TECHNICAL AND COST PROPOSAL

DEMONSTRATION OF WRI'S PRE-COMBUSTION MERCURY REMOVAL PROCESS FOR LIGNITE-FIRED POWER PLANTS

Total LRC Funds Requested: $188,000

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28 March 2007

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Foreword to the Proposal and a Statement of Clarification

A team of co-sponsors and project participants – Western Research Institute (WRI), WY; Etaa Energy, NJ; Foster Wheeler North America Corp. (FWNA), NJ; Iowa State University (ISU), IA; Washington Group International (WGI), CO; Energy and Environmental Research Center, (EERC), ND; Electric Power Research Institute, CA; Southern Company, AL; Basin Electric Power Cooperative, ND; North Dakota Industrial Commission (NDIC), ND; Montana Dakota Utilities, ND; Detroit Edison, MI; and SaskPower, Canada - submitted a proposal entitled, "Pilot Testing of WRI's Novel Mercury Control Technology by Pre-Combustion Thermal Treatment of Coal " in response to the US DOE's request for proposals DE-PS26-05NT42510-04 in 2005. The proposal was competitively evaluated and selected for an award. A contract was signed in December 2006 between the US DOE and the prime contractor, WRI. About1/3rd of the total project costs are shared by the co-sponsors. Key elements of the proposal include testing of a set of subbituminous coals and a set of lignites. The tests involve bench-scale screening, and PDU processing of the fuels followed by pulverized coal testing of the WRI-processed coals in a PC combustor at the EERC. Data to be generated will confirm the capability of the WRI process to remove major fraction of mercury before the fuel is fed into the furnace. The proposal also included a study of integration of the process to a commercial plant by Foster Wheeler North America and an estimation of process costs by Washington Group International. The Project Summary of the DOE-awarded project is provided at the end of this Foreword section.

Due to the recent developments with regard to the availability of U.S. DOE funds, the U.S. DOE has released to the WRI only a partial amount of the monies earmarked for the first year of the 30-month project. However, the co-sponsoring utilities have committed monies to WRI if the DOE funds can be authorized. As a result of this stalled DOE funding, the WRI has submitted a proposal to the Wyoming Business Council (WBC) for partial funding of the project with WRI/DOE Cooperative Agreement Joint Sponsored Research funds. The application (to the WBC) will cover only the subbituminous coals testing. This proposal to the NDIC will cover only the lignite tests. Thus, there is no duplication of efforts between the two proposals. The co-sponsorships' cost-share monies have been divided accordingly to reflect the fuel of interest , thereby focusing on MDU, BEPC, Sask Power and NDIC support with matching DOE JSR funds. It is important to emphasize that the research findings of the two parallel efforts will be shared between all industry sponsoring organizations, NDIC and U.S. DOE. The NDIC proposal is also scheduled to proceed under identical time frame to the subbituminous coal testing, evaluation and milestone plan. Both projects will be completed by June 30, 2009.. A successful award of the contract by the NDIC will result in a scenario of getting the best value for the government research funds for both the subbituminous and lignite coal customers.

DOE RFP: DE-PS26-05NT42510-04

WRI Project Contract Number: DE-FC-07NT42785

Project period: Dec. 18, 2006 - Jun. 17, 2009

PROJECT SUMMARY

Applicant: Western Research Institute (WRI), Laramie, WY

Project Director: Dr. Alan E. Bland

Project Title: Pilot Testing of WRI's Novel Mercury Control Technology by Pre-Combustion Thermal Treatment of Coal

Objectives

The objective of the proposed study is to develop and demonstrate pre-combustion mercury removal of raw coal by thermal treatment. A mercury removal efficiency improvement of at least 50% in the incoming coal will be achieved at less than $30,000/lb of mercury removed.

Methods to be Employed

Key process steps in the WRI technology include treating the fuel at two selected temperature windows. In the first stage, the moisture in the fuel is driven-off; in the second stage, coal is heated by nearly inert gas resulting in significant removal of coal-bound mercury. The inert gas flow is an order of magnitude lower than the combustor flue gas and hence the stripping of mercury in the effluent streams becomes easier. The product coal is cooled and then directly fed into the boiler plant pulverizer.

A set of representative subbituminous, western bituminous and lignite coals will be evaluated. Project activities include bench-scale testing of eight coals followed by pilot-scale testing of three coals. In the bench-scale tests, the mercury removal will be characterized as a function of time and temperature. In the pilot scale testing, the effluent streams from the dryer and heater will be characterized. Two of these coals will be selected for further testing on a pilot pc-fired combustor to demonstrate the viability of removing more than the research target.

WRI will lead the research effort on the bench- and pilot-scale units and coordinate the project activities. WRI will be assisted by Etaa Energy, Inc. (EEI) in the design of the process development unit, analysis of the test data and preparation of the test reports. Energy and Environmental Research Center (EERC) will perform the pulverized coal combustion testing on a pilot plant using the product coal from WRI and measure the baseline and treated coal mercury emissions. Foster Wheeler North America Corp (FWNA) will model the integrated performance of the coal thermal treatment unit with a pulverized coal-fired utility unit. Washington Group International (WGI) will perform an economic study of the commercial-scale application of the WRI process. The research program is expected to be completed in 30-months.

Potential Impact

The proposed pre-combustion mercury removal process has shown very promising results in the preliminary tests. Mercury removal of 60-80% in the pre-combustion process will help improve the net (including the boiler island) mercury capture to 90% and above in low rank coals. A successful demonstration of the WRI process will lead to an accelerated deployment of commercial systems in subbituminous (such as PRB) and lignite (such as Fort Union) coals. Co-benefits are also expected through significant reductions of NOx.

Participants

WRI, WY; Etaa Energy, NJ; FWNA, NJ; WGI, CO; Electric Power Research Institute, CA; Southern Company, AL; Basin Electric Power Cooperative, ND; North Dakota Industrial Commission, ND; Montana Dakota Utilities, ND; Detroit Edison, MI; and SaskPower, Canada.

ABSTRACT

Coal-based power generation will continue play a major role for decades. However, coal use will face challenges through continuously evolving regulatory actions with regard to gaseous emissions, such as mercury. While research efforts by others are addressing post-combustion emission control technologies and plant efficiency improvements, Western Research Institute (WRI) is developing a patented pre-combustion mercury removal technology that deals specifically with emission reduction, efficiency improvement and water harvesting from high moisture fuels, such as Fort Union lignite. Earlier research at WRI demonstrated that the process is able to remove between 70 and 80% of the mercury present in both subbituminous coal (Powder River Basin) and lignite (North Dakota). The proposed development program addresses the need to scale-up the process via a process development unit in order to define the engineering data needed to design commercial size units. Data from the coal processing tests at WRI and pulverized coal combustion tests in the North Dakota Energy and Environmental Research Center (EERC) test unit will form the basis to study the integration of the process in a lignite-fired 400-500 MWe power plant and compare the cost of mercury removal to other control technologies. The program will also study the water capture from the coal dryer effluent and will determine the potential of WRI's process in removing sulfur and other trace elements such as arsenic and selenium. Three lignites-two from North Dakota and one from Canada-will be tested. The 24-month project is divided into eight tasks. The proposed costs are to be shared by-lignite-based power producers (MDU, BEPC and Sask Power), as well as NDIC and the U.S. Department of Energy, National Energy Technology Laboratory. Utilities will contribute $100,000 in cash and $32,000 of in-kind services and personnel costs associated with the process integration activities and project management. It is requested that NDIC provide $188,000 to be matched with $275,000 of WRI/U.S. DOE Cooperative Agreement JSR funds.

1.0 PROJECT SUMMARY

1.1 Objectives

Coal-based power generation will continue to play a major role for decades. However, the coal use faces challenges through continuously evolving regulatory requirements with regard to gaseous pollutant emissions that impact the air quality. The challenges are being addressed through research and development efforts that focus on the emission control technologies and plant efficiency improvements.

One of the key pollutants of concern is mercury. Many post-combustion mercury control technologies are under development with funding under DOE's Phase I, II and III awards. Some of these technologies face challenges such as finding a suitable sorbent, and the impact of mercury-laden sorbents on ash sales and/or disposal. An alternate approach contained in this proposal deals with pre-combustion mercury removal. Western Research Institute's (WRI)'s patented (Patent No. 5,403,365) pre-combustion mercury removal technology deals specifically with reducing emissions, improving power plant efficiency, and allowing for water harvesting when treating high moisture low-rank fuels such as Fort Union lignite.

Under this proposed program, WRI will conduct bench- and pilot-scale coal treatment and combustion testing to evaluate the effectiveness of WRI's novel thermal pretreatment process to achieve >50% mercury removal, and at costs of <$30,000/lb of Hg removed. The objectives of the project are structured in three phases are: Phase 0 (Task 0) - project planning; Phase I (Tasks 1-5) - coal selection and characterization, bench-and PDU-scale WRI process testing and pilot-scale PC combustion testing; and Phase III - design of an integrated boiler commercial configuration, its impacts on the boiler performance and the economics of the technology related to market applications.

1.2. Scope of Work

WRI has identified issues during the prior work on the pre-combustion process and the proposed scope of work combines these technical issues with the overall project objectives and involves the following key activities:

- Bench-scale testing of coals to determine optimum temperature and residence time for coal drying and mercury removal.
- Process Development Unit testing to verify the bench-scale finding, and evaluate mercury removal concepts.
- Pilot-scale pulverized coal combustion testing of an untreated (baseline) and WRI-treated lignite coal combined with small amounts of ACI and/or SEA addition upstream of an ESP or an SDA–FF to evaluate and optimize Hg control efficiency.
- Design guidelines development for integrating the WRI process at utility unit, modeling of the integrated unit performance, and estimation of the cost of mercury removal.

1.3. Tasks to be Performed

The scope of work for the proposed project is contained in following phases and the associated series of tasks

Phase 0 - Project Planning

<u>Task 0.0:</u> A detailed operations, sampling, and quality assurance (QA)/quality control (QC) plan will be prepared and presented to the NDIC.

Phase I - Bench-Scale Tests

Task 1.0 – Coal Selection and Characterization: Three coals, two Fort Union North Dakota lignite and one Canadian Fort Union lignite, will be selected by the utility sponsors and others and thoroughly characterized.

Task 2.0 - Bench-Scale Testing: The existing bench-scale unit at WRI will be modified to perform parametric testing of the three coals, including time temperature and mercury evolution relationships. Testing will identify the optimum temperature for drying and for mercury removal.

Task 3.0 - PDU Testing: The results of the bench-scale testing will be assessed and used to scale-up from the bench-scale tests to the PDU-scale. The existing PDU at WRI, designed to operate up to 100 lb/hr will be upgraded to evaluate alternative mercury removal configurations, different high temperature sorbents, and to verify the temperature-removal curves defined in Tasks 2. Arsenic and selenium distribution will be measured and assessed relative to build-up in the recycle sweep gas and removal options.

Task 4.0 – Water Harvesting: A water-cooled heat exchanger has been added to a slipstream of the dryer effluent to condense the moisture and analyze the water quality for use at the power plant. Water quality will be analyzed relative to requirement for cooling tower use.

Task 5.0 - Pilot-Scale Combustion Tests: Testing using the EERC's 160 kW pulverized coal combustor will examine the combustion properties of the WRI-treated lignites, and assess the potential of enhancing post-combustion native mercury capture. Testing will also examine the impact of activated carbon injection in the gas stream with and without the addition of the EERC's mercury oxidation agent on mercury species and removal.

Phase II - Technology Engineering Design and Commercial Application

Task 6.0 - Data Analysis and Design Guidelines Development: This task is to evaluate the data from the bench and PDU tests in order to define the optimal operating conditions for the process.

Task 7.0 - Commercial Configuration Development: This task will assess the impact of the integration of the WRI process in a lignite coal-fired power plant. Foster Wheeler North America Corp. in conjunction with WRI and Etaa Energy, will model the behavior of an existing 400 MWe power plant on integration with WRI process and develop necessary engineering information for the economic study.

Task 8.0 - Economic Evaluation: This task will assess the economic impacts of the results of the testing and the final commercial configuration for the process. Specifically, Washington Group International will assess capital and O&M costs for lignite-fired facilities, compare the WRI costs with commercial Hg removal systems, and evaluate other pollutant reduction co-benefits.

1.4 Deliverables

As required by the NDIC, periodic, interim, and final reports will be submitted in accordance with the *NDIC guidelines*. The primary deliverable will be a project final report that documents the testing, data analysis and reduction, design and mercury removal cost study along with water removal and arsenic and selenium release during the WRI process. WRI will prepare briefings and technical presentations for NDIC. Test results and conclusions will be presented at U.S. technical conferences as per NDIC guidelines.

2.0 PROJECT DESCRIPTION

2.1 Pre-Combustion Mercury Removal and Technology Development Pathway

The WRI process is designed to remove mercury and potentially other (arsenic and selenium) from low-rank coals, allow for water harvesting for power plant use, and increase plant efficiency. Each of these is described below.

2.1.1 Mercury Removal Technology Outline: The patented WRI pre-combustion mercury removal process is a two-stage thermal pretreatment of raw coal to remove both the moisture and mercury, wherein coal is first heated to remove the moisture and then heated to a higher temperature in a separate zone to evolve the mercury (Fig. 2.1.1).

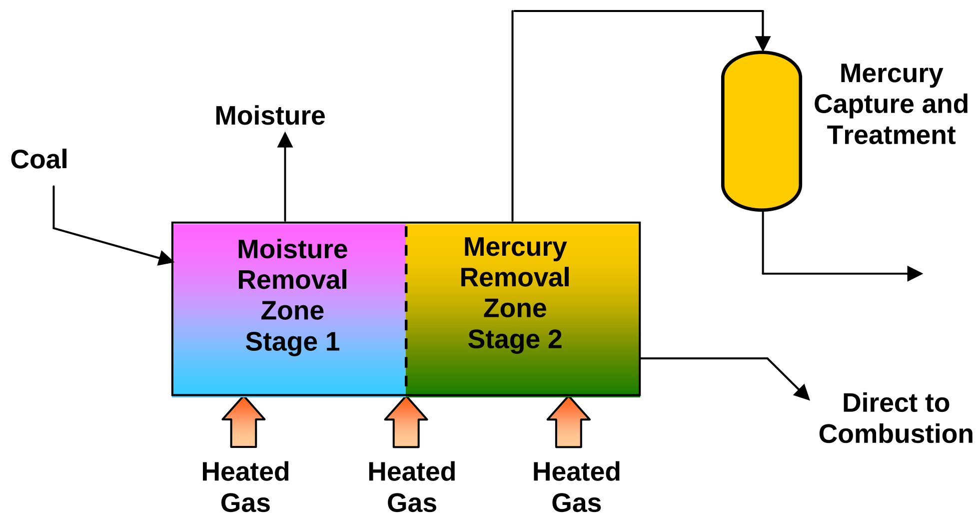


Fig. 2.1.1. Schematic of the WRI Process

Raw coal, crushed to 1-inch x 0, enters the moisture removal zone where it is heated to a temperature not exceeding 300°F and the free water and most of the more tightly bound water is vaporized and removed from the zone by a sweep gas. The coal is then transferred to the mercury removal zone where it is heated to a temperature of approximately 550°F, wherein 60 to 80 percent of the mercury in

Powder River Basin (PRB) and lignite coals is volatilized and removed by the inert sweep gas. The treated coal is then ready for additional size reduction and combustion. The sweep gas stream containing the evolved mercury is cooled, passed to mercury capture equipment and the cleaned sweep gas is returned to the process. The evolved mercury (99% elemental) is entrained at a high concentration in a small volume of relatively clean sweep gas and is amenable to removal by carbon-based sorbents at high removal rates (99.5%) below 300 ºF. Reduced water vapor in the gas helps mercury removal (Ghorishi et al. 1999). The first and second stage of heating will use flue gas to maximize the regenerative efficiency of the boiler flue gas heat. The second stage of heating must be performed in a low oxygen atmosphere to avoid spontaneous ignition of coal at these (>500ºF) temperatures. A major feature of the WRI two-stage process is the fact that the moisture and mercury can be evolved separately, wherein water/moisture phase contains no mercury, and the mercury-containing sweep gas contains very low moisture (Fig.2.1.2).

