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March 31, 2010

Ms. Karlene Fine
Executive Director
ATTN: Lignite Research Program
North Dakota Industrial Commission
State Capitol
600 East Boulevard Avenue Dept. 405
Bismarck, ND 58505-0840

Dear Ms. Fine:

Subject: EERC Proposal No. 2010-0210

The Energy & Environmental Research Center (EERC) of the University of North Dakota is pleased to submit the subject proposal. Enclosed please find an original and one copy of the proposal entitled "Evaluation of Novel Technologies for CO_2 Capture." Also enclosed is the $100 application fee. The EERC is committed to completing the project as described in this proposal if the Commission makes the requested grant.

If you have any questions, please contact me by telephone at (701) 777-5065 or by e-mail at bpavlish@undeerc.org.

Sincerely,

Brandon M. Pavlish
Research Engineer

Approved by:

Dr. Barry I. Milavetz
Associate VP for Research & Economic Development
Research Development & Compliance

BMP/kal

Enclosures

EERC
Energy & Environmental Research Center

EVALUATION OF NOVEL TECHNOLOGIES FOR CO_2 CAPTURE

EERC Proposal No. 2010-0210

Submitted to:

Karlene Fine

North Dakota Industrial Commission
600 East Boulevard Avenue
State Capitol, 14th Floor
Bismarck, ND 58505-0840

Proposal Amount $50,000

Submitted by:

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March 2010

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EVALUATION OF NOVEL TECHNOLOGIES FOR CO_2 CAPTURE

ABSTRACT

The Energy & Environmental Research Center initiated the development of the Partnership for CO_2 Capture (PCO_2C) to develop, test, and demonstrate a wide variety of postcombustion and oxyfuel technology platforms for use at coal combustion power plants. During Phase I of the program, two state-of-the-art carbon capture systems were designed and fabricated for use in multiple applications. Several weeks of testing have occurred to evaluate some of the most promising technologies that could be deployed in the next 5 to 10 years. More testing is planned during Phase I, as all the results are being compiled and reviewed. Phase II of the program is designed to utilize the results from Phase I to advance the most promising technologies (evaluated during Phase I) toward commercialization. During Phase I, several novel CO_2 capture technologies were discovered through the development of partner relationships with technology developers. These technologies do not necessarily fit within the scope of Phases I and II of the PCO_2C but, rather, fit into a project that will assist in the scale-up and optimization of these technologies. These technologies are not as proven as the technologies currently being considered in Phases I and II but show greater promise for large cost reductions.

The goal of this proposed effort is to demonstrate and evaluate the NeuStream-C system, a system that has shown effective performance with the potential to provide game-changing economics to enable large-scale implementation of carbon capture.

The estimated cost for the project is $1,935,156. Of this amount, DOE will provide $1,530,000. The remaining cost share of $355,156 will be provided by industry participants in the form of cash and noncash cost share. Of the industry cost share, Neumann Systems Group, Inc., is proposing to provide noncash cost share in the amount of $42,683. The funding amount requested from NDIC is $50,000. The proposed effort is expected to take 16 months.

EVALUATION OF NOVEL TECHNOLOGIES FOR CO_2 CAPTURE

PROJECT SUMMARY

Growing concerns about the impact of CO_2 emissions on global climate change have prompted increased research attention on the development of new technologies for CO_2 capture. Postcombustion capture, oxygen-fired combustion, and precombustion capture are among the most popular of the currently used approaches, although most of these are still in small-scale applications. In Phase I – The Partnership for CO_2 Capture (PCO_2C), the Energy & Environmental Research Center (EERC) proposed to conduct pilot-scale demonstration testing of selected CO_2 separation and capture technologies for fossil fuel and biomass-fired systems. PCO_2C Phase I was aimed at providing government and industry with key technical and economic information that can be used to examine the feasibility of technologies as a function of fuel type and system configuration. The technologies tested in the pilot-scale systems at the EERC included solvent scrubbing, solid sorbents, and oxygen-fired combustion. The overall goal of PCO_2C is to identify and help commercialize a range of CO_2 capture technology systems that can be implemented in the electric utility fleet to meet environmental emission constraints and requirements of CO_2 sequestration. In Phase II, the second phase of PCO_2C was funded and will involve continuing research and new research for the promising technologies identified during Phase I. PCO_2C Phase II utilizes the information gathered during Phase I for the development of lower-cost and more effective capture technologies and also their integration into a total system that provides substantial economic and environmental benefits.

During Phase I, several novel CO_2 capture technologies were discovered through the development of partner relationships with technology developers. These technologies do not necessarily fit within the scope of Phases I and II of the PCO_2C but, rather, fit into a project that

will assist in the scale-up and optimization of these technologies. These technologies are not as proven as the technologies currently being considered in Phases I and II but show greater promise for large cost reductions. Hence, the EERC is proposing to conduct a project that will help to further develop and demonstrate these novel technologies at a scale that is appropriate for each developing technology. This project has been proposed for U.S. Department of Energy (DOE) funding and is awaiting approval.

The overall goal of this project is to evaluate technologies that have the potential to dramatically reduce the costs of CO_2 capture. The end result of the program is focused on the development of lower-cost and more effective capture technologies and their integration into a total system that provides substantial economic and environmental benefits. The technology that has been chosen for evaluation and optimization is Neumann System Group's (NSG's) NeuStream™-C technology. The system has been proven at the bench scale to have the potential to meet or exceed DOE's targets for cost and efficiency of CO_2 capture. In order to get this technology ready for commercial deployment, small- and large-scale pilot studies are required to not only validate the technology but to optimize what the technology can achieve.

PROJECT DESCRIPTION

Goals and Objectives

The overall goal of this project is to evaluate technologies that have the potential to dramatically reduce the costs of CO_2 capture. The end result of the program is focused on the development of lower-cost and more effective capture technologies and their integration into a total system that provides substantial economic and environmental benefits. The technology chosen for evaluation and optimization under this round of funding is NSG's NeuStream-C technology. In order to achieve the goals of this project, several objectives have been defined and are shown below, along with who will be primarily responsible for achieving the objective:

- Design and fabricate the NeuStream-C system (NSG)
- Perform system design verification and integration (NSG)
- Integrate and install the NeuStream-C system on the EERC combustion test facility (CTF) (EERC)
- Perform shakedown and initial verification testing (EERC)
- Perform system baseline testing (EERC)
- Define and design system modifications for optimization based on baseline testing (EERC and NSG)
- Perform system optimization testing including testing of multiple solvents from other technology suppliers (EERC)
- Evaluate and compare baseline testing results to the current results of the EERC's conventional solvent system (EERC and NSG)
- Perform an economic analysis of the system at different points in the optimization to determine feasibility (EERC and NSG)
- Perform a sensitivity analysis to include the parameters of importance when considering scale-up (EERC and NSG)

In order to achieve these objectives, five main tasks have been identified and are as follows:

1. Pilot System Design, Integration, and Installation
2. System Calibration and Baseline Testing
3. Optimization Testing

4. Systems Engineering, Analysis, and Outreach
5. Project Management and Reporting

Statement of Work

Task 1 – Pilot System Design, Integration, and Installation. Task 1 involves the design, integration, and installation of the pilot system that will be used to evaluate and optimize the NSG technology. Two subtasks have been defined in order to complete Task 1.

