key Milestone Dates:

DOE selected project	7/24/86
Comprehensive report to Congress issued	6/5/87
DOE signed cooperative agreement	7/14/87
NEPA clearances expected for three sites	9/88
Complete design and permitting	9/88
Complete construction and start-up	5/90
Begin operation	1/90
Complete project	11/91



Project Status:

Phase I (design and permitting), which commenced in June 1987, is in progress, and overall the project is proceeding satisfactorily. Initial efforts have focused on review of the host units' design and operating data and on an initial evaluation of alternate approaches to applying GR/SI to the three types of coal-fired boilers that are typical of pre-NSPS design (i.e., wall-, corner-, and cyclone-fired units). One firm has been selected to assist in the engineering design for the GR/SI application, and a contract with a major boiler manufacturer is being negotiated for the fabrication and installation of the designed equipment.

Industrial cofunders have established the Industry Advisory Panel to assist in developing the approach to the application, provide input for the test program, and assure widespread technology transfer.

Preparation of the environmental information is in progress, and the necessary NEPA clearance needed to start the detailed design for the first site by April 1988 is well under way. The NEPA documentation for the two remaining sites is scheduled for May and June 1988.

Problems/Potential Problems:

None.

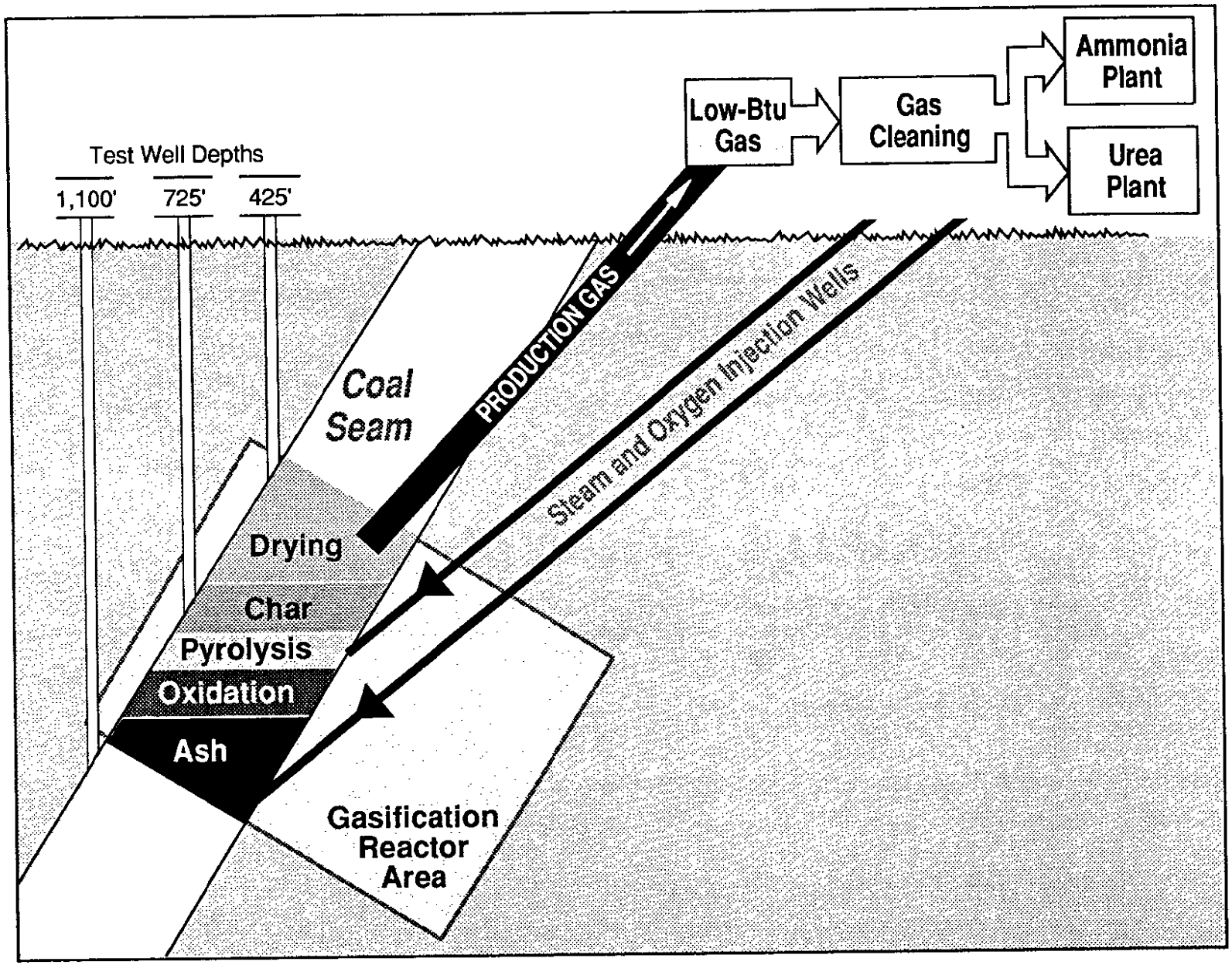
Underground Coal Gasification Demonstration Project

Energy International, Inc.

Underground Coal Gasification Demonstration Project

ENERGY INTERNATIONAL, INC.

PROCESS FLOW DIAGRAM



Project: Underground Coal Gasification Demonstration Project

Industrial Participant: Energy International, Inc.

Cofunders: Energy International, Inc. Venture Pacific, Ltd.

Process: Underground coal gasification

Location: Rawlins, Carbon County, WY

Coal Feed Characteristics: Wyoming subbituminous

Feed Rate: 500-1,000 tons of coal per day

Plant Capacity/Production: 450 tons of urea and 90 tons of ammonia per day (preliminary, subject to change)

Estimated Total Cost:	$70,115,454
DOE:	$11,792,362
Industrial Participant:	$58,323,092

Project Objectives:

To demonstrate that underground gasification of steeply dipping subbituminous coal beds is a cost-effective, reliable, and environmentally acceptable alternative to conventional mining with subsequent surface gasification. The specific objective of this project is to conduct a commercial-scale demonstration of steeply dipping bed underground coal gasification to provide synthesis gas for a small, commercial ammonia and urea plant.

Process Description:

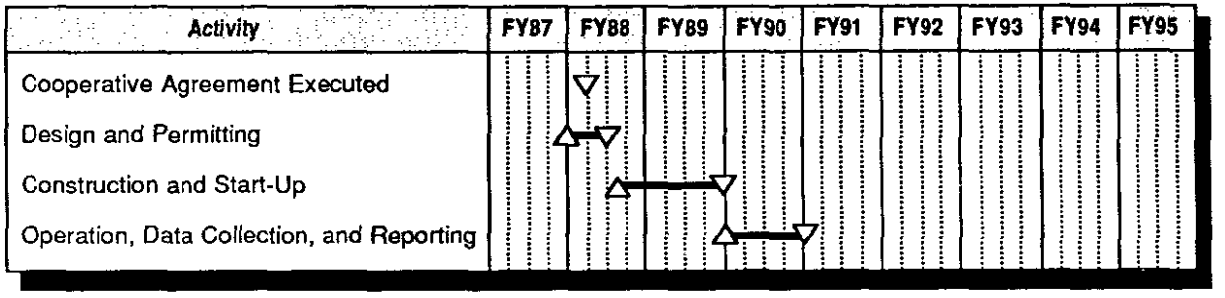
Underground coal gasification (UCG) is the process by which coal is burned underground (*in situ*), and the heat generated by the oxidation pyrolytically decomposes and gasifies additional coal to produce combustible gases. As the coal is consumed, a cavity develops in the coal seam. The most straightforward type of UCG process requires drilling one well to inject oxygen-containing gases and another to remove the gaseous products.

This project will demonstrate UCG technology in steeply dipping beds of subbituminous coal in Wyoming. The demonstration facility will operate for 12 months, gasifying 500 to 1,000 tons of coal per day to produce 24-48 million standard cubic feet per day of product gas. This gas will then be used to produce 450 tons of urea and 90 tons of ammonia per day. The feedstock gas for the ammonia and urea plants will be produced by using two UCG modules operating simultaneously.

In this application, a module is an area in the coal bed containing the gasification reaction zone and the necessary injection and production wells that would comprise a single process unit in a commercial plant. One coal gasifier in a surface coal gasification plant is the equivalent of one *in-situ* gasification module. Each UCG module consists of two steam/oxygen injection wells and one producer well located above the two injection wells. After combustion is initiated, gasification will continue until the coal in the module is exhausted. The gas produced will flow successively to heat exchange equipment, a gas/liquid separation unit, a sulfur removal unit, and then to conventional ammonia and urea synthesis units.

Key Milestone Dates:

DOE selected project	7/24/86
Comprehensive report to Congress issued	11/9/87
DOE signed cooperative agreement	12/23/87
Complete design and permitting	3/88
Complete construction	10/89
Begin operation	10/89
Complete project	10/90



Project Status:

The cooperative agreement for this project was signed by DOE on December 23, 1987. Phase I (site characterization) is under way. Exploratory core holes and groundwater monitoring wells are being drilled, and a channel has been excavated across the coal seam outcrop to better evaluate seam characteristics. A limited amount of civil engineering work has been completed to provide access to the site for the characterization effort. Phase I design activities are scheduled to be completed in March 1988.

Problems/Potential Problems:

None.

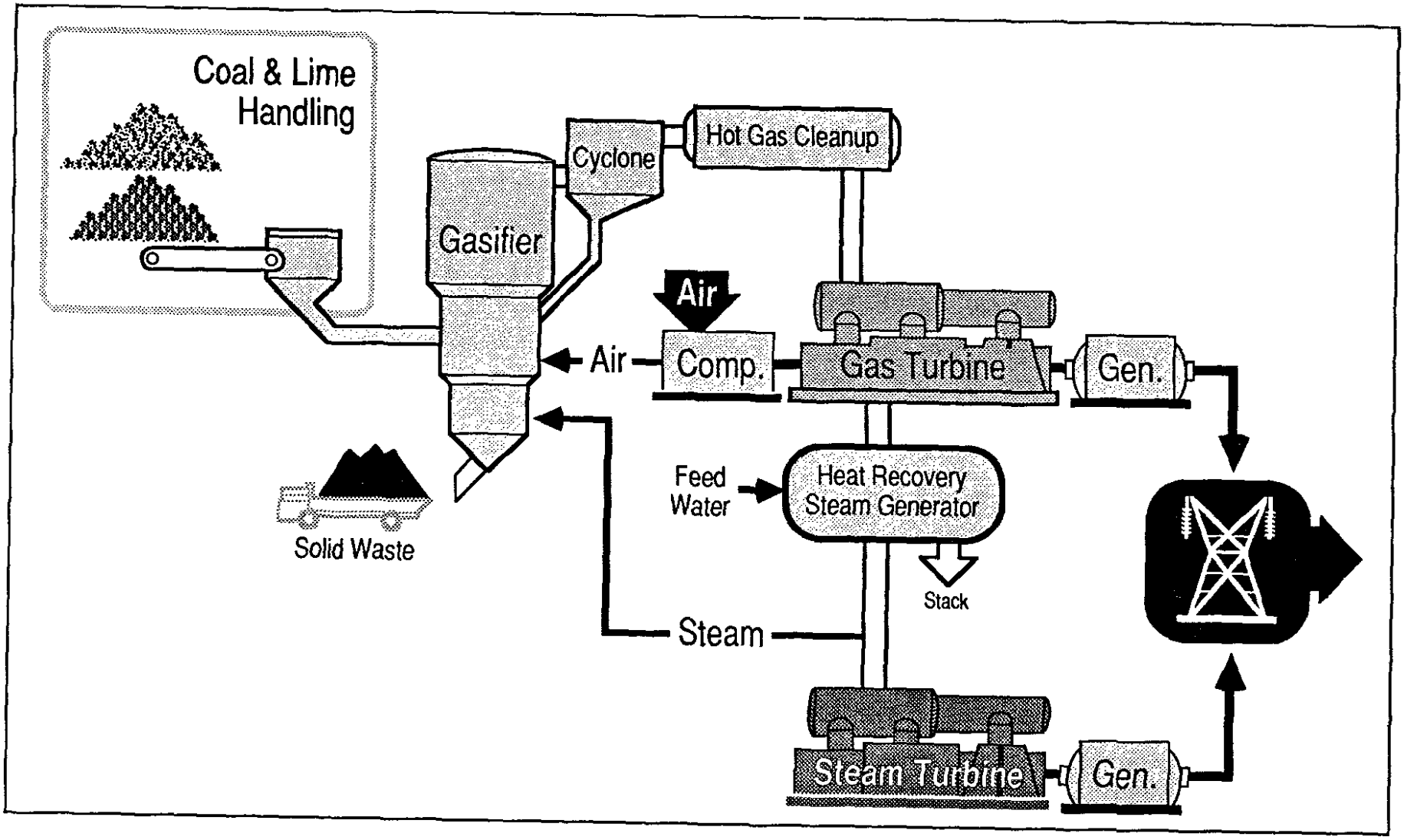
The Appalachian IGCC Demonstration Project

The M.W. Kellogg Company/Bechtel Development Company

The Appalachian IGCC Demonstration Project

THE M.W. KELLOGG COMPANY/BECHTEL DEVELOPMENT COMPANY

PROCESS FLOW DIAGRAM



Project: The Appalachian IGCC Demonstration Project

Industrial Participants:
The M.W. Kellogg Company
Bechtel Development Company

Cofunders:
The M.W. Kellogg Company
Bechtel Development Company

Process: Integrated coal gasification combined cycle

Location: Quemahoning Industrial Park, Somerset County, PA

Coal Feed Characteristics:
Local Pennsylvania high-sulfur, bituminous coals from the Brookville, Upper Freeport, and Pittsburgh seams

Plant Capacity: 63.5 MW_e (net)

Feed Rate: 551 tons of coal per day

Estimated Total Cost:	$243,837,000
DOE:	$87,528,500
Industrial Participants:	$156,308,500

Project Objectives:

To design, build, and operate a grass roots, advanced coal gasification combined-cycle, power generation plant that will utilize high-sulfur, Eastern U.S. bituminous coal to demonstrate an efficient, economical, and environmentally advantageous method of generating electric power.