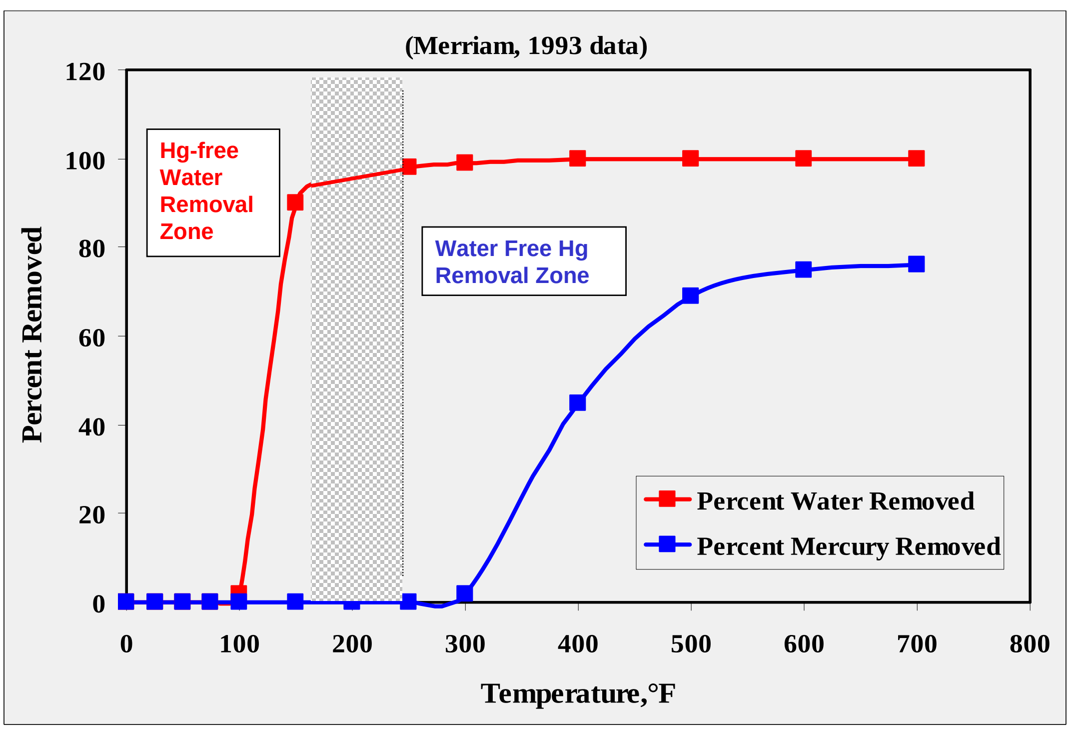


Fig. 2.1.2. Evolution of Moisture and Mercury with WRI Process

There is a temperature window of 50 to 80ºF between the two zones, wherein neither moisture nor mercury is evolved. This is advantageous in controlling the coal treatment process.

2.1.2 Logical Progression of the Technology: The technology has evolved from coal drying and low temperature gasification research, where it was observed that mercury in PRB coal evolved in specific temperature ranges (Merriam 1993). This testing indicated that approximately 70–80% of the mercury in PRB coals could be thermally removed at temperatures up to 550°F, resulting in the issuance of U.S. Patent No. 5,403,365 "Process for Low Mercury Coal" (by Merriam 1995). The remainder of mercury, believed to be in the pyrite, is not released.

More recently, bench-scale studies have expanded the understanding of the fundamental parameters that control the process using a PRB coal (Bland et al. 2001, Guffey et al. 2002). These studies concluded that (1) mercury can be removed from both PRB and lignite coals over essentially the same temperature range; and (2) inert sweep gas flow rate significantly affects the amount of mercury removed, with higher flow rates resulting in increased mercury removal. These preliminary bench-scale studies were not able to define the minimum residence time needed for neither maximum mercury removal, nor the impact of particle size on residence time. In order to confirm the results of these bench-scale batch tests, to a limited extent, and to address integration issues, a 100 pph process development unit (PDU) was constructed and operated at WRI using a Powder River basin (PRB) and a North Dakota lignite. Testing addressed both moisture and mercury removal. Pre-combustion mercury removal was 55-87%, averaging 77%.

Treated PRB coal from the Process Development Unit (PDU) was combusted using a PC-fired pilot combustor at the EERC, and employed different backend particulate and gas clean-up equipment (Benson et al, 2005). The elemental mercury fraction in the flue gas at the ESP outlet (<5%Hg removal) was 40% with the WRI-treated coal, down from 90% with the raw coal. Lowering the elemental mercury in the flue gas assists with native removal or with activated carbon injection (ACI). Compared with ACI mercury control technologies, the WRI process results are promising (Fig. 2.1.3). Fig 2.1.3 shows that the performance of ACI at a PRB coal-fired power plant (Pleasant Prairie) was not able to achieve mercury removals above 65%. However, by using WRI treated PRB coal and very minimal ACI rates, it is possible to remove total mercury to over 90%. Therefore, the WRI process shows preliminary promise for both PRB and lignite coals: two coal types that represent over 36% of the power generation in the U.S. However, refinement of operating parameters and system integration can improve heat efficiency and boiler performance while lowering the cost of mercury removed.

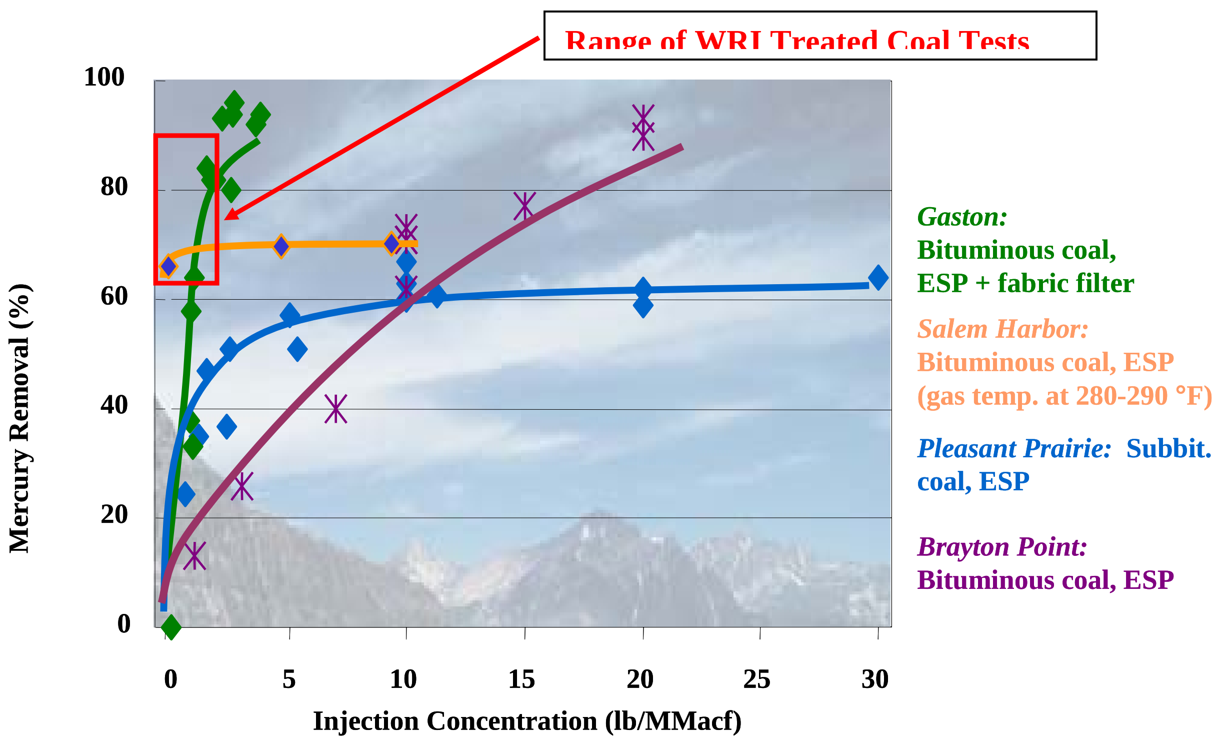


Fig. 2.1.3. WRI-Treated Coal Performance with the ACI Mercury Capture Tests

2.1.3 Arsenic and Selenium Removal

The Clean Air Act Amendments of 1990 (Public Law 101-549) required the U.S. EPA to conduct studies of 15 elements in coal including As and Se. These two elements are present in low quantities on the order of parts per million (ppm). However, the release of these elements upon combustion and subsequent release into the atmosphere in some forms is harmful to the environment and toxic to human beings. Selenium compounds are five times as toxic than arsenic. As such, many have speculated that As and Se emissions may be regulated. Existing air pollution control devices (APCDs) do remove with the fly ash and sulfur control materials some of the As and Se in the combustion flue gas.

Since As and Se are affiliated with sulfides in the coal, only a partial release is expected with WRI's thermal treatment process. Research by WRI has shown an apparent release of As and Se during the mercury removal stage (temperature window of 250-575°F). This temperature range for release of As and Se is confirmed in the work by Yan et al (2001). The release of As and Se from the coal along with Hg during processing can result in a build-up of these species in the Stage 2 recycle sweep gas. Methods to remove the As and Se, along with the Hg, at high temperatures (550°F) from the sweep gas needs to be developed. It is known that Se can be removed with activated carbon, but it requires the cooling of the stage 2 recycle from 550°F to under 300°F. Clearly this has a negative impact on the efficiency of the WRI process. As such, WRI is working with various vendors and sorbent developers to produce a high temperature sorbent capable of removing all three of the gaseous species that ends up in the process recycle sweep gas.

2.1.4 Water Harvesting in the WRI Process

Fresh water availability for human consumption and agricultural use is one of the key issues in this century. Among the consumers, power plants are the second largest consumer of fresh water (DOE, 2006). Current interest is to identify alternate water sources of acceptable water quality to supplement the makeup cooling water to the cooling tower, which forms the largest fraction of water in-take. Cooling water availability concern is enhanced much more in areas like the West where there is abundant supply of high moisture coal and large capacity power plants located near limited source of fresh water supply. It is difficult to use groundwater for the power plants when a large fraction of the population in western states depends on the groundwater for drinking. However, North Dakota lignite contains about 30-40% water and once fed into the combustion system, this large volume of water escapes as vapor through the stack into the atmosphere. Research is needed in order to harvest a substantial fraction of this coal-bound water before being fed into the boiler furnace.

Coal dryer effluent gas from the WRI process has a substantial fraction of water vapor (Table 2.1.1). This provides for possible condensation of water vapor if it reaches temperatures in the region of 150°F and below. If the coal is heated indirectly or with dry steam there is a possibility for condensing the moisture in the effluent from as high as 212°F at ambient pressure.

Fig. 2.1.4 describes the coal drying island of the WRI's patented pre-combustion mercury removal scheme with the water harvesting concept (Bland and Sellakumar, 2006). The dryer effluent gas leaving the dryer at about 250°F will be cleaned by a baghouse filter and then cooled. It is possible to remove most of the water in the cooled flue gas when the gas temperature is below 70°F. Fig. 2.1.5 presents a typical level of water that can be condensed from the dryer effluent due to changes in humidity with gas temperature.

Table 2.1.1. Increase in Water Vapor in the Drying Medium at the Dryer Outlet

	Dryer Hot Gas In		**Dryer Hot Gas Out**	
	Vol. Fraction	**Partial Pr.**	**Vol. Fraction**	**Partial Pr.**
	%	psia	%	psia
CO2	14.43		12.96	
H2O	7.90	1.16	17.24	2.53
N2	74.41		66.85	
O2	3.24		2.91	
SO2	0.03		0.03	
Total	100.0		100.0	

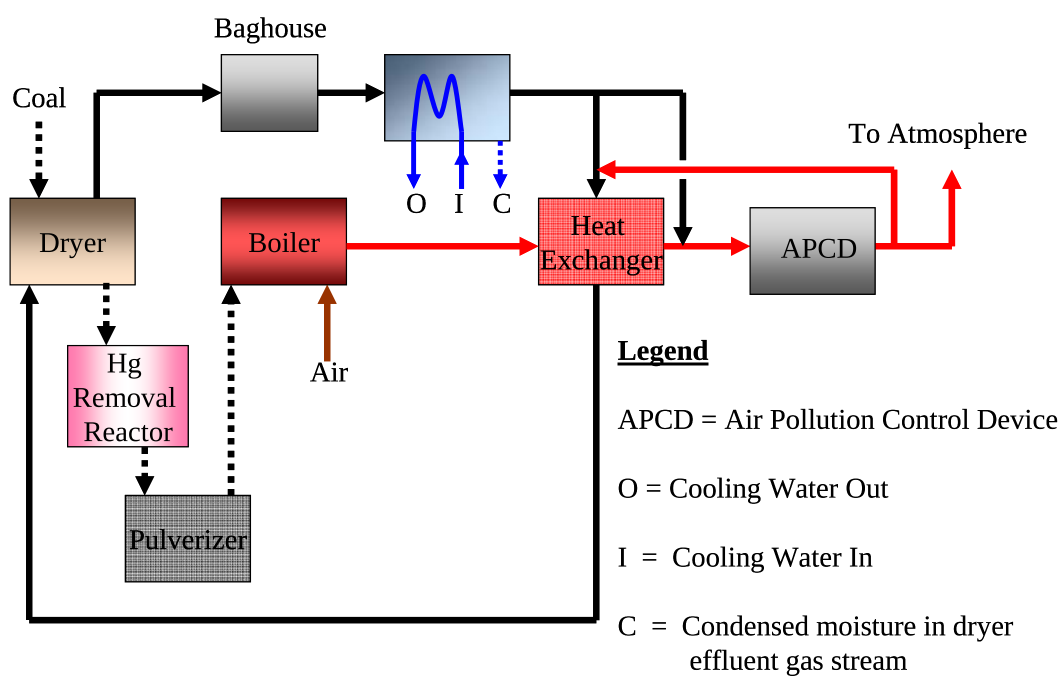


Fig. 2.1.4. Schematic of WRI's Pre-Combustion Process with Water Harvesting

The “C” and “O” refer to the streams in Fig. A.2. The saturation temperature of water at 2.53 psia partial pressure is about 135°F. Thus any cooling below this temperature will yield condensed water from the dryer effluent stream since the saturation pressure of the water vapor also goes down during cooling.

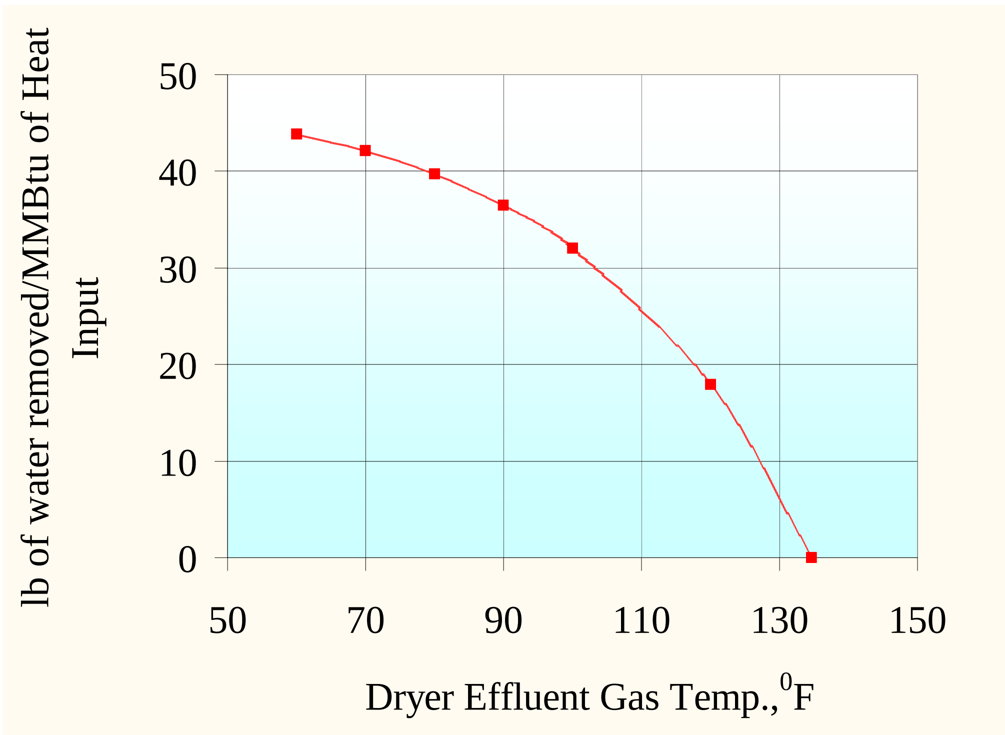


Fig. 2.1.5. Quantity of Water Removed From Coal Dryer Gas Effluent

2.2 Project Objectives

Key objectives of the proposed project are presented below.

a. Demonstrate >50% mercury removal by WRI’s pre-combustion thermal treatment of lignite coal;

b. Develop bench- and pilot-scale data to support an engineering platform for demonstration-scale testing of the WRI process;

c. Demonstrate the water harvesting potential from the coal dryer exhaust and assess the water quality for use at the power plant;

d. Assess the potential presence of arsenic and selenium in the mercury removal step recycle gas and assess the potential of high temperature sorbents to remove As and Se along with the Hg;

e. Evaluate and model the integration of the WRI process for lignite-fired large size commercial pulverized coal (pc) boiler;

d. Achieve an integrated 90%+ mercury removal in an integrated process/power plant configuration; and

e. Estimate the cost of the WRI process and show that the cost of mercury removal to be less than $30,000 per pound of mercury removed.