Subtask 1.1 – Design, Fabrication, and Delivery. In this subtask, a pilot-scale system able to handle the full flow from the EERC's CTF will be designed, fabricated, and shipped to the EERC. A description of the CTF can be found in Appendix A. In this subtask, NSG will be responsible for designing and fabricating a 160-scfm NeuStream-C capture and separation system to be delivered to the EERC for testing. This system will consist of a two-stage equilibrium absorber and a two-stage vacuum stripper system. Figure 1 shows a conceptual illustration of the proposed system. More details about the system to be supplied by NSG can be found in Appendix B. In order for NSG to complete this task, it has outlined five steps as follows:

Step 1 – System Design (2 weeks). Qualitative and quantitative system requirements will be established and flowed down to the subsystem level (capture and separation), including performance, manufacturability, and serviceability. From these requirements, system architecture will be developed to Level 3 (system, subsystem, and module). From these requirements, the system and subsystem design will be finalized and system physical and performance models developed.

Step 2 – Design Verification Testing (6 weeks). Verification testing on chemical performance and specific surface area will be conducted to meet the necessary

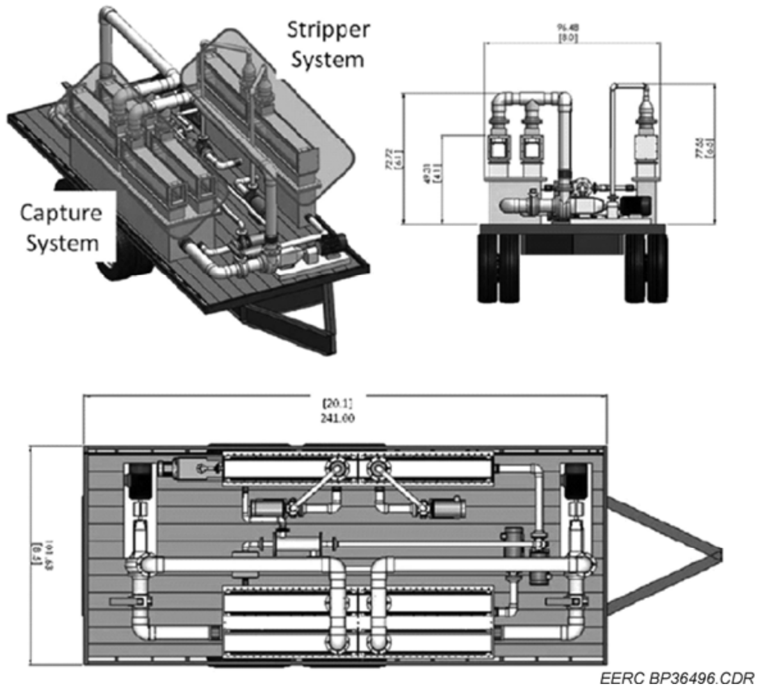

Figure 1. Conceptual illustration of the proposed NeuStream-C pilot system.

requirements to drive 90% CO_2 capture. To meet the 90% capture efficiency level, increasing the specific surface area to 10 cm^{-1} is necessary. Jet box, nozzle design, and chemical additives necessary to accomplish this will be tested, and modifications to the design will be completed as necessary to ensure this goal.

Step 3 – System Fabrication and Integration (6 weeks). All component drawings will be completed and fabricated. The system will be assembled at NSG facilities on a trailer to facilitate transport to the customer site.

Step 4 – System Checkout (2 weeks). System performance testing will be conducted using available CO_2 sources. Jet quality, specific surface area, and chemical integrity will be recorded and reviewed in accordance with a predefined acceptance test plan.

Step 5 – System Transport and Site Installation (2 weeks). The system will be transported and installed on-site. An additional system performance check will be conducted.

Subtask 1.2 – Modification and Installation. During this subtask, the EERC will make the proper modifications to the CTF to enable the proper installation of the NeuStream-C pilot system. The EERC will work with NSG as it designs the pilot system in order to provide the adequate plot space and ensure utility hookups are available upon arrival of the system. At a minimum, the EERC will have to modify existing decking structures, piping, and utility streams. Utility streams will include access to proper power connections, water, and steam, if required. A secondary induced-draft fan will be revitalized for the project to provide for adequate pressure drive through the system. Once the system is delivered, the EERC will place it in the proper location and make all final connections to the system.

Task 2 – System Calibration and Baseline Testing. During this task, the system will be brought online and verification testing will occur to quantify that the system was installed and fabricated as planned. In this task, small modifications may need to be made in order to achieve the desired operating conditions necessary to evaluate the system. Once the verification (calibration) testing has been completed, several days of "baseline" testing will occur in order to gather the appropriate data necessary to perform a preliminary assessment of the technology. The goal of this testing will be to understand where the technology stands in comparison to a conventional solvent-based system. Also during this test period, issues surrounding the technology will be identified. In order to complete this task, two subtasks have been identified.

Subtask 2.1 – Shakedown Phase. This subtask will involve the shakedown and calibration testing of the CO_2 scrubber and gas-conditioning systems. The shakedown testing will involve verifying operational parameters and performance optimization. Performance will be compared to models and process simulators used during the design stage of the project. From this, operation manuals for each of the units will be created to support future testing. This subtask is expected to take approximately 5 days of testing on the CTF.

Subtask 2.2 – Baseline Testing. After the initial calibration testing is complete, baseline testing will begin. The baseline testing will focus on gathering the information necessary to characterize each of the units. NSG's standard solvent will be used, and the results will be compared to the results from the EERC's conventional solvent system. If the budget permits, a monoethanolamine (MEA) solvent will be used in the NeuStream-C system to directly compare the equipment to the conventional solvent system data that the EERC has cataloged. Data such as CO_2 removal; CO_2 purity; required regeneration heat; and the effects of SO_x, NO_x, particulate, and trace metals (such as Hg) will be gathered. The pre-gas-conditioning systems will be used to vary the concentrations of SO_x, NO_x, and other gas constituents to determine their effects on the CO_2 capture system. Seven to 10 days of testing is expected to complete this subtask.

Task 3 – Optimization Testing. Task 3 will involve the optimization of the pilot system to determine the optimal operation of the NeuStream-C system. The overall goal of Task 3 is to determine the lowest-cost, highest-efficiency system configuration. Based on preliminary calculations, it has been determined that the NeuStream-C system may have the potential to exceed DOE's targets for the increased cost of electricity and energy penalty associated with capturing CO_2. During this task, the preliminary cost estimate and energy penalty, based on the results of the baseline testing, will be examined. Strategies for reducing cost and increasing efficiency will be developed, and with the help of modeling, the best strategies will be implemented. Some parameters of interest include the evaluation of other advanced solvents, heat integration, and equilibrium stages. Approximately 20 days of testing are expected to occur during this period to validate the changes and fully optimize the system. Based on the results of the testing, several economic analyses will be done to verify the optimizations.

