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Comprehensive Report to Congress Clean Coal Technology Program

Warren Station EFCC Demonstration Project

A Project Proposed By:
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Assistant Secretary for Fossil Energy
Office of Clean Coal Technology
Washington, D.C. 20585

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1.0 EXECUTIVE SUMMARY

Public Law 102-154, provided funds to the U.S. Department of Energy (DOE) to conduct cost-shared Clean Coal Technology (CCT) projects for the design, construction, and operation of facilities that "...shall advance significantly the efficiency and environmental performance of coal-using technologies and be applicable to either new or existing facilities...." This Act, together with Public Law 101-512, made available a total of $600 million for a fifth general request for proposals under the Clean Coal Technology V (CCT-V) Program. To that end, a Program Opportunity Notice (PON) was issued by DOE in July 1992.

In response to the PON, 24 proposals were received by DOE in December 1992. After evaluation, five projects were selected for award. These projects involve technologies that are capable of both exceptional environmental performance and efficiency and that are applicable to either new or existing facilities.

One of the five projects selected for funding is a project proposed by the Pennsylvania Electric Company (Penelec) of Johnstown, Pennsylvania. Penelec proposes to enter into a cooperative agreement with DOE to design, construct and operate a 600 ton-per-day, 66-megawatt (MWe), coal-fueled, externally-fired combined cycle (EFCC) electric power generation facility.

The EFCC is an emerging technology with promise for operating high-efficiency combined gas- and steam-turbine cycles on coal. The central feature of EFCC is its coupling of the gas turbine to an external, atmospheric-pressure, coal combustor via a high-temperature ceramic heat exchanger (CerHx®) developed by Hague International. The EFCC technology is attractive because, unlike competing combined cycles such as Integrated Gasification (IGCC) and Pressurized Fluidized Bed Combustion (PFBC), it eliminates the need for a costly gas cleanup system to protect the gas turbine components from the corrosive and abrasive elements in the combustor exhaust. In an EFCC, the gas turbine expands clean air which is heated in the CerHx® by externally-fired combustion gases which never pass through the gas turbine. Downstream of the power system, environmental requirements are met through cleanup of combustion gases.

The proposed project, the Warren Station EFCC Demonstration Project, will repower Penelec's Warren Station, a coal-fueled steam plant located in Warren, Pennsylvania, approximately 130 miles northeast of Pittsburgh, Pennsylvania (Figure 1). The EFCC will replace two of Warren Station's four coal-fired boilers, increasing the station's net generating capacity by 22 MWe and reducing emissions of sulfur (SO_2) and nitrogen (NO_X) oxides. The repowered unit's improved efficiency will also reduce the amount of carbon dioxide (CO_2) released per kilowatt-hour (kWh) of electric energy generated. The project is scheduled to last 64 months at a total

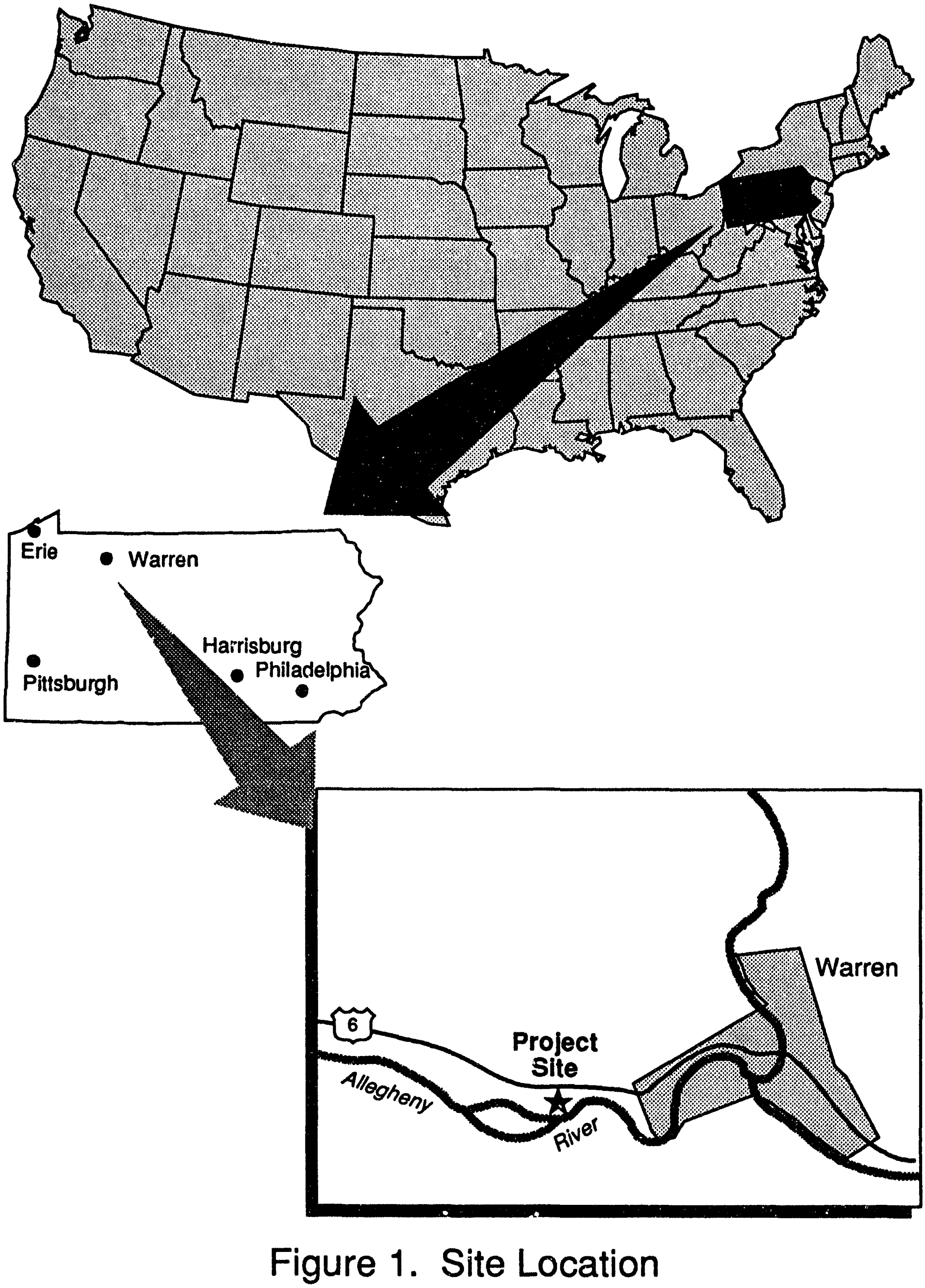

Figure 1. Site Location

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cost of $146,832,000. DOE's share of the project cost will be 50 percent of this amount, or $73,416,000.