2.3 Methodology

WRI and project participants and co-sponsors (Montana-Dakota Utilities, Basin Electric Power Cooperative, SaskPower and U.S. DOE) are proposing to NDIC a two-year program to address specific process issues to provide the results necessary for scale-up of the technology, and to provide cost estimates for commercial utility units. The project will be conducted by WRI, Etaa Energy, Energy and Environmental Research Center (EERC), Foster Wheeler North America Corp. (FWNA), and Washington Group International (WGI). The proposed project involves both bench- and pilot-scale testing followed by analysis of a commercial integrated configuration of the technology and process economics. The following phases are proposed:

Phase 0 – Project Planning

Task 0 - Project Planning: A detailed operations, sampling, and QA/ QC plan will be prepared. The plan will include details of the bench-scale, PDU-scale process testing, as well as the pilot-scale combustor conditions. Guidelines for utility concept development, commercialization pathways, and cost estimates will be prepared.

2.3.1 Phase I - Bench- & Pilot-Scale Testing:

Task 1 – Lignite Coal Selection and Characterization: The coals will be selected to provide a range of compositional properties. The coals for the study will be acquired by WRI from co-sponsors and others. Three coals will be Fort Union lignites from North Dakota and Saskatchewan, representing varying ash, sulfur and mercury concentrations.

Proximate and ultimate analyses will be conducted on the composite coal samples using ASTM Methods D3172, D5142, and D3176, total chlorine by ASTM Method D6721-01, and coal Hg by EPA Method 245.1 and EPA SW-846 Method 7470.

2.3.2 Task 2 - Bench-Scale Testing: Existing bench-scale processing units shown in Fig. 2.2.1 will be used for parametric testing of Task 1 coals. The instrumentation and operation of the bench-scale equipment was described earlier (Section 2.2). Each of the three coals will be evaluated as to their release of mercury as a function of five temperatures and the impact of two residence times. The testing will result in the selection of optimum temperature for drying and an optimum temperature for mercury removal.

2.3.3 Task 3 - Process Development Unit Testing: The existing PDU at WRI, shown earlier in Figure 2.2.2, designed to handle up to 100 pph of coal flow, will be modified to provide continuous process operations, to accommodate two different mercury removal configurations. Key instrumentation and operation were described earlier (Section 2.2). Mercury removal configuration A is a second vibratory fluid bed dryer, while configuration B involves hot sweep gas injection into a coal disengagement zone. This second configuration has a much smaller footprint and thereby is easier to integrate into the power plant.

The coals will be evaluated in the PDU to confirm the moisture and mercury removal profiles observed in the bench-scale testing, to evaluate each of the two mercury removal configurations described above, and to evaluate high temperature sorbent performance with trials conducted at optimal PDU operating conditions (Table 2.3.1).

Table 2.3.1. PDU Testing Plan

Test Conditions	**Configuration A-Coal Tests**	**Configuration B Testing**	**Production Runs***
Coals	3	1	1
Configuration	A	B	A or B
Temperatures (T ºF)	5 (250-600)	Opt. Temp.	Opt. Temp.
Residence Times (minutes)	2 (6 and 10)	Opt. RT	Opt. RT

* Long duration production runs may be necessary to produce treated coal for the combustion tests (Task 5). RT=Residence Time; Low T= Low Temperature; Opt.=Optimum

2.3.4 Task 4 -Water Harvesting: The PDU has been modified with a heat exchanger and additional piping to provide a slipstream of the effluent gas. Key instrumentation includes the pressure, flow, temperature and humidity of the dryer effluent slipstream gas at the inlet and outlet of the heat exchanger. The condensate flow and the temperature will also be measured. The coolant circuit will have a water heater to maintain the temperature. Any particulate that is collected will also be collected and filtered out if necessary. The coal dryer will be operated at a nominal raw coal feed rate of 50 lb/hr at the drying gas temperature between 500 and 600°F. The slipstream flow will be controlled using the bypass valve such that the slipstream dryer effluent gas temperature at the heat exchanger outlet will be maintained at 25°F more than the cooling water temperature. The coolant flow will also be maintained in such a way that the coolant outlet temperature is less than 175°F. Samples will be collected and analyzed for moisture fraction at the inlet and outlet of the dryer. At each drying gas temperature, the coolant temperature will be maintained. Three coolant temperature conditions to get three test points for each drying gas temperature. Water samples will be analyzed for parameters of interest for power plant cooling use.

2.3.5 Task 5 - Pilot-Scale PC Combustor Testing – WRI-Treated Coal: Treated-coal representing optimum PDU operating conditions (one lignite) will be used for the pilot-scale PC combustion tests at the EERC. The PTC facility and its operations are described in Section 2.5. Pilot-scale ESP and SDA+FF APCD configurations will be tested including detailed assessment of gaseous emissions (SO_2, CO, CO_2, NOx, O_2 and particulate), as well as mercury species and total mercury in the flue gas before the APCD and at the stack. In addition, testing will examine baseline conditions of the raw and treated coals and the impact of small amounts of DARCO ACI (<1.26 lb ACI/MMacf) with and without the addition of EERC's SEA mercury oxidation agent (Table 2.3.2). The potential of achieving 90%+ mercury removal through the WRI pre-treatment process and minimal ACI/SEA injection will be evaluated.

Table 2.3.2 Pilot-Scale PC Combustion Tests

Coal	Number of Tests	APCD	ACI (lbs/MMacf)	SEA (lbs/MMacf)	Hg Analysis
Raw Lignite	2*	ESP	0 and 1.26	0 and 0.2	OH &CMM
	1	SDA+FF	0	0	OH &CMM
Treated Lignite	4**	ESP	0 and 1.26	0 and 0.2	OH &CMM
	2	SDA+FF	0 and 1.26	0	OH &CMM

*****Test Rates: (1) ACI (0)/SEA (0); (2) ACI (1.26)/SEA (0); (3) ACI (1.26)/SEA (0.2); **Test Rates: (1) ACI (0)/SEA (0); (2) ACI (1.26)/SEA (0); (3) ACI (1.26)/SEA (0.2); (4) ACI (1.26)/SEA (0.2)

Phase II - Technology Engineering Design and Commercial Application

2.3.6 Task 6 - Data Analysis and Design Guidelines Development: Data generated from Phase I testing will be compiled in a systematic way and presented in the format agreed upon during the QA/QC plan for the Task. Key parameters of interest for scale-up are fuel, heat source temperature ranges, and oxygen and moisture concentrations in each stream, mercury balance and speciation around each reactor-dryer, heater, and combustor. These factors will form the basis for scaling-up and integrating the process with a large-scale utility and will be included in Tasks 7 and 8.

2.3.7 Task 7 - Evaluating Integration of the Technology into Existing Power Plants

FWNA will study the characteristics of the WRI-treated lignite coal-fired 400-500 MWe PC unit. Mercury emissions data will be defined at key nodes in the fuel and gas flow path in order to conceptualize the utility-scale unit. Care will be taken to identify potential market needs for subbituminous- and lignite–fired units. Key activities in this study are (1) modify existing 400 MWe power plant system model for lignite-firing and run reference case (raw coal); (2) modify reference system model to include pre-combustion thermal coal treatment process and run at full load; (3) incorporate results of the furnace model into system model; (4) revise system model to run in performance mode and run one part load case; (5).create 1-D furnace thermal model based on 3-D CFD simulation of existing 400 MWe unit; (6) determine furnace thermal performance for reference case using 1-D model (raw coal); (7) determine furnace thermal performance for full load case using 1-D model (processed coal); (8) determine furnace thermal performance for part load case using 1-D model (processed coal); and (9) determine thermal/hydraulic design of air heaters.

2.3.8 Task 8 - Process Economic Studies and Comparison to Competing Technologies

Based on the results of the WRI PDU process performance, WRI and Etaa Energy, along with Washington Group International (WGI), will develop an estimate basis to define the design, performance and economic criteria that will serve as the basis for the development of the WRI process economic evaluations. Cost estimates will include both capital and operating/maintenance cost analyses for Fort Union lignite for a 400-500 MWe plant. The costs for all components within the WRI process will be included in the analysis, along with any other balance of plant (BOP) equipment that might be impacted by the installation of the WRI process as defined in Task 7. Impacts on the boiler efficiency will be considered in the economic analysis for each coal type to develop and compare the Hg control costs in terms of $/pound of Hg removed. WGI's effort is covered in a companion subbituminous coal study and will be made available to all participants and co-sponsors of this study.

2.4 Anticipated Results

The following results are expected from the research project.

- WRI technology will remove >50% of the mercury from lignite prior to combustion, through a thermal evolution of the mercury;
- WRI technology will not only remove mercury, but will also dry the coal and at operating costs lower than post-combustion processes;
- WRI technology will be shown that water harvesting is viable and water quality is or can be made suitable for cooling use at the power plant;
- WRI technology will be shown to be able to be integrated into existing power plants and will increase plant efficiency; and
- WRI treated coal when combusted employing very low levels of sorbents, such as activated carbon that will not affecting ash quality, will achieve 80% to 90% Hg removal.

2.5 Facilities and Resources

Bench-Scale Facilities. Fig. 2.5.1 shows a schematic of the bench-scale unit at WRI that will be used for parametric testing of coals. Inert gas is heated in an electric heater and is used to heat the coal samples. The particles are kept in a fluidized state simulating the gas-particle contact behavior in the PDU reactors. The bench-scale and PDU facilities will have instrumentation enabling measurement of temperatures, flow rates and gas constituents. . Mercury adsorption over a specified time will also be measured with the objective of determining mercury loading.

PDU Facility. The PDU is located at WRI's Advanced Technology Center and is depicted in Figure 2.5.2. The drying and mercury removal processes will be carried out in two steps, either in sequence using the same vibratory fluid bed dryer for both the moisture (up to 300ºF) and then mercury removal (up to 550-570 ºF) (Configuration A), or as a continuous unit with the drying being accomplished in the vibratory fluid bed dryer operating at <300 ºF and a separate mercury removal reactor employing hot sweep gas injection into a disengagement zone operated at 550-575 ºF (Configuration B). The PDU facilities will be instrumented for temperature, pressure, flow rates, and gas collection and mercury measurements.

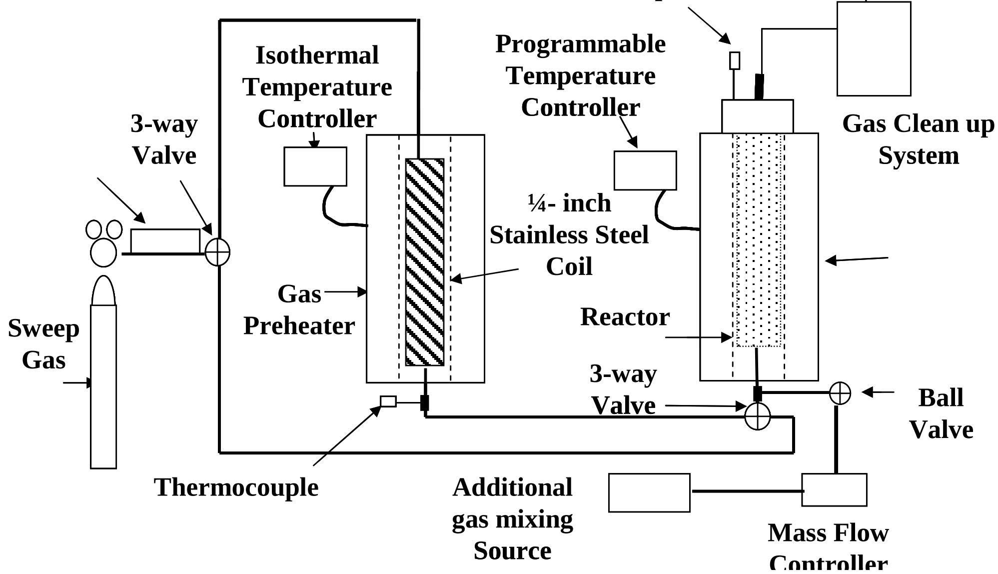


Fig.2.5.1 Schematic of the Bench-Scale Unit at WRI

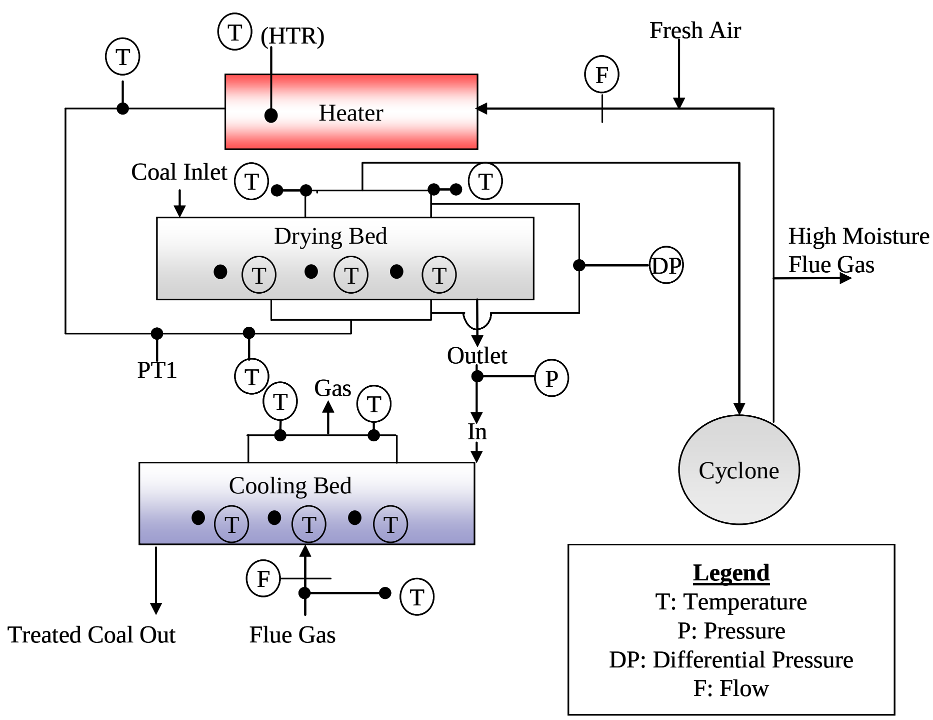


Fig.2.5.2. Process Flow Diagram of the WRI PDU

Particulate Test Combustor (PTC). The 160 W pilot-scale (550,000-Btu/hr) pulverized coal combustion system, shown schematically in Fig. 2.5.3, is located at the EERC.