Process Description:

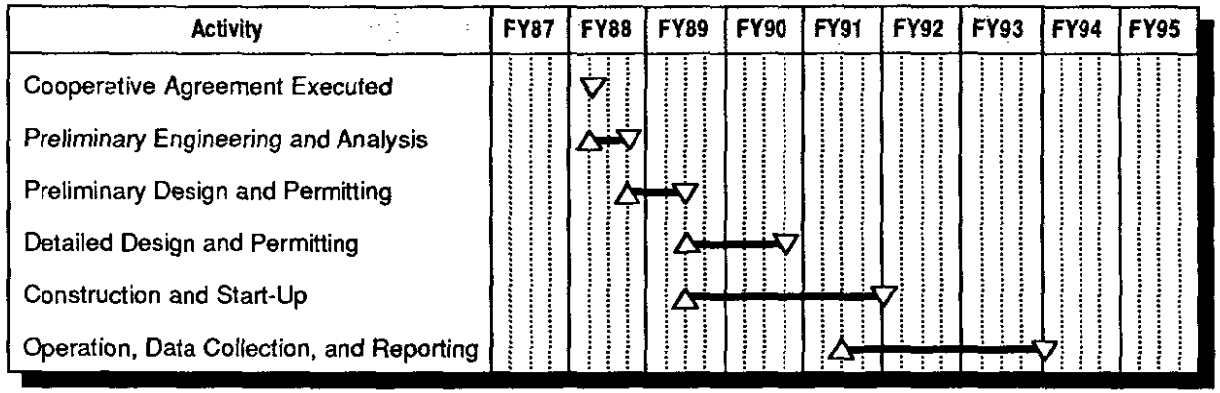
Substantial effort already has been focused on the development of power generation systems utilizing coal gasification coupled with gas turbines in integrated gasification combined cycle (IGCC) configurations. From an economic standpoint, such systems show promise for significantly outperforming conventional coal-fired steam plants with FGD. They also have the potential to meet increasingly stringent environmental emission and siting requirements while taking full advantage of the Nation's vast coal resources.

A major milestone in the development of IGCC technology in the U.S. was achieved recently with the successful operation of the Cool Water facility at Daggett, California. The Cool Water demonstration successfully integrated oxygen-blown, entrained-flow gasification; cold gas scrubbing technology for contaminant and sulfur removal; and a modern combined-cycle gas turbine system for power generation.

An advanced concept has been developed that improves upon this first-generation IGCC technology. By using a KRW air-blown gasifier (which consumes less auxiliary power than an oxygen-blown system), hot gas cleanup, and an innovative tail gas treatment processing scheme, the concept provides higher thermal efficiency and superior environmental performance when compared to first-generation systems. This advanced approach will offer an excellent option for meeting future and potentially more stringent environmental emission constraints. Its standardized modular design and simple process configuration are also expected to yield significantly lower engineering and equipment costs, while providing excellent flexibility in the capital expenditure required.

Key Milestone Dates:

DOE selected project	7/24/86
Comprehensive report to Congress issued	12/22/87
Execute cooperative agreement	1/88
Complete design and permitting	7/90
Complete construction and start-up	10/91
Begin operation	4/91
Complete project	10/93



Project Status:

DOE expects to sign the cooperative agreement in January 1988. Phase I is proceeding on schedule and is subdivided into:

IA--Preliminary Engineering and Analysis (6 months)
IB--Preliminary Design and Permitting (9 months)
IC--Detailed Design (15 months)

Problems/Potential Problems:

A long-term sales agreement needs to be obtained on terms satisfactory to service the project debt and operating costs, otherwise the ability of the sponsors to obtain financing will be in jeopardy.

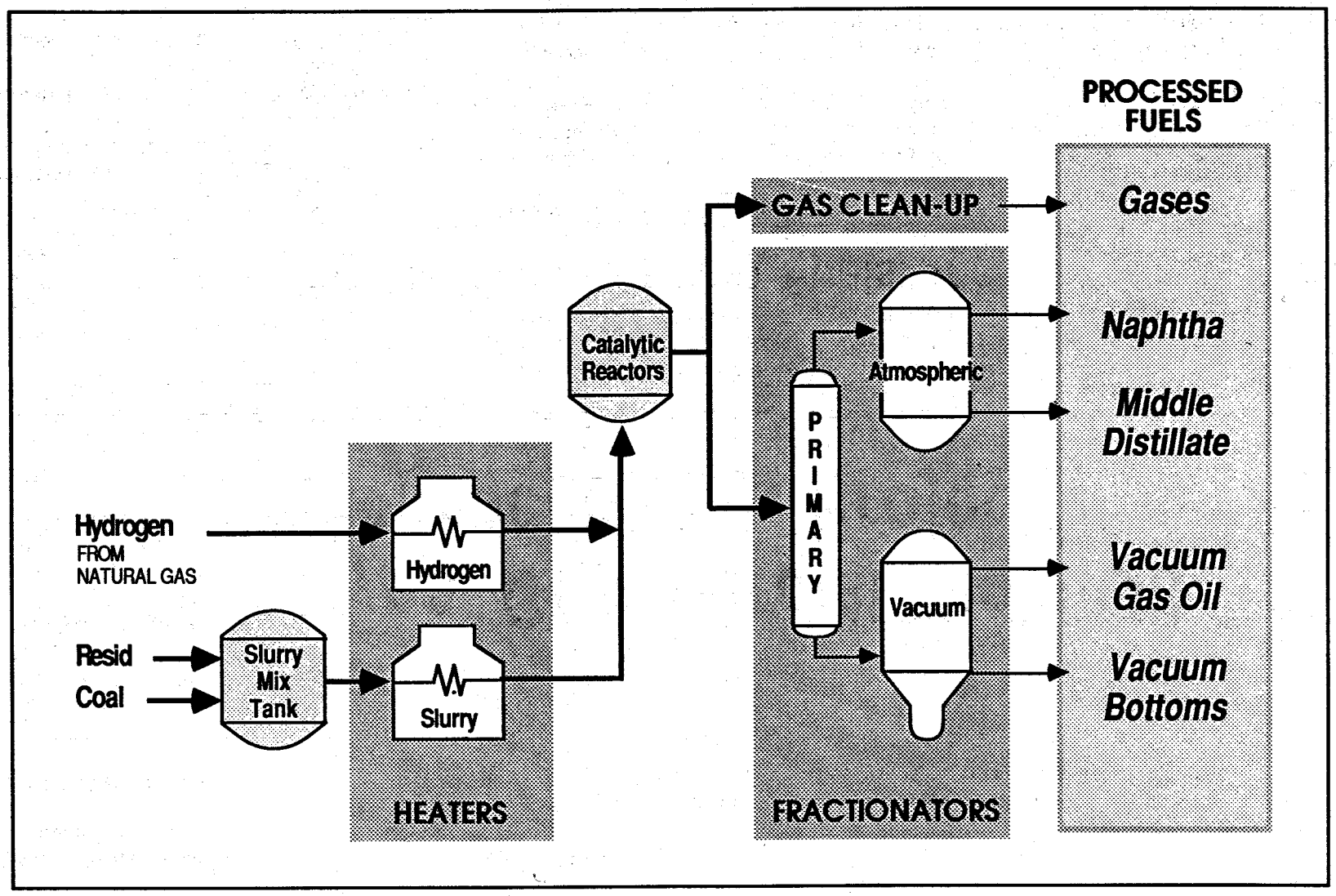
Prototype Commercial Coal/Oil Coprocessing Project

Ohio Ontario Clean Fuels, Inc.

Prototype Commercial Coal/Oil Coprocessing Project

OHIO ONTARIO CLEAN FUELS, INC.

PROCESS FLOW DIAGRAM



Project: Prototype Commercial Coal/Oil Coprocessing Project

Industrial Participant: Ohio Ontario Clean Fuels, Inc.

Cofunders: State of Ohio
Stone and Webster Engineering Corp.
Air Products and Chemicals, Inc.
Canadian Occidental Petroleum, Ltd.
EPRI (providing funding only for product combustion testing)
Equipment vendors
Merrill Lynch

Process: Coprocessing of coal and residual oil to produce clean liquid fuels

Location: Warren, Trumbull County, OH

Coal Feed Characteristics: Ohio Nos. 5 and 6 (high-sulfur bituminous)

Feed Rate: 800 tons of coal and 8,675 barrels of oil per day

Production: 12,280 barrels per day of clean distillate products and 57 tons of sulfur

Estimated Total Cost:	$225,674,805
DOE:	$45,000,000
Industrial Participant:	$180,674,805

Project Objectives:

To build a grass-roots prototype, commercial coal/oil coprocessing plant to convert high-sulfur, high-nitrogen, bituminous coal and poor-quality petroleum residues to clean liquid fuels, using ebullated-bed reactor technology.

Process Description:

Coal/oil coprocessing yields liquid fuels that are low in sulfur, nitrogen, and trace metals, and high in heating value. These liquid products can be used directly as a clean-burning boiler fuel or further processed in a conventional petroleum refinery to produce transportation fuels. Nitrogen (in the form of ammonia) and sulfur are recovered as byproducts, thereby avoiding their introduction into the atmosphere as SO_x and NO_x. Hydrocarbon gases are also collected as byproducts in the form of liquefied petroleum gases (LPG).

Crushed and prepared coal, the petroleum residues, and a recycle solvent (oil) are mixed, pressurized, and heated and are introduced as a slurry along with pressurized hydrogen into the first of two process reactors.

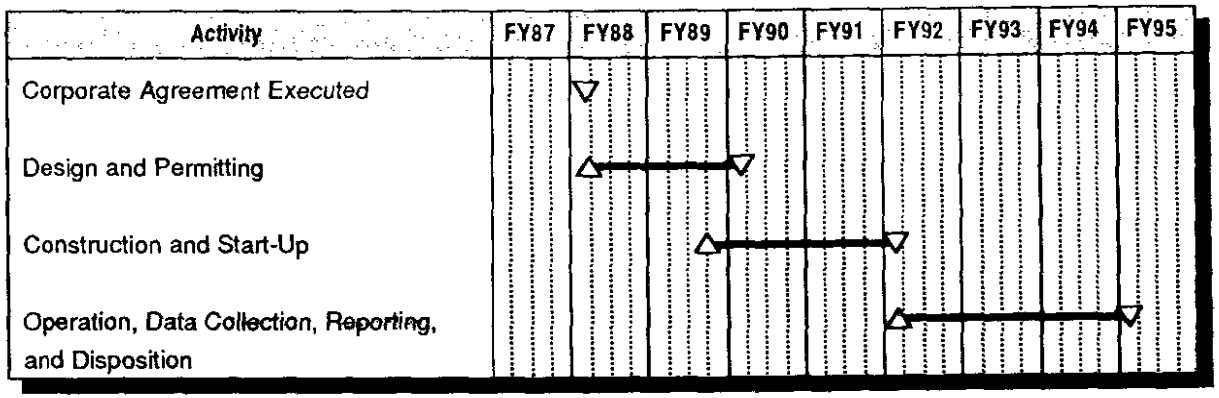
In the reactor, hydrogen reacts with molecules of coal and heavy residual oil to produce lighter molecules. The hydrogen also reacts with the sulfur and nitrogen in the feed to form gaseous hydrogen sulfide (H_2S) and ammonia (NH_3) that are subsequently collected as waste products. Hydrogen consumption is reduced, and product yield is increased by using a second reactor. The liquid effluent from the second reactor is separated from the gases, and the light, clean liquids are then collected through a series of pressure reductions and cooling steps. The heavy liquid stream is cleaned and separated in several distillation steps. Both the lighter and heavier liquids are further distilled and blended to produce clean naphtha and clean distillate. The gases are cleaned and separated into butane, propane, and fuel gas.

During the gas cleanup, the water soluble waste products are collected in a sour water stream. The sour water is treated by conventional refinery processes to recover elemental sulfur and ammonia as byproducts. The wastewater is further treated to remove organic compounds before it is discharged from the plant.

The vacuum bottoms from the distillation process contain unreacted coal, ash, and residue, which forms a solid material at ambient temperature. These bottoms can be solidified, flaked, and burned to generate sufficient steam to meet the plant's requirements.

Key Milestone Dates:

DOE selected project	7/24/86
Comprehensive report to Congress issued	10/30/87
DOE signed cooperative agreement	12/15/87
Complete design and permitting	12/89
Complete construction	12/91
Begin operation	12/91
Complete project	12/94



Project Status:

DOE signed the cooperative agreement on December 15, 1987, and the project is currently in Phase I (design). Ohio Ontario is actively negotiating with its key subcontractors, Stone and Webster Engineering Company (SWEC) and HRI, Inc.

Problems/Potential Problems:

- The project schedule may be delayed if an environmental impact statement is required. DOE is working with SWEC to plan the environmental program. A comprehensive environmental report will be prepared by SWEC.
- A slow start with the development of preliminary engineering activities may cause a delay in the project schedule.

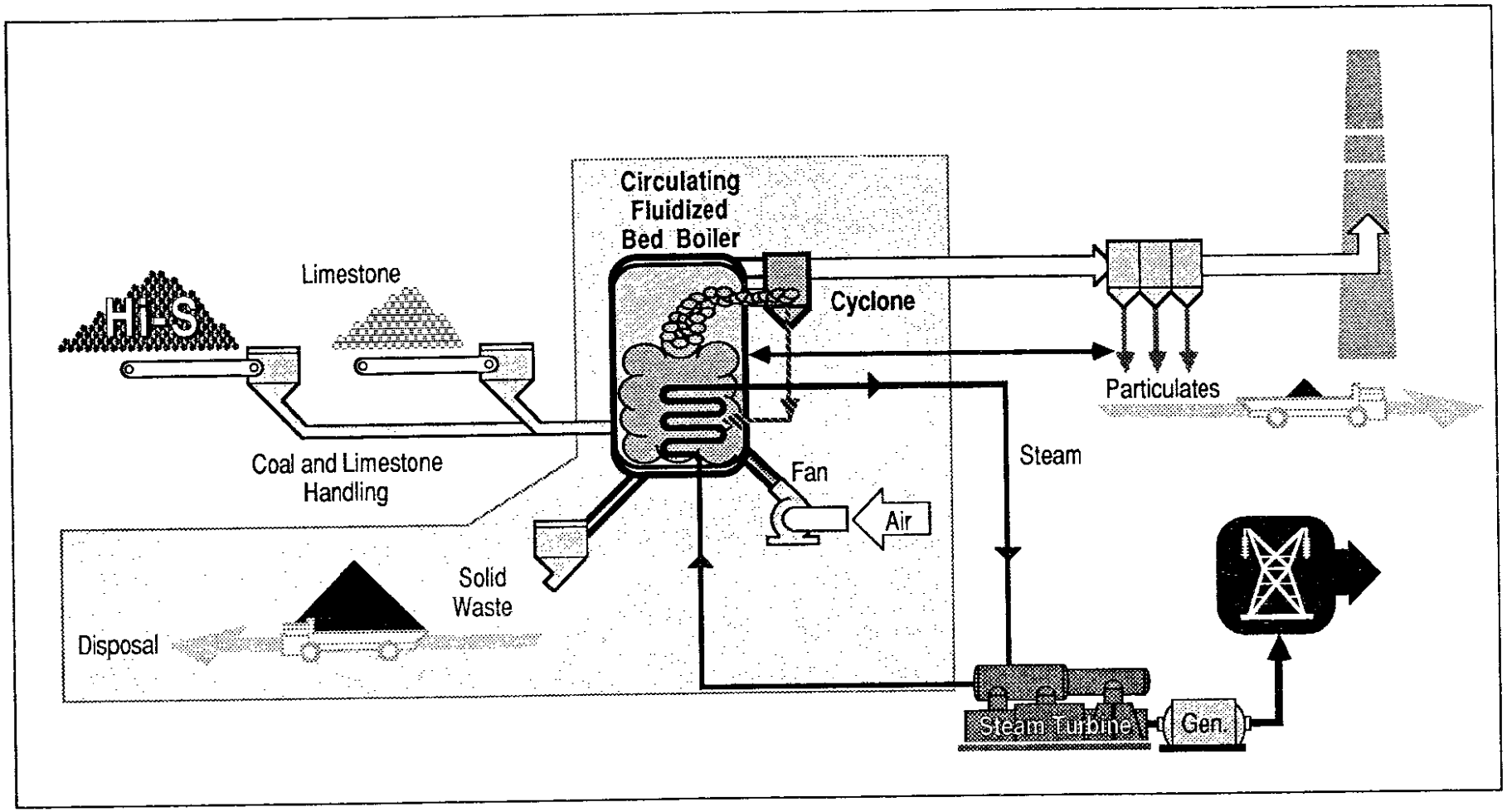
Nucla CFB Demonstration Project

Colorado-Ute Electric Association, Inc.