The objective of the proposed project is to demonstrate an EFCC system at a scale sufficient for use in commercial electric generating plants. Using high-sulfur bituminous coal as a base feedstock, the project will demonstrate the operation, performance and reliability of the equipment and system, as well as its ability to reduce emissions of SO_2, CO_2, and NO_X. If successful, the project will show that the EFCC technology is a cost effective, reliable, efficient, and environmentally superior alternative to conventional coal-fired electric power generating stations.

The near-term market for EFCC technology is the repowering of pulverized coal plants which have ratings over 30 MWe. Compared to a conventional pulverized coal plant, EFCC offers the higher efficiencies associated with a gas turbine combined cycle plant. More than 125 operating coal-fueled power plants in the United States, rated from 30 to 100 MWe, are over 30 years old. To penetrate this market, utilities will need data on costs, equipment reliability, operation and maintenance procedures, and demonstrated plant performance.

If successful, the project will demonstrate the following advantages of the EFCC technology:

- high-efficiency, low-cost power generation;
- the capability of matching or surpassing (within a few percentage points) the emission reduction of any other coal-fired conversion cycle;
- use of a wide range of run-of-mine U.S. coals; and
- equipment and components which are familiar items to utility power plants.

Two companies will become team members to the project and will be signatories to the repayment agreement. Hague International will be responsible for providing the EFCC power island equipment and Black & Veatch will be responsible for overall project management, design engineering, construction management, and balance-of-plant design.

2.0 INTRODUCTION AND BACKGROUND

2.1 REQUIREMENT FOR A REPORT TO CONGRESS

On November 13, 1991, Public Law 102-154, the Department of the Interior and Related Agencies Appropriations Act, 1992 (Act), was signed into law. This Act, among other things, provided funds to DOE to conduct cost-shared CCT Projects for design, construction, and operation of facilities that "...shall advance significantly the efficiency and environmental performance of coal-using technologies and be applicable to either new or existing facilities...." This Act directed DOE to issue the fifth solicitation of the CCT Program no later than July 6, 1992, and specified that selection of projects for negotiations shall take place "...not later than ten months after the issuance date of the fifth general request for proposals...."

The Act, together with Public Law 101-512, made available a total of $600 million for the fifth general request for proposals under the CCT Program. Of these monies, $7.2 million were required to be reprogrammed for the Small Business and Innovative Research Program and $25.0 million were designated as Program Direction funds for costs incurred by DOE in implementing the CCT-V Program. All of the remaining appropriated funds, $567.8 million, were made available for Award under the CCT-V PON.

The purpose of this Comprehensive Report is to comply with Public Law 102-154 which directs the Department of Energy to prepare a full and comprehensive report to Congress on each project selected for award under the CCT-V Program.

2.2 EVALUATION AND SELECTION PROCESS

DOE issued a draft PON for public comment on April 20, 1992, receiving a total of 42 responses from the public. The final PON was issued on July 6, 1992, and took into consideration the public comments on the draft PON. On December 7, 1992, DOE received 24 proposals in response to the CCT-V solicitation. One proposal, which was received after the deadline date, did not qualify under any of the exceptions for late proposals specified in the PON and was thereby not considered in the evaluation process.

2.2.1 PON Objective

As stated in PON Section 1.2, the objective of the CCT-V solicitation was to obtain "proposals to conduct cost-shared Demonstration Projects that advance significantly the efficiency and environmental performance of coal using technologies and that are applicable to either new or existing facilities."

2.2.2 Qualification Review

The PON established seven Qualification Criteria and provided that, "In order to be considered in the Preliminary Evaluation Phase, a proposal must successfully pass Qualification." The Qualification Criteria were as follows:

(a) The proposed Demonstration Facility must be located in the United States.

(b) The proposed Demonstration Facility must be designed for and operated with coal. These coals must be from mines located in the United States.

(c) The Proposer must agree to provide a cost share of at least 50 percent of total allowable Project cost, with at least 50 percent in each of the Budget Periods.

(d) The Proposer must have access to, and use of, the proposed site of the Demonstration Facility and any proposed alternate site for the duration of the Demonstration Project.

(e) The proposed Project Team must be identified and firmly committed to fulfilling its proposed role in the Project.

(f) The Proposer agrees that, if selected, it will submit a "Repayment Agreement" consistent with PON Section 7.7.

(g) The Proposal must be signed by a responsible official of the proposing organization authorized to contractually bind the organization to the performance of the Cooperative Agreement in its entirety.

2.2.3 <u>Preliminary Evaluation</u>

The PON provided that a Preliminary Evaluation would be performed on all proposals that successfully passed the Qualification Review. In order to be considered in the Comprehensive Evaluation phase, a proposal must be consistent with the stated objectives of the PON, and must contain sufficient finance, management, technical, cost, and other information to permit the Comprehensive Evaluation described in the solicitation to be performed.

2.2.4 <u>Comprehensive Evaluation</u>

The Technical Evaluation Criteria were divided into two major categories: (1) the Demonstration Project Factors were used to assess the technical and environmental merit of the project and the technical and management approaches to execute the project, and (2) the Commercialization Factors were used to assess the potential of the proposed technology to significantly improve environmental performance and efficiency in new or existing facilities and to achieve wide commercial acceptance.

The Cost and Finance Evaluation criteria were used to determine the business performance potential and commitment of the proposer.

The PON provided that the Cost Estimate would be evaluated to determine the reasonableness of the proposed cost. Proposers were advised that the Cost and Finance Evaluation Criteria were of least importance to the selection, and that successful proposers would be required to submit a more detailed cost estimate after selection and before award. Proposers were cautioned that if the total project cost estimate after selection was greater than the amount specified in the proposal, DOE would be under no obligation to increase the amount of funding above that which was requested in the proposal.

2.2.5 Program Policy Factors

The PON advised proposers that the following Program Policy Factors would be considered by the Source Selection Official to select a range of projects that would best serve program objectives:

(a) The desirability of selecting projects that collectively represent a diversity of methods, technical approaches, and applications.

(b) The desirability of selecting projects that collectively utilize a broad range of U.S. coals and are in locations which represent a diversity of Environmental Health & Safety Standards (EHSS), regulatory, and climatic conditions.

The word "collectively," as used in the foregoing program policy factors, was defined to include projects selected in this solicitation and prior CCT solicitations, as well as other ongoing demonstrations in the United States.

2.2.6 Other Considerations

The PON provided that in making selections, DOE would consider giving preference to projects located in states for which the rate-making bodies of those states treat the CCTs the same as pollution control projects or technologies. This consideration could be used as a tie breaker if, after application of the evaluation criteria and the program policy factors, two projects receive identical evaluation scores and remain essentially equal in value. This consideration would not be applied if, in doing so, the regional geographic distribution of the projects selected would be altered significantly.