Task 4 – Systems Engineering, Analysis, and Outreach. A systems engineering analysis will be used to model the process as accurately as possible. Aspen software will be used where applicable. Excel models will be created based on experimental results to determine the costs and energy penalties of each of the system runs. The systems engineering and analysis task will include reducing and interpreting all of the data generated during the testing activities. Plots will be made in order to fully evaluate the data. Sensitivity studies will be performed around important parameters to identify the impact of certain parameters on overall cost and performance. This task will rely on the expertise of EERC modelers and CO_2 capture experts as well as NSG for specific technology inputs pertaining to the NeuStream-C system.

Task 4 will also include a component of outreach to educate the public and utilities on the current status and options of CO_2 capture technologies. This will include the creation of fact sheets and other documents that will outline capture options, cost, and performance based on plant type and configuration.

Task 5 – Project Management and Reporting. Task 5 is the management and reporting task. Its success will be demonstrated by the timely and cost-effective accomplishment and contractual deliverables and milestones as outlined in the Project Management Plan. Task 5 includes three main subtasks:

1. Management and Summary Progress Reporting: Summary reports will be provided on a regular basis. Additionally, regular conference calls with project participants will be conducted to allow for the exchange of information and input on test plans.

2. Presentations and Travel: Also incorporated in the management task are two detailed project presentations at sites to be selected by the Project Team Advisory Committee. The first presentation will be conducted after the shakedown test campaigns have been completed. The second presentation will occur after all testing has been completed and the results analyzed.
3. Final Report: This subtask will provide a detailed final report discussing all of the project results.

Deliverables

The main deliverable of this project will be a final report that will include the results of all of the tasks discussed above. The final report will include the following:

- Results from testing the NeuStream-C system
- Analysis results of evaluating system integration approaches
- CO_2 capture feasibility studies
- CO_2 capture economic sensitivity analysis
- Evaluation of the NeuStream-C system
- Results from the optimization of the NeuStream-C system (cost and performance)

Quarterly reports and other reports will be generated when necessary. A summary of the other deliverables from this subtask follows:

- Information on mechanisms of CO_2 capture and its integration into overall systems.
- Collaborative research between stakeholders with an interest in developing cost-effective capture technologies.
- Immediate access to data in interim reports.

- Data that can be used to prepare a proposal for consideration to scale-up and for demonstration at full scale.

These deliverables will be incorporated into the appropriate quarterly and final reports.

STANDARDS OF SUCCESS

The ability to assess the success of the project is based primarily on the EERC's quality management system (QMS). To ensure successful projects, the EERC adheres to an organizationwide QMS. It is authorized and supported by EERC management to define the requirements and the organizational responsibilities necessary to fulfill governmental and client requirements relating to quality assurance/quality control (QA/QC), applicable regulations, codes, and protocols.

BACKGROUND

Coal will continue to play a major role in meeting energy demands well into the 21st century. EERC research is ensuring that coal can be utilized as cleanly and efficiently as possible in existing facilities as well as with emerging technologies. Coal research at the EERC pursues a scientific understanding of the physical, chemical, and mineralogical nature of coal and its associated earth materials as the foundation for predictively engineering coal conversion and power systems. The EERC team has more than five decades of basic and applied research experience producing energy from all ranks of coal, with particular emphasis on low-rank coals. As a result, the EERC has become the world's leading low-rank coal research center. EERC research programs are designed to embrace all aspects of energy-from-coal technologies from cradle to grave, beginning with fundamental resource characterization and ending with waste utilization or disposal in mined-land reclamation settings.

CO_2 Is an Environmental Concern

In 1992, international concern about climate change led to the United Nations Framework Convention on Climate Change, the ultimate objective of which is the "stabilization of greenhouse gas concentrations in the atmosphere at a level that mitigates anthropogenic interference with the climate system" (1). Research by DOE and the International Energy Agency has suggested that carbon separation and sequestration can play an important role in reducing CO_2 in the atmosphere in the first part of the twenty-first century (2).

Currently, global warming is perceived by many as the largest environmental challenge facing the world. An increased level of CO_2 in the atmosphere has been interpreted as the dominant contributor to the apparent increase in global warming. The primary source of anthropogenic CO_2 is fossil fuel-fired power plants, automobile engines, and furnaces used in residential and commercial buildings. Ninety-seven percent of anthropogenic CO_2 emissions come from energy-related activities (3). CO_2 emissions from coal-fired power plants contributed more than one-third of the anthropogenic CO_2 emissions in the United States in 2004. A breakdown of stationary U.S. CO_2 emissions is outlined in Table 1, which shows that CO_2 from coal-fired electric utilities is the single largest contributor of all stationary emitters. Because of the abundant supply of coal, especially lignite, subbituminous, and bituminous coals, the United States will rely on the use of fossil fuels for its energy needs for many years to come, thus sustaining or increasing the level of CO_2 emissions. Since lignites produce more CO_2 per unit of energy compared to the other ranks of coal, they will be the most impacted by any move to force CO_2 removal from power plants.

Table 1. Annual U.S. CO_2 Emissions

Sources	U.S. Total, tonnes
Power Generation (1)*	**2,239,700,000**
Coal (1)	1,868,400,000
Natural Gas (1)	299,100,000
Oil (1)	72,200,000
Industries	**324,789,000**
Refinery (2)	184,918,000
Iron and Steel (3)	54,411,000
Cement (3)	42,898,000
Ammonia (3)	17,652,000
Aluminum (3)	4,223,000
Lime (3)	12,304,000
Ethanol (3)	8,383,000
Total	**2,564,489,000**

* Numbers in parentheses are references.

CO_2 Capture Technology Review Summarized

The three main options for reducing CO_2 emissions from fossil fuel-based energy systems are 1) increasing fuel conversion efficiency, 2) switching to a fuel with a lower fossil carbon content, and 3) capturing and storing the CO_2 emitted from the fossil fuel (4). Options 1 and 2 are currently not sufficient options for reducing CO_2, as the United States relies, and will continue to rely, heavily on coal for energy production. Reduction of anthropogenic CO_2 emissions is focused on CO_2 separation and subsequent sequestration, which includes capture and separation, transportation, and storage. Sixty percent of the total cost for CO_2 sequestration occurs in the capture and separation step, with the remaining 40% coming from transportation and storage (2). It is technically feasible to separate CO_2, but the costs associated with the method are currently too high to be practical because of the large energy requirements of these systems.

Postcombustion Capture (5)

Removal of CO_2 from low-pressure (<2 psig), low-CO_2-concentration (<15 vol%) flue gases takes place following the pollution control devices, as shown in the schematic in Figure 2.