Nucla CFB Demonstration Project

COLORADO-UTE ELECTRIC ASSOCIATION, INC.

PROCESS FLOW DIAGRAM



Project: Nucla CFB Demonstration Project

Industrial Participant: Colorado-Ute Electric Association, Inc.

Cofunder: Colorado-Ute Electric Association, Inc.

Process: Circulating fluidized-bed combustion

Location: Nucla, Montrose County, CO

Coal Feed Characteristics: Bituminous, subbituminous

Plant Capacity: 110 MW_e

Estimated Total Cost: Subject to negotiation
DOE: To be determined
Industrial Participant: To be determined

Project Objectives:

To demonstrate the feasibility of circulating fluidized-bed (CFB) combustion technology and to evaluate the economical, environmental, and operational benefits of CFB steam generators on a utility scale.

Process Description:

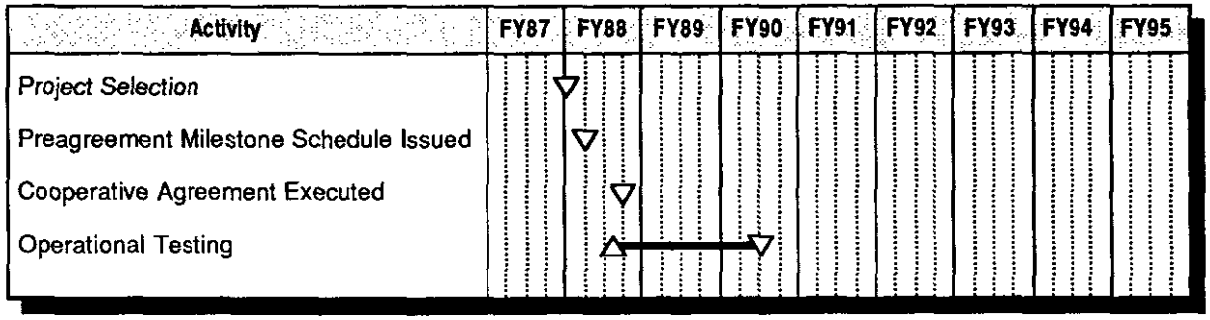
Circulating fluidized-bed combustion is a technology that offers several potential benefits. These include lower capital costs, reduced SO_x and NO_x emissions, and control of pollutants at lower costs than are offered by existing technologies. Emissions will be lower because NO_x is reduced by lower combustion temperature and SO_2 is reduced by reacting with limestone in the fluidized bed. The fluidized-bed combustor operates at atmospheric pressure, and the bed temperature usually ranges between 1,400 ^oF and 1,600 ^oF which helps prevent furnace slagging and NO_x emissions. The atmospheric circulating bed system was chosen for this project instead of an atmospheric bubbling bed system because of the potential for higher combustion efficiency and better utilization of limestone.

As part of this project, three small, coal-fired, stoker-type boilers at the Colorado-Ute Nucla Station are being replaced with a single CFB steam generator capable of driving a new 74-MW_e turbine generator. Extraction steam from this turbine-generator will power the three existing turbine generators of 12 MW_e each. The majority of other existing plant equipment is also being utilized to minimize costs and to demonstrate the suitability of CFB technology for retrofit and life extension of existing units.

Key Milestone Dates:

DOE selected project	10/7/87
Kick-off meeting for fact-finding process	11/10/87
Complete negotiations	4/88*
Issue comprehensive report to Congress	6/88*
Execute cooperative agreement	6/88*
Begin operational testing	6/88*
Complete project	3/90*

* Preliminary; subject to negotiation



Project Status:

Fact-finding and negotiating activities are in progress.

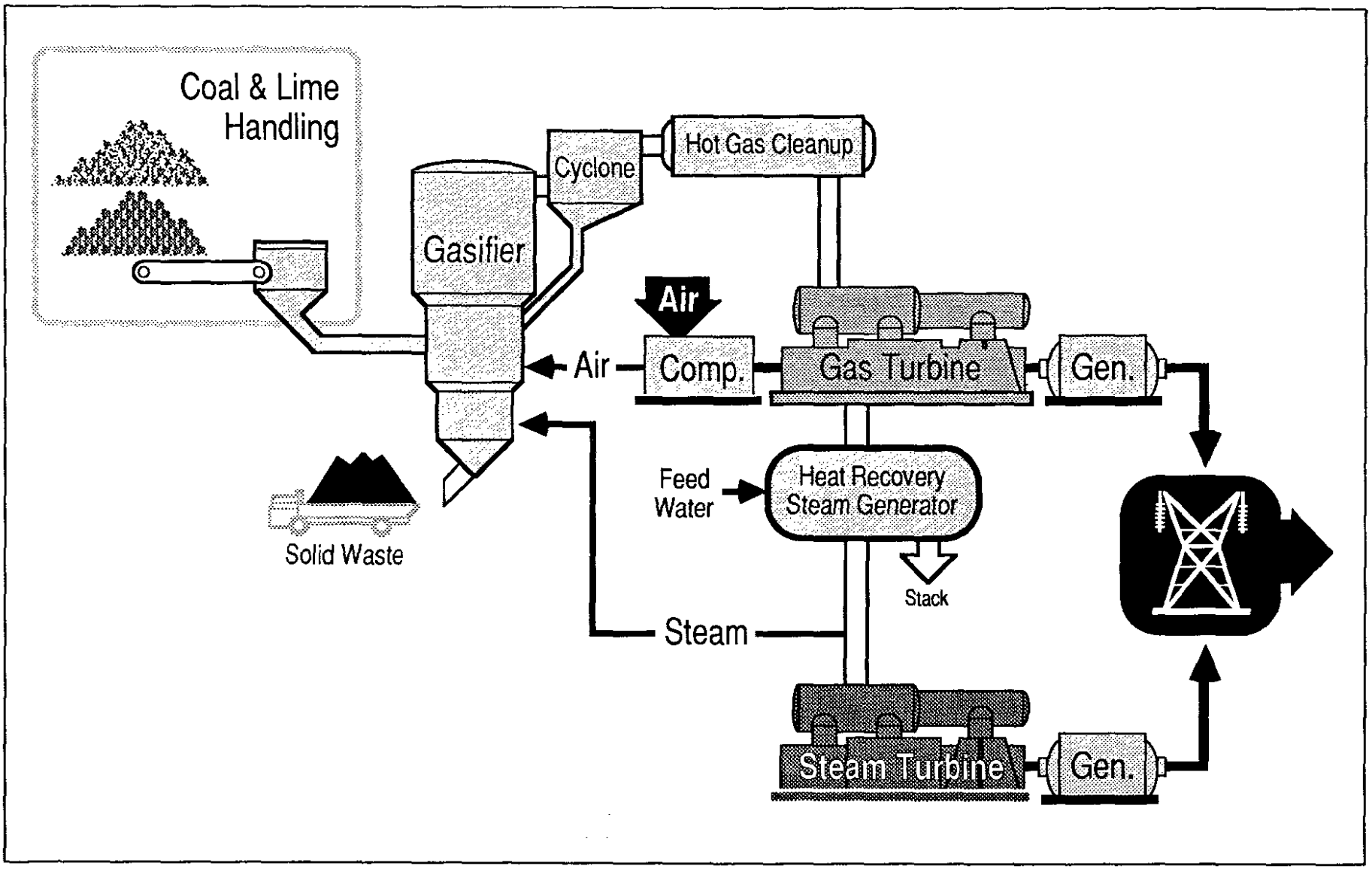
Clean Energy IGCC Demonstration Project

Consolidation Coal Company/Foster Wheeler Power Systems, Inc.

Clean Energy IGCC Demonstration Project

CONSOLIDATION COAL COMPANY/FOSTER WHEELER POWER SYSTEMS, INC.

PROCESS FLOW DIAGRAM



Project: Clean Energy IGCC
Demonstration Project

Industrial Participants:
Consolidation Coal Company
Foster Wheeler Power Systems, Inc.
Others to be determined

Cofunders:
Foster Wheeler Power Systems, Inc.
Consolidation Coal Company
Others to be determined

Process: Integrated gasification combined cycle using IGT U-Gas process

Location: West Virginia

Coal Feed Characteristics:
High-sulfur West Virginia coal

Feed Rate: 600 tons of coal per day

Production: 44 MW_e and 200,000 pounds of steam per hour (59 MW_t)

Estimated Total Cost: Subject to negotiation
DOE: To be determined
Industrial Participant: To be determined

Project Objectives:

To demonstrate the technical, environmental, and economic performance of an advanced integrated gasification combined-cycle system in a repowering/cogeneration application at the integrated commercial scale. The system will utilize IGT's U-Gas process (fluidized bed gasifier) with hot gas cleanup.

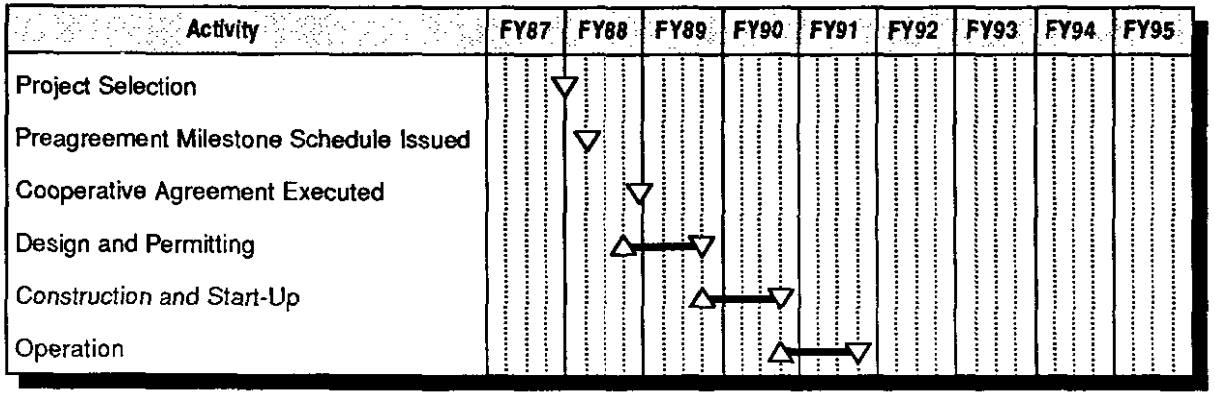
Process Description:

An integrated gasification combined-cycle powerplant will be designed to convert high-sulfur West Virginia coal into electric power and steam in an environmentally acceptable manner, while offering a significant reduction in capital and operating costs over conventional coal-based technologies with flue gas cleaning. The proposed project concept is based on the U-Gas coal-gasification process with limestone injection for sulfur removal. Hot particulate removal will be accomplished by a zinc-ferrite sulfur removal process. The product, low-Btu gas, will be combusted in a gas turbine with a steam generator to recover residual heat. The low-Btu gas will be combusted in a gas turbine combined-cycle powerplant.

Key Milestone Dates:

DOE selected project	10/7/87
Kick-off meeting for fact-finding process	11/5/87
Issue preagreement milestone schedule	1/88*
Issue comprehensive report to Congress	8/88*
Execute cooperative agreement	9/88*
Complete design and permitting	7/89*
Complete construction	7/90*
Begin operation	7/90*
Complete project	7/91*

* Preliminary; subject to negotiation



Project Status:

Fact-finding and negotiating activities are in progress.

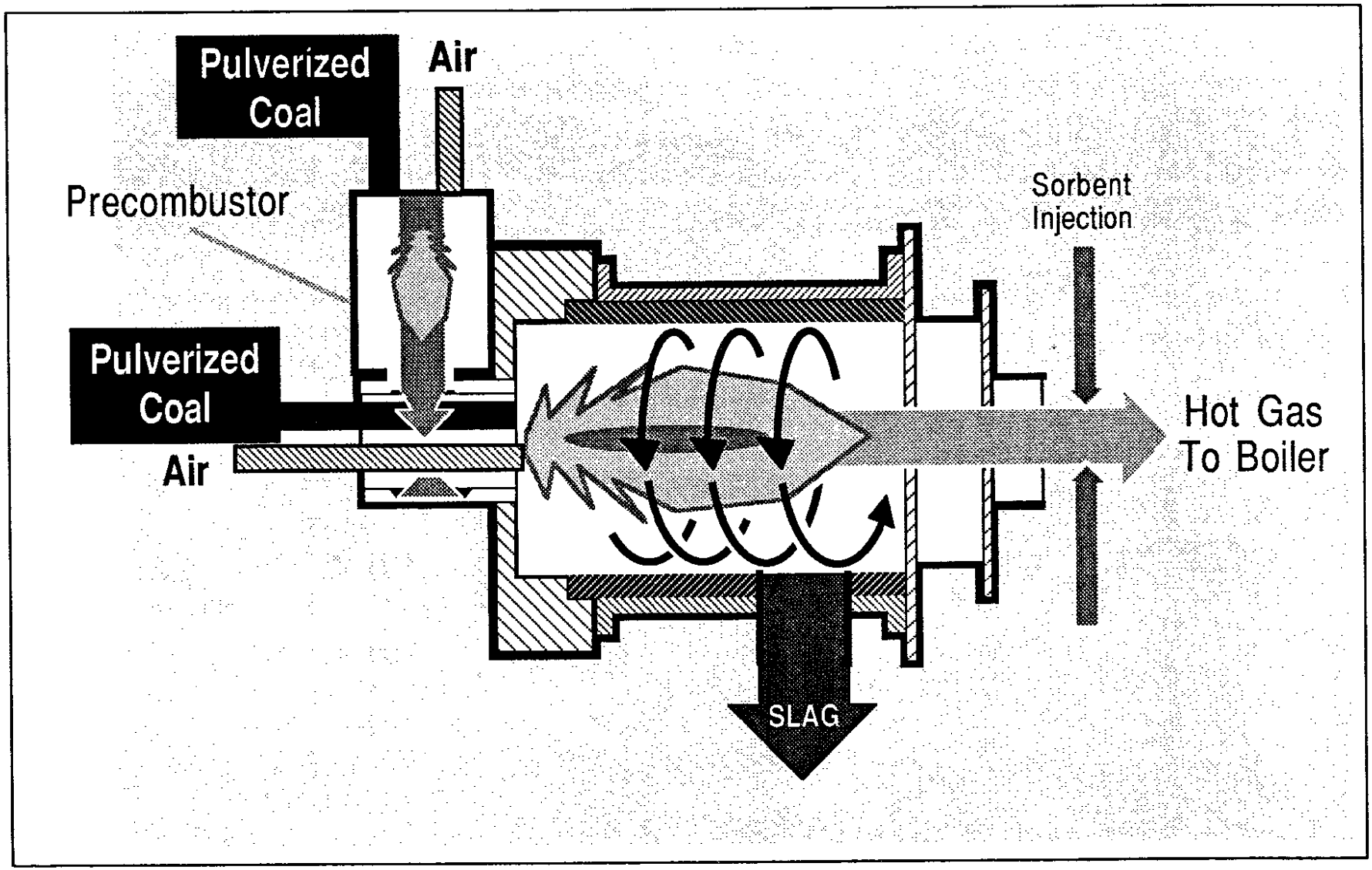
Advanced Slagging Coal Combustor Utility Demonstration Project

TRW, Inc.