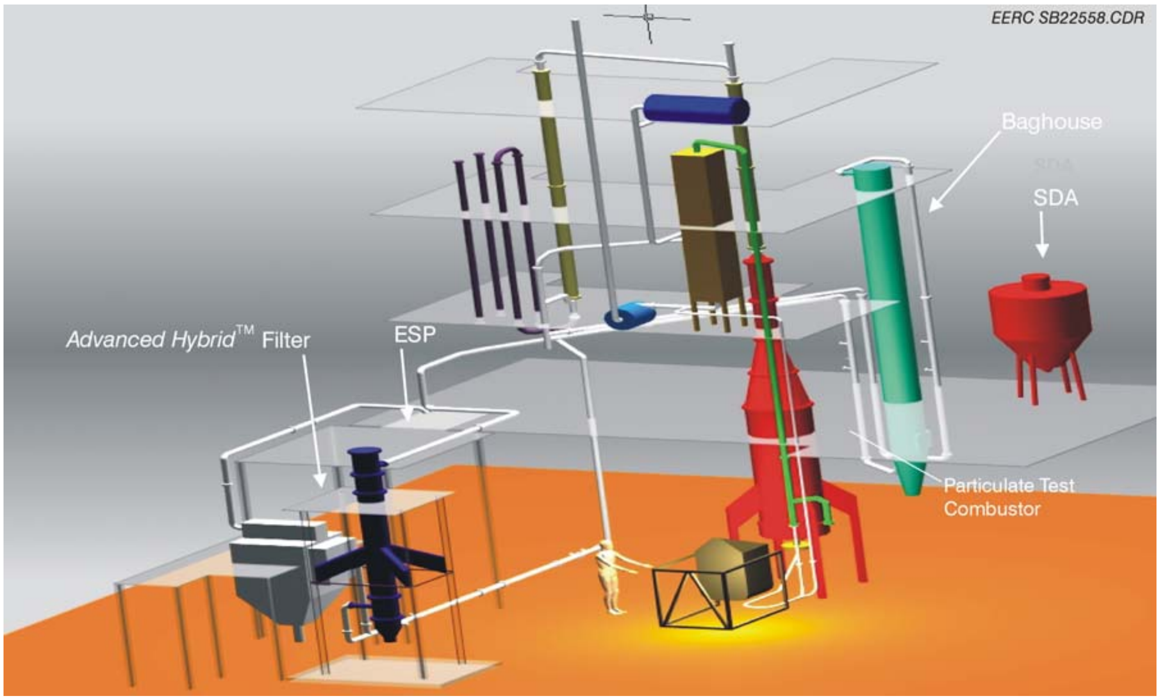
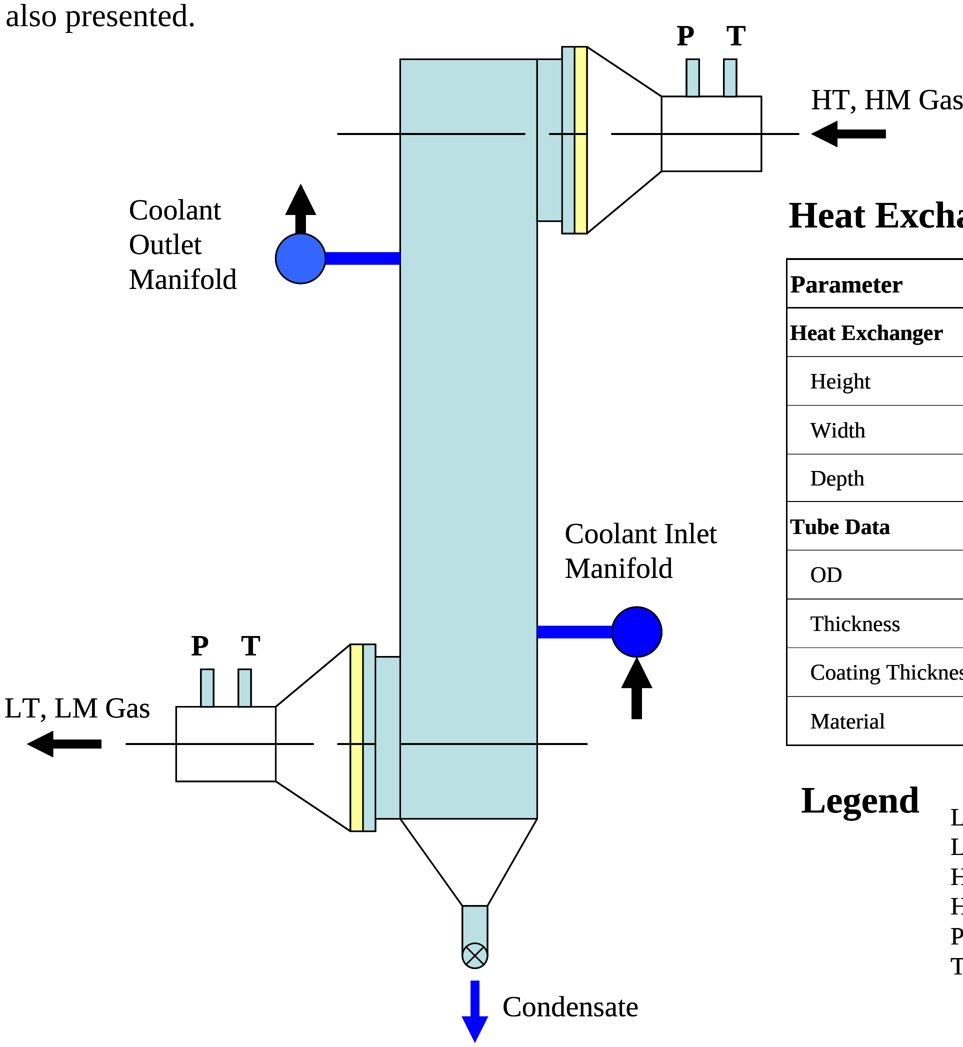


Fig. 2.5.3. Schematic of the EERC PTC 550,000 Btu/hr Combustion Unit

The burner is refractory lined and vertically oriented with a mean particle residence time in the combustor being approximately 3 seconds. The coal nozzle fires axially upward and secondary air is introduced concentrically to the primary air with turbulent mixing. PTC instrumentation monitors temperatures, pressures, flow rates, flue gas constituent concentrations, and particulate control device operating. Flue gas is analyzed with Thermoelectron NOx analyzers, Beckman O_2, CO, and CO_2, and DuPont SO_2 analyzers. The PTC will also deploy fabric filter (FF), electrostatic precipitator (ESP) and/or spray dryer adsorber (SDA). The fabric filter (FF) includes three 13-ft by 5-in. high-collection efficiency (>99.995%) bags with an air-to-cloth ratio of 4 ft/sec. The ESP is a single-wire, tubular design with a specific collection area of 125 at 300°F, gas velocity through the ESP of 5 ft/min and plate spacing of 11 inches. The SDA is a Niro Production Minor™ design that operates on a lime slurry. The drying chamber is 1.2-m (3.9 ft) in diameter with a 0.75-m (2.5-ft) cylindrical height and a 60º conical bottom providing a residence time of 10 seconds.

Water Harvesting Heat Exchanger: A heat exchanger has been added to a slipstream of the dryer effluent gas stream. Fig. 2.5.4 shows a schematic of the heat exchanger. Tube and duct materials are of the same type that will be used in a commercial-scale designs. Design data is also presented.



Heat Exchanger Data

Parameter	**Unit**	**Value**
Heat Exchanger		
Height	ft	7.4
Width	ft	4.1
Depth	ft	3.7
Tube Data		
OD	in	1.125
Thickness	in	0.049
Coating Thicknes	in	0.015
Material		Copper Alloy

Legend

LT=Low Temperature;
LM= Low Moisture
HT= High Temperature
HM= High Moisture
P= Pressure
T= Temperature

Fig. 2.5.4. Schematic of the Water Harvesting Heat Exchanger

Performance Analysis Models: FWDC and WGI will use established commercial in-house design procedures and models for the integration and evaluation of the WRI process.

2.6 Environmental and Economic Impacts of the Project While It Is Underway

The WRI has reviewed the environmental impact of drying, and heat treating about ten 55-gallon drums (4000 lbs) of as-received lignite. The product streams from the process include the high moisture dryer gas effluent, dry coal (2,400 lbs of lignite with less than 5% moisture) and condensate from the low temperature heat exchanger. The EERC will burn the WRI-processed lignite on a pilot-scale PC combustor. The product streams include the flue gas stream and lignite ash. The dust laden flue gas will be cleaned by state-of-the-art pollution control devices. At each location, the concerned EPA authorities will be notified of the fuel drying and combustion and also the disposal procedures of the by-products. No large scale impact on the air and water streams are expected.

2.7 Ultimate Technological and Economic Impacts

EPRI/WGI 2005 report provided a positive preliminary techno-economic assessment of the WRI process based on proof-of-concept studies with representative PRB and lignite coals. In this program, the study findings will yield data on the application of the WRI technology for lignite fuels.

To further consolidate the study findings and take the results to commercial implementation, technology development steps are being proposed by WRI with participation from four companies (WRI, Etaa Energy, Foster Wheeler North America, and Washington Group

International) specialized in design guidelines development and scale-up analysis, performance design modeling integrating the WRI process, design review and cost estimation of the commercial plant and identification of market potential/obstacles for the technology in the 2010 timeframe.

2.8 Need for the Project

The successful development of the WRI technology will be beneficial to lignite-fired power plants in that it will reduce emissions, increase plant efficiency, and allow for water harvesting for cooling make-up water. WRI's process has been demonstrated at a feasibility level with bench- and to a limited extent on pilot-scale equipment using one PRB subbituminous coal and one North Dakota lignite. The proposed tests are expected to compliment the existing data and provide operating ranges of process parameters for optimum performance in terms of mercury removal, co-pollutant generation and by-product characteristics. In addition, preliminary pilot-scale data have shown about 40-60% of the total flue gas mercury is oxidized when burning WRI-treated coal, compared to <10% oxidized mercury in the when firing with raw PRB coal. WRI-treated coal appears to help enhance the post-combustion mercury removal by reducing sorbent injection and achieving >90% total mercury capture. Further testing is a logical progression from prior research, to resolve the cause for the oxidation, demonstrate increased thermal performance, demonstrate more than 90% mercury removal and establish costs of large-scale commercial integrated power plants (<$30,000/lb Hg removed).

3.0 STANDARDS OF SUCCESS

The measure of success of the project will be: (1) the ability to achieve >50% mercury removal for Fort Union lignite, (2) the achievement of >90 Hg removal with WRI's process and small amounts of post-combustion ACI; (3) the establishment of cost estimates for the process at <$30,000/lb Hg removed, and (4) the development of an understanding of integrating the process at lignite-fired power plants.

The following milestones will be used to measure the success of the project. These milestones are incorporated in the timetable for the project.

- ***Milestone 1.a. Award Contracts*** by ND Industrial Commission by June 2007. Assume to be under contract with all funding sponsors by the end of June 2007.
- ***Milestone 1b. Procure Fuels and Characterize Them***. Three Fort Union lignite samples –two from North Dakota and one from Canada will be procured and analyzed for their physical and chemical characteristics by September 30th 2007.
- ***Milestone 2. Bench-scale Tests***. The results of bench-scale evaluation of the processing variables on mercury removal will be reported by January 31st 2008.
- ***Milestone 3. Verification of Bench-Scale Data in PDUs***. The results of the PDU testing, including As and Se evaluations will be reported by May 31st 2008.
- ***Milestone 4. Water Harvesting:*** Water recovery testing will be reported by June 30th 2008.
- ***Milestone 5. Interim Report on Evaluation of Product Coal Combustion Characteristics***. The results of the product coal combustion characteristics from the ND EERC test data will be reported by August 31st 2008.

- ***Milestone 6:*** Data ***Analysis and Design Guidelines Development***. Bench-scale, PDU and EERC data will be analyzed towards developing input for the boiler plant and WRI system integration study by November 30th 2008.
- ***Milestone 7. Process Integration of Technology at Power Plant***. The results of the assessment are to be completed by February 28th 2009.
- ***Milestone 8. Cost Estimation of the Mercury Removal***. The results of the economic evaluation, including the WGI effort (from companion subbituminous coal study) will be reported by May 31st 2009.
- ***Milestone 9. Final Report.*** The final report of the project will be completed by June 30th, 2009**.**

4.0 BACKGROUND

Out of 320 GWe (of coal-fired) installed capacity in the country, over 36% of the units are fired with high-moisture subbituminous and lignite coals. Another 100 GWe of high moisture coal-fired units are expected to be added over the next two decades (DOE, 2005). Post-combustion mercury control technologies are challenged for these units due to the high elemental mercury in their flue gas. Western Research Institute (WRI)'s pre-combustion thermal process may be a technically and economically viable alternative for these units to meet mercury emissions limits.

WRI has been developing a patented, pre-combustion thermal process for the removal of mercury from coal. The early work evolved from research studying coal drying, where it was observed that mercury was evolved in specific temperature ranges (Merriam 1993). This initial work was conducted in an inclined fluidized bed reaction system. Those tests demonstrated that up to 80 percent of the mercury in PRB coal could be removed, as well as 25-40 % of As and Se species. The results of the early testing indicated that approximately 70–80% of the mercury in PRB coals can be thermally removed at temperatures below 290°C (554°F). The remaining 20% remains in the coal up to temperatures of 600ºC (1,102°F). Very little of the mercury was removed with the moisture up to temperatures of 150ºC (302°F). This implied that a process could be developed that removes mercury in an essentially dry gas stream in the temperature range of 150−290ºC (302−554°F). There was also little loss of volatile matter from the coal, which is essential for proper coal ignition and combustion flame stability. The results from this early research resulted in the issuance of the patent "Process for Low Mercury Coal" (Merriam 1995), number 5,403,365.

4.1 Summary of Prior Development Work by WRI

Western Research Institute (WRI), in association with the government and industrial co-sponsors, spearheaded a program to develop a technology that differs from other mercury control pathways. The U.S. DOE (under Cooperative Agreement number DE-FC26-98FT4032), North Dakota Industrial Commission (under contract number FY03-XLIX-122), Alliant Energy, and Montana-Dakota Utilities co-funded prior research efforts. The Energy and Environmental Research Center (EERC) performed pilot-scale pulverized coal combustion tests. (Bland et al, 2005, 2006).

<u>Bench-Scale Tests</u>**:** A bubbling fluidized bed reactor (BFBR) was fabricated and used in the study. The testing used two coals: a subbituminous coal from the Powder River Basin of Wyoming and a lignite coal from North Dakota. Processing temperatures, sweep gas flow rate, and residence time were examined. Substantial amount of mercury removal was achieved. About 50-57% and for PRB subbituminous well over 70% of the mercury is removed from the lignite coal with the WRI patented process. Further in-depth studies are necessary to resolve the mechanism of higher level of mercury removal in subbituminous coal than in lignite. These bench-scale investigations have demonstrated the applicability of the technology for removal of mercury from coal and outlined the data required to identify the remaining technical issues that needed to be addressed at a Process Development Unit (PDU)-scale.

<u>PDU Tests:</u> The goal of the Process Development Unit (PDU) testing was used to evaluate the potential of scaling-up the WRI thermal-based technology for the removal of mercury from low rank coals, both subbituminous and lignite. The PDU was designed to process a nominal 100

lb/hr of raw subbituminous and lignite. It has three major subsystems; namely, coal drying system, mercury removal system and the sweep gas treatment system. Each individual system is designed in such a way that the units are scaleable. To ascertain the mercury species evolved during the WRI treatment process, Ontario-Hydro testing was conducted on the sweep gas. The results of that testing showed that 98.5% of the mercury evolved was of the elemental form. Three coals – two lignites (Westmoreland Seam 1 and Seam 2) and one PRB subbituminous coal (Caballo) were tested. The mercury concentration in the product (treated) coal was consistently lower and it showed a mercury reduction varying from 50% to 57% for lignite. The corresponding numbers for the Caballo coal was 55-87% and mostly above 70%.