2.2.7 National Environmental Policy Act (NEPA) Compliance

As part of the evaluation and selection process, the CCT Program developed a procedure for compliance with the NEPA of 1969, the Council on Environmental Quality (CEQ) NEPA regulations (40 CFR Parts 1500-1508), and the DOE guidelines for compliance with NEPA (52 FR 47662, December 15, 1987). DOE final NEPA regulations replacing the DOE guidelines were published in the Federal Register on April 24, 1992 (57 FR 15122) and are now codified at 10 CFR Part 1021. This procedure included the publication and consideration of a publicly available Final Programmatic Environmental Impact Statement (DOE/EIS-0146) issued in November 1989 and the preparation of confidential preselection project-specific environmental reviews for internal DOE use. DOE also prepares publicly available site-specific documents for each selected demonstration project, as appropriate, under NEPA.

2.2.8 Selection

After considering the evaluation criteria, the program policy factors, and the NEPA strategy as stated in the PON, the Source Selection Official selected five projects as best furthering the objectives of the CCT-V PON. These selections were announced on May 4, 1993, during a press conference.

3.0 TECHNICAL FEATURES

3.1 PROJECT DESCRIPTION

The EFCC is an emerging technology with promise for operating high-efficiency combined gas- and steam-turbine cycles on coal. The central feature of EFCC is its coupling of the gas turbine to an external, atmospheric-pressure combustor via a high-temperature ceramic heat exchanger (CerHx®) developed by Hague International. As shown in Figure 2, hot, dirty combustion gas is passed through a CerHx® before going to the steam cycle and a downstream gas

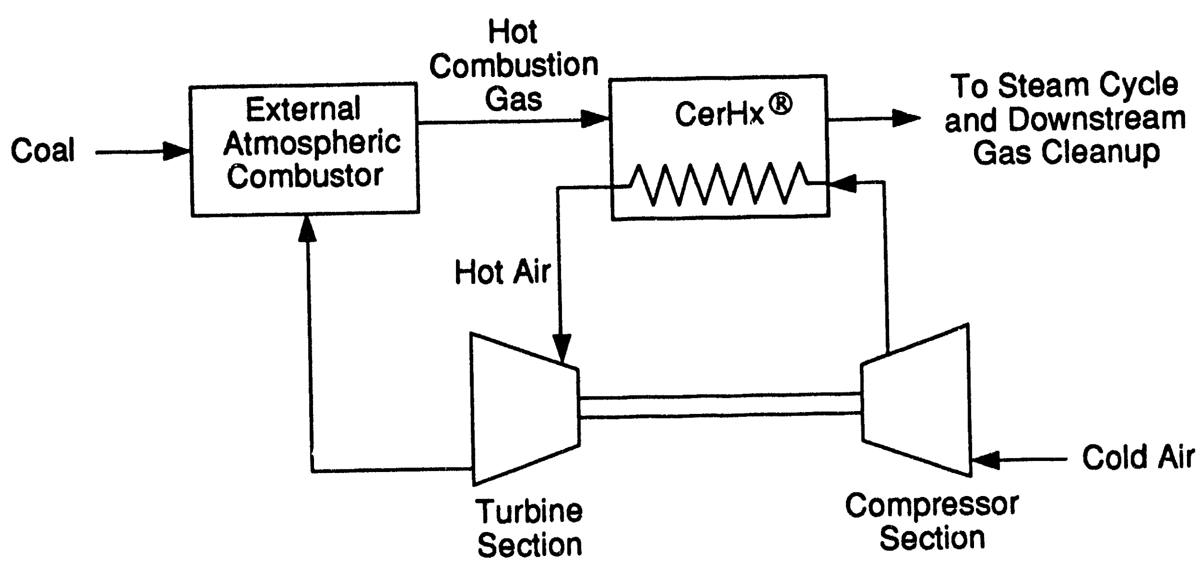

Figure 2. The EFCC Concept

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cleanup system. In the CerHx®, the hot combustion gas heats clean, pressurized air from the gas turbine compressor. This heated air exits the CerHx® and is expanded through the gas turbine, producing electric power.

In competing coal-fired combined cycles, such as IGCC and PFBC, hot exhaust gases are expanded directly through the gas turbine. However, these exhaust gases must first pass through a costly gas cleanup system to protect the gas turbine from their corrosive and abrasive constituents. This need to clean the hot, high-pressure gas upstream of the gas turbine reduces the system's efficiency because of added pressure drop. The efficiency is reduced even more if the hot gas must be cooled before cleanup. EFCC technology avoids these problems by operating the gas turbine directly on clean air, permitting the use of an atmospheric-pressure combustor and eliminating the need for an upstream gas cleanup system to protect the gas turbine.

The Warren Station EFCC Demonstration Project provides for the design, construction and operation of a 66-MWe EFCC at an existing Penelec power generation plant located in Warren, Pennsylvania. In its present configuration, the Warren plant produces 88 MWe of electricity with two, 44-MWe steam turbines. Each turbine is driven by steam produced from two pulverized coal boilers. Fly ash produced in the boilers is removed by two sets of electrostatic precipitators. The sulfur content of the current bituminous coal feedstock ranges from 1 to 2.5 percent, leading to SO_2 emissions of up to 2.8 lb/million Btu. The EFCC repowering will replace two of Warren Station's four coal-fired boilers, increasing the station's net generation capacity by 22 MWe while significantly reducing emissions of SO_2 and NO_x. The repowered unit's improved efficiency will also reduce the amount of CO_2 released per kWh of electricity generated.

The project activities include engineering and design, permitting, procurement, construction, start up, and demonstration. During the demonstration phase, the EFCC system will be operated exclusively on eastern bituminous coal. This project will represent a critical step in the commercialization of EFCC systems by demonstrating the performance of the high-temperature CerHx® and by showing that repowering with EFCC results in a clean and highly efficient process with attractive operating characteristics and competitive capital and operating costs.

Successful demonstration of this project will encourage electric utilities and industrial power producers to construct systems of similar or larger size and will foster the eventual wide-scale deployment of EFCC technology.

3.1.1 Project Summary

Title:	Warren Station EFCC Demonstration Project
Proposer:	Pennsylvania Electric Company
Location:	Pennsylvania Electric Company's Warren Station in Warren, Pennsylvania
Technology:	Externally-Fired Combined Cycle
Applications:	Repowering and replacement of existing power generation facilities; new utility and industrial electric power generation; cogeneration; and small, biomass-fueled power generation and cogeneration plants
Type of Coal Used:	Bituminous coal from Clarion and Butler Counties, Pennsylvania
Products:	Electric power
Project Size:	66 MWe, 600 tons of coal per day
Project Start Date:	July 1994
Project End Date:	October 1999

3.1.2 Project Sponsorship and Cost

Project Participant:	Pennsylvania Electric Company
Co-Funder:	U.S. Department of Energy
Estimated Project Cost:	$146,832,000
Cost Distribution:	Participant share, 50 percent DOE share, 50 percent

3.2 EFCC PROCESS

3.2.1 Overview of Process Development

Externally-fired gas turbine power plants have been studied since the 1930s. The first closed-cycle gas turbine with a peat-fired, metallic air heater was built and operated in the early 1950s. This early machine led to the installation of several cogeneration facilities that performed reliably. Simultaneously, experimental studies began on an open-cycle, externally-fired gas turbine in which heat from the combustion air was input to the gas turbine through a metallic heat exchanger. Although the cycle was operated successfully, the metallic heat exchanger did not allow sufficiently high turbine inlet temperatures for economic power production.