Advanced Slagging Coal Combustor Utility Demonstration Project

TRW, INC.

PROCESS FLOW DIAGRAM



Project: Advanced Slagging Coal Combustor Utility Demonstration Project

Industrial Participant: TRW, Inc.

Cofunders: Dependent on negotiations

Process: Advanced slagging coal combustor

Location:
Orange and Rockland Utilities' Lovett Station, Stony Point, NY
TRW Slagging Combustor Test Facility, Cleveland, OH

Coal Feed Characteristics: Eastern U.S. bituminous coal of low- to medium-sulfur content (0.7% and 2.5%)

Plant Capacity: 69 MW_e retrofit with four 160-MMBtu per hour combustors

Estimated Total Cost: Subject to negotiation
DOE: To be determined
Industrial Participant: To be determined

Project Objectives:

To demonstrate an advanced slagging coal combustor at a scale suitable for utility application. The project will involve converting an existing utility boiler from oil to coal, while meeting environmental standards and without derating the unit.

Process Description:

The slagging combustor removes coal ash in the form of a molten slag and is similar to a unit currently being developed for industrial scale by TRW. A key distinction in the proposed demonstration effort is the addition of several techniques designed to remove potential sulfur pollutants. Limestone, which acts as a sulfur absorber, will be injected into the combustion gases before they are sent into the boiler. To enhance sulfur capture, a lime recycling system will be installed and tested. If successful it will economically control SO_x from low- to medium-sulfur coals to the NSPS level.

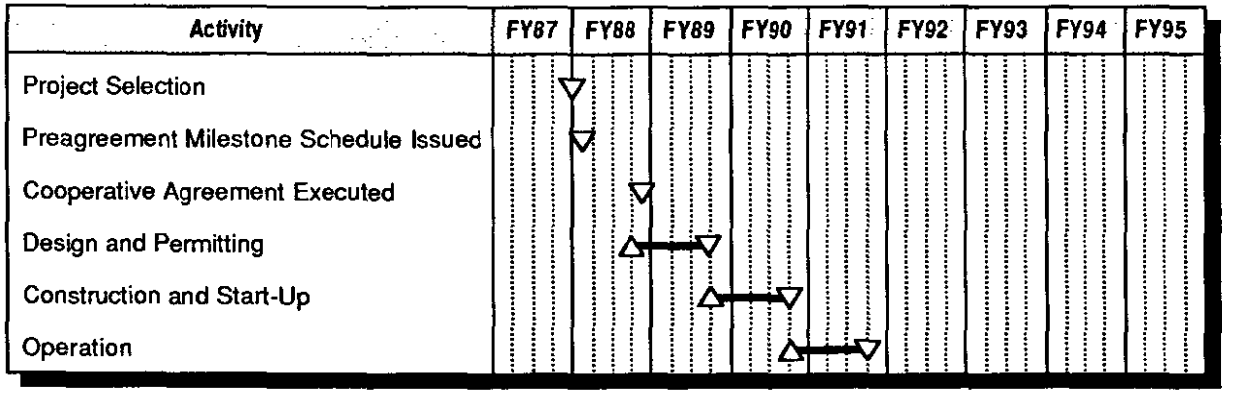
This project will extend TRW's demonstration of its slagging coal combustor from the small industrial boiler demonstration (40 MMBtu per hour) to a full-scale utility boiler retrofit demonstration, converting oil-firing to coal-firing using four 160-MMBtu-per-hour combustors and controlling NO_x, SO_x, and particulate emissions to meet environmental standards both economically and without derating the boiler.

A boiler in an Orange and Rockland Utilities power plant located at Stony Point, NY, will be retrofitted with four combustors, including pulverized coal and limestone feed systems, slag handling and particulate filter systems, and modification of heat exchange and gas flow systems. During the design phase of the Orange and Rockland project, coal-burning tests and calcined limestone recycle tests will be conducted at TRW's industrial-scale slagging combustor test facility located in Cleveland, OH.

Key Milestone Dates:

DOE selected project	10/7/87
Kick-off meeting for fact-finding process	11/24/87
Preagreement milestone schedule issued	11/24/87
Issue comprehensive report to Congress	7/88*
Execute cooperative agreement	8/88*
Complete design and permitting	7/89*
Complete construction	7/90*
Begin operational testing	7/90*
Complete project	7/91*

* Preliminary; subject to negotiation



Project Status:

Fact-finding and negotiating activities are in progress.

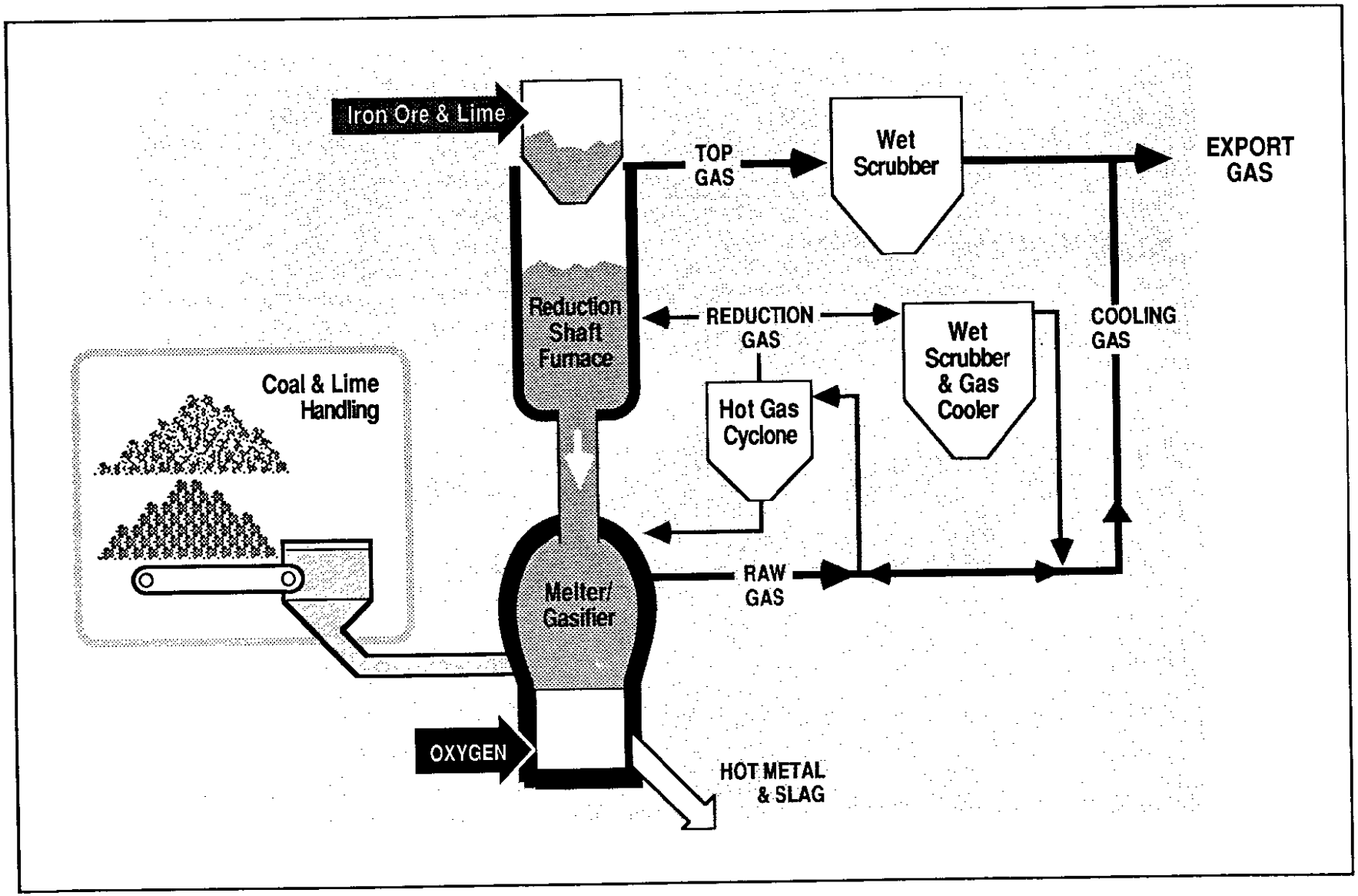
COREX Ironmaking Demonstration Project

Minnesota Department of Natural Resources

COREX Ironmaking Demonstration Project

MINNESOTA DEPARTMENT OF NATURAL RESOURCES

PROCESS FLOW DIAGRAM



Project: COREX Ironmaking Demonstration Project

Industrial Participant: Minnesota Department of Natural Resources

Cofunders:
Minnesota Department of Natural Resources
Others to be determined

Process: COREX

Location: To be determined

Coal Feed Characteristics: Low volatile coals and coal blends

Feed Rate: 240,000-400,000 tons of coal per year

Plant Capacity/Production:
300,000-600,000 tons of iron per year

Estimated Total Cost: Subject to negotiation
DOE: To be determined
Industrial Participant: To be determined

Project Objectives:

To demonstrate at a commercial scale (300,000 metric tons per year of pig iron minimum) that the COREX process can be used to produce pig iron of blast furnace quality directly from U.S. coals and ores, thereby eliminating the coke plant and its environmental problems from the ironmaking process.

Process Description:

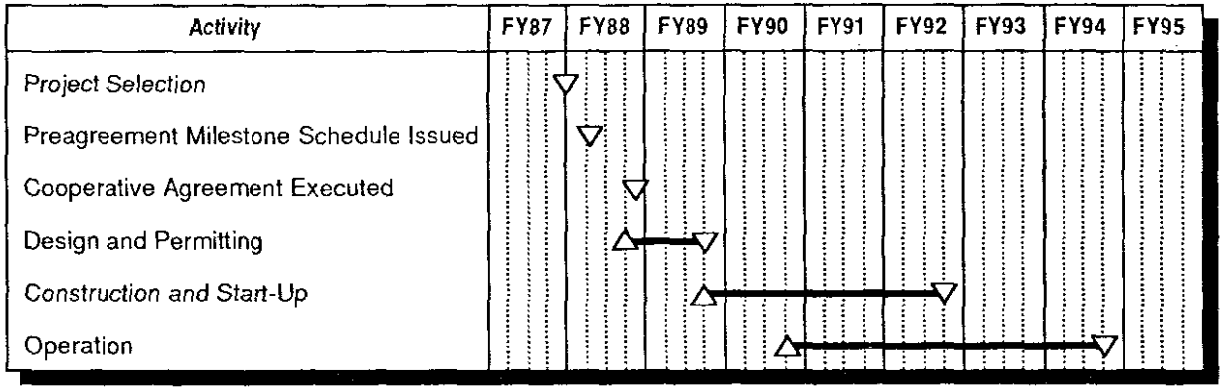
The COREX process, developed by Korf Engineering (a West German company), replaces the two-step coke oven/blast furnace approach to producing pig iron from iron ore and metallurgical coal with an integrated two-component system capable of operation on a variety of U.S. coals. The system consists of an upper "reduction shaft" and a lower "melter-gasifier" component. Iron ore, along with an appropriate flux (e.g., limestone), is fed into the top of the reduction shaft where it is reduced to sponge iron by the off-gas from the lower melter-gasifier section into which it is then introduced along with coal. This lower section is an oxygen-blown fluidized-bed gasifier. In this section, the sponge iron is melted and the resulting pig iron and slag are separated and tapped as in a blast furnace. The low- to medium-Btu, sulfur-free off-gas from the process (sulfur is captured by the limestone and remains in the slag) is scrubbed to remove particulates and is available for site use.

The practicality of ironmaking by the traditional method of reducing iron ore material in a coke-fed blast furnace has been severely impacted due to environmental problems. The problems lie principally with the coke-manufacturing operation which generates emissions and effluent that have proven to be exceedingly difficult to control to levels meeting environmental regulations. The COREX process, by eliminating the coking step, is environmentally superior to established ironmaking methods. The process offers other advantages as well, including attractive economics, the ability to operate on a wide range of coal and iron feedstocks, the capability for rapid start-up and shutdown, and flexibility in terms of product slate and plant scale up.

Key Milestone Dates:

DOE selected project	10/7/87
Kick-off meeting for fact-finding process	11/3/87
Issue preagreement milestone schedule	1/88*
Issue comprehensive report to Congress	8/88*
Execute cooperative agreement	9/88*
Complete design and permitting	7/89*
Complete construction and start-up	7/92*
Begin operation	7/90*
Complete project	7/94*

* Preliminary; subject to negotiation



Project Status:

Fact-finding and negotiating activities are in progress.

3.0 INNOVATIVE CLEAN COAL TECHNOLOGY DEMONSTRATIONS

3.1 Background

Two separate activities confirmed the need for and established the viability of a second clean coal technology solicitation. The first was when Congress passed the Department of the Interior and Related Agencies Appropriations Act for FY 1987 on October 18, 1986. Through this act, Congress required DOE to solicit "statements of interest in, and informational proposals for, emerging clean coal technologies capable of retrofitting, repowering, or modernizing existing facilities." Complying, DOE published a Program Announcement in the November 12, 1986, issue of the *Federal Register* (51 FR 41060-6) and a Notice in the November 17, 1986, issue of the *Commerce Business Daily*.