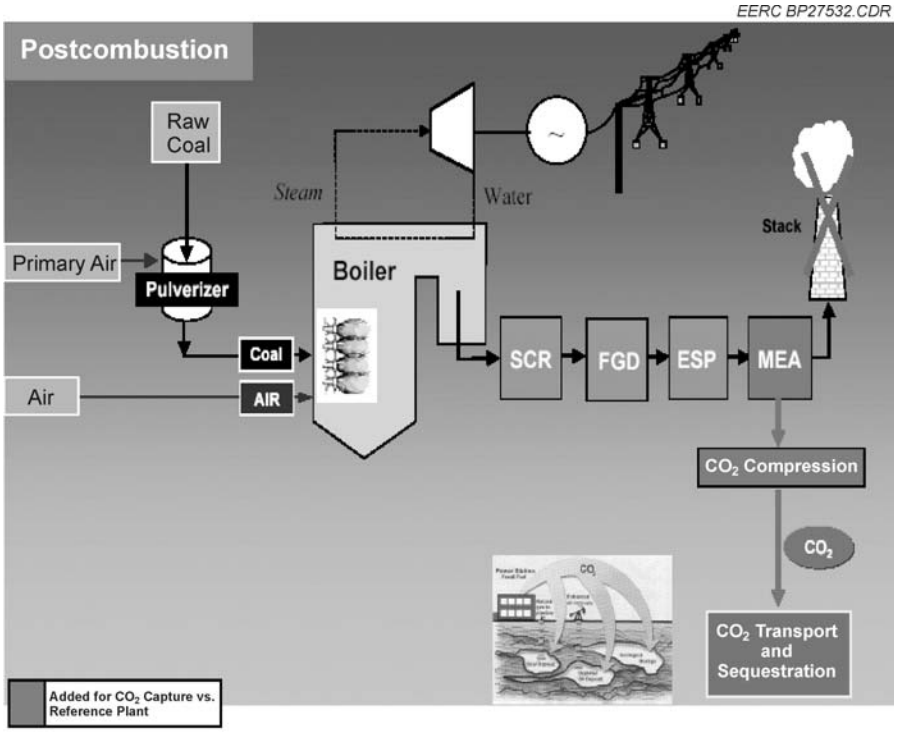

Figure 2. Schematic for postcombustion CO_2 capture (4). SCR is selective catalytic reduction; FGD is flue gas desulfurization; and ESP is electrostatic precipitator.

Several types of processes have been or are being developed to separate and remove CO_2 from a flue gas stream. Figure 3 summarizes the basic types of processes. In general, when postcombustion capture is being considered, three main categories of technologies are being considered that can be employed within the next 5 to 10 years:

1a. Absorption (amine-based)

i. Fluor Daniel Econamine FG^{SM}

– 30% MEA solution incorporating additives to control corrosion and (oxidative and thermal) degradation; more than 20 commercial plants ranging in size from 5 to 400 tons CO_2/day

ii. Lummus Technology (formerly ABB Lummus Global)

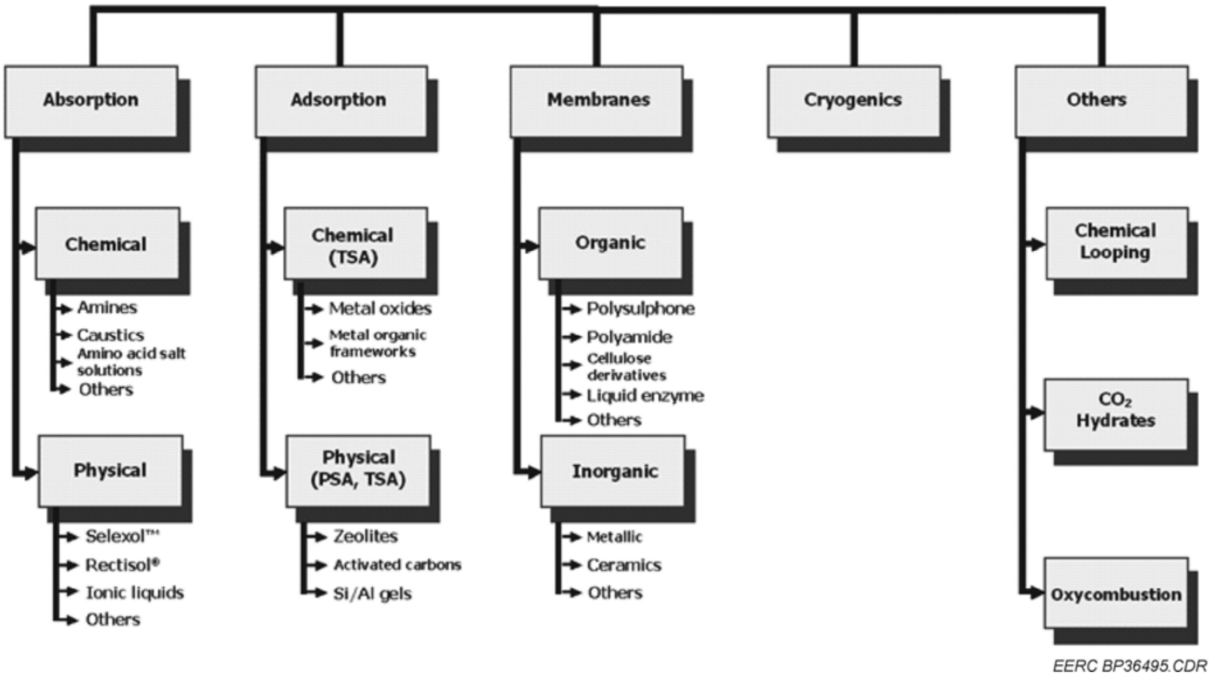

Figure 3. CO_2 capture and separation technology types.

– 15%–20% MEA solution; four commercial plants ranging in size from 150 to 850 tons CO_2/day

iii. Mitsubishi Heavy Industries (MHI)

– KS1 – sterically hindered amines; two commercial plants: ~210 and 330 tons of CO_2/day

iv. Cansolv

– Mixture of amines; commercial plant case study at NSC (Japan)

v. HTC Pure Energy

– Mixture of amines with focus on a modular 1000-ton/day system

vi. DOW/Alstom Power

– Advanced amine process

vii. Hitachi

   – Proprietary mixture of amines

viii. Huntsman Chemical

   – Proprietary mixture of amines with bench- and pilot-scale data

ix. Praxair

   – Mixture of amines

1b. Absorption (ammonia-based)

i. Powerspan

   – ECO_2 Ammonia Process; 1-MW slipstream pilot plant

ii. Alstom

   – Chilled ammonia; American Electric Power demonstration, We Energies pilot plant and other slipstream demonstrations

2. Adsorption (solid sorbents)

   a. Research Triangle Institute international dry carbonate process

   b. ADA-ES carbon-based amine-enriched sorbents

   c. DOE National Energy Technology Laboratory amine-enriched sorbents

   d. Sud Cheme

   e. TDA

   f. Metal organic frameworks

   g. Zeolites

3. Membranes

   a. Thermally optimized polymer membrane

   b. Inorganic nanoporous membrane

c. Molecular gate membrane (Research Institute of Innovative Technology for the Earth)
d. Kvaerner hybrid membrane absorption system (Kvaerner Process Systems)
e. Enzymatic liquid membranes (Carbozyme)
f. CO_2 selective membrane (Media and Process Technology, University of Southern California)
g. Membrane water–gas shift reactor (Eltron Research/SOFCo/Chevron Texaco)

Precombustion

Precombustion removal refers to near-complete capture of CO_2 prior to fuel combustion and is usually implemented in conjunction with gasification (of coal, coke, waste, residual oil, biomass) or steam/partial oxidation reforming of natural gas to produce syngas. Syngas contains CO and H_2. Subsequent conversion via the water–gas shift reaction produces CO_2 from CO, resulting in H_2-rich syngas. This syngas (often with N_2 added for temperature control) can be combusted in gas turbines, boilers, or furnaces. Figure 4 is a schematic showing precombustion CO_2 removal.