In the early 1970s, Hague International began a series of experiments with ceramic materials that culminated in the construction of the first ceramic heat exchanger in 1973. These early tests were intended to identify problems and assess the concept's potential. Most of the commercial work during this period was on heat recovery equipment (recuperators) for the secondary metals industry. From the middle to the end of the 1970s, Hague International performed a series of studies and experiments, including tests of coal-fired ceramic air heaters. This work was funded in part by the British General Electric Company, the government of Great Britain, the U.S. DOE and the U.S. Economic Development Administration.

By the early 1980s, the most promising mechanical arrangement had been identified, and Hague International had over fifty low pressure ceramic heat exchangers in operation. Since then, these units have accumulated several million hours of successful operation in corrosive and high-temperature environments. Hague International began detailed design studies with internal funds, seeking to increase the pressure capability of the CerHx® to meet the requirements of an EFCC gas turbine.

In 1987, the DOE and a consortium of electric utilities and industrial organizations began joint funding (separate from the CCT Program) of Hague's development of the EFCC concept. Presently, Hague International is continuing to develop the coal-fired CerHx® at its Kennebunk Test Facility (KTF) with the aid of the consortium, which presently consists of 17 utility and industrial partners, and DOE. This test effort includes technical assessments of all new technology associated with the EFCC system. The size and arrangement of the experimental CerHx® at Kennebunk are appropriate for scaling to the Warren Station EFCC. The ceramic tubes are similar in all aspects except length. KTF test conditions are equal to or more demanding than the requirements to be met in the Warren Station EFCC Demonstration Project. Additional research is taking place at several other sites, where ceramic coupons are being exposed to coal combustion products for extended periods.

3.2.2 Process Description

Figure 3 illustrates the EFCC process to be demonstrated at Warren Station. Approximately 25 tons of pulverized coal per hour are transported by ambient air into the top of the low-NO_x coal combustor. In the combustor, staged combustion of coal occurs using gas turbine exhaust air and ambient air which are carefully mixed to provide combustion temperature control. The heat generated from combustion is carried away from the combustor by the hot combustion exhaust gas and by steam that is generated in waterwall tubes. These waterwall tubes, which are imbedded in the combustor's refractory lining, prevent the combustor wall temperature from exceeding its design limit in a reducing environment.

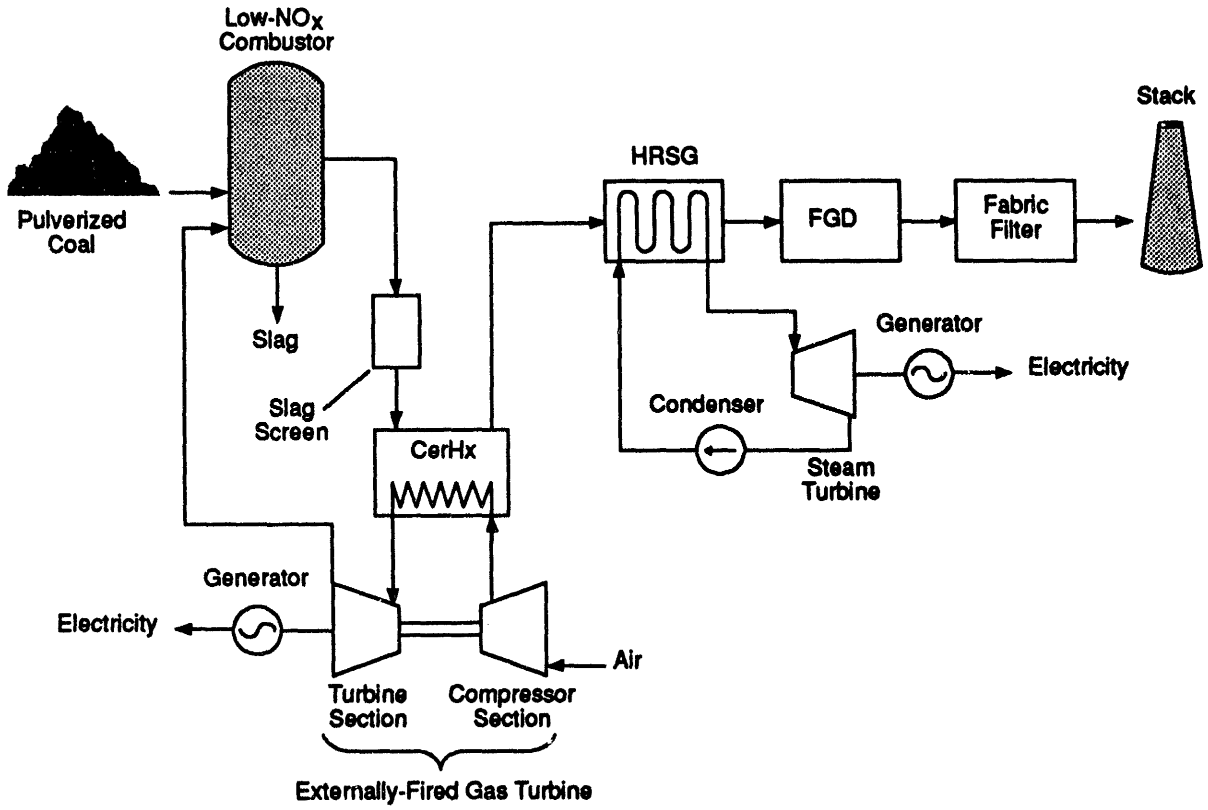

Figure 3. Simplified Diagram of Warren EFCC Process

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The hot combustion gas exits the lower section of the combustor and enters a slag screen. The slag screen is an impact separator composed of an array of ceramic rods. As the combustion gas flows through the slag screen, ash particles larger than 10 microns are removed as they impact and stick to the ceramic rods. Periodically, ash is removed from the rods and quenched in a water pit. Ash collected from the slag screen, as well as ash collected from the combustor, is crushed and transported to an ash disposal system.

Hot combustion gas exiting the slag screen passes through the CerHx® shell, transferring heat through the walls of the ceramic tubes to the clean, pressurized air that is discharged from the compressor section of the gas turbine. This clean, hot, pressurized air is then expanded through the gas turbine, producing 22 MWe. This is the central feature of EFCC. In this way, costly turbine components are not exposed to the corrosive and abrasive substances in the combustor exhaust gas. Instead, clean air, heated in the CerHx® by the exhaust gas from the external combustor, is expanded through the turbine. Additional efficiency is achieved by sending the exhaust air from the turbine to the combustor where it serves as pre-heat air.