In response to this Program Announcement, DOE received 139 submissions for projects valued at over $5 billion as well as some letters commenting on various aspects of the solicitation. These submissions were collected, reviewed, and correlated, and the results were forwarded to Congress on March 6, 1987. This effort provided evidence that industry was prepared to participate in a joint Government-industry clean coal technology program oriented toward existing coal-burning utilities and industrial facilities.

The second activity was initiated in March 1985 when the President appointed Drew Lewis to the position of U.S. Special Envoy on Acid Rain, and, at the same time, Prime Minister Brian Mulroney appointed William Davis as the Canadian Special Envoy. Charged with the responsibility "to assess the international environmental problems associated with transboundary air pollution, and then recommend actions that would solve them," the appointees issued in January 1986 the *Joint Report of the Special Envoys on Acid Rain*, also popularly known as "the Lewis/Davis Report." The Special Envoys provided 12 recommendations, the first one of which was the following:

> Therefore, the U.S. government should implement a five-year, five-billion-dollar control technology commercial demonstration program. The federal government should provide half the funding - 2.5 billion dollars - for projects which industry recommends and for which industry is prepared to contribute the other half of the funding.

These two activities provided the basis for what was probably the most important event in the history of the Clean Coal Technology Demonstration Program. This event was the President's decision, announced on March 18, 1987, to seek

$2.5 billion to fund the demonstration of innovative clean coal technologies over a 5-year period, provided that appropriate projects were proposed that met, among other things, cost-sharing requirements similar to those provided in the February 17, 1986, CCT-I solicitation. Accordingly, the Administration amended the FY 1988 budget request and supporting outyear estimates for the program. The Administration requested as funding for demonstration projects the remaining $350 million from the Clean Coal Technology Reserve Fund in FY 1988 and advanced appropriations of $500 million each year for fiscal years 1989 through 1992. The cost-sharing requirements would ensure that industry will invest an equal or greater amount over this period to stimulate deployment of innovative clean coal technologies.

On March 23, 1987, the Secretary of Energy announced that the 1988 and 1989 funding ($350 million and $500 million) would be combined into a single $850 million solicitation to be issued, subject to the provision of appropriations. Further funding of $500 million for each of the fiscal years 1990, 1991, and 1992 would be used to structure multiple rounds of competitions. The competitive procurements would be sequenced in such a way as to encourage new, potentially improved clean coal concepts to continue their development and to be considered as candidate technologies once they achieve sufficient maturity.

3.2 Informational Solicitations

In a manner similar to that which initiated the CCT-I Program, Congress again directed DOE to solicit information from the private sector in the Department of the Interior and Related Agencies Appropriations Act for FY 1987, Section 101(h), Public Law Nos. 99-500 and 99-591, signed on October 18, 1986, and October 30, 1986, respectively. This information was to establish the level of interest of potential industrial participants in another solicitation for clean coal technologies capable of retrofitting, repowering, or modernizing existing facilities. The act further provided that projects to be submitted in response to the solicitation must meet cost-sharing criteria set for the first clean coal technology program (CCT-I) by Public Law No. 99-190, which provided the authority and the funding for DOE's issuance of the February 17, 1986, Program Opportunity Notice. Among other things, those criteria specified that "the Secretary [of Energy] shall not finance more than 50 percent of the total costs of a project as estimated by the Secretary as of the date of award of financial assistance: provided further, that cost-sharing by project sponsors is required in each of the design, construction, and operating phases proposed to be included in a project . . . ."

Additionally, Public Law No. 99-500, which contains the direction to perform a second solicitation for statements of interest, stipulated that DOE "shall . . . no later than March 6, 1987, submit to Congress a summary report of statements of interest and informational proposals received and no later than one hundred and twenty days after the receipt of such statements and proposals submit to Congress a report that analyzes the information contained . . . and assesses the potential usefulness and commercial viability of each emerging clean coal technology for which a statement of interest or informational proposal has been received."

The *Summary Report to Congress on Emerging Clean Coal Technologies Capable of Retrofitting, Repowering, or Modernizing Existing Facilities* was issued March 6, 1987, and was the first of the two transmittals to Congress that were provided for in Public Law No. 99-500. The first chapter of this report provided a short history of the Clean Coal Technology Program, including the congressional background to the "retrofit" informational solicitation of November 12, 1986. The

second chapter presented statistical data and other basic information on the responses that were received. The following technologies accounted for 126 of the total 139 submittals: flue gas cleanup (49), coal preparation (25), fluidized bed combustion (15), advanced combustors (13), alternative fuels (13), and surface coal gasification (11).

The *Second Report to Congress on Emerging Clean Coal Technologies Capable of Retrofitting, Repowering, or Modernizing Existing Facilities*, issued May 12, 1987, analyzed the information and assessed the potential usefulness and commercial viability of each emerging clean coal technology for which a statement of interest or informational proposal was received. This report categorized the submittals according to the products or yields that would result from the suggested demonstration projects, i.e., steam, electricity, clean coal, etc., and the market sectors that the proposed technologies, if successfully commercialized, would most readily serve. Projects and the typical sulfur contents of the coals that would be used were summarized. Technology assessments were also provided that included discussions of related projects in progress, the relationship between DOE's research and development program and the ongoing CCT-I Program, applicability of the technologies to retrofitting, repowering, or modernizing existing facilities, and summary overviews of the responses received in the relevant technology categories.

3.3 President's Initiative

On March 18, 1987, the President initiated a major expansion of the Clean Coal Technology Demonstration Program. He directed that three major steps be taken:

- The first was to seek the full amount of the Government's share of funding recommended by the Special Envoys--$2.5 billion--for demonstration of innovative control technology over a 5-year period. Five hundred million dollars would be requested for fiscal years 1988 and 1989 to fund innovative clean coal technology projects. Industry would be encouraged to invest an equal or greater amount over this period.

- The second step was direction to the Secretary of Energy to establish an advisory panel. This panel, which would include participation by State governments and by the Government of Canada, would advise the Secretary of Energy on funding and criteria for the selection of innovative clean coal technology projects. Projects would be selected, as fully as practicable, using the criteria recommended by the Special Envoys.

- The third step was a request to the Presidential Task Force on Regulatory Relief to review Federal and State economic and regulatory programs to identify opportunities for addressing environmental concerns under existing laws. The Task Force would examine incentives and disincentives to the deployment of new clean coal technologies and other cost-effective, innovative emission reduction measures now inhibited by various Federal, State, and local regulations.

3.3.1 Innovative Control Technology Advisory Panel

On June 9, 1987, DOE announced that the Energy Secretary had established an Innovative Control Technology Advisory Panel (ICTAP) to advise him on the innovative clean coal technology activity. Members of the panel include senior representatives of several Federal agencies, representatives from a cross-section

of affected States, and representatives of private sector and citizens groups, such as producers and users of coal, environmental groups, unions, and the research community. Two senior representatives of the Government of Canada are also members. The Secretary of Energy designated the Under Secretary as panel chairman. Terms are for 2 years, and members may be reappointed to additional 2-year terms. The 38-member panel is expected to operate for 5 years.

ICTAP's Charter states the objectives and scope of activities for the panel:

> The Innovative Control Technology Advisory Panel (ICTAP) provides the Secretary of Energy advice and recommendations concerning innovative control technologies that will broaden cost-effective and efficient options for controlling precursor emissions associated with acid deposition. The scope of programs to be reviewed for developing advice include fully funded and cost-shared projects of the United States Department of Energy, other Federal programs, State funded programs, and other domestic projects. Advice and recommendations shall include:
>
> a. Review of programs (scope defined above) to determine whether programs might provide relevant control options.
>
> b. Review, evaluation, and advice on proposed criteria to be used to select projects for U.S. Federal cost-shared projects. To the maximum extent possible, this shall include consideration of the criteria recommended by the Joint Report of the Special Envoys on Acid Rain.
>
> c. Development of relevant information that would fill in gaps in technology development and deployment or would be otherwise appropriate for consideration in implementing more effectively future Federal solicitations concerning innovative control technologies.

ICTAP held its first meeting in September 1987. At that meeting, ICTAP was requested to perform its first study: to provide recommendations to the Secretary of Energy on factors that should be considered by DOE in defining evaluation criteria to be used to implement the ICCT Program. In December 1987, ICTAP issued its report and recommended the following:

1. Two factors should be considered as equally important:

   - The Federal Government should cofund technologies that have the potential for greatest emissions reductions as measured by percentages of SO_x and/or NO_x removed.

   - The Federal Government should cofund technologies that reduce emissions at the lowest cost per ton of emissions reduced for specific types of coals.

   In the first factor, the total system productive efficiency (e.g., cost per kilowatt produced) should be considered together with greatest emissions reduction in order to increase the likelihood of commercial acceptance.

2. Two factors that apply to technologies in their commercial form should be used:

   - More consideration should be given to technologies that are applicable to the largest number of existing sources that contribute to transboundary air pollution.

   - Special consideration should be given to technologies that can be applied to facilities currently dependent on the use of high sulfur coal.

3. A fifth factor should be:

   - The program should lead to some near-term reductions in U.S. SO_x and NO_x emissions that affect Canadian ecosystems.

4. There should be no absolute limitation on the location of a demonstration project, other than it be located in the United States.

5. If two projects have equal merit otherwise, the project that results in most near-term reductions should be selected.

6. Both the need for replication of technology demonstrations to accelerate commercial acceptance and the goal of technological diversity in the total suite of demonstration projects should receive emphasis.

7. Some demonstrations in new facilities are appropriate if the technology can be linked directly to SO_x and/or NO_x emissions control in existing high sulfur coal facilities in the subsequent commercialization.

8. The non-Federal fraction of cost sharing should be a minimum of 50 percent of total project costs.

9. Innovative control technologies that reduce emissions while minimizing the potential for other environmental problems, such as solid wastes from pollution control, should receive added credit.

10. The readiness of a technology to be commercialized should be a factor.

11. Other factors that should be considered include:

    - The extent of project financing obtained at the time of proposal

    - The ability and desire of the proposer to commercialize the technology

    - Evidence that access to the demonstration site is available to the proposer at the time of proposal

    - Ability of the proposer to carry out the project

    - The degree to which the legal entity responsible for the project is determined.

Essentially all of the above recommendations are being adopted and will become part of the new solicitation for the ICCT Program.

3.3.2 Presidential Task Force on Regulatory Relief

Technology demonstration is only one part of the equation that will determine the extent to which clean coal technologies are deployed in the marketplace. Successful commercial deployment in the utility industry especially will also depend upon the regulatory environment under which electricity is generated and sold.

Policies of State utility commissions for the retail sale of electricity and of the Federal Energy Regulatory Commission for wholesale transactions will be fundamentally important to the commercial success of these technologies. Likewise, existing environmental regulations can play a major role in encouraging, or impeding, the demonstration and deployment of first-of-a-kind clean coal technologies.

Recognizing that the path to the marketplace will be dictated, in large part, by the regulatory climate in which clean coal concepts must compete, the President commissioned his Task Force on Regulatory Relief, chaired by the Vice President, to examine regulatory incentives and disincentives to the demonstration and deployment of new emission control technologies.

The Task Force's recommendations were announced in January 1988.

3.4 Public Meetings

Four public meetings were convened by the Department of Energy in August and September 1987 to obtain views, comments, and recommendations on the forthcoming ICCT solicitation. The meetings took place as follows:

Albuquerque, New Mexico	August 13, 1987
St. Louis, Missouri	September 3, 1987
Pittsburgh, Pennsylvania	September 10, 1987
Washington, DC	September 22, 1987

Each meeting commenced with a brief plenary session that included introductory remarks and program overviews by DOE officials. The audience then formed into discussion workshops, which ran concurrently to facilitate discussions in small groups and to make efficient use of the time available. All workshops discussed the same issues; the number of workshops varied from city to city in response to the attendance. Finally, the attendees met in a plenary session. The highlights and recommendations of each of the workshops were reviewed and summarized, and the meeting was concluded. The opening and closing plenary sessions were transcribed. The November 1987 report, *Summary Proceedings: Public Meetings for Views and Comments on the Conduct of the Innovative Clean Coal Technology Solicitation*, documents the discussions that took place at each of the four meetings and presents the views, recommendations, and concerns that were expressed by attendees. The report also includes a compilation of the written comments that were received and a list of the organizations that were represented at the public meetings. Full consideration is being given by DOE to the recommendations and advice of the ICCT public meetings in preparing the Program Opportunity Notice to implement the ICCT Program.

3.5 Congressional Funding and Guidance

In Public Law No. 100-202, "An Act Making Appropriations for the Department of the Interior and Related Agencies for the Fiscal Year Ending September 30, 1988, and for Other Purposes," Congress provided DOE with $575 million for clean coal technology demonstrations. The appropriation is for $50 million in fiscal year 1988 and $525 million in fiscal year 1989. Funds are to remain available until expended. Exhibit 3-1 reproduces relevant portions of the act.

The act directs DOE to issue a general request for proposals within 60 days and allows industry 90 days to respond and DOE 160 days to evaluate proposals and make selections. In addition, the act established the allowability of preaward costs in the event that a cooperative agreement is signed and to the extent that they are related to (1) the preparation of materials requested by DOE and identified as required for negotiations and (2) the preparation and submission of environmental data requested by DOE to complete the requirements of the National Environmental Policy Act.

Congressional guidance includes concepts such as the following:

- Milestones and guidelines for negotiations should be used to expedite the process.
- Non-utility as well as utility applications could be funded.
- Demonstration of clean coal technology projects intended solely for new, stand-alone applications could not be funded.

This guidance from Congress, along with the recommendations of ICTAP, the Task Force on Regulatory Relief, and the public meetings, is being used to prepare the Program Opportunity Notice to implement the ICCT Program.

3.6 Solicitation Activities

A second solicitation for proposals to demonstrate innovative clean coal technologies was prepared to set into motion the President's clean coal initiative. This solicitation was subsequently released for public review and comment. The comments were considered by the Source Selection Board in preparing the final Program Opportunity Notice (PON).

The Innovative Clean Coal Technology Program solicitation for the second round of demonstration projects was released on February 22, 1988. Issuance of the solicitation started a nation-wide competition for Federal cofunding for projects that demonstrate innovative concepts for reducing coal-burning emissions thought to cause acid rain.

The competition is for nearly $536 million in Federal funds, the amount appropriated by Congress in December 1987 minus funds required for Federal expenses in managing the program and for the legislatively directed Small Business Innovative Research Program. Private industry proposers will be required to at least match the Federal funding share for each selected project. The Program Opportunity Notice for the ICCT Program differs in several respects from the solicitation used for CCT-I in 1986.