Pilot-Scale Combustion Tests: Testing was performed using Brigham Young University's MFR and at Energy and Environmental Research Center's (EERC's) particulate test combustor (PTC). The EERC effort was conducted as part of a DOE-sponsored study entitled "Mercury Control for Electric Utilities Burning Subbituminous Coals". The PTC was fired at a rate of 550,000Btu/hr to produce a particulate-laden flue gas stream. It was configured with various air pollution control devices (APCD) to simulate different configurations. Tests revealed that the treated PRB coal was amenable to combustion as the raw coal. Key findings from PTC tests include:

- The total mercury in the flue gas from raw and treated coal combustion streams confirms the mercury concentration measurements on the solid raw and treated coals providing good mass balance for mercury. Activated carbon addition helped in removing the residual mercury.
- The combustion of raw PRB subbituminous coal releases a very high fraction of elemental mercury, about 80 to 90%.

- The fraction of oxidized mercury increases when burning the same PRB Caballo coal after WRI treatment process. The absolute value of the oxidized fraction went up from 1.92 to 2.82 µg/Nm^3 and the normalized value goes up from 15% with raw coal to nearly 60% for the treated coal. Though the mechanism(s) for such favorable variation is not identified yet, it gives an opportunity for the plants operating with the treated fuel to remove much higher fraction of the mercury with sorbent injection or a wet FGD at the back end of the boiler.

Combined Mercury Removal Rates: Based on the limited PDU and pilot-scale testing, the mercury removal rates with the WRI-treatment and the potential co-benefit from conventional boiler backend systems with or without small addition of sorbents provided total removal in the 80-95% range for the subbituminous coal. Although the lignite tests have shown comparatively lower (50 to 57%) mercury evolution in the treatment process than in subbituminous coal (60+ %), further process optimization in the WRI process and the conventional boiler will also help the lignite-fired units to achieve higher total mercury removal. A plot of mercury removal rates achievable in WRI thermal treatment process is superimposed on the large scale test data from PRB coal-fired plants (Fig. 2.1.3). The rectangle shows the WRI mercury removal data with an activated carbon injection rate of 0 to 2.5 lb/MM acf.

Characteristics of Thermally Treated Coals: The treated coals exhibit some positive characteristics. In addition to the reduction of moisture, there is some evidence from this program and from other historical data of reduction in NOx, SO_2 and certain trace metals (arsenic and selenium). The treated coal also showed low losses of volatile matter, speculated to be principally CO_2 from the partial decarboxylation of these low rank coals. The Cl/Hg ratio has been found to increase in the treated coal. This higher Cl/Hg ratio implies that there may be an improvement in the chances for more oxidation of the elemental mercury in the treated coal as was observed in the PTC performance data.

Physical characteristics of the coals before and after thermal treatment show that the subbituminous coal becomes a little harder; the Hardgrove Grindability Index (HGI) goes down and there is no change in HGI for lignite. However, the fragmentation in subbituminous coal is more pronounced than in lignite.

Process Integration and Boiler Performance Impact Analysis: The intention is to integrate the WRI process at the power plant site. This facilitates a source of heat, avoidance of spontaneous combustion and dustiness, and can provide a use of the clean water produced by the WRI process for cooling tower or plant use. Two options can be considered as heat sources for drying and heat treatment of the coal, including an independent coal combustion and hot gas generation system or the use of boiler flue gas heat. The use of in-house boiler plant flue gas was analyzed in a preliminary integrated boiler flue gas flow design.. The performance behavior analysis of subsystems must be the subject of future work.

The benefits (in the power plant performance) resulting from WRI pre-combustion thermal treatment of coal on mercury control and overall plant performance improvement were also studied. With a typical reduction in coal moisture content from 28.2 to 5.4%, the loss due to sensible and latent heat in flue gas is reduced by about 43% (from 8.16 to 4.64%) resulting in boiler thermal efficiency improvement of 3.47%.(HHV). With increased boiler thermal efficiency and reduction in the flue gas, air and fuel flow rates, the auxiliary power consumption can be significantly reduced. Fuel flow can be reduced considerably due to removal of moisture in coal by nearly 25%, resulting in a reduced total energy for pulverizing. In addition, the reduction in oxygen content in the fuel enhances propensity for increasing the mill outlet temperature that in turn helps improve combustion efficiency and flame stability.

Commercial Potential Analysis: A major consideration of the WRI process is that the pre-combustion thermal treatment island can be added with little difficulty compared to adding or modifying the boiler island subsystems to achieve similar mercury control performance. An Electric Power Research Institute (EPRI)/ Washington Group International study compares the cost of mercury removal using the WRI process with the costs of the TOXECON configuration as the baseline. The results of the study indicate that the WRI process as a mercury removal option compares favorable for both low-rank coals as shown in Table 4.1.1.

Table 4.1.1. Comparison of Cost of Mercury Control Technology with WRI Process

Coal Type	Analysis Basis	% Reduction with WRI Technology
PRB	WRI Processed PRB	16.13
	Base Case (TOXECON)	
LIG	WRI Processed Lignite	27.50
	Base Case (TOXECON)	

In summary, the preliminary findings of the study have shown that the WRI process is capable of removing mercury before the fuel is fed into the combustor.

4.2 Summary of Prior Work by Other Participants and Organizations

Four of the current proposing organizations have been involved in the preliminary research effort of the process that was outlines in Section 4.1. Etaa Energy, Inc. has considerable processing and combustion experience and has been a partner in the development of the technology with WRI. The EERC has been involved in mercury control technology development for over a decade and in mercury measurements in utility units for nearly two decades. EERC was a participant in the combustion of the WRI treated product.

In addition to the state of the art know-how these two organizations possess on mercury control needs and the potential of the competing post-combustion technologies, Foster Wheeler North America Corp. (FWNA) and Washington Group International (WGI) have also joined in the current R&D effort. These two organizations are the leaders in the application and technology evaluation expertise respectively in the coal-based power generation application. FWNA has extensive experience in advanced coal based technology modeling. Similarly, WGI has extensive experience in plant costing of novel technologies scaled up for commercial application.

These same team members have proposed the DOE-awarded project to evaluate the WRI process for mercury removal using subbituminous and bituminous coals to which this proposal refers.

5.0 QUALIFICATIONS

Montana-Dakota Utilities and Western Research Institute have assembled a team including Etaa Energy (EE), EERC, Foster Wheeler North America (FWNA), and Washington Group International (WGI) that bring together professionals with science, engineering, and commercialization experience necessary to successfully perform the scope of the project as outlined above. Both Montana-Dakota Utilities and Western Research Institute are very qualified to conduct this project with expertise from EE, EERC, FWNA, and WGI in the area of emission technology development, boiler design and operation and cost estimation.

In addition, Etaa Energy, Inc. has considerable processing and combustion experience and has been a partner in the development of the technology with WRI. EERC has been involved in the preliminary combustion tests on the treated product and as such they have the knowledge and operating experience to conduct the proposed combustion tests. FWNA Corp. (FW) and Washington Group International (WGI) are the leaders in the application and technology evaluation expertise respectively in the coal-based power generation application. FWNA has extensive experience in advanced coal-based technology modeling. WGI has extensive experience in plant costing of novel technologies scaled up for commercial application. (This is the same team that will undertake the subbituminous companion study).

Key Personnel

Mr. Duane O. Steen of Montana-Dakota Utilities will manage the project. Western Research Institute will conduct the testing as outlined herein under the direction of Dr. Alan E. Bland, who will serve as the Principal Investigator. Mr. Jesse Newcomer of Western Research Institute and Kumar M. Sellakumar of Etaa Energy Inc will assist in directing key components of the testing program. Mr. Andrew Seltzer of Foster Wheeler will carry out the system integration performance studies on a 400-500 MWe lignite-fired plant. Mr. Bob Keeth of Washington Group will estimate the cost of the mercury removal technology and verify against the preliminary estimates and confirm the capability of the WRI process to achieve the DOE target. A brief description of the key personnel and their project responsibilities is provided below. Resumes of the key personnel are given in Appendix A.

Duane O. Steen: Mr. Steen is Director of New Generation Development in the Corporate Office of Montana-Dakota Utilities. Mr Steam was Administration and Special Projects Manger where he oversaw the accounting end of Montana-Dakota Utilities' power plants as well as to manage various projects. He has working on projects for utilization of coal ash, analysis of in-house and outside investment in future generation projects, and a number of economic development projects. Mr Steen joined Montana-Dakota Utilities in 1974 and has held various engineering and management positions in operation and performance analysis of lignite-fired plants. He has been results engineer and results supervisor at the Lewis and Clark Station, a 50-MW lignite-fired power plant. Mr. Steen will serve as Project Manager with NDIC. In addition, Mr. Steen will manage the MDU assessment of the integration of the process in lignite-fired power plants.

Alan E. Bland, Ph.D.: Dr. Bland is the Vice President of Waste and Environmental Management (W&EM) at the Western Research Institute. As Manager of W&EM, Dr. Bland is responsible for the administrative, budget, marketing and execution of projects to commercialize technologies in the waste and environmental management area. Current research, development and demonstration activities are directed at emissions controls (e.g., mercury) and ash management technology development for the utility industry (SYNAG™ and Ready-Fill™ technologies); reclamation techniques for the mining industry (Haz-Flote and MaxiAcid); coal bed methane produced water management for the CBM industry in the Powder River Basin; bioremediation technologies for the oil industry, both in the U.S. and in Egypt; and development of bio-refinery processes for waste biomass, producing fuel additives (ethanol) and other chemical products. Earlier, Dr Bland served as a research Manager at the Kentucky Center for Applied Energy Research (formerly Kentucky Energy Research Laboratory), involved in clean coal fuels and coal preparation. He is a co-developer of the Ken-Flote technology, a counter current column flotation technology for fine coal cleaning. Dr. Bland will be responsible for the overall project testing by WRI and will provide the point of reporting to MDU and thereby to NDIC. Dr. Bland will also be responsible for the technology enhancement assessments and will assist in the assessment of the data from the WRI testing and, other project participants.

Collin Greenwell, P.E.: Collin Greenwell is a Lead Engineer at Western Research Institute. Mr. Greenwell brings over 10 years of power plant engineering experience with Xcel Energy and Apogee. Mr. Greenwell has been involved in mercury monitoring and control at power plants, such as at Xcel Energy. Collin Greenwell will be responsible for the conduct of the bench-scale and PDU studies.

Kumar M. Sellakumar, Ph.D.: Dr Sellakumar is the President of Etaa Energy Inc , a consulting firm, on contract with Western Research Institute. Etaa Energy is involved in mercury control technology assessments and technology development, combustion of difficult fuels and development of air pollution control technologies for power plants. Prior to joining Etaa Energy

Dr. Sellakumar was with Foster Wheeler Power Group, New Jersey for about 15 years. He was Research Manager responsible for the development of fossil energy systems emission reduction technologies. He also consulted on boiler performance, fuels and combustion, boiler heat transfer, emission reduction technologies and ash management issues. Dr. Sellakumar will be responsible for the design and fabrication of the PDU, oversight of the combustion tests at the EERC, working with MDU, Foster Wheeler and Washington Group will assist in the integration of the technology in lignite-fired power plants and develop cost estimates for the commercial application of the technology.

Kevin Galbreath, Ph.D.: Dr. Kevin Galbreath is Research Manager responsible for the PC combustion testing of the WRI-treated coals on the EERC PC pilot unit. Mr. Galbreath has over 15 years of experience in fuels and combustion research including trace element transformations and speciation in fossil fuel conversion flue gases.

Andrew Seltzer: Mr. Andy Seltzer of FWDC is a Research Associate with over 25 years of engineering experience in design and analysis of heat and fluid transport systems and the development of advanced fossil fuel components including high efficiency, low NOx burners and boilers. He is currently the project manager on two DOE NETL contracts.

Robert Keeth: Mr. Robert Keeth of WGI will perform the design review and cost estimate of the commercial plant. Mr. Keeth has 27 years of experience in pollution control, utility plant design, operation, trouble shooting and economic evaluations. Mr. Keeth was involved in the EPRI-sponsored techno-economic evaluations of emerging mercury control technologies.

Facilities

Well instrumented test facilities, a bench-scale and two pilot-scale units, are available at WRI for Phases I of the project. The bench-scale facility uses a small fluid bed and mass-flow controlled inert gas for fluidization. The PDUs can handle up to 100lbs/hr of raw coal. Two coals have been tested on the 100lb/hr PDU in order to assess subsystems performance. Necessary heat exchanger for water harvesting has been added to the PDU. Since the test facilities are operational, no major new infrastructure needs to be created. Three representative coals of (1"x0) will be procured by WRI. The WRI has a full range of analytical and laboratory testing instruments available for use in its research programs. Key instruments have been identified that will be utilized in the project including Quick Silver Process Sentinel Elemental Mercury Monitor, Leco AMA 254 Total Mercury Detector, Thermo Environmental Instruments Model 42H NO-NO_2-NO_xAnalyzer, Clean Air FLW-5 SO_2/NO_x/CO/CO_2 Analyzer, and Schimadzu GC-14 Gas Chromatograph with TCD for H_2/CO/CO_2/O_2/N_2 . Air Pollution Testing, Inc. (Colorado) will perform OH mercury species measurements at WRI., if required

The EERC is well equipped for gas analyses, sample analyses, and sampling equipment needed to support the test activities. The EERC PCT facility, described in Section 2.2, includes an ESP, FF and SDA and an ACI system. The PCT is completely instrumented for process conditions and gas analyses. The EERC analytical facilities include a Mercury Analytical Laboratory and the Analytical Research Laboratory for routine and specialized analysis (including chlorine). The EERC has available three different CMMs for continuous mercury monitoring: a PS Analytical Sir Galahad, a Tekran, and a Nippon/Horiba DM-6.

For integrated performance analysis of 400-500 MWe utility employing the WRI-process for mercury removal, FWNA will use the established in-house thermal power plant system model (ASPEN). A 1-D furnace thermal model based on 3-D CFD simulation of an existing unit will be developed for the study. Similarly, WGI will use the Integrated Power Plant Cost model (IECCOST) for cost estimation.

6.0 VALUE TO NORTH DAKOTA

Lignite is a major source for power production and North Dakota has substantial quantity of this resource. Mercury emission from power plants that are regulated and may impact the current and future use of lignite. Lignite –fired plants have the most difficult challenge to control mercury because of very large fraction of elemental mercury species from the combustion process. A pre-combustion removal is the most optimum approach since it removes substantial quantity (50-70%) of the mercury in raw coal. The removal of moisture from the feed coal with WRI's process providing for increased efficiency of the power plant, thereby affecting COE and/or plant outplant. In addition, water harvesting from flue gas and the potential removal of arsenic and selenium can add to the benefits of the process to the utilities. The proposed effort will provide the most technically and economically viable process to control mercury emissions at levels mandated. Without a wide range of potential control options specific for low ranked coals, lignite use could significantly decrease as power plants switch to fuel sources that are more economical in the terms of fuel and emissions control costs. This may result in a significant negative impact on the lignite industry thus causing a loss of market share, which has a negative impact on the economy of North Dakota through loss of jobs in mining, transportation and power generation.