Combustion gas discharged from the CerHx® shell enters the heat recovery steam generator (HRSG), where a portion of its remaining sensible heat is used to generate steam. This steam is then expanded in the steam turbine/generator, producing about 44 MWe. Combustion gas exiting the HRSG enters the flue gas desulfurization (FGD) vessel for SO_2 removal.

In the FGD vessel, SO_2 reacts with hydrated lime to form calcium sulfate and calcium sulfite, which are removed from the combustion gas. An 80% reduction of SO_2 in the combustion gas is achieved in this process step. The combustion gas stream exits the absorber vessel carrying fly ash, absorber reaction products, and excess lime. The gas then passes through a pulse-jet fabric filter where entrained solids are collected. SO_2 is further reduced by approximately 10% in the fabric filter cake, yielding a 90% total SO_2 removal from the combustor off-gas. Finally, the combustion gas is discharged through Warren Station's existing stack at a temperature of approximately 167 °F.

3.3 GENERAL FEATURES OF THE PROJECT

3.3.1 Evaluation of Developmental Risk

After selection, DOE performed a detailed evaluation of the Warren Station EFCC Demonstration Project and determined it to be reasonable and appropriate. The evaluation focused on the project's technical, schedule, and cost risks. A team of experts both from within DOE and available under contract contributed to the evaluation. The evaluation was based on data from Participant-furnished documentation and fact-finding discussions with the Participant.

The project's components have little or no technical risk with the exception of the combustor, the slag screen and the CerHx®. Each of these components constitutes new EFCC technology and has a medium amount of technical risk. In addition to supplying the EFCC power island equipment, Hague International will also perform extensive research and development work (funded separately from this project) at their KTF to obtain design data and operational requirements for these new EFCC components. Hague International's research and development work is more critical to the success of this project than any aspect of the project itself. Technical risks are further discussed in Section 3.3.1.2.

The project schedule is ambitious, but reasonable. The schedule is based in part on DOE's determination that an Environmental Assessment is the appropriate level of NEPA documentation. Should an Environmental Impact Statement be required, the schedule may change. The most critical factor affecting the schedule is the selection of a final ceramic tube design for the CerHx® and the subsequent identification of a vendor who can manufacture and deliver these ceramic tubes. The selection of a final ceramic tube design hinges on Hague International's timely construction and successful operation of their KTF and corrosion test facility (again, activities that are not part of this project).

The total proposed cost is based on reasonable estimating approaches. The cost estimate, evaluated during the fact-finding process, was prepared using conceptual engineering, equipment layout and structural drawings, significant vendor input, and in-house historical labor and material costs. The cost estimate was presented by work breakdown structure, by project phase, and by major equipment. Sufficient information was presented to allow a reasonableness evaluation of the cost estimate and a cost overrun analysis. A financial risk analysis program was used by DOE to evaluate the risk in the estimate. Based on the review and evaluation of the information provided, including cost estimating methodologies and pricing bases, DOE concludes that the estimated project cost is acceptable. Aggressive management of possible cost reductions from reduced inflation rates and deletion of some direct costs can offset any potential overruns.

DOE recognizes that demonstrating the commercial readiness of new technologies carries a certain amount of risk. Careful assessment of the risks associated with this project, coupled with the potential benefits of the technology, lead DOE to conclude that those risks are acceptable and worth taking.

3.3.1.1 Similarity of Project to Other Demonstration and Commercial Efforts

There are no other indirectly coal-fired projects that are ready for demonstration using a ceramic heat exchanger. Hague International identified the attractiveness of this concept in the late 1980s and has pursued it since that time.

3.3.1.2 Technical Feasibility

DOE recognizes that technical uncertainties exist in the proposed project, especially with regard to the combustor, the slag screen, and the CerHx®.

The coal combustor for this project is a new design that must satisfy multiple functions, including low-NO_x production with complete combustion and molten slag removal. However, Hague International has accumulated considerable data on low-NO_x

combustors, having a number of low-NO_x combustors in industrial service.

The ceramic rods and tubes which compose the CerHx® and the slag screen present the largest technical risk in this project. Although the analytical techniques to design ceramic components as large as the CerHx® and the slag screen are currently available, it is not a well-established technology. Furthermore, neither of these components have been tested at the sizes which will be required in the demonstration project. In addition, the proposed ceramic materials have not been fully tested in a hot, corrosive coal gas environment and their long-term material strength and corrosion properties are not available.

To address these major technical risks, a research and development program has been planned at Hague International's KTF. DOE's Morgantown Energy Technology Center is providing the largest share of funding for this work under a cost-shared research and development contract. The EFCC consortium is providing the balance of the funding. The KTF will feature extensive testing of a small-scale EFCC system under operating parameters which are more severe than those proposed for the demonstration project. The combustor performance at the KTF will be used to establish key parameters in reducing NO_x and carbon monoxide.

Hague International is also pursuing the construction of a corrosion test facility. If funded, built and operated, this facility will provide design data in parallel with the KTF. Hague International's plan to collect design, materials strength, and corrosion data in a test facility indicates that they are pursuing the critical issues necessary to ensure success.

The overall project is deemed technically feasible because its completion path contains research and development programs which are designed to find risk mitigating solutions to the expressed concerns.

3.3.1.3 Resource Availability

All of the resources required for the project are available. The Participant owns the proposed site and has committed to provide project financing through each budget period. Essential infrastructure services are available, including water, natural gas, rail and highway access, electric service, and sanitary waste disposal.

3.3.2 <u>Relationship Between Project Size and Projected Scale of Commercial Facility</u>

In this repowering application, the EFCC system was sized to fully utilize the 44-MWe steam turbine which was available at Warren Station. The size of the project was also dictated by market opportunity and by limits imposed in scaling up from the KTF. No further scale-up of the demonstrated system will be required for the EFCC system to become commercially viable. All technical, economic, and environmental data from the project will be directly applicable to commercial projects.

There are more than 200 operating coal-fueled power units in the United States in the size range of 30 to 100 MWe. The Warren Station falls in the middle of this size distribution. Therefore, the demonstrated system could be essentially replicated to serve this market.

Larger EFCC systems, from 100 to 500 MWe, would be built by replication of modules or by moderate scaling of the CerHx®. The size of the steam turbine and other balance-of-plant systems could be based on the final plant capacity, since the economies of scale are essentially achieved in these systems. The plant's capacity could then be incrementally increased according to growth projections by adding EFCC modules.