Exhibit 3-1.

ICCT Provisions in Public Law No. 100-202

An Act Making Appropriations for the Department of the Interior and Related Agencies for Fiscal Year Ending September 30, 1988, and for Other Purposes

DEPARTMENT OF ENERGY
Clean Coal Technology

For necessary expenses of, and associated with, Clean Coal Technology demonstrations pursuant to 42 U.S.C. 5901 et seq., $50,000,000 are appropriated for the fiscal year beginning October 1, 1987, and shall remain available until expended, and $525,000,000 are appropriated for the fiscal year beginning October 1, 1988, and shall remain available until expended.

No later than sixty days following enactment of this Act, the Secretary of Energy shall, pursuant to the Federal Nonnuclear Energy Research and Development Act of 1974 (42 U.S.C. 5901 et seq.), issue a general request for proposals for emerging clean coal technologies which are capable of retrofitting or repowering existing facilities, for which the Secretary of Energy upon review may provide financial assistance awards. Proposals under this section shall be submitted to the Department of Energy no later than ninety days after issuance of the general request for proposals required herein, and the Secretary of Energy shall make any project selections no later than one hundred and sixty days after receipt of proposals: Provided, That projects selected are subject to all provisos contained under this head in Public Law 99-190: Provided further, That pre-award costs incurred by project sponsors after selection and before signing an agreement are allowable to the extent that they are related to (1) the preparation of material requested by the Department of Energy and identified as required for the negotiation; or (2) the preparation and submission of environmental data requested by the Department of Energy to complete National Environmental Policy Act requirements for the projects: Provided further, That pre-award costs are to be reimbursed only upon signing of the project agreement and only in the same ratio as the cost-sharing for the total project: Provided further, That reports on projects selected by the Secretary of Energy pursuant to authority granted under the heading "Clean coal technology" in the Department of the Interior and Related Agencies Appropriations Act, 1986, as contained in Public Law 99-190, which are received by the Speaker of the House of Representatives and the President of the Senate prior to the end of the first session of the 100th Congress shall be deemed to have met the criteria in the third proviso of the fourth paragraph under the heading "Administrative provisions, Department of Energy" in the Department of the Interior and Related Agencies Appropriations Act, 1986, as contained in Public Law 99-190, upon expiration of 30 calendar days from receipt of the report by the Speaker of the House of Representatives and the President of the Senate.

DEPARTMENT OF ENERGY
Administrative Provisions

None of the funds made available to the Department of Energy under this Act shall be used to implement or finance authorized price support or loan guarantee programs unless specific provision is made for such programs in an appropriations Act.

The Secretary is authorized to accept lands, buildings, equipment, and other contributions from public and private sources and to prosecute projects in cooperation with other agencies, Federal, State, private, or foreign: Provided, That revenues and other moneys received by or for the account of the Department of Energy or otherwise generated by sale of products in connection with projects of the Department appropriated under this Act may be retained by the Secretary of Energy, to be available until expended, and used only for plant construction, operation, costs, and payments to cost-sharing entities as provided in appropriate cost-sharing contracts or agreements: Provided further, That the remainder of revenues after the making of such payments shall be covered into the Treasury as miscellaneous receipts: Provided further, That any contract, agreement, or provision thereof entered into by the Secretary pursuant to this authority shall not be executed prior to the expiration of 30 calendar days (not including any day in which either House of Congress is not in session because of adjournment of more than three calendar days to a day certain) from the receipt by the Speaker of the House of Representatives and the President of the Senate of a full and comprehensive report on such project, including the facts and circumstances relied upon in support of the proposed project.

Overall, the new solicitation is expected to result in projects tailored to the recommendations of the Special Envoys on Acid Rain. As already noted, the Special Envoys recommended the demonstration of technologies that can reduce the release of transboundary air pollutants from existing U.S. facilities. The earlier competition was oriented toward a wide range of technologies for the full spectrum of U.S. energy markets.

Existing and new plant sites, in both the Eastern and Western United States, will be considered in ICCT as long as the technologies demonstrated can be used to control emissions from existing coal-fired facilities.

The solicitation also changes DOE's policy for recouping the Federal share of costs if a demonstration project becomes a commercial success. The revised provisions call for the private sponsor to repay the Government's share of costs based on simple percentages of revenues from commercialization.

Revisions were also included based on the recommendations of ICTAP, the public meetings, and the Presidential Task Force on Regulatory Relief.

Firms will have 90 days to prepare proposals, as opposed to the 60 days allowed in the first round. A preproposal conference was held March 15, 1988, in Washington, DC. The selection of projects by DOE for this activity is expected by October 1988.

4.0 ENVIRONMENTAL ASPECTS

In implementing the Clean Coal Technology Demonstration Program, an overall strategy for compliance with the National Environmental Policy Act (NEPA) was developed that is consistent with the Council on Environmental Quality regulations and the DOE guidelines for compliance with NEPA. The strategy included both programmatic and project-specific environmental impact considerations during and subsequent to the selection of projects.

This NEPA strategy for the CCT-I Program had three major elements. The first involved preparing a comparative programmatic environmental impact analysis based on information provided by the offerors and supplemented by DOE when necessary. This environmental analysis ensured that the relevant environmental consequences of the program were understood and that reasonable programmatic alternatives were evaluated. The Preselection Programmatic Environmental Impact Analysis was performed so that a comparison could be made between (1) the projected environmental emissions nationally and regionally within the United States, assuming no new technologies, and (2) the projected emissions, assuming each proposed project that passed preliminary evaluation was commercialized and achieved the market penetration estimated by the offerors. The analysis also included, in qualitative terms, discussions about the environmental characteristics of the clean coal technologies, unresolved environmental issues, areas where important environmental information was incomplete or unavailable, and trade-offs between short-term and long-term effects. The discussions included air quality, water quality, and solid waste disposal issues that a fully commercialized technology may ameliorate or aggravate. The key air quality issues examined included criteria pollutants, acid rain, and, to a lesser extent, visibility impairment and global warming due to increasing concentrations of carbon dioxide. The analysis also contained strengths and weaknesses of each proposal relative to the environmental criteria addressing the projected commercialization of the proposed technology.

The second element of the NEPA strategy for the program involved preparation of a Preselection Project Specific Environmental Review. For each proposed project that passed preliminary evaluation, this analysis contained a discussion of the site-specific environmental, health, safety, and socioeconomic issues associated with the demonstration project. It included a discussion of alternative sites and/or processes reasonably available to the offeror, a discussion of the environmental impacts of the proposed project and practical mitigating measures, and a list of known permits that had to be obtained to implement the proposal. It also contained the strengths and weaknesses of each proposal relative to the demonstration project's environmental and site-related criteria. These two bodies

of information were provided to the Source Selection Official for consideration in the project selection process. As a result of the analysis, the following conclusions were reached:

1. None of the selected projects in their commercial applications are judged to have unacceptable adverse environmental consequences relative to the environmental baseline for the year 2010. In every case, sulfur dioxide and nitrogen oxides emissions and hazardous wastes for the commercial technologies are projected to remain approximately the same or decline. With the exception of one case where water use may increase slightly, water use also is projected to remain approximately the same or decline. Particulate matter emissions and total suspended solid (TSS) releases are projected to remain approximately the same or decline, except in one case where particulate matter and one case where TSS are projected to increase as much as 5%. In seven cases, non-hazardous solid wastes could increase (in no case more than 4%) as a direct result of the SO_2 reduction achieved. However, the potential problems were deemed to be manageable.

2. The group of projects selected provide a good balance between minimizing environmental impacts and expanding the use of coal.

The third element of the NEPA strategy provided for DOE to prepare site-specific documentation for each project selected for financial assistance. Funds from the program would not be provided to a project for detailed design, construction, operation, and/or dismantlement until this element of the NEPA process was successfully completed. Exhibit 4-1 summarizes the status of environmental actions for the seven negotiated agreements. As shown, the NEPA process has been completed for three of the projects. All three resulted in a determination by DOE that the project clearly does not constitute a major Federal action significantly affecting the quality of the human environment. In accordance with the DOE guidance for implementing NEPA, the determinations were documented in Memos-to-File and no further NEPA review was required. For Energy International's underground coal gasification/clean fuels proof-of-concept project, it was necessary to address the environmental impacts of the proposed action and its alternatives in an Environmental Assessment (EA). Preliminary findings suggest that the EA is likely to result in a Finding of No Significant Impact (FONSI).

As a result of the withdrawal of General Electric and Weirton Steel projects, funds which would have been required to meet the Government's cost share for these two projects became available for award of new projects. With the monies available, four replacement proposals were designated for cooperative agreement negotiations.

As in the original selection, an overall strategy for compliance with NEPA has been developed. The same environmental analysis procedure was followed for the selection of the four projects, and the following conclusions were reached:

1. None of the selected projects in the commercial applications have unacceptable adverse environmental consequences

Exhibit 4-1.

Status of Environmental Actions for CCT-I Projects with Negotiated Agreements

Project and Industrial Participant	NEPA Process		Environmental Monitoring Plan
	Type of Action	Date	
Tidd PFBC Demonstration Project (Ohio Power Company)	Memo-to-File (MTF)	3/5/87	3/88
LIMB Demonstration Project Extension (The Babcock & Wilcox Company)	MTF	6/2/87	5/88
Advanced Cyclone Combustor Demonstration Project (Coal Tech Corporation)	MTF	3/26/87	4/87
Gas Reburning/Sorbent Injection Demonstration Project (Energy and Environmental Research Corporation)	Hennepin Site - - MTF Lakeside Site - - To be determined Edwards Site - - To be determined	5/9/88 8/88 9/88	7/88 7/88 7/88
Underground Coal Gasification Demonstration Project (Energy International, Inc.)	Environmental Assessment - - Finding of No Significant Impact.	2/9/88	3/88
The Appalachian IGCC Demonstration Project (The M.W. Kellogg Company/ Bechtel Development COmpany)	To be determined	9/88	1/89
Prototype Commercial Coal/Oil Coprocessing Project (Ohio Ontario Clean Fuels, Inc.)	To be determined	3/89	5/89

relative to the environmental baseline for the year 2010. In every case, SO_2 emissions and total suspended solid releases for the commercial technologies are projected to remain approximately the same or decline. With the exception of one case for both retrofit and new source applications, hazardous waste releases are projected to remain approximately the same or decline. With the exception of one case where particulate matter and another case in which NO_x emissions for the commercial projects used in new source applications may increase slightly, particulate matter and NO_x emissions are expected to remain approximately the same or decline. With the exception of two cases where water use for the projects in their commercial form when used for new and retrofit applications may increase slightly, water use is expected to remain the same or decline. Non-hazardous solid wastes could increase for three projects in their commercial form for retrofit applications and two projects for new applications (in one case up to 16 percent). However, the wastes are expected to be easily disposed of with no adverse environmental impacts. All of the potential problems were deemed to be manageable.

2. The group of projects selected provide a good balance between minimizing environmental impacts and expanding the use of coal. None of the selected projects are judged to have unacceptable adverse environmental consequences at the sites at which they are to be conducted.

In addition to complying with these elements of the NEPA strategy, each cooperative agreement requires that an Environmental Monitoring Plan be prepared, approved, and implemented to ensure that significant site- and technology-specific environmental data are collected and disseminated. Similar activities are in progress on the remaining projects in the program for which the NEPA requirements have not yet been met. As of the end of December 1987, no issues had been identified that would prevent the fulfillment of these requirements.

The following sections summarize the results of the site-specific analyses performed through December 1987 on the projects selected for financial assistance.

Tidd PFBC Demonstration Project

The deactivated Tidd Plant, south of Brilliant, Jefferson County, OH, is the site of Ohio Power Company's pressurized fluidized-bed combustion (PFBC) combined-cycle demonstration project. This site was selected because of the minimal environmental impact and cost savings associated with the use of existing plant equipment.

Air quality impacts due to construction will be those typical of any construction activity, such as fugitive dust and exhaust fumes. Fugitive dust will be minimized through a dust-suppression program, and exhaust fumes will be quite minimal. The site area is designated as a nonattainment area for SO_2 and total suspended particulates (TSP). These emissions will be reduced. NO_x will increase slightly,

and the increase in SO_2 emissions will be less than NO_x and below the minimum value.

The effects on the surface water quality during construction are expected to be small. Construction will not be required for barge unloading facilities (the site is on the Ohio River). Minor maintenance involving dredging of the existing intake and outfall structures for cooling water could increase the turbidity of the river temporarily. Three effluent streams will be associated with PFBC operations: sanitary wastes to be treated in the plant's sewage treatment facility, once-through cooling water, and effluent from the plant's fly ash pond. However, no measurable impacts are expected to occur.

Impacts to the groundwater are limited to withdrawals and infiltration; neither is expected to have a significant effect. The plant site is not within range of any federally listed endangered species; therefore, ecological impacts are nil. Floodplains and wetlands are not involved, and the noise level will have no significant impact. All associated permits will be obtained from the proper authorities.

LIMB Demonstration Project Extension

The Babcock & Wilcox Company's project, which involves extending the testing of the limestone injection multistage burner (LIMB), will be performed at the Ohio Edison Company's Edgewater Station in Lorain, Lorain County, OH. An alternative technology, Coolside, is also to be funded. This technology will reduce SO_2 by injecting sorbent and water into the flue gas duct work downstream of the boiler.

This demonstration project is located in an area designated as attainment for SO_2 and as nonattainment for TSP. Operation will result in a net decrease in SO_2 and NO_x emissions. As to surface and groundwater impacts, these will be small in comparison to the presently operating Edgewater Station.

Generation of solid waste consisting of ash, sorbent, additive, and hydration water will be greater than the baseline by a factor of 2 to 4; this represents a 100-percent to 300-percent increase in solid waste. The total solid waste is estimated at about 30-acre-feet. The Ohio EPA requires a hydrologic study of the solid waste disposal area and the installation of monitoring wells to ensure that groundwater impacts from solid waste disposal will be clearly insignificant.

There will be no impacts on ecological, floodplains, wetlands, noise, land use, or historic areas. Consumption of raw materials is expected to be the same level as present consumptions. Again, all associated permits will be obtained from the proper authorities.

Advanced Cyclone Combustor Demonstration Project

The Coal Tech Corporation advanced combustor project is to be located in Williamsport, Lycoming County, PA. The county is designated by the Pennsylvania Department of Environmental Resources as a Non-Air Basin area of the State and is classified as having attained Secondary National Ambient Air Quality Standards for all Clean Air Act criteria pollutants. Presently, there are no

major emission sources located in the county, and this will not change with the Coal Tech combustor.

Air quality impacts due to construction are negligible; construction is limited to equipment installation because all facilities already exist. A venturi scrubber will be included to ensure compliance with State standards on particulate emissions. Total emissions resulting from the testing will be well below the minimum standard and will not result in any significant impacts on existing air quality.