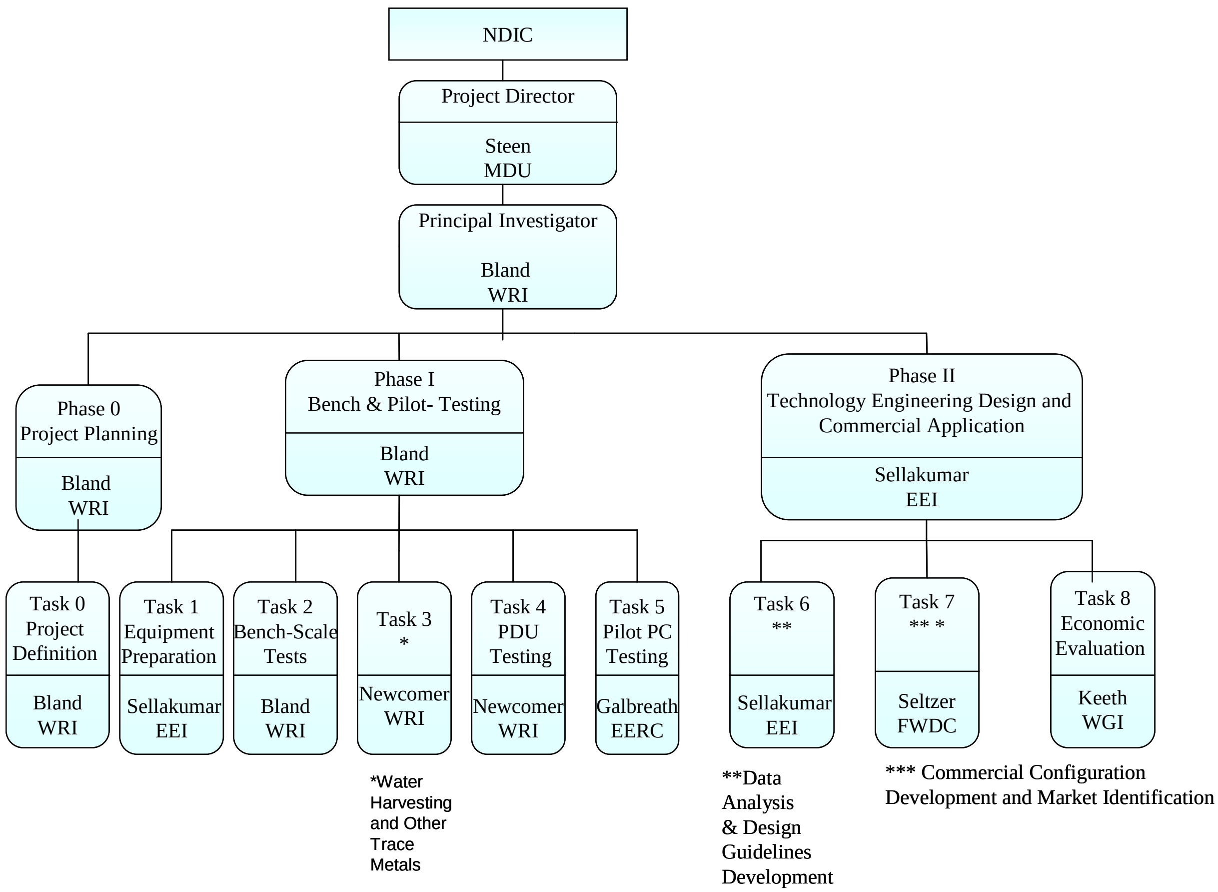
The overall goal of this program is to scale-up the WRI technology for the thermal pretreatment removal of mercury from lignite. Successful completion of this program will assess both the technical and economic viability of the WRI technology as an alternative process for controlling mercury emissions from coal-fired power plants. Successful deployment of this process would maintain or increase the market share for North Dakota lignite. Such deployment would result in significant environmental improvements, increase the potential use and market of North Dakota lignite as a fuel, and both create and preserve jobs in the lignite industry.

7.0 PROJECT MANAGEMENT

Mr. Duane Steen of Montana-Dakota Utilities will serve as the project manager for the NDIC project. Western Research Institute will conduct the testing as outlined herein under the direction of Dr. Alan E. Bland, who will serve as the WRI Principal Investigator. The project organizational chart is presented in Figure 7.1. Mr. Steen will be an integral part of the commercial-scale process integration activities, as well as project manager reporting to NDIC. The U.S. Department of Energy reporting will be through WRI's Jointly Sponsored Research Program administered by Dr. Vijay K. Sethi of WRI. Other key personnel include Mr. Collin Greenwell (WRI), Dr. Kumar M. Sellakumar (Etaa Energy), Dr Kevin Galbreath (EERC), Mr Andrew seltzer (Foster Wheeler) and Mr. Robert Keeth (Washington Group International). All reports, including Interim Reports, as well as the Final Report will be prepared by Dr. Bland with contributions from other key personnel.

7.1 Management, Coordination and Control Procedures/Systems. Dr. Bland will organize meetings/conference calls, as appropriate, to review the progress of the work. Research plans and findings at the conclusion of each phase of the work will be summarized and reported to the participating organizations. Key items include the selection of coal, mobilizing personnel resources, and setting test priorities in consultation with DOE addressed in monthly and quarterly reports to the DOE in accordance with RFP guidelines.

Fig. 7.1. Project Organizational Chart



Coal sampling and analyses will be carried out per ASTM procedures by qualified technicians and scientist/engineers, one of whom will be identified to follow the chain of custody procedures to maintain the integrity of samples at all steps. Data collection and storage will be handled by engineers and engineering technicians. Mercury sampling during the WRI PDU tests will be carried out by EPA-certified testing companies. The EERC will also follow QA/QC procedures based on ISO 9000 standards. During parametric testing, a minimum duration of 4 hours of steady state operation is contemplated. A completeness of 100% will be targeted on the key performance parameters. Data will be reviewed for reasonableness and any failed and incomplete tests may be repeated. All lab samples will be analyzed in duplicate and every tenth sample will be measured in triplicate. At the PC pilot combustor testing, mercury mass balance will be computed with target values of 100±20%.

7.2 Reporting

The project results will be reported to NDIC in three formats- Interim reports, Special reports and Final report. The Interim Reports will summarize the project's accomplishments and expenditures to date. Special Reports will be submitted if substantial progress on a project occurs earlier than anticipated. The Final Report will be a comprehensive one that will include a single page project summary describing the purpose of the project, the work accomplished, the project's results, and the potential applications of the project as required in the NDIC reporting guidelines. These reports will be submitted to North Dakota Industrial Commission and the U.S. Department of Energy after review by MDU and co-sponsors. The first quarterly report will be made to coincide with the U.S. DOE reporting schedule in order to minimize the reporting requirements. Teleconference calls with MDU personnel, WRI personnel, and NDIC will take place as the need arises. A draft Final Report on the project will be delivered May 31st 2009 with the finalized version due in June 30th 2009.

8.0 TIMETABLE

It is anticipated that the project will take approximately 24 months to complete with the following milestones (Fig. 8.1). Upon selection, the contract is expected to be finalized by June 30th, 2007. Based on this date, a project schedule has been developed that will also go in sequence with the DOE project that will progress on a similar completion schedule for subbituminous PRB fuels. Each milestone is indicated by the completion date.

Fig. 8.1. Project Schedule

Phase	Task Number	Milestone Activity	End of Months (Jul. 1, 2007- Jun. 30, 2009)											
			8	10	12	2	4	6	8	10	12	2	4	6
Phase 0	Task 0	Project Planning												
Phase I	Task 1	Coal Selection and Characterization												
	Task 2	Bench-Scale Testing												
	Task 3	PDU Testing												
	Task 4	Water Harvesting and Other Trace Metals Removal												
	Task 5	Pilot-Scale Combustion tests												
Phase II	Task6	Data Analysis and Design Guidelines Development												
	Task 7	Commercial Configuration Development												
	Task 8	Economic Evaluation												

9.0 BUDGET AND MATCHING FUNDS

The estimated cost to conduct the project as described in the proposal is $595,000. A summary of the project costs is presented in Table 9.1.

Table 9.1. Summary of Project Estimated Costs – Years 1 and 2

Cost Category	NDIC	U.S. DOE	Industrial Sponsors[1]	Total
Personnel (burdened[3])	$54,942	$114,765	$82,379	$252,086
Travel		$4,916		$4,916
Specialized Analytics	$21,384	$6,909		$28,293
Supplies and Materials		$2,250		$2,250
Subcontract – EERC	$90,000			$90,000
Subcontract – Etaa Energy		$47,906		$47,906
Subcontract – Foster Wheeler		$60,000		$60,000
Subcontract – Washington Group[2]				
Equipment				
G and A	$21,674	$38,254	$17,621	$77,548
In-kind Services and Personnel			$32,000	$32,000
Total Costs	$188,000	$275,000	$132,000	$595,000

1. Industry sponsors include Montana-Dakota Utilities, Basin Electric Power Cooperative., and SaskPower.
2. Subcontract for the WGI scope of work is covered in the companion subbituminous coal study. Results of that study will be made available as part of this contract.
3. Includes Fringe Benefits, Labor Overhead Costs, and G&A Overhead

The costs for the program are to be shared by industry co-sponsors (MDU, BEPC, Sask Power), NDIC, and WRI through its Cooperative Agreement with the U.S. Department of Energy National Energy Technology Laboratory (NETL). Industry co-sponsors will contribute $100,000 of cash and $32,000 of in-kind services and personnel costs associated with the process integration activities, as well as project management. It is requested that the NDIC provide $188,000. WRI and the U.S. DOE will match both the industry co-sponsors and NDIC funding for the amount of $275,000. Budget information, including the nature of the cost estimating procedures, is presented in Appendix B.

10.0 TAX LIABILITY STATEMENT

Neither Montana-Dakota Utilities nor Western Research Institute have any outstanding tax liability with the state of North Dakota. Affidavits are provided in Appendix C.

11.0 CONFIDENTIAL INFORMATION

None of the information presented in this proposal is considered confidential.

12.0 RELATED REFERENCES

Benson, S.A., Mackenzie, J.M., McCollor, D.P., and Galbreath, K.C., "*Mercury Control Technologies for Electric Utilities Burning Subbituminous Coals*", Task 73 Final Report, U.S.DOE Cooperative Agreement No. DE-FC26-98FT40321, June 2005, 137 p.

Bland, A., Sellakumar, K.M., Johnson, L., Walling, G., Steen, D., and Klunder, E., "*Beneficial Options for the Pre-Combustion Thermally Treated Subbituminous Coal: Initial Findings,*" 22nd Intl. Pittsburgh Coal Conf., Pittsburgh, Sep. 12-15, 2005

Bland, A.E., and Sellakumar, K.M., Invention disclosure entitled, "*Method and System for Harvesting Water from Coal Dryer Effluent Gas Using Coal Bed Methane Water and Using the Harvested Water in Power Plants,*" dated Oct. 25, 2006.

Bland, A., Newcomer, J., Sellakumar, K.M., Walling, G., Steen, D., and Klunder, E "*Pre-Combustion Thermal Treatment of Coal to Remove Mercury: Process Data Validation with Bench and Pilot-Scale Units – Preliminary Results,*" 20th (Intl.) Western Fuels Conf., Denver, CO, Oct. 24-26, 2006.

DOE., *Estimating Freshwater Needs to Meet Future Thermoelectric Generation Requirements,* DOE/NETL-2006/1235, August, 2006.

Ghorishi, S.B., Lee, C.W., and Kilgroe, J.D., "*Mercury speciation in combustion systems: studies with simulated flue gases and model fly ashes*." Paper presented at the 92nd Annual Meeting of Air & Waste Management Association, St. Louis, MO. June 20-24, 1999.

Guffey, F.D., A.E. Bland and Brown, T.H., "*Pre-combustion Removal of Mercury from Coal*" in Proc. of the 27th Intl. Conf. on Coal Utilization and Fuel Systems, Clearwater, FL, March 4-7, 2002.

Merriam, N., "*Removal of Mercury from Powder River Basin Coal by Low-Temperature Thermal Treatment,*" U. S. Department of Energy, Morgantown Energy Technology Center, DE-FC21-93MC30126, pg. 23, 1993.

Merriam, N.W., Grimes, R. W., and Tweed, R.E., "*Process for Low Mercury Coal*," US Patent 5,403,365, April 4, 1995.

Yan, R., Gauthier, D., Flamant, G., Peraudeau, G., Lu, J., Zheng, J. (2001) "*Fate of selenium in coal combustion: volatilization and speciation in the flue gas*" Environ. Sci. Technol. 35 1406-1410

APPENDICES

APPENDIX A: RESUMES OF KEY PERSONNEL

DUANE O. STEEN, P.E.

Director, New Generation Development, Montana-Dakota Utilities

400 North 4th Street, Bismarck, ND 58501

Ph: 701-222-7804 E-Mail: duane.steen@mdu.com

EDUCATION

B.S. Mechanical Engineering, North Dakota State University

Registered Professional Engineer in the state of North Dakota

EXPERIENCE

Director, New Generation Development - Corporate Office, Montana-Dakota Utilities. Earlier he was Administration and Special Projects Manager for Montana-Dakota Utilities where he oversaw the accounting end of Montana-Dakota Utilities' power plants, as well as manage various projects. Currently working on projects for utilization of coal ash, analysis of in-house and outside investment in future generation projects, and a number of economic development projects.

In 1974 Mr. Steen was Results Engineer at the Lewis and Clark Station, a 50-MW lignite-fired power plant. Shortly after joining MDU, he was promoted to Results Supervisor, where he was responsible for engineering and supervision of the Instrument and Control group, as well as the Electrical Maintenance group.

In 1979, Steen accepted a position as Operations Coordinator in the Power Production Department at Corporate Headquarters. In this position, he was responsible for supervision of the Power Production Departments' engineers, which assist the various Montana-Dakota power plants.

Steen accepted the position of Station Superintendent at the Lewis and Clark Station in 1984. In 1985, he transferred to the R. M. Heskett Station as Station Manager. In both positions he was responsible for the overall operation of these two coal-fired generating units. The R. M. Heskett Station is a two-unit lignite-fired plant consisting of a 20-MW unit and a 66-MW unit. As Station Manager at the R. M. Heskett Station, Steen was directly involved with the conversion of the 66-MW stoker-fired unit to an 80-MW fluidized-bed combustion unit. His responsibilities included initial design review, on-site construction supervision, start-up, and operation.

Duane Steen is a professional engineer in the state of North Dakota and has more than 25 years experience in the power generation industry, including lignite coal-fired fluidized-bed combustion.

ALAN E. BLAND, Ph.D.

465 North 9th Street, Laramie, Wyoming 82072

Ph: 307-721-2386 Cell: 307-760-8090 E-Mail: abland@uwypo.edu

EDUCATION AND TRAINING

B.S. Geology, St. Lawrence University, 1970

M.S. Geology/Geochemistry, University of North Carolina, 1972

Ph.D. Geology/Geochemistry, University of Kentucky, 1978

RESEARCH AND PROFESSIONAL EXPERIENCE

Western Research Institute, Laramie, WY 82072 1991-Present

Vice President, Waste and Environmental Management, 2004 to present

Dr. Bland is responsible for the technical services provided by WRI in the areas of air pollution control including mercury control technology development and combustion and energy system design and performance studies. He has over 30 years of experience in research and product development and commercialization of new technologies. Dr. Bland currently is leading DOE-funded programs that address pre-thermal treatment of coal to remove mercury from coal, measure and analyze mercury emission from subbituminous coal-fired stations and develop methods of calibrating mercury CEMs. Dr. Bland also oversees a program that addresses uses for the produced water from coal bed methane (CBM) development.

Business Unit Manager - Waste and Environmental Management, 2000 to 2004.

As Business Unit Manager, Dr. Bland was responsible for the developing and commercializing technologies in the waste and environmental management area, including:

- Ash management options for utilities (SYNAG™ and Ready-Fill™ technologies);

- Environmental remediation at mines (Haz-Flote, MaxiAcid and BioEnhanced Acid Mine Drainage Mitigation (BEAMMit)) for metals-contaminated mine drainage being demonstrated in Tennessee; and a patent-pending bioremediation technology development for oil-contaminated sites in the U.S. and Egypt;
- Developing and commercializing a patented mercury control process at coal-fired utilities;
- Environmental instrumentation and sensor development resulting in commercial deployment of Diesel Dog, and EnChem and En Novative Samplers, and the X-Wand for environmental cleanup applications.

Program Manager – Waste Management, Western Research Institute, 1991-2000.

Dr. Bland was responsible for a range of research and development programs related to advanced ash management concepts for solid waste including the emerging clean coal technologies as well as hazardous wastes. Dr. Bland is also responsible for a unique flowable fill material, such as Ready-Fill™ technology, a joint venture between WRI and Montana-Dakota Utilities.

Technical Director and Co-Owner – Ash Management Engineering Inc., 1988-1991.

Dr. Bland was responsible for advanced ash management systems for the power plants, including the process design and construction of a first-of-a-kind 60-ton/hour ash pelletizing plant for the AES Thames facility in Connecticut. (co-patent holder on process).