3.3.3 Role of Project in Achieving Commercial Feasibility of Technology

The near-term market for EFCC technology is the repowering of existing steam power plants which produce 30 MWe or more. The initial marketing effort will target a group of utilities owning approximately 500 steam power units that are more than 30 years old. Approximately one-third of these older plants are believed to be candidates for repowering because they are no longer competitive with other means of converting thermal energy to electric power. In addition, their owners cannot economically add equipment to reduce stack emissions to meet the requirements of the Clean Air Act. The 500 plants represent 11,000 MWe, or approximately 10 percent, of the country's installed power generation capacity, and have a replacement cost of approximately 85 billion dollars.

To penetrate this market, utilities will need data on costs, equipment reliability, actual operations, procedures for operating and maintaining the plant, and demonstrated plant performance. The proposed Warren Station EFCC Demonstration Project will serve as the source of initial data on which this technology can be evaluated. The project, which incorporates all of the new EFCC technology, will be a full-size, utility-operated power plant fueled exclusively with coal.

The central EFCC feature to be demonstrated is the CerHx®. Additional EFCC components that need to be demonstrated include a low-NO_x coal combustor, a slag screen, and a high-temperature turbine control valve. Although the gas turbine, the steam turbine, and the HRSG are commercially available, the integrated operation of all components in an overall EFCC process configuration needs to be demonstrated as well.

If successful, the proposed project will eliminate barriers to commercialization by demonstrating the following:

- The technology is applicable to repowering small coal-fueled utility plants.
- Plants repowered with EFCC technology will operate reliably.
- Maintenance requirements will not keep EFCC plants off-line for extended periods.
- Spare parts, specialized technology services, and manpower skills required for maintaining EFCC components are readily available.
- The EFCC technology can evolve at a rate that will keep its costs competitive with future industry needs.
- Extensive retraining of a utility's existing work force is not necessary for successful plant operations and maintenance.
- The technology can be scaled to sizes that would be of long-term interest to the power generating industry.

Following successful demonstration, EFCC technology could capture a share of the small utility repowering market in the near-term. As the EFCC repowering technology gains acceptance, it is expected that utility planners will become interested in larger EFCC unit sizes to meet new power plant needs. Concurrently, the industrial and biomass-fueled power markets are expected to offer additional opportunities for the proposed technology.

4.0 ENVIRONMENTAL CONSIDERATIONS

The overall strategy for compliance with NEPA, cited in Section 2.2, contains three major elements: a Programmatic Environmental Impact Statement (PEIS); a preselection, project-specific environmental analysis; and a post-selection, site-specific environmental analysis. To satisfy the first element, DOE issued the final PEIS to the public in November 1989 (DOE/EIS-0146). In the PEIS, results derived from the Regional Emissions Database and Evaluation System were used to estimate the environmental impacts that might occur in 2010 if each technology were to reach full commercialization, capturing 100 percent of its applicable market. The environmental impacts were compared to the no-action alternative, which assumed continued use of conventional coal technologies through 2010, with new plants using conventional FGD to meet New Source Performance Standards (NSPS). As described in the PEIS, Table 1 presents a summary of environmental characteristics for direct coal-fueled turbine systems. There is no summary available in the PEIS for the indirect fired system proposed here. Since the direct fired system is the closest technology which compares to the proposed system from a technical standpoint, it is being provided as the standard in this case. In each system, coal is first combusted to fire a gas turbine and the products of combustion must be treated prior to release to the environment.

Table 1. Summary of environmental characteristics for coal-fueled gas turbines.

Applicable coal sulfur content	Any
SO_2 removal[a]	85-95
NO_x[b] (lb/10^6 Btu)	0.2-0.3
Total suspended particulates (lb/10^6 Btu)	0.01-0.003
Solid waste (lb/10^6 Btu)	11.8
Sulfur removal byproducts	Not Applicable
Heat rate (Btu/kWh)	8,460

[a] Based on utilization of sorbent injection.

[b] With staged combustion, NO_x emission rates would be well below NSPS requirement of 0.6 lb/10^6 Btu.

Source: Programmatic Environmental Impact Statement (DOE/EIS-0146), November 1989.

The second element of DOE's NEPA strategy for the CCT program involved preparation of a preselection environmental review based on project-specific environmental data and analyses that offerors supplied as part of their proposals. The review summarized the strengths and weaknesses of each proposal against the environmental evaluation criteria. It included, to the extent possible, a discussion of alternative sites and processes reasonably available to the offeror, practical mitigating measures such as the options for controlling discharges and for management of solid and liquid wastes, impacts of each proposed demonstration on the local environments, and a list of required permits. Finally, the risks and impacts of each proposed project were assessed. This analysis was provided for the Source Selection Official's use before the selection of proposals.

As the final element of the NEPA strategy, the Participant must submit to DOE the environmental information specified in Appendix J of the PON. This detailed site- and project-specific information will be used as the basis for the site-specific NEPA document to be prepared by DOE. For this project DOE has determined that an Environmental Assessment is the appropriate level of NEPA documentation. This document will be prepared in full compliance with NEPA and the CEQ and DOE regulations for compliance with NEPA, and must be completed and approved before Federal funds are provided for any activity that would limit the choice of reasonable alternatives to the proposed action o^ have an adverse environmental impact.

Table 2 shows the environmental characteristics of the EFCC unit to be installed at the Warren Station. In addition to the three-stage combustor and higher efficiency, the EFCC unit will use a state-of-the-art air quality control system composed of a new FGD system and a pulse jet fabric filter baghouse.

Table 2. Summary of environmental characteristics for EFCC unit.

Applicable coal sulfur content (%)	1-2.5
SO_2 removal[a] (%)	85-90
NO_x[b] ($lb/10^6$ Btu)	0.25
Total suspended particulates[c] ($lb/10^6$ Btu)	0.03
Solid waste ($lb/10^6$ Btu)	14.6
Sulfur removal byproducts	Not Applicable
Heat rate (Btu/kWh)	9,650

[a] Based on use of lime in FGD unit.

[b] Based on three-stage combustion.

[c] Based on use of the slag screen and pulse jet fabric filter baghouse.

In addition to the NEPA requirements outlined above, the Participant must prepare and submit an Environmental Monitoring Plan (EMP) for the project following the guidelines provided in Appendix N of the PON. The purpose of the EMP is to ensure that sufficient technology, project, and site environmental data are collected to provide health, safety, and environmental information for use in subsequent commercial applications of the technology.

5.0 PROJECT MANAGEMENT

5.1 OVERVIEW OF MANAGEMENT ORGANIZATION

As the signatory to the Cooperative Agreement, Penelec will be responsible for all aspects of the project, including the operation and maintenance of the EFCC during the demonstration, but excluding repayment. Additional project team members include Black & Veatch of Kansas City, Missouri, providing engineering and construction management services and Hague International of South Portland, Maine, supplying the EFCC technology. Penelec will accomplish the project objectives by means of the organizational relationships shown in Figure 4.