Effects of the waste water stream will also have negligible effects on the normal flow of water to the sanitary plant. The quantity and characteristics of the solidified slag generated from the combustion process will not result in any significant effects. There will not be any ecological, noise, or socioeconomic impacts. All associated permits will be obtained from the proper authorities.

Underground Coal Gasification Demonstration Project

The project of Energy International, Inc., is an underground coal gasification (UCG) project to be located in Rawlins, Carbon County, WY.

An EA is being prepared by DOE to address the potential impacts of the proposed action. Preliminary EA findings suggest that no significant impacts would result from the proposed project; there would be minimal or no impacts on surface water, land use, air quality, aquatic ecology, archaeological sites, and socioeconomics in the area.

The project does raise some potential environmental concerns regarding groundwater contamination, long-term land subsidence, and impacts on terrestrial ecology. However, these concerns would be mitigated to below significant levels by adopting a measure recommended by the Wyoming Department of Environmental Quality and the U.S. Fish and Wildlife Service. In addition, impact levels and mitigative measures would remain constant during the commercial operation of the project.

Alternatives to this project were studied but were all dismissed. This project was selected to further advance the commercialization of UCG technology. A smaller-scale project would not provide the required revenue to make the project economically feasible, and a larger-scale project would increase the associated risks unnecessarily. The present site was selected because studies have shown it to be environmentally superior to others considered.

All potential project effluents are to be controlled so that there would be zero discharge to any surface water. The probability of spills and releases is considered low, and the risk of significant impact is minimal due to precautions that would be included in the facility design and implementation of a spill-prevention, containment, and countermeasure plan. Measures will be taken to mitigate any impacts to groundwater that are considered minimal. Preventive measures include environmental controls as well as monitoring groundwater quality.

As demonstrated by a simulation, there should be no measurable subsidence at the land surface if the reactor modules are developed as designed with 225 feet between module centers and a 75-foot buffer zone of unburned coal. However, the model could not predict long-term effects. The EA conservatively estimated that there would be no effects as long as the proposed action was pursued.

5.0 FUTURE ACTIVITIES

Calendar year 1988 will be a pivotal year for the Clean Coal Technology Demonstration Program as additional funding and programmatic priorities clearly establish the importance of the program as a key component of the efforts in progress to resolve the acid rain issue. During 1988 the size of the program (in funds) will more than double. Projects now in the program will continue their progress toward commercialization, and new projects will be started. Additional guidance will be received from ICTAP, and other activities required to implement fully the President's initiative will be continued.

5.1 Demonstration Project Activities

Considerable progress is expected in the design and construction activities of the projects now in the program. Completion of Phase I (design and permitting) is expected on 3 of the 11 CCT-I projects, initiation of Phase II (construction and start-up) is expected on 4 projects, and operation is expected to begin in 2 projects. The projects and their respective stages of development follow:

- Completion of Phase I: Design and Permitting

  1. LIMB Demonstration Project Extension
  2. Gas Reburning/Sorbent Injection Demonstration Project
  3. Underground Coal Gasification Demonstration Project

- Initiation of Phase II: Construction and Start-Up

  1. Tidd PFBC Demonstration Project
  2. LIMB Demonstration Project Extension
  3. Gas Reburning/Sorbent Injection Demonstration Project
  4. Underground Coal Gasification Demonstration Project

- Initiation of Phase III: Operation

  1. Advanced Cyclone Combustor Demonstration Project
  2. Nucla CFB Demonstration Project

Key milestones planned for each of the 11 CCT-I projects are shown in Exhibit 5-1.

Exhibit 5-1.
Planned Key Milestones for CCT-I Projects

	Comprehensive Report to Congress Issued	Cooperative Agreement Executed	NEPA Requirements Met	Start Phase I (Design and Permitting)	Complete Phase I	Start Phase II (Construction and Start-Up)	Complete Phase II	Start Phase III (Operation, Data Collection, Reporting, and Disposition)	Complete Phase III
Tidd PFBC Demonstration Project (Ohio Power Company)	2/87	3/87	5/87	3/87	7/89	1/88	10/90	10/90	10/93
LIMB Demonstration Project Extension (The Babcock & Wilcox Company)	5/87	6/87	6/87	5/87	11/88	8/87	7/89	11/88	3/91
Advanced Cyclone Combustor Demonstration Project (Coal Tech Corporation)	2/87	3/87	3/87	1/87	7/87	7/87	11/87	11/87	4/89
Gas Reburning/Sorbent Injection Demonstration Project (Energy & Environmental Research Corp.)	6/87	7/87	9/88	6/87	9/88	11/88	5/90	1/90	11/91
Underground Coal Gasification Demonstration Project (Energy International, Inc.)	11/87	12/87	2/88	10/87	3/88	5/88	10/89	10/89	10/90
The Appalachian IGCC Demonstration Project (The M.W. Kellogg Company/ Bechtel Development Company)	12/87	1/88	9/88	1/88	7/90	4/89	10/91	4/91	10/93
Prototype Commercial Coal/Oil Coprocessing Project (Ohio Ontario Clean Fuels, Inc.)	10/87	12/87	3/89	1/88	12/89	7/89	12/91	12/91	12/94
Nucla CFB Demonstration Project* (Colorado-Ute Electric Association, Inc.)	6/88	6/88						6/88	3/90
Clean Energy IGCC Demonstration Project* (Consolidation Coal Co./Foster Wheeler Power Systems, Inc.)	8/88	9/88		7/88	7/89	7/89	7/90	7/90	7/91
Advanced Slagging Coal Combustor Utility Demonstration Project* (TRW, Inc.)	7/88	8/88		7/88	7/89	7/89	7/90	7/90	7/91
COREX Ironmaking Demonstration Project* (Minnesota Dept. of Natural Resources)	8/88	9/88		7/88	7/89	7/89	7/92	7/90	7/94

* Projects in fact-finding; milestones subject to negotiations.

5.2 A New Competitive Solicitation

As directed by Congress, a second competitive solicitation will be initiated and completed during 1988. This activity will result in the selection of additional projects and the start of a new series of fact-finding and negotiation activities. The key milestones for this ICCT effort include:

Public Law No. 100-202 signed	Dec. 22, 1987
Draft PON to be issued for public comment	Jan. 28, 1988
Public comments on draft PON schedule to be received	Feb. 5, 1988
Final PON planned to be issued	Feb. 22, 1988
Preproposal conference planned	March 15, 1988
Proposals due to DOE	May 23, 1988
DOE selection process	June-Sept. 1988
DOE announcement of selected proposals	Sept.-Oct. 1988

5.3 Advisory Panel Efforts

In keeping with its role, the Innovative Control Technology Advisory Panel will continue to perform key studies to generate data needed for guidance of the program. These efforts will be initiated, reviewed, and finalized during periodic meetings held throughout the year.

Innovative Control Technology Advisory Panel meeting	Feb. 25, 1988
Innovative Control Technology Advisory Panel meeting	July 13, 1988
Innovative Control Technology Advisory Panel meeting	Oct. 19, 1988

5.4 Negotiation of New Projects

By late-1988, the projects selected for the ICCT effort will be assigned to the respective Energy Technology Centers, and fact-finding and negotiation activities will be initiated.

Fact-finding and prenegotiation discussions planned	Oct.-Dec. 1988
Cooperative agreements to be negotiated	Jan.-June 1989

6.0 COMMERCIALIZATION AND MARKETING ASPECTS

6.1 U.S. Markets

A significant potential exists for using clean coal technologies in the U.S. marketplace. This potential is being created by a number of factors that include:

- The need to limit and reduce the ever increasing quantity of foreign oil that is being imported to accommodate the U.S. demand for energy
- The projected increase in electricity generating capacity that will be required over the next 25 years
- The expected requirement for technologies that permit the use of coal in a manner consistent not only with existing but with tightened environmental emissions standards
- The increasing level of international competition in the market for coal-based technologies that can accomplish a number of objectives simultaneously (i.e., increased efficiency, greater flexibility, minimized environmental impact, etc.).

Because the clean coal technologies are expected to be more advanced, more efficient, and more environmentally responsive than the state of the art being used in all associated energy consuming sectors, it is anticipated that they will realize this potential.

The opportunity for clean coal technologies in the marketplace will grow to the degree that the use of coal increases. A significant 47-percent increase in direct coal use is expected to occur in the United States between 1986 and 2010. Clean coal technologies can contribute to relieving the pressures caused by high oil imports through the substitution of coal-derived liquids and other new fuel forms. Further, clean coal technologies can contribute to satisfying natural gas demand, and synthesis gas produced from coal could make a major contribution in chemical production.

To evaluate the market potential for clean coal technologies, a review of the projected energy supply and demand and the general economic forecast is useful.* Analyses suggest that the total primary U.S. energy consumption is projected to increase from 77.0 quadrillion Btu (quads) in 1986 to 98.4 quads in the year 2010

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* Quantitative data were drawn from the DOE/EIA *Monthly Energy Review*, June 1987, and the Gas Research Institute's *1987 GRI Baseline Projection of U.S. Energy Supply and Demand to 2010*, December 1987.

at a rate of 1 percent per year. The Gross National Product (GNP) is projected to grow at 2.5 percent a year. The relative difference between growth in energy consumption and GNP growth reflects improved energy efficiency in the economy and continued reductions in energy intensity.

Coal consumption is projected to increase steadily from 17.3 quads in 1986 to 25.4 quads in 2010 at an average annual rate of 1.6 percent. By 2010 coal will comprise over one-quarter of the U.S. primary energy consumption. The electric utility sector will account for most of this projected growth. Electric utility consumption of coal is forecast to grow from 14.5 quads in 1986 to 21.0 quads in 2010. Coal is expected to continue to comprise over half of the energy consumed in this sector.

The electric utility industry stands at the threshold of a fundamental change in the power generation technological base, just as the Clean Coal Technology Demonstration Program is getting underway. By the mid-1990's, many utilities will be increasingly confronted by the dual problem of an aging boiler inventory and the potential long-term need for increasing their power generating capacity. More than half of all coal-fired boilers will be 25 years old or older by the mid-1990's. Utility decisionmakers will have to make some fundamental choices about many of these units--to retire, refurbish, repower, or replace them.

In this same time frame, demand for electricity will be growing, and reserve margins in generating capacity will be declining. Utility decisionmakers have been reluctant in recent years to invest in large, conventional baseload plants--either coal- or nuclear-fueled. Moreover, uncertainty over anticipated growth in power demand, coupled with uncertainty regarding future environmental regulations, have stalled many construction projects.

Thus, the uncertainty in the timing associated with the anticipated future demand for new facilities, either to meet new demand or as a replacement for older units, plus today's slowdown in construction, has created a "window of opportunity" for new clean coal technologies in the 1990's.

Exhibit 6-1 shows the status of the various clean coal technologies. Many are expected to reach commercial readiness by the mid-1990's. The clean coal technology market in power generation, shown in Exhibit 6-2, illustrates the low-growth, reference, and high-growth outlook.

It is anticipated that the utility sector will be the largest U.S. market for clean coal technologies, assuming that market conditions encourage increased use of coal as other fuels either become less plentiful or more expensive. The utility market includes:

- New coal electricity generating capacity
- Repowering of existing oil and gas capacity with coal
- Replacement or repowering of coal-fired generating capacity.

6.2 International Markets

International markets also offer commercial opportunities for the clean coal technologies being developed and demonstrated in the United States. Energy consumption in OECD Europe, Japan, and developing economies combined is projected to grow significantly faster than in the United States through the year 2000 (Exhibit 6-3).

Exhibit 6-1.
Status of Clean Coal Technologies

	Development Status	Commercial Readiness
Advanced Combustors		
- Slagging Combustor	D	1990-1995[2]
- Sorbent Injection (LIMB)	D	1990-1995[2]
- Gas Reburning	D	1990-1995[2]
Alternative Fuels	D	1990-1995[2]
Coal Liquefaction		
- Direct Liquefaction	D	1986-1990[1]
- Indirect Liquefaction--Advanced	D	1986-1990[1]
Coal Preparation		
- Physical Cleaning--Advanced	D	1990-1995[2]
- Chemical/Biological Cleaning	P	1995-2000[1]
Flue Gas Cleanup		
- Advanced	P	1995-2000[2]
- In-Duct Sorbent Injection	D	1990-1995[2]
Fluidized Bed Combustion (FBC)		
- Atmospheric FBC	C	1986-1990[1]
- Pressurized FBC	P	1995-2000[1]
Fuel Cells/Gasification	L	1990-1995[1]
Gas Stream Cleanup	P	1990-2000[1]
Heat Engines	P	1990-1995[1]
Industrial Processes		
Magnetohydrodynamics	P	2000-2010[1]
Surface Coal Gasification		
- Gasification	D	1986-1990[1]
- Gasification Combined Cycle	D	1990-1995[2]
Underground Coal Gasification	P	1995-2000[1]

L - Laboratory P - Pilot D - Demonstration C - Commercial

[1] *Supplemental Report to Congress on Emerging Clean Coal Technologies*, Department of Energy, August 1985.
[2] *America's Clean Coal Commitment*, Department of Energy, February 1987.

Exhibit 6-2.