Typical CO_2 stream concentrations before capture are 25 to 40 vol% at pressures of 363 to 725 psia. The high partial pressure of CO_2, relative to that in combustion flue gas, enables easier separation through solvent scrubbing. In refineries and ammonia production facilities, where H_2-rich syngas is produced by gas reforming, CO_2 is recovered during acid gas removal using chemical solvents (e.g., Benfield or MDEA [methyldiethanolamine] processes described in the postcombustion section). Pressure swing adsorption is also used, but the CO_2-rich stream may have significant residual fuel value that makes it attractive for in-plant use.

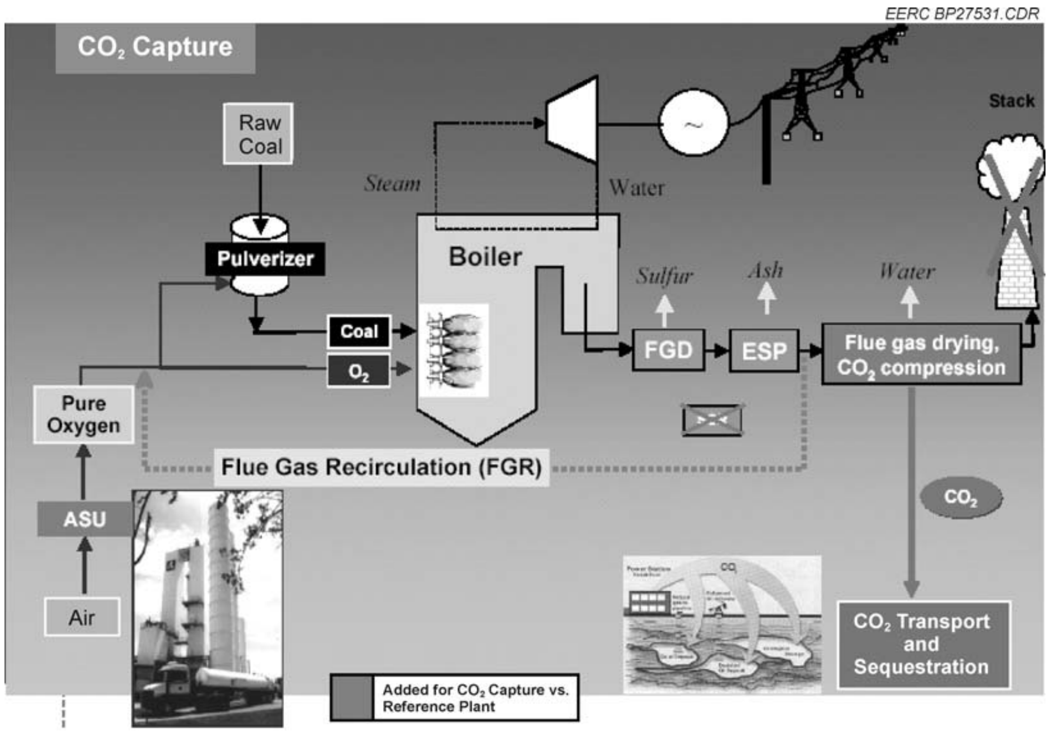

Figure 4. Schematic of an oxygen combustion system (4).

Oxycombustion

Substitution of oxygen and recycled flue gas for all of the combustion air has been proposed to produce a CO_2-rich flue gas requiring minimum separation for use or sequestration. Conventional air combustion processes in boilers or gas turbines produce flue gas that contains predominantly N_2 (>80 vol%) and excess O_2 in addition to CO_2 and water. Separation technologies must separate CO_2 from these other components. If the air is replaced by oxygen, the nitrogen content of the flue gas approaches zero (assuming minimal air leakage into the system), and the flue gas contains predominantly CO_2 along with a small amount of excess oxygen and combustion water. The CO_2 can be recovered by compressing and cooling, followed by dehydration. The adiabatic flame temperature can be moderated by recirculating a part of the recovered CO_2.

The levels of noncondensable impurities and thermodynamics limit recovery of CO_2 and affect the purity of the product stream. The concentration of CO_2 can be targeted to a specific intended end-use application such as sequestration. For enhanced coalbed methane recovery or saline aquifer sequestration, only condensation of moisture may be required because some constituents (e.g., N_2) can be present and a supercritical, dense-phase fluid is not required. Under this scenario, zero emissions would be possible. Where a supercritical fluid is required for enhanced oil recovery or deep reservoir injection, noncondensable contaminants such as N_2, NO_x, O_2, and Ar are removed by flashing in a gas–liquid separator.

There are several advantages to oxygen combustion. The volume of flue gas reaching downstream systems is one-third to one-fifth that of conventional coal boilers. The process produces a flue gas stream containing more than 80 vol% CO_2, depending upon the fuel composition, purity of oxygen from air separation, and air leakage into the boiler. Impurities such as SO_2, NO_x, particulate, trace elements, and mercury become concentrated in the flue gas, thus reducing capital and operating costs for contaminant removal. NO_x may be low enough to eliminate further control, and capital and operating cost savings (for control systems) may offset air separation capital and operating costs.

Issues with oxygen combustion center principally around the high cost for air separation, which is currently attainable at a very large scale only by cryogenic distillation. Relative to coal gasification, combustion requires up to three times the amount of oxygen because all of the carbon is converted to CO_2. The air separation unit capacity (and parasitic power load) likewise will be commensurately larger. Other issues include expected lower flue gas exit temperature (that may increase the risk of low-temperature corrosion from condensation of sulfuric acid), burner operation, flame stability, levels of unburned carbon, flame luminosity and length, and changes in slagging/fouling characteristics under the different atmosphere.

Retrofit applications would be designed to maintain the same steam outlet conditions. The higher heat capacity of the gas should potentially facilitate greater heat absorption while producing lower flue gas temperature. Higher heat absorption would result in higher boiler efficiency, but this would be offset by higher auxiliary power load for fan power to the recycle gas for temperature control.

Development efforts involving conventional pulverized coal (pc) testing with oxygen combustion are at the scale of several hundred kilowatts and less. Developers and testing organizations include CANMET, Mitsui Babcock, American Air Liquide, Babcock & Wilcox, Foster Wheeler North America, and the EERC.

Oxygen firing in circulating fluid-bed boilers may have an advantage over pc firing in that a significant degree of temperature control can be achieved by recirculating solids, but this has not been proven. Lower flue gas recycle would reduce parasitic power load for fans. In addition, higher O_2 concentrations may be possible, resulting in a smaller boiler island size and reduced capital cost. Development issues center around continuous solids recirculation. Currently, testing is at the large pilot scale, with development efforts being conducted by Alstom Power, Lummus Technology (formerly ABB Lummus Global), Praxair, and Parsons Energy.