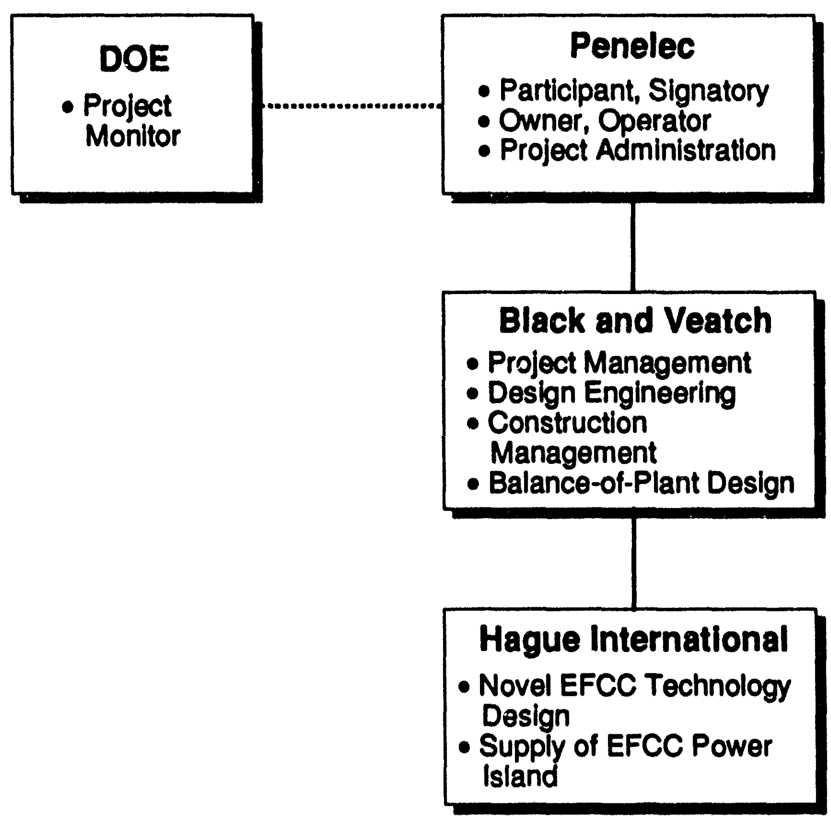

Figure 4. Project Organization M94000633

5.2 IDENTIFICATION OF RESPECTIVE ROLES AND RESPONSIBILITIES

5.2.1 DOE

DOE will be responsible for monitoring all aspects of the project and for granting or denying approvals required by the Cooperative

Agreement. A DOE Project Manager will be designated by the DOE Contracting Officer to act as a Contracting Officer's Representative. The Project Manager will be the primary point of contact for the project and will be responsible for DOE management of the project.

5.2.2 Participant

Penelec, as the Participant, will be responsible for all aspects of the demonstration project, including project administration, permitting, design, contract decisions and execution, disbursement, construction, operation and maintenance, and reporting, but excluding repayment. Penelec will appoint a Project Manager who will have the responsibility for oversight of the project and decision-making on behalf of Penelec. Penelec has retained Black & Veatch to provide overall project management, the design of the balance-of-plant, construction management, and operations data collection and analysis. Hague International will provide the design and equipment for the novel technology, including the CerHx®.

5.3 PROJECT IMPLEMENTATION AND CONTROL PROCEDURES

Penelec will prepare and maintain a Project Management Plan which presents project procedures, controls, schedules, budgets, baseline design information, and other activities required to adequately manage the project. This document, which will be finalized shortly after execution of the Cooperative Agreement, will be used to implement and control project activities. Throughout the project, reports dealing with the technical, management, cost, and environmental monitoring aspects of the project will be prepared and delivered to DOE.

5.4 KEY AGREEMENTS IMPACTING DATA RIGHTS, PATENT WAIVERS, AND INFORMATION REPORTING

With respect to data rights, DOE has negotiated terms and conditions that will generally provide for rights of access by DOE to all data generated or used in the course of or under the Cooperative Agreement by Penelec and its subcontractors. DOE will have unlimited rights to data first produced in the performance of the Cooperative Agreement that is not proprietary nor protected CCT data, limited rights of access to proprietary data utilized in the course of the demonstration, and the right to use, but not disseminate for five years, protected CCT data. DOE will have the right to have relevant proprietary information delivered to it under suitable conditions of confidentiality.

With regard to patents, data and other intellectual property, Penelec has made a contractual commitment to exercise its best efforts to commercialize, or assist others to commercialize, the EFCC technology to be demonstrated in this project. To this end, Penelec has made a contractual commitment to provide tours of the Demonstration Project Facility and to work with Black & Veatch and Hague International in preparing papers and reports to the power generation industry.

Penelec has requested, for itself and Black & Veatch, a waiver of patent rights in any subject invention, i.e., any invention or discovery by either of them which is conceived or first actually reduced to practice in the course of or under the Cooperative Agreement. Favorable action is anticipated to be given to the patent waiver request considering the level of Penelec's cost sharing and the commitment by Black & Veatch to commercialization of the EFCC technology. Any grant of a patent waiver will reserve to the Government a nonexclusive, nontransferable, and irrevocable paid-up license to practice or to have practiced any waived subject invention for or on behalf of the United States.

5.5 PROCEDURES FOR COMMERCIALIZATION OF TECHNOLOGY

The demonstration of EFCC is a vital step toward its widespread commercial application and is dependent on the design, construction, and operation of this project. It is essential that a demonstration of the technology be conducted to produce long term reliability, availability, maintainability, and environmental performance at a scale sufficient to illustrate commercial potential. Demonstration of the technology with commercially available and large scale equipment will provide valuable information for the private sector to use in making future commercialization decisions. The proposed Warren Station EFCC Demonstration Project incorporates all of the new EFCC technology in a full-sized, utility-operated power plant and will serve as the source of initial data on which this technology can be evaluated.

Following successful demonstration, EFCC technology is expected to capture a share of the small utility repowering market in the near-term. Throughout the U.S., particularly in the Midwest and East, there are numerous coal-fired utility boilers without SO_2 controls. If repowered with EFCC, the efficiency and capacity of these aging units would be increased and their net emission rates of SO_2, NO_x, and CO_2 would be reduced. As the EFCC repowering technology gains acceptance, it is expected that the new power plant market will become interested in new, larger EFCC unit sizes. Concurrently, the foreign power equipment market is expected to offer additional opportunities for the proposed technology.

The commercialization plan focuses on Hague International leading the commercialization effort for the EFCC Technology in the U.S. Hague International owns all of the rights necessary to commercialize the EFCC Technology. Hague has shown accomplishments in developing and marketing heat exchanger products over two decades and has been able to cultivate substantial interest in their current product development line, i.e., the CerHx®, over the last several years. They intend to utilize the same type of strategy employed in these earlier successes to market the EFCC Technology. Specifically, Hague International has proposed to exchange intellectual property rights for the tangible and intangible resources of established organizations that are recognized as leaders in specific market segments which would complement the EFCC Technology offering. For example, a manufacturer of heat recovery steam generators or of gas combustion turbines would be identified. A business association would then be formed between or among these parties. Together, the parties would offer the EFCC Technology, or portions thereof which would include the CerHx®, to the marketplace. The parties would remain in an alliance to continue to improve the functional capability of the product, reduce costs, continue to broaden the scope of applications, and develop a strong financial affiliation to offer customers a complete project service.