Utility Market Potential (Gigawatts Capacity)

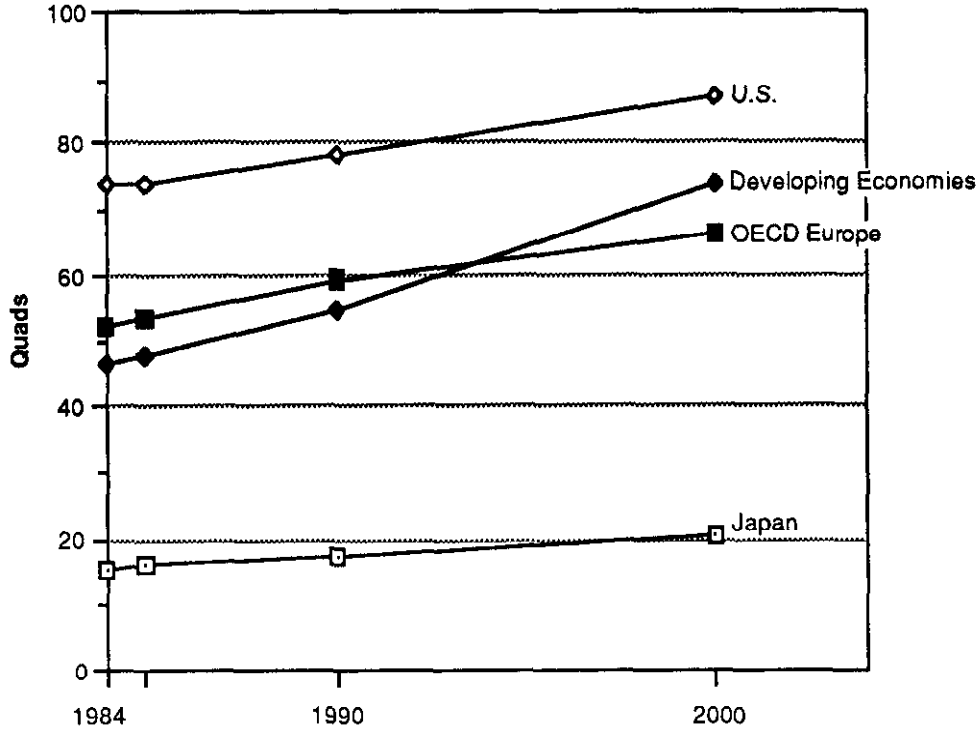
Years	Demand Growth: New Capacity and Repowering Oil & Gas*			Replacements, Repowering, of Existing Coal-Fired Capacity**	Cumulative Potential		
	Low	Ref.	High		Low	Ref.	High
1991-1995	33	51	66	26	59	77	92
1996-2000	35	55	75	47	82	102	122
2001-2005	53	61	90	63	116	124	153
2006-2010	42	51	80	60	102	111	140
Total Potential	163	218	311	196	359	414	507

* Projected demand growth and repowering oil and gas capacity with coal was derived from NEPP V data (Table 4-8, Alternate Economic Growth Cases - - Energy Transformation in the U.S. Economy). These data were converted into capacity assuming an average efficiency of 32% (assumed in NEPP V) and a capacity factor for coal-fired capacity of 0.59 in 1985 and 0.64 for 1995 to 2020 (derived from the *Annual Outlook for U.S. Electric Power 1986,* Energy Information Administration, 1987).

** The replacement market potential assumes replacing or repowering coal-fired capacity at 30 years. This potential was based on data contained in *Fuel Choices in Steam Electric Generation,* Table 3, Nameplate Capacity Additions by Type 1951-1984, Energy Information Administration.

Exhibit 6-3.

Energy Consumption in the U.S., OECD Europe, Japan, and Developing Economies 1984-2000 (Quadrillion Btu)



	1984	1985 Estimated	1990 Base Projection	2000 Base Projection
U.S.	74.1	73.9	78.6	87.3
OECD Europe	52.3	53.7	59.1	66.3
Japan	15.6	15.7	17.3	20.1
Developing Economies (Including OPEC)	46.6	47.7	54.9	74.1

Source: *International Energy Outlook 1986,* Energy Information Administration, April 1987.

Japan, however, has made enormous strides in reducing energy intensity per capita, and it is likely that energy consumption will remain relatively low despite economic expansion. To some degree, growth in the projected energy demand may depend upon the extent to which foreign consumer products penetrate the Japanese domestic markets.

The developing economies are expected to increase energy consumption at a greater rate than other global economies. The International Energy Agency (IEA) projects that between 1990 and 2000 developing economies will increase their energy consumption so that by 2000 developing economies will consume more energy as a group than will Western Europe. In developing economies, the commercial sector is expected to account for the increases. Capital constraints affecting powerplant construction and other industrial enterprises may temper those numbers, but the trend is appropriately cast.

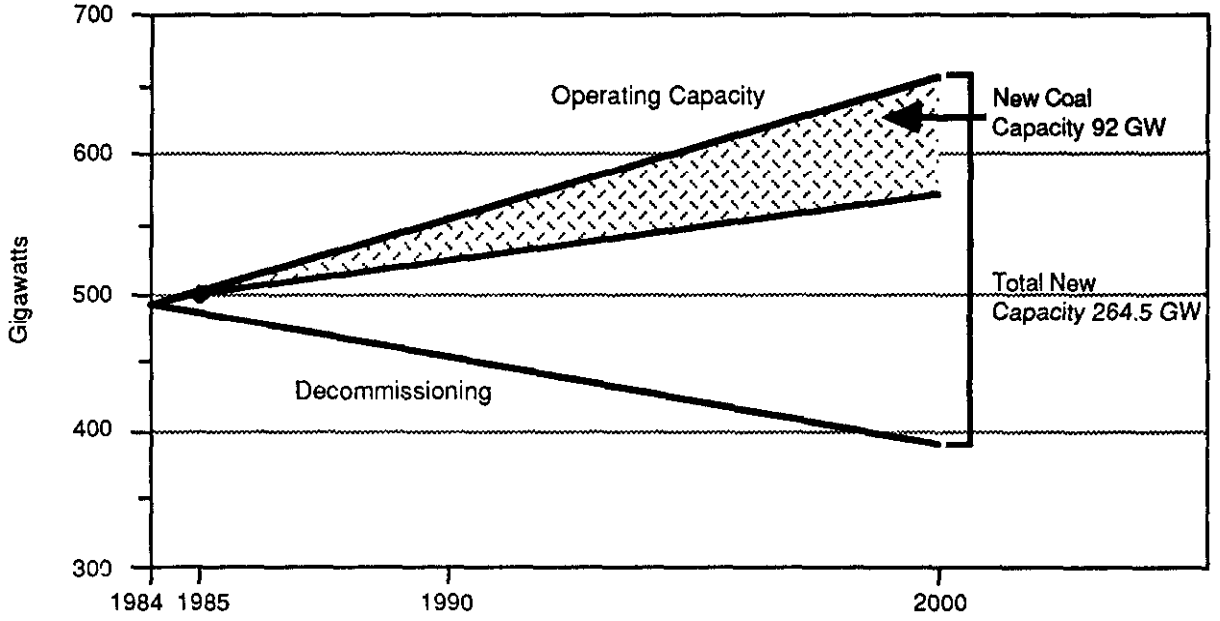
In Western Europe, nations are establishing stringent environmental regulations. Pollution control technologies are of interest rather than just using lower sulfur coal as a pollution control strategy. This suggests some opportunity for U.S. clean coal technologies. IEA projects that OECD Western Europe as a region will require 264.5 gigawatts (GW) of new electric capacity by the year 2000 (Exhibit 6-4). Of this new capacity, 92 GW is expected to be coal-fired. For comparison, IEA projects that the United States will require 103 GW of new capacity by the year 2000, as shown in Exhibit 6-5. Of this, 44.4 GW will be coal-fired capacity. By 2000, Western Europe will require new coal-fired capacity that is more than double the size of the new coal-fired capacity projected in the United States.

This large projected growth in energy consumption worldwide offers a potentially sizable market for U.S. exports of coal and coal-based fuels. New technology is a major factor in making the coal export package attractive. The technologies coming out of the Clean Coal Technology Demonstration Program may provide the single most important advantage that the United States could have in the global race for new technologies and new energy supplies.

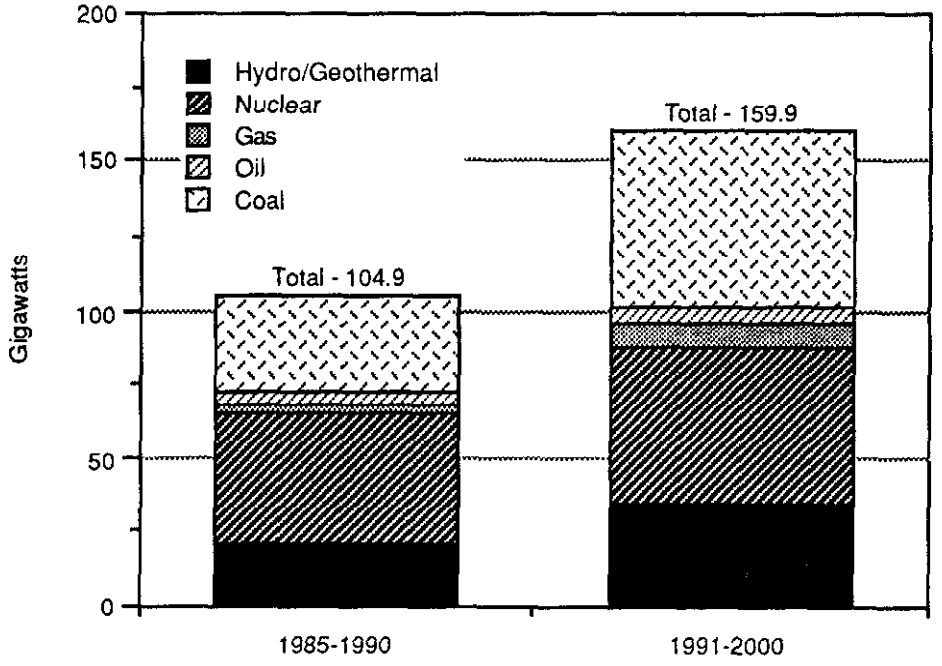
Exhibit 6-4.

Electric Capacity Projections for OECD Europe

1984 Operating Electric Capacity, Projections, and New Capacity



Projections for New Capacity and Fuel Mix in Two Time Periods

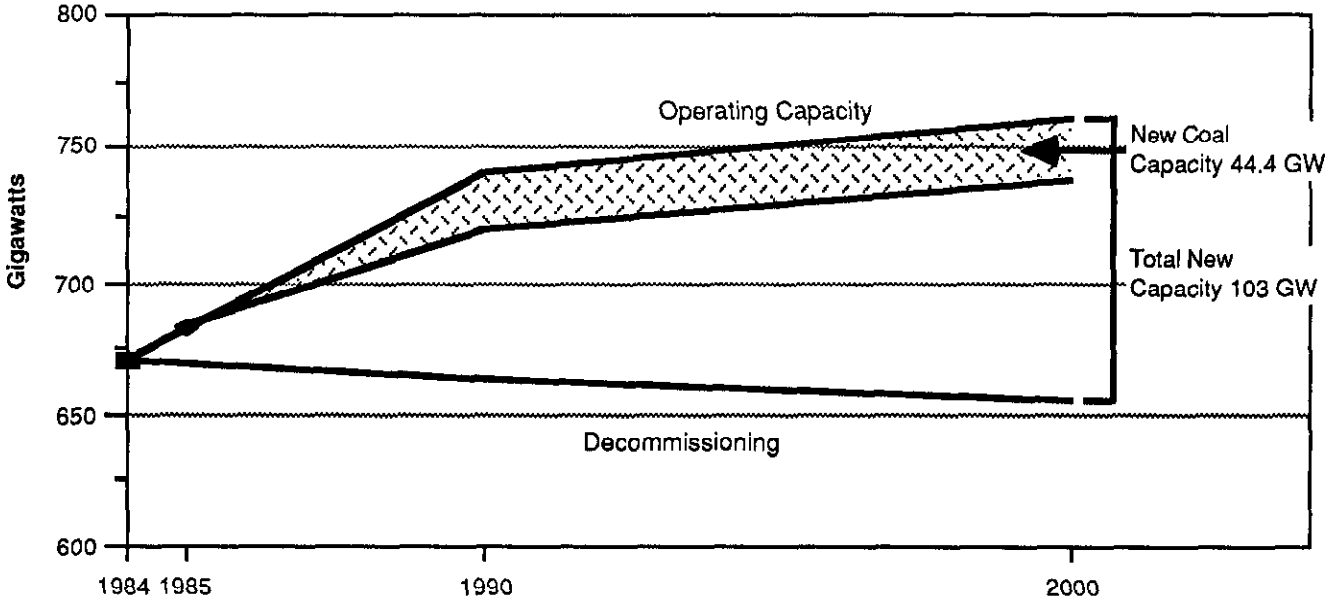


Source: IEA/OECD Electricity Statistics and IEA Country Submissions 1985.
IEA, *Coal Information*, 1986.

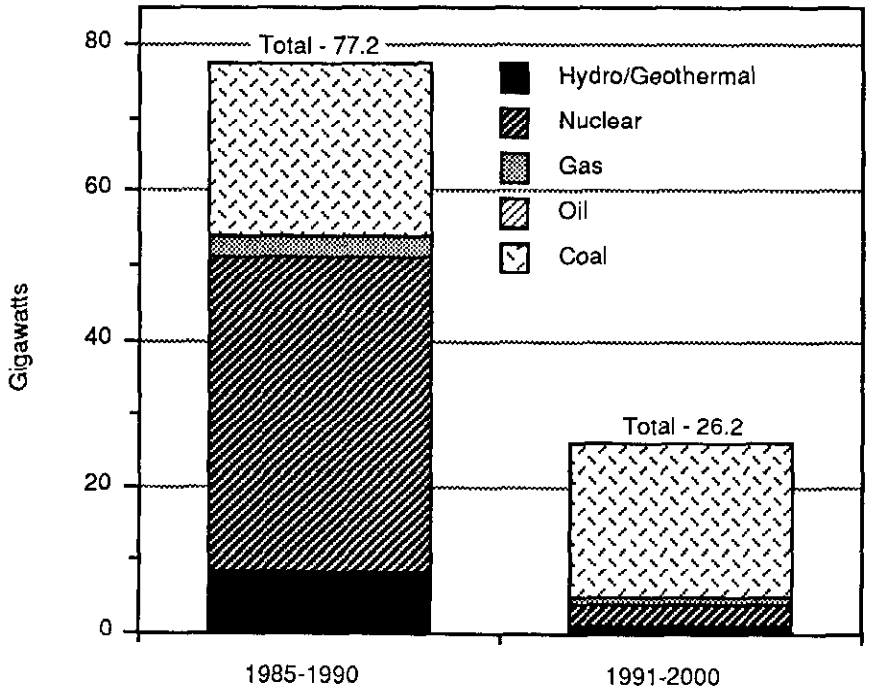
Exhibit 6-5.

Electric Capacity Projections for the United States

1984 Operating Electric Capacity, Projections, and New Capacity



Projections for New Capacity and Fuel Mix in Two Time Periods



Source: IEA/OECD Electricity Statistics and IEA Country Submissions 1985.
IEA, *Coal Information,* 1986.

7.0 PROGRAM PUBLICATIONS

Since its inception late in 1984, the Clean Coal Technology Demonstration Program has been responsible for preparing and publishing a number of reports. These reports present the results of each of the major activities initiated and completed. The following chronologically arranged list includes all the reports that have been distributed through December 31, 1987.

1. *Report to Congress on Emerging Clean Coal Technologies.*
   Report No. DOE/S-0034. U.S. Department of Energy. May 1985.

2. *Supplemental Report to Congress on Emerging Clean Coal Technologies.*
   Report No. DOE/MC/22121-1. U.S. Department of Energy. August 1985.

3. *Comprehensive Report to Congress on Proposals Received in Response to the Clean Coal Technology Program Opportunity Notice.*
   Report No. DOE/FE-0070. U.S. Department of Energy. August 1986.

4. *Report to Congress on the Relationships between Projects Selected for the Clean Coal Technology Program and the Recommendations of the Joint Report of the Special Envoys on Acid Rain.*
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