Economics of CO_2 Capture

Several studies have been completed in the past that have estimated the cost of capturing CO_2 from coal-fired power plants. Although advanced solvents are currently thought of as being the most readily available technology, there are still many unanswered questions about the economics of these systems. For most of the advanced solvents under development, the economics are still unknown, as only small-scale data are available. A study by the University of New South Wales was completed that compared the economics of a conventional solvent (MEA) to an advanced solvent ([MHI's] KS1) (6). This study shows a good example of what advanced solvent can do in terms of decreasing the costs of capturing CO_2. Figure 5 from this analysis shows the breakdown of costs for capturing CO_2 with a conventional MEA solvent vs. the advanced MHI KS1 solvent. This analysis shows how advanced solvents can reduce the amount of energy required, therefore reducing the overall cost of the capture system.

The results of the study show that the biggest area for reducing cost is in the reduction of the energy required for the system. This is shown in Figure 6. This is accomplished by designing a solvent with favorable thermodynamics. When kinetics are considered, capital cost can be reduced significantly if favorable kinetics are discovered. When looking at the cost to capture CO_2, this study predicted that for a conventional MEA solvent, it would cost \$55–\$74/ton of CO_2

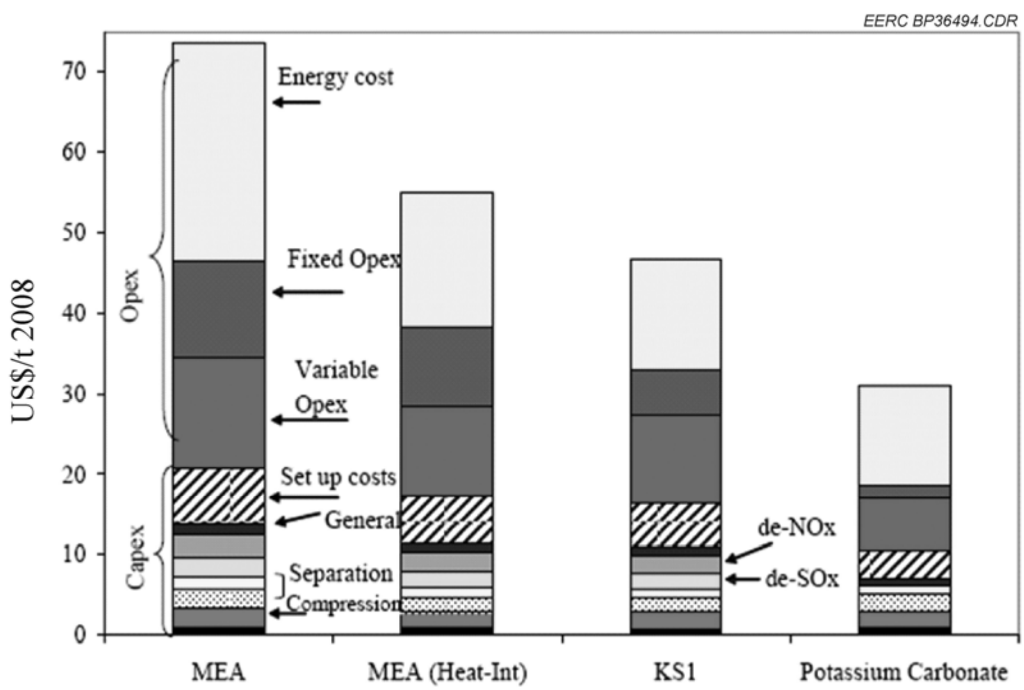

Figure 5. Capital and operating cost breakdown for MEA and KS1 solvents.

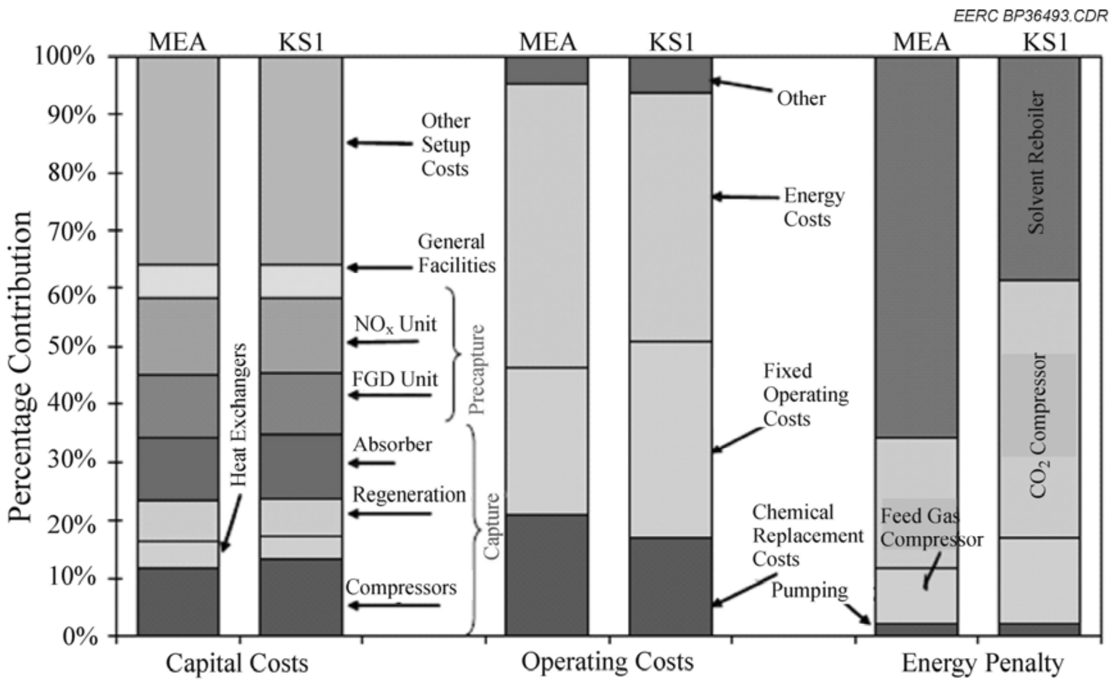

Figure 6. Capital and operating costs and estimates of energy penalties for both MEA and KS1 solvents.

captured, depending on the level of heat integration. Just by switching to an advanced solvent, the cost can be reduced to \$30–\$47/ton in this example. Many solvents exist, and the economics for each are dependent on the properties that were discussed above, creating a wide variety of cost estimates. These data show the importance of advanced solvents and support the statement that it will not be a "silver bullet" approach for capturing CO_2; several CO_2 capture technologies will need to be used on a site-by-site evaluation. Further cost reductions can be realized if capital equipment costs can be decreased. This can be accomplished by increasing the mass-transfer rate between the CO_2 and the liquid solvent.

NSG NeuStream-C Technology

The core of the NeuStream-C technology is the patented orifices used to generate the flat jets. The flat-jet orifices are interlaced in a dense packing arrangement to create 10× the specific surface area, *as*, of conventional droplet spray systems. The liquid jets, which are nominally 100 mm thick and 25 cm in length, form well-defined elliptical sheets, or curtains, whose specific surface area can be analyzed geometrically and verified experimentally. The gas flow is directed horizontally in between the jets and parallel to the jet face. The flat jets are aerodynamically shaped so that higher gas velocities (greater than 17 m/s) can be operated without incurring jet breakup or significant droplet entrainment in the gas flow. Practical jet lengths are 25–30 cm without significant breakup, and jet widths of 1.5–3.0 cm are typical, depending on the solution's physical properties (liquid viscosity, surface tension, and driving pressure). A threefold enhancement of *as* can be achieved by designing a higher orifice packing density and adding solvent viscosity enhancers. For an equivalent specific surface area, the flat jet packing density is ~6 jets/cm^2, and one flat jet produces the same surface area as ~30 round jets. A high specific surface area with reduced numbers of drilled jet orifices translates into smaller contactor/duct volumes and reduced manufacturing costs and lead times for orifice manufacturing. The technology has been evaluated by the Electric Power Research Institute as a system for "reducing significantly the capital costs and space requirements of control systems for criteria pollutants and CO_2" (7). NSG's proposal provides more details on its technology and is found in Appendix B.