Clean Coal Fuels Program Director - Kentucky Energy Cabinet Laboratory, 1983-1987. Responsible for research and development activities in coal preparation and processing equipment performance studies, coal processing computer simulations, fine coal cleaning for synthetic fuels and coal water slurry fuels applications, fluidized bed combustion of coal cleaning wastes for energy recovery and cogeneration applications, and production of coal ash based concrete and construction materials for mining and commercial construction applications. Developed and commercially deployed a counter-current column flotation coal cleaning technology (Ken-Flote).

PROFESSIONAL ACTIVITIES

American Chemical Society: Environmental Chemistry and Fuel Section

American Coal Ash Association - Representative for Western Research Institute

International Conference on Fluidized Bed Combustion, Steering Committee

Subbituminous Energy Coalition, Chair, 2004-2005, Vice Chair 2003-2004

Western Region Ash Group Member since 1994

PUBLICATIONS

Bland, A., Sellakumar, K.M., Johnson, L., Walling, G., Steen, D., and Klunder, E., "*Beneficial Options for the Pre-Combustion Thermally Treated Subbituminous Coal: Initial Findings,"* 22nd Intl. Pittsburgh Coal Conf., Pittsburgh, Sep. 12-15, 2005

Bland, A., Sellakumar, K.M., Johnson, L., Walling, G., Steen, D., and Klunder, E., "*Mercury Control at Low Rank Coal-fired Power Plants by a Pre-Combustion Thermal Treatment Process: Techno-Economic Study,"* Air Quality V, Washington D.C., Sep. 19-21, 2005.

Bland, A., Sellakumar, K.M., Guffey, F., Walling, G., Steen, D., and Klunder, E., "*Mercury Control at Low Rank Coal-fired Power Plants by a Pre-Combustion Thermal Treatment Process*" 19th Intl. Conf. on Lignite, Brown, and Subbituminous Coals, Oct. 12–14, 2004.

Bland, A., Sellakumar, K.M., Guffey, F., Walling, G., Steen, D., and Klunder, E., "*A Novel Approach to Mercury Control by Pre-Combustion, Thermal Treatment of Low-Rank Coals,"* AWMA's 97th Annual Conf., Indianapolis, IN, June 22-25, 2004

Bland, A., Sellakumar, K.M., and Kormylo, C., "*Mercury Emissions Testing at Power Plants Burning Subbituminous Coals,"* 19th Intl. Conf. on Lignite, Brown, and Subbituminous Coals, Oct. 12–14, 2004.

SELECTED PATENTS

Dr. Bland has been issued four U.S. patents and has submitted a number of patent applications.

KUMAR M. SELLAKUMAR, Ph.D.

240 Longview Road, Bridgewater, New Jersey 08807

Ph: 908- 252-9650 Cell: 908-872-5459 E-Mail: ksellakumar@etaaenergy.com

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EDUCATION AND TRAINING

B. S., Mechanical Engineering, University of Madras, Chennai, India (1970)

M. S., Design of Thermal Power Equipment, University of Madras, Chennai, India (1972)

M. S. (1982) **and Ph.D., Energy Science**, New York University, New York (1988)

RESEARCH AND PROFESSIONAL EXPERIENCE

Etaa Energy, Inc. Bridgewater, New Jersey **2003-Present**

President.

Dr. Sellakumar is responsible for the technical services provided by the company in the areas of air pollution control including mercury control technology development and combustion and energy system design and performance studies. He has over 30 years of experience in research and product development and commercialization of new technologies. His current projects include pre-thermal treatment of coal to remove mercury, measure and analyze mercury emission and control in subbituminous coal fired stations and evaluate novel mercury removal technologies.

Foster Wheeler Development Corporation, Livingston, New Jersey **1988-2003**

Product Development Manager, 1997-2003

Dr. Sellakumar was responsible for the development of fossil energy systems emission reduction technologies. He also consulted on boiler performance, fuels and combustion, boiler heat transfer, emission reduction technologies and ash management issues. He was actively involved in the development of reliable hot gas filter systems for clean coal projects and has been playing a pioneering role in the testing and development of various types of particulate and gas cleaning system, combustor/gasifier-filter-gas turbine system integration, material selection and new energy technologies development including multi-fuel applications. He was a key individual in providing technical input to commercial designs.

<u>Assistant Research and Development Manager</u>, 1993-1997

- Conceptualized, built and successfully demonstrated a pilot–scale (15000 lb/hr) material transfer and cooling system to handle pressurized hot solids (800-1600ºF) to low-pressure, low-temperature vessels. Two patents awarded. Commercial design developed.
- Tested Gas Turbine (GT) materials for coal-based energy systems.

<u>Research Specialist</u>, 1990-1993

- Evaluated and developed hot flue gas cleanup systems for combined cycle power plants. Technology development has reached the commercial threshold. Two patents awarded.
- Successfully managed clean coal projects funded by the DOE and Illinois Clean Coal Research Institute/Electric Power Research Institute. Contract values ranged from $0.16m to $3m.

<u>Research Engineer</u>, 1988-1990

- Saved the company $0.1m by designing a Distributed Control System configuration and graphics (Bailey Network 90) and training engineers.
- Conducted pilot tests and developed process design parameters for burning gob in CFBs.

Prior to joining Foster Wheeler in 1988, Dr Sellakumar worked at BHEL, India (1972-1983) and at New York University, New York (1983 and 1988) in energy and pollution control R&D.

PROFESSIONAL ACTIVITIES

Life Member, Association of Energy Engineers, Atlanta

Past member,

- Executive Committee, and Director, Particulate Solid Research Institute, Chicago,
- Council of Ind. Boiler Owners (CIBO) Energy and Env. Committees, Washington D.C.
- Iowa State University Research Center Program Review Panel.

- Clean Coal Technology and Boiler Specialist in the US DOE Team - India-U.S. "Coal Advisory Group" Meetings, April 2003, Washington DC and November 2004 and April 2006, New Delhi.

PUBLICATIONS

Bland, A., Sellakumar, K.M., Johnson, L., Walling, G., Steen, D., and Klunder, E., "*Beneficial Options for the Pre-Combustion Thermally Treated Subbituminous Coal: Initial Findings,*"22nd Intl. Pittsburgh Coal Conf., Pittsburgh, Sep. 12-15, 2005

Bland, A., Sellakumar, K.M., Johnson, L., Walling, G., Steen, D., and Klunder, E., "*Mercury Control at Low Rank Coal-fired Power Plants by a Pre-Combustion Thermal Treatment Process: Techno-Economic Study,*" Air Quality V, Washington D.C., Sep. 19-21, 2005.

Bland, A., Sellakumar, K.M., Guffey, F., Walling, G., Steen, D., and Klunder, E., "*Mercury Control at Low Rank Coal-fired Power Plants by a Pre-Combustion Thermal Treatment Process*" 19th Intl. Conf. on Lignite, Brown, and Subbituminous Coals, Oct. 12–14, 2004.

Bland, A., Sellakumar, K.M., Guffey, F., Walling, G., Steen, D., and Klunder, E., "*A Novel Approach to Mercury Control by Pre-Combustion, Thermal Treatment of Low-Rank Coals,*" AWMA's 97th Annual Conf., Indianapolis, IN, June 22-25, 2004

Bland, A., Sellakumar, K.M., and Kormylo, C., "*Mercury Emissions Testing at Power Plants Burning Subbituminous Coals,*" 19th Intl. Conf. on Lignite, Brown, and Subbituminous Coals, Oct. 12–14, 2004.

Wu, S., Hiltunen, M., and Sellakumar, K.M. "*Combustion of Pitch and Related Fuels in Circulating Fluidized Beds,*" CFB-7, Niagara Falls, Canada, May 5-8, 2002

Manjunath, A., Cotton, J., Ekambaram, A., Sellakumar, K.M. and Palonen, J., "*Efficient and Clean Biomass Gasification and Combustion Technologies for Bagasse'*" Int. Workshop on Alternative Bagasse Cogeneration, New Delhi, Feb. 27, 1999.

SELECTED PATENTS

Dr. Sellakumar holds seven US patents.

COLLIN GREENWELL, P.E.

13672 W. 64th Drive, Arvada, CO 80004

Ph: 303-475-5844 E-Mail: collingreenwell@aol.com

EDUCATION

Chemical Engineering – Bachelor of Science University of Wyoming 1998

EXPERIENCE

Sr. Production Engineer 1999 – 2007

XCEL ENERGY GOLDEN, COLORADO

- Responsible for oversight of the emissions source sampling assessment and auditing groups including supervision of engineers, technical specialists, and interns within the department. Primarily responsible for coordinating, scheduling, and ensuring completion of all regulatory required emissions certifications for the Colorado based electric power generating facilities owned and operated by Xcel Energy.
- Coordinated and reported on various air pollution surveys at the facilities including particulate matter (PM) quantification for Title V Operating Permits, acid aerosols and mercury (Hg) source sampling and mass balance, carbon monoxide (CO) after low-NOx burner (LNB/OFA) installation, compressor engine compliance testing, dry sorbent injection performance testing, and lime spray dryer (SDA) acceptance testing.
- Participated on several problem solving teams and represented the business unit at the annual awards exhibition. Total savings realized exceed $4 million in credits, $300,000 in feedstock, and $200,000 in O&M annually for each of three previous projects. Implemented management principles and procedures to maximize operating efficiencies

by diagnosing problems, identifying needs, proposing changes, and tracking solutions. Reduced the departmental O&M budget by 40% and improved the success rate by 110%. Also optimized the process with issuance of schedules, protocols, and tracking of performance and results indicators

Site Engineer 1998 – 1999

Halliburton - HES Casper, Wyoming

- Engineer for the tools, testing, tubing conveyed perforating and completion product services department. Primarily responsible for daily operations of data acquisition services for the Rocky Mountain Region.
- Maintained a central support facility including technical advising and product technical support in addition to programming, download/uploading, analysis, technical report writing, revenue tracking, procurement and maintenance.

Senior Associate Engineer 1996 - 1997

ADA TECHNOLOGIES, INC. ENGLEWOOD, COLORADO

• Completed the design (including as built PFD, P&ID), materials procurement and construction of a mercury monitoring and removal pilot-scale unit with a team of engineers and technicians. Aided in the design and construction of pilot-scale pollution control and monitoring instrumentation for CAA Title III hazardous air pollutants (HAPs) focusing on vapor phase mercury.

- Provided field service engineering at U.S. DoE facilities during testing and implementation processes.

- Research: Roberts, et. al., "Novel Process for Removal and Recovery of Vapor Phase Mercury," Phase 1 Final Report, Department of Energy, Federal Energy Technology Center, 30 July 1997.

Engineering Lab Technician 1996

CHA CORPORATION LARAMIE, WYOMING

- Performed testing of air pollution abatement technologies for diesel engine exhaust utilizing various absorbents.
- Utilized Camile® (Dow Chemical) software system and laboratory instrumentation for data acquisition.
- Constructed and aided in the design of pollution control equipment for NOx and SO_2 removal utilizing activated carbon and microwave absorbent regeneration technology.

ANDREW SELTZER

Research Project Manager, Foster Wheeler North America Corp.

12 Peach Tree Hill Rd, Livingston NJ 07039

Ph: (973) 535-2200 E-Mail: Andrew_seltzer@fwc.com

EDUCATION

B.S. (1979) Mechanical Engineering from the Cornell University

PE- State of New Jersey

EXPERIENCE

Mr. Seltzer is a Research Associate with over 25 years of engineering experience in design and analysis of heat and fluid transport systems and components in the power and process industries. He is responsible for the development of advanced fossil fuel components including high efficiency, low NOx burners and boilers. He is currently the project manager on two DOE/NETL contracts, The Conceptual Design of an Oxygen-Based Pulverized Coal Boiler, and the Conceptual Design of an Oxygen-Based Supercritical Pulverized Coal Boiler.

Mr. Seltzer has performed extensive 3D computer simulations of combustion in commercial and developmental (including HIPPS and High Pressure Coal Combustion Kinetics programs) PC and CFB coal-fired furnaces using FW-FIRE, Fluent and CFX. He has also designed and tested novel heat exchangers, including syngas coolers for coal gasification applications, and developed software to design and analyze shell and tube and finned heat exchangers and utility boilers. Previously, Mr. Seltzer was Supervisor of Performance Engineering of the Heat Transfer Products Department, where he was responsible for the supervision of all Heat Recovery Steam Generator (HRSG) performance engineering and component design and developed extensive HRSG computer programs for product design and performance prediction.

PUBLICATIONS

Mr Seltzer has published over fifteen technical papers on heat transfer, fluid flow, heat exchangers, and combustion and holds two patents.

KEVIN C. GALBREATH

Research Scientist, Energy & Environmental Research Center (EERC)

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Phone (701) 777-5000 Fax (701) 777-5181 E-Mail: kgalbreath@undeerc.org

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EDUCATION

M.S., Geology, South Dakota School of Mines and Technology, 1987.

B.S., Earth Science, North Dakota State University, 1984.

PROFESSIONAL EXPERIENCE

Mr. Galbreath's principal areas of interest and expertise include trace element transformations and speciation in fossil fuel conversion flue gases and the thermal metamorphism of coal mineral matter.

2001 –Research Manager, Environmental Health, Energy Conversion Systems Group, EERC, UND. Procure and supervise projects involving trace metal emissions and characterization, ambient air quality, and inhalation health effects.

1997 –Manager, Sampling and Analytical Methods Development Program, Center for Air Toxic Metals®, EERC, UND. Procure and supervise projects involving trace metal emissions and characterization, ambient air quality, and inhalation health effects.

1994 – 2001 Research Associate, Fuels Performance, EERC, UND. Mr. Galbreath's responsibilities include conducting research on fuels and their combustion and gasification by-products, investigating such topics as fuel quality assessment and production, ash and deposit formation mechanisms, and trace element emissions. He employs full-, pilot-, and bench-scale combustion and gasification systems in solving fundamental problems related to fuel utilization.

1991 – 1994 Research Associate, Natural Materials Analytical Research Laboratory, EERC, UND. Mr. Galbreath's responsibilities included maintaining, operating, and supervising the use of scanning electron microscopes (SEMs) and image analysis systems. He provided analytical support for research programs and developed and applied automated SEM and image analysis techniques.

1990 – 1991 Research Specialist, Inorganic Analytical Research Laboratory, EERC, UND. Mr. Galbreath's responsibilities included operating and maintaining an automated x-ray diffractometer and an energy-dispersive x-ray fluorescence spectrometer and performing mineralogical and chemical analyses on coal, coal combustion products, and related materials.

1988 – 1990 Manager, AA/ICP and Chemistry Laboratories, Engineering and Mining Experiment Station, South Dakota School of Mines and Technology. Mr. Galbreath's responsibilities included operating, maintaining, and supervising the use of an AA/ICP spectrophotometer system and performing chemical analyses on a variety of materials (e.g. ores, wastewaters, manufactured products, solid wastes) for the academic, private, and public sectors.

PROFESSIONAL MEMBERSHIPS

- Air & Waste Management Association, 1998, 1999, 2001, and 2002
- Mineralogical Society of America, 1984–1999
- Geological Society of America, 1983–1987

RELEVANT MERCURY PUBLICATIONS

Galbreath, K.C.; Zygarlicke, C.J. Mercury Speciation in Coal Combustion and Gasification Flue Gases. *Environmental Science & Technology* **1996**, *30 (8)*, 2421–2426.

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ROBERT J. KEETH, PE

Project Engineering Manager, Washington Group International

7800 E. Union Avenue, Suite 100, Denver, Colorado 80237

Phone: (303) 843-3179 E-Mail: Robert.Keeth@wgint.com

EXPERIENCE SUMMARY

Mr. Keeth has more than 29 years of experience working in all areas of sulfur oxides, nitrogen oxide, mercury and particulate control systems, including pilot plant and full-scale utility design, operation, troubleshooting and economic evaluations. Mr. Keeth has published more than 50 reports and papers dealing with the technical and economic evaluations of air pollution control technologies, including the EPRI "Economic Evaluation of FGD Systems", "Opacity and Mist Eliminator Trouble-shooting Guidelines", "FGDCOST Model & User's Manual", "Integrated Emissions Control – Process Reviews" and the "IECCOST Model & User's Manual."