Black & Veatch will assist Hague International's commercialization efforts by lending their expertise in general power plant design and construction management, along with the specific experience gained in participating in the design and construction management of the project, to Hague International's EFCC Technology customers. Penelec will assist Hague International's commercialization efforts by providing tours of the completed and operating Warren Station EFCC Demonstration Project.

6.0 PROJECT COST AND EVENT SCHEDULING

6.1 PROJECT BASELINE COSTS

The estimated cost and the cost sharing for the work to be performed under the Cooperative Agreement are as shown below.

Pre-award

DOE Share	$ 370,000	50.0%
Participant Share	$ 370,000	50.0%
	$ 740,000	100.0%

Phase 1

DOE Share	$ 11,126,500	50.0%
Participant Share	$ 11,126,500	50.0%
	$ 22,253,000	100.0%

Phase 2

DOE Share	$ 39,266,500	50.0%
Participant Share	$ 39,266,500	50.0%
	$ 78,533,000	100.0%

Phase 3

DOE Share	$ 22,653,000	50.0%
Participant Share	$ 22,653,000	50.0%
	$ 45,306,000	100.0%

Total Estimated Project Cost

DOE Share	$ 73,416,000	50.0%
Participant Share	$ 73,416,000	50.0%
	$146,832,000	100.0%

Sequential budget period costs shall be shared by DOE and the Participant as shown below. At the beginning of each budget period, DOE intends to obligate sufficient funds to pay its share of the expenses for that period.

TOTAL ESTIMATED PROJECT COST		$146,832,000
* Budget Period 1	DOE Share	$ 2,200,000
	Participant Share	$ 2,200,000
Budget Period 2	DOE Share	$ 9,296,500
	Participant Share	$ 9,296,500
Budget Period 3	DOE Share	$ 39,266,500
	Participant Share	$ 39,266,500
Budget Period 4	DOE Share	$ 22,653,000
	Participant Share	$ 22,653,000

* Preaward costs are included in Budget Period 1.

6.2 MILESTONE SCHEDULE

The project is divided into three phases and is expected to take 64 months to complete. The phases and their expected durations are as shown below:

Phase 1:	Design and Permitting	13.5 months
Phase 2:	Procurement, Construction & Startup	27.0 months
Phase 3:	Operation and Data Collection	33.0 months

Phase 1 overlaps Phase 2 by 7.5 months. Phase 2 overlaps Phase 3 by 2.0 months.

Budget periods are used to manage the financial risk of the project and to facilitate project decision making. The project is divided into four sequential budget periods as follows:

Budget Period 1 -- 6 months
Budget Period 2 -- 7.5 months
Budget Period 3 -- 18 months
Budget Period 4 -- 32.5 months

A project schedule is shown in Figure 5. Phase 2 work is expected to be completed by March 1997 and the project is expected to be completed in October 1999.

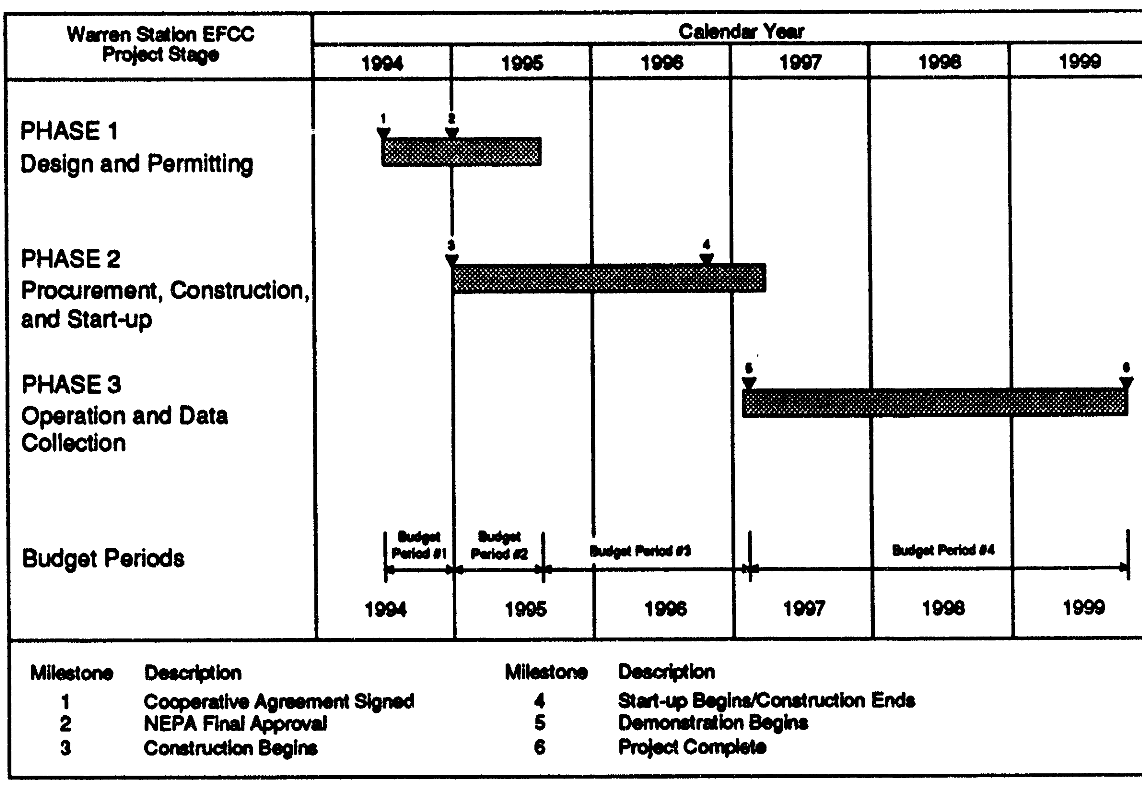

Figure 5. Project Schedule

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6.3 REPAYMENT AGREEMENT

Based on DOE's recoupment policy as stated in Section 7.7 of the PON, DOE plans to recover an amount up to the Government's contribution to the project. Hague International and Black & Veatch, the two parties responsible for commercializing the EFCC Technology, have agreed to pay the Government in accordance with the Repayment Agreement to be executed at the time of award of the Cooperative Agreement.

Hague will administer the repayment agreement and provide recoupment of DOE's investment from sales, leases and licensing of the EFCC technology. Black & Veatch will provide an additional source of recoupment from revenues realized from engineering and construction services that involve the demonstration technology.

DATE

FILMED

10/12/94

END