Phase I Results

Much information has been obtained through Phase I of the PCO_2C program. Highlights from Phase I can be found below.

Task 1 – Postcombustion Test System(s) Design, Construction, and Implementation. The postcombustion efforts involved the design of a flexible CO_2 capture system to test a variety of technologies that are currently in the development stage. Several CO_2

capture technologies that are under development involve the use of an adsorption column for gas–liquid contacting and a stripper (or regenerator) column to regenerate the spent solvent and produce an almost pure stream of CO_2 ready to be dehydrated and compressed. Therefore, a portable system was designed and constructed to be operated with pilot-scale combustion equipment at the EERC and as a slipstream for larger-scale testing. A piping and instrumentation diagram (P&ID) of the finalized system can be seen in Figure 7.

Task 2 – Oxygen-Fired Retrofit. The oxy-fired combustion task involved retrofitting one of the EERC's existing pilot-scale combustion systems for oxygen firing. The pulverized fuel-fired unit that was retrofitted was the EERC's combustion test facility (CTF). The CTF is fired at a rate of 550,000 Btu/hr and is uniquely equipped with the ability to develop an understanding of heat-transfer issues along with fouling and slagging problems that may arise

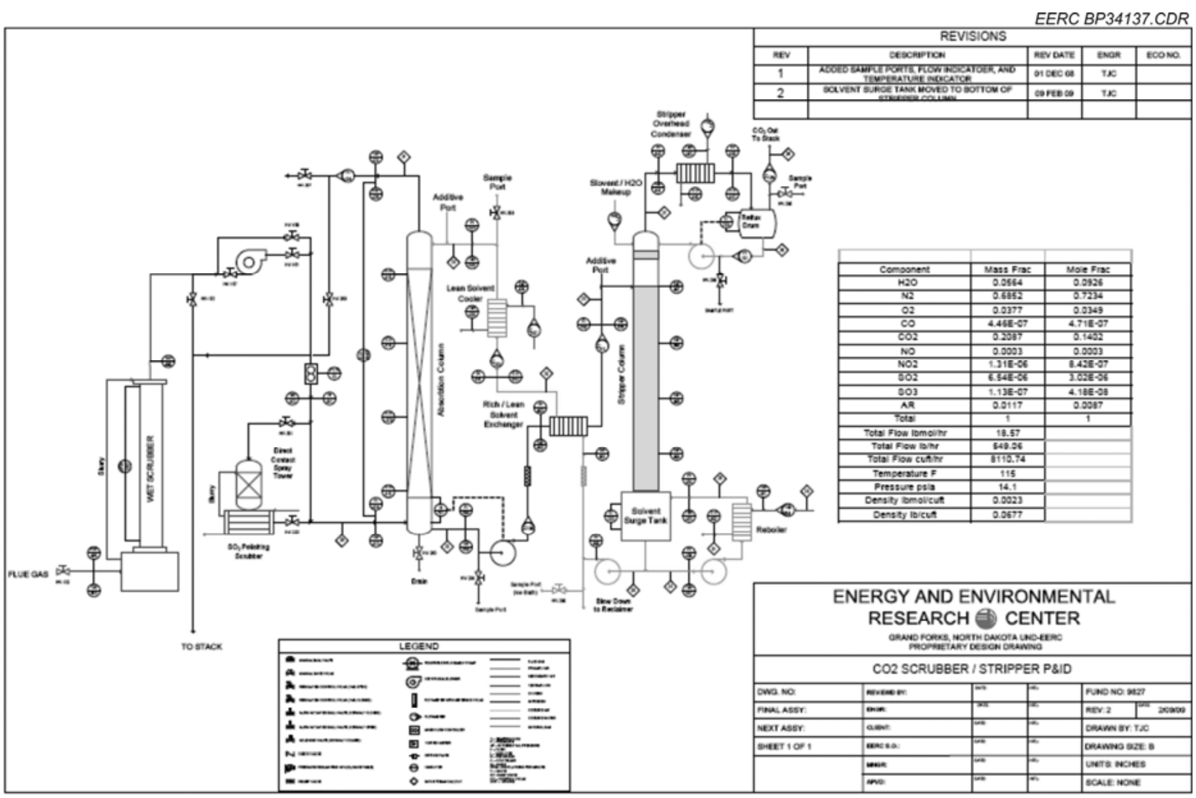

Figure 7. P&ID of the solvent absorption/stripper system designed during Phase I.

because of the CO_2-rich atmosphere in the furnace and convective pass. In addition, the CTF has the ability to operate with various types of burners and a suite of gas cleanup systems that include ESPs, fabric filtration, SCR, spray dryer absorbers (dry scrubbers), and wet scrubbers. The CTF has the ability to incorporate heat exchange surfaces to simulate alloys used in supercritical and ultrasupercritical applications to determine the potential increases in ash deposition as a result of higher metal temperatures. The CTF is fully instrumented to provide online analysis of the flue gas. Three flue gas-sampling ports are available. Flue gas concentrations of O_2, CO_2, and SO_2 are obtained simultaneously at the furnace exit and stack. Emissions of CO and NO_x are obtained at the furnace exit. All system temperatures, pressures, and flue gas analyses are recorded continuously to chart recorders and the system's computer-controlled data acquisition system. Figure 8 shows a P&ID of the oxygen-fired retrofit system.

Task 3 – Conduct CO_2 Capture Technology Testing. Task 3 involved the pilot-scale testing of the CO_2 scrubber and oxy-fired combustion retrofit systems. Several weeks of pilot-scale testing of selected postcombustion solvents are planned. The solvents and technologies selected were based on input from sponsors. The postcombustion capture testing consisted of baseline testing using an MEA solvent in the scrubber system. Sufficient testing was conducted to produce enough data to perform an economic analysis of CO_2 capture using this solvent. The MEA solvent was selected as a baseline because it is used in the CO_2 capture technology industry and will be compared to other solvents.