Recent work has included projects for multiple utility clients to develop the most cost-effective compliance strategies to meet future air pollution control regulations. Current projects focus on the development of economic models used to develop capital and operating cost estimates for both circulating fluid bed boilers, as will as integrated emissions control systems including both commercial and developing control technologies for NOx, SO_2/SO_3, mercury, CO_2 and particulate emissions from fossil fuel fired power generating plants.

Recently completed the evaluation of more than 50 developing technologies capable of multi-pollutant control within a single system. Also managing projects that provide utility clients with economic models to evaluate system-wide compliance options based on any future set of regulatory requirements for all primary pollutants.

Professional Engineer in Colorado – P.E., #33764

APPENDIX B

BUDGET DETAILS

Amount Requested from Funding Sources

The University of Wyoming Research Corporation, d.b.a. Western research Institute (WRI), proposes to perform the work described in the technical proposal for a total project cost of $595,000, including $132,000 from Montana-Dakota Utilities, Basin Electric Power Corporation, $275,000 from United States Department of Energy, National Energy Technology Center under WRI's Cooperative Agreement Jointly Sponsored Research Program, and $188,000 from North Dakota Industrial Commission. Industry co-sponsors (MDU and SaskPower) and participants (FWNA and Etaa Energy) are providing $32,000 of in-kind services and personnel. Detailed cost estimates for NDIC, U.S. DOE NETL, and industrial cosponsors are shown in EXHIBIT A.

Estimating Procedures

Labor Costs – Western Research Institute's (WRI's) budget identifies labor categories, labor hours and hourly labor rates for those identified to perform the work described in the technical proposal. Labor rates are based on the actual hourly labor rate, when an individual is identified to perform the work, or the hourly labor rate (30^{th} percentile of the appropriate labor category), when an individual is not identified. As a baseline, actual hourly labor rates are based upon rates paid to employees for the most recent month.

Salary Increase Provision -- The Institute applies a salary increase provision to direct labor cost estimates. The estimated salary increase provision is five percent compounded by year.

Travel Costs -- The Institute uses currently applicable Institute or Federal Travel Regulation (FTR) rates for estimating ground transportation and subsistence costs (lodging, meals, and incidental expenses) for employee travel.

Equipment Costs -- For equipment estimates, the Institute uses vendor quotes, catalog prices, historical costs, costs from current invoices or the professional judgment of task managers from contracts of a similar nature. Freight, postage, and tax are included in the equipment price estimates.

Supply Costs -- For supplies, materials, or parts estimates, the Institute uses vendor quotes, catalog prices, historical costs, costs from current invoices or the professional judgment of task managers from contracts of a similar nature.

Contractual (Subcontract) Costs -- For estimates of contractual (subcontract) costs, the Institute uses subcontractor proposals, vendor quotes, historical costs, costs from current invoices or the professional judgment of task managers from contracts of a similar nature.

Other Direct Costs -- For each other direct cost (ODC) proposed, the Institute uses technical input on the anticipated costs for such items, or the Institute uses vendor quotes or catalog prices. Other direct costs may include, but are not limited to, analytical services, vehicle use, computer software, dry ice and liquid nitrogen, freight and postage, maintenance and repair, printing and reproduction, and rents and leases.

Indirect Costs – The indirect costs in WRI's budget are estimated using WRI's Fiscal Year 2007 provisional indirect cost rates. WRI's indirect rates for the fiscal year 2007 shown in EXHIBIT A were used in the preparation of this cost estimate. The indirect rates and their allocation base are shown in Attachment C and summarized below.

Fringe Benefits:	46.43% applied to direct salary
Labor Overhead	68.90% applied to direct salary
G & A Overhead	21.39% applied to Modified Total Direct Costs (MTDC) MTDC is defined as the total costs incurred, excluding G&A expenses, subcontracts exceeding $25,000 in cumulative cost, and Capital Equipment exceeding $25,000.

The U.S. Department of Energy (DoE), National Energy Technology Laboratory, WRI’s cognizant Federal agency, approved the Fiscal Year 2007 provisional indirect cost rates in a letter dated July 17, 2006. The Fiscal Year 2007 Provisional Billing/Bidding Rate Agreement is included as EXHIBIT A.

EXHIBIT A

FY 2007 Provisional Billing/Bidding Rate Agreement

PROVISIONAL BILLING / BIDDING RATE AGREEMENT

Awardee: Western Research Institute
365 No. 9th Street
Laramie, WY 82070-3380

Applicable
Period: July 1, 2006 through June 30, 2007

The U.S. Department of Energy hereby approves the following provisional rates for billing purposes as requested by your letter dated May 26, 2006. The rates are approved for your **Fiscal Year 2007** beginning July 1 and ending June 30, and supersede any prior approvals.

INDIRECT COST RATES:

Indirect Cost Pool	Billing Rate	Allocation Base
Benefits	46.43%	(a)
Labor Overhead	68.90%	(b)
General & Administrative	21.39%	(c)

BASIS FOR ALLOCATION:

(a) Total Labor Dollars
(b) Total Direct Labor Dollars
(c) Modified Total Direct Cost (MTDC)

Notes:

1. MTDC is defined as total costs incurred, excluding G&A expenses, subcontracts exceeding $25,000 in cumulative cost, and Capital Equipment exceeding $25,000.

Pending establishment of final indirect cost rates, you may bill for indirect expenses using the above rates for the period specified for existing Government contracts, grants, or cooperative agreements. However, this approval shall not change any monetary ceiling, contract obligation, or specific cost allowance or disallowance provided for in such awards. Additionally, if any award contains indirect rate ceilings, and these ceilings are less than the above rates, the lesser rates shall prevail.

Acceptance of these provisional rates for billing purposes does not imply final acceptance nor commit the Government to any specific rate in final rate negotiations.

Nothing herein shall be construed to prejudice, waive, or in any other way affect any rights of the Government under the provisions of any contracts, grants, or other cooperative agreements respecting limitation of the Government's obligation thereunder.

This agreement is effective as of the date of this letter. Questions regarding this agreement should be directed to my attention as indicated in the footer on the cover page of this correspondence.

For the U.S. Department of Energy:

Andrew J. Ferlic
Cognizant Contracting Officer
Indirect Cost Rate Management

JUL 17 2006
Date

Attachment A

Detailed Cost Estimate

DETAILED COSTS AND JUSTIFICATION

Personnel – The distribution of personnel costs for the project are detailed in the budget attachment.

Travel Costs – Costs associated with the attendance of the Principal Investigator to attend and present the project results and a DOE Mercury Contractors meetings and Air Quality Conference. Estimated costs are $4,916.

Supplies and Analytical Costs – Costs include the costs for supplies for analytical, office supplies and bench and PDU operations. Also includes the costs for shipping of the coals to WRI and shipping of the product to EERC for combustion tests. Also included are the costs for analytics performed by WRI or externally. These costs are being shared between all of the participants. Estimated costs are $30,545.

Subcontractor Costs – Subcontractor costs arise from three distinct subcontracts as defined below. These costs do not include G&A.

Etaa Energy of Bridgewater NJ will be contracted by WRI for engineering services in each of the tasks related to the scope of work. NDIC is NOT being asked to contribute to the costs from this subcontract. These costs are being paid by U.S. DOE, through the WRI/DOE Cooperative Agreement. Etaa Energy is also contributing $16,000 if in-kind services. Estimates costs are $47,906.

EERC of Grand Forks North Dakota will be contracted for combustion tests at their facility using the EERC PTC 550,000 Btu/hr Combustion Unit. This also includes the associated analytical costs and the issuance of a report of the testing. This subcontract would be funded with NDIC funds. Estimated costs are $90,000.

Foster Wheeler North America will be contracted to provide engineering services associated with Task 7 relative to assess and modeling the integration of the process in a lignite fired power plant. This subcontract will be funded with DOE funds through the WRI/DOE Cooperative Agreement. Foster Wheeler North America will contribute $7,000 of in-kind engineering services. Estimated costs are $60,000.

Washington Group International will be contracted under the subbituminous companion study. As such, this subcontract is not shown in the detailed budget. The estimated costs are $60,000.

Equipment – No equipment is to be bought under this project.

Attachment B

Tax Liability Affidavits – MDU and WRI

WESTERN RESEARCH INSTITUTE
"Providing solutions to energy and environmental problems"
365 No. 9th St., Laramie, WY 82072-3380 • Phone: (307) 721-2011 • Fax: (307) 721-2345

March 29, 2007

Mr. Duane O. Steen
Director, New Generation Development
Montana-Dakota Utilities
400 North Fourth Street
Bismarck, ND 58501

Dear Mr. Steen:

This letter certifies that, to the best of my knowledge, the University of Wyoming Research Corporation d/b/a/ Western Research Institute of Laramie, Wyoming, does not have any outstanding tax liability with the state of North Dakota.

Sincerely,

Terry P. Roark, Ph.D.
Interim Chief Executive Officer

"Leadership in energy and environmental technology"

Attachment C

Letter of Commitment – WRI

WESTERN RESEARCH INSTITUTE
"Providing solutions to energy and environmental problems"
365 No. 9th St., Laramie, WY 82072-3380 • Phone: (307) 721-2011 • Fax: (307) 721-2345

March 29, 2007

Mr. Duane O. Steen
Director, New Generation Development
Montana-Dakota Utilities
400 North Fourth Street
Bismarck, ND 58501

Dear Mr. Steen:

This letter is to confirm the intention of the University of Wyoming Research Corporation d/b/a/ Western Research Institute, to cofunding of the project entitled **"Demonstration of WRI's Pre-Combustion Mercury Removal Process for Lignite-Fired Power Plants"** through our Jointly Sponsored Research Program with the U.S. Department of Energy (DOE), National Energy Technology Laboratory. The level of this cofunding commitment is $275,000.

This funding commitment is contingent upon approval of the project by the DOE, funding by the North Dakota Industrial Commission and Montana-Dakota Utilities, as well as the availability of funds from these entities.

We look forward to continuing to work with you on this important research and wait to hear from you on the proposal to North Dakota Industrial Commission.

Sincerely,

Terry P. Roark, Ph.D.
Interim Chief Executive Officer

pc: Alan E. Bland, WRI
Vijay K. Sethi, WRI
File

"Leadership in energy and environmental technology"

Attachment D

Letter of Commitment – Industry Co-sponsors

BASIN ELECTRIC
POWER COOPERATIVE

1717 EAST INTERSTATE AVENUE
BISMARCK, NORTH DAKOTA 58503-0564
PHONE 701-223-0441
FAX: 701/224-5336

September 6, 2005

Mr. Alan E. Bland
Vice President
Western Research Institute
365 North 9th Street
Laramie WY 82072

Dear Mr. Bland:

Subject: Letter of Interest and Financial Commitment for the Proposal by the WRI to the U.S. Department of Energy's (DOE) Solicitation No. DE-PS26-05NT42510-04

As Senior Vice President of Generation of Basin Electric Power Cooperative (BEPC), I am pleased to submit this letter of support and interest to participate in the testing activities that are described in Western Research Institute's (WRI) proposal "Pilot Testing of WRI's Novel Mercury Control Technology by Pre-Combustion Thermal Treatment of Coal" being submitted under DOE Solicitation No. DE-PS26-05NT42510-04.

Basin Electric has a particular interest in this program because we own and operate multiple units firing lignite and subbituminous coal. We believe there is a need to examine strategies for removing mercury from coal prior to combustion. The approach proposed allows the industry to test whether this mercury control technology is a feasible option that can be considered for meeting regulations with or without post-combustion sorbents.

Basin Electric is pleased to offer support to the proposed program in the form of cash cost share valued at $40,000. We will request $20,000 of this from EPRI in tailored collaboration funds. It is understood that Basin Electric's funding for this project will provide cost share to federal funding from DOE; therefore, Basin Electric hereby certifies that our cost-share funding will be comprised of nonfederal dollars and will not be used as federal match on any other project.

Bob Eriksen, Basin Electric's Environmental Compliance Administrator, is serving as project manager for our mercury control test programs. Please coordinate this test program with Bob at (701) 355-5654 or beriksen@bepc.com.

We hope that DOE gives careful consideration to this program, as there is a significant need for field data applicable to low-rank coals. Again, we express our support and look forward to working with DOE and WRI on this project.

Sincerely,

Wayne Backman

Wayne Backman

cc: Bob Eriksen
Bob Boettcher
Mike Paul

(Note: The contributions are divided 50:50 between the two companion studies. $20,000 budgeted to this proposal)

MONTANA-DAKOTA
UTILITIES CO.
A Division of MDU Resources Group, Inc.

400 North Fourth Street
Bismarck, ND 58501
(701) 222-7900

September 12, 2005

Alan E. Bland, Ph.D.
Vice President
Western Research Institute
365 North 9th Street
Laramie, WY 82072

Sub: DE-PS26-05NT42510-04 – Cost Share Commitment Letter

Dear Dr. Bland,

We are please to submit this letter of support and commitment by Montana-Dakota Utilities (MDU) to cosponsor WRI's proposal entitled "Pilot-Testing of WRI's Novel Mercury Control Technology by Pre-Combustion Thermal Treatment of Coal" being submitted to DOE under solicitation DE-PS26-05NT42510-04.

Montana-Dakota Utilities is actively involved in a number of technologies that show promise in reducing mercury emissions at our coal-fired units, including this technology over the last several years.. We consider Western Research Institute's pre-combustion thermal treatment of coal for mercury removal very promising but needs further development before it is ready to be commercially deployed. The proposal provides for that continued development.

Montana-Dakota Utilities is pleased to offer support of the proposed program in the form of cash cost share in the amount of $40,000 plus $10,000 in the form of in-kind contributions related to management efforts with the North Dakota Industrial Commission project support. MDU would be the host utility for the NDIC involvement. MDU will distribute their cost-share over the first two years of the 30-month program beginning in the March 2006 timeframe. It is understood that MDU's funding will provide cost share to federal funding from DOE. MDU hereby certifies that our cost share will be comprised of non-federal dollars and will not be used as federal match on any other project.

Duane Steen, MDU's Administration and Projects Manager, will coordinate this test program and can be reached at (701) 222-7804 or at duane.steen@mdu.com.

We wish you success with the proposal and hope that DOE responds positively to this worthwhile and promising technology.

Regards,

Andrea Stomberg
Vice-President – Electric Supply

SaskPower

September 13, 2005

Alan E. Bland, Ph.D.
Vice President
Western Research Institute
365 North 9th Street
Laramie, WY 82072

Sub: DE-PS26-05NT42510-04 – Cost Share Commitment Letter

Dear Dr. Bland

SaskPower is prepared to cosponsor the work in WRI's proposal entitled "Pilot-Testing of WRI's Novel Mercury Control Technology by Pre-Combustion Thermal Treatment of Coal" being submitted to DOE under solicitation DE-PS26-05NT42510-04.

SaskPower is actively involved in a number of technologies that show promise in reducing mercury emissions at our coal-fired units. In particular, there is an activated carbon injection project being conducted at our Emissions Control Research Facility. One of the key members of out test consortium is EERC and US DOE is providing significant support to their work. We are also supporting several projects being funded by the US DOE in the USA. We consider Western Research Institute's pre-combustion thermal treatment of coal for mercury removal as a promising approach. SaskPower is interested in this project since our plants burn lignite and this project offers opportunities to gain operating benefits in addition to removing mercury.

SaskPower understands that several lignite burning utilities from North Dakota will be participating in this program at a cost of US$40,000 each. SaskPower would contribute the same amount with our costs spread over the life of the project. We understand that our participation in the project would result in one of our coals being tested. SaskPower would supply this coal as a further contribution to the project. SaskPower also looks forward to the opportunity to provide input into and otherwise participate in this project so that the most cost effective approach to removing mercury and improving fuel quality to reduce operating expenses can be achieved.

At this time I would be the primary contact for SaskPower and be reached at (306) 566-2290 or at dsmith@saskpower.com.

We hope that DOE will look favorably upon your submittal and look forward to a successful project.

Yours truly

David W. Smith

*D. W. (Dave) Smith, Project Leader, Environmental Initiatives, Operations Support, 2901 Powerhouse Drive
Regina, SK S4N 0A1*