Pilot-scale testing of the oxy-fired platform was conducted in two phases. Testing in the first phase began by performing baseline testing with a selected coal to develop an understanding of the issues associated with the technology with regard to heat transfer, fouling and slagging, equipment issues, and air pollution control device performance. In the second phase, more

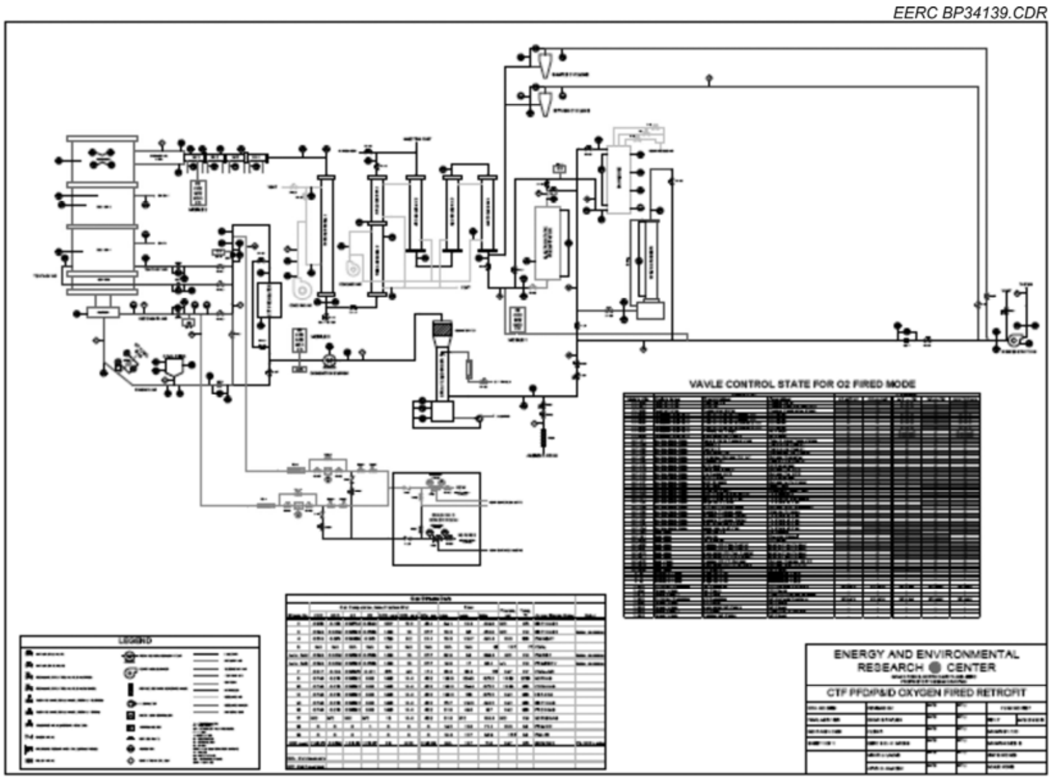

Figure 8. Schematic of oxygen-fired retrofit on the CTF and auxiliary systems.

extensive testing with several fuels will occur. These data were used to prepare initial economic analyses comparing several technologies.

Task 4 – Systems Engineering and Design. A systems engineering analysis was used to model the integration of CO_2 capture technologies in the three technology platforms under consideration for CO_2 capture. Aspen was the primary tool and was used with other engineering calculations and data collected during demonstration testing. As part of this Phase II project component, all three platforms will be modeled with and without CO_2 capture technologies employed. This analysis will be used to determine the economic and technical feasibility of using different fuels when CO_2 capture is considered. This task also includes a comprehensive market analysis of the business aspects that affect the feasibility of capturing CO_2. These system engineering studies were also used to help design the flexible scrubbing systems discussed above.

Task 5 – Management and Reporting. Task 5 was the management and reporting task. Its success was demonstrated by the timely and cost-effective accomplishment of contractual deliverables and milestones.

QUALIFICATIONS

The EERC is a research facility that operates as a business unit of UND. The EERC, with more than $43.9 million in annual contract awards in FY09, has worked with nearly 1100 clients in all 50 states and 51 countries since 1987. The EERC has a multidisciplinary staff of over 340 people, who have expertise and partnerships in a broad spectrum of energy and environmental programs, including more than 55 years of research experience on lignite properties and variability; gasification processes; ash-related impacts; the fate of pollutants including Hg, particulate, and acid gases; Hg sampling, measurement, and speciation; development, demonstration, and commercialization of combustion and environmental control systems; field testing and demonstrations; and advanced analysis of materials.

For the past several years, the EERC has been involved in multiple projects related to the capture and storage of CO_2. The more recent projects of interest are described below:

1. The PCO_2C is a multiclient program led by the EERC that is designed to evaluate several CO_2 capture technologies for retrofit application. The focus of the project is to perform pilot-scale tests utilizing several postcombustion technologies as well as oxyfuel combustion. The data generated from the pilot-scale testing are used in the technical and economic evaluation of each technology.

2. The Plains CO_2 Reduction (PCOR) Partnership at the EERC is one of the seven DOE Regional Carbon Sequestration Partnerships focused on climate change and CO_2 sequestration, covering part or all of nine states and four Canadian provinces.
3. Feasibility of Amine Scrubbing/Oxyfuel Combustion for Existing North Dakota Lignite-Fired Pulverized Coal Boilers developed a spreadsheet model to estimate cost and performance of amine-based and oxy-fired retrofits for lignite-fired power plants.

Specific CO_2 capture experience that the EERC will bring to this project revolves around the PCO_2C Program. The overall goal of the PCO_2C is to demonstrate a wide range of CO_2 capture technologies to identify the key challenges associated with each in order to develop strategies for cost-effective and efficient implementation at the commercial scale. During this process, a pilot-scale system similar to the system being considered for this project has been designed and fabricated by the EERC. Testing is currently under way with this system. This system mimics what is currently considered the state of the art but is more of a conventional capture system. The results that we have obtained from the testing of this unit will be used to compare against the results of the novel technologies tested during the proposed program.

VALUE TO NORTH DAKOTA

In North Dakota, over 18,000 jobs, $1.8 billion in business volume, and $75 million in tax revenue are generated by the lignite industry each year. North Dakota produces over 30 million tons of lignite annually, and thousands of tons of lignite are fired by North Dakota power plants daily (4). North Dakota’s economy depends on lignite production and use. Lignite combustion produces more CO_2 per Btu of energy as compared to other coals, thus a low-cost, effective means of separating CO_2 will be critical to ensure lignite’s future use if regulations limit CO_2

emissions in the future. A letter of support from a North Dakota power utility affirming its interest in the research provided in this project is included in Appendix D.

MANAGEMENT

This project will be executed by the EERC (Table 2), with guidance from the project team made up of the industrial sponsors and DOE. Mr. Brandon Pavlish will be responsible for overall project management. Task managers have been assigned for each of the tasks discussed above and include Mr. Nate Fiala (EERC), Mr. Joel Downs (EERC), Mr. John Kay (EERC), and Mr. Josh Stanislowski (EERC). The PCOR Partnership team, along with Mr. Jason Laumb, will serve as project advisors. Figure 9 provides an overview of the project management structure. Resumes for key personnel can be found in Appendix C.

TIMETABLE

The proposed tasks will take 16 months to complete. An overview of the schedule for the project is shown in Table 3.

Table 2. Key Personnel

Name	Role
Brandon Pavlish	Project Manager
John Kay	Task Manager
Josh Stanislowski	Task Manager
Nate Fiala	Task Manager
Joel Downs	Task Manager
Jason Laumb	Project Advisor

Table 3. Schedule of Tasks

Task	Duration
1 – Pilot System Design, Integration, and Installation	1–7 months
2 – System Calibration and Baseline Testing	7–9 months
3 – Optimization Testing	9–14 months
4 – Systems Engineering, Analysis, and Outreach	3–14 months
5 – Project Management and Reporting	1–16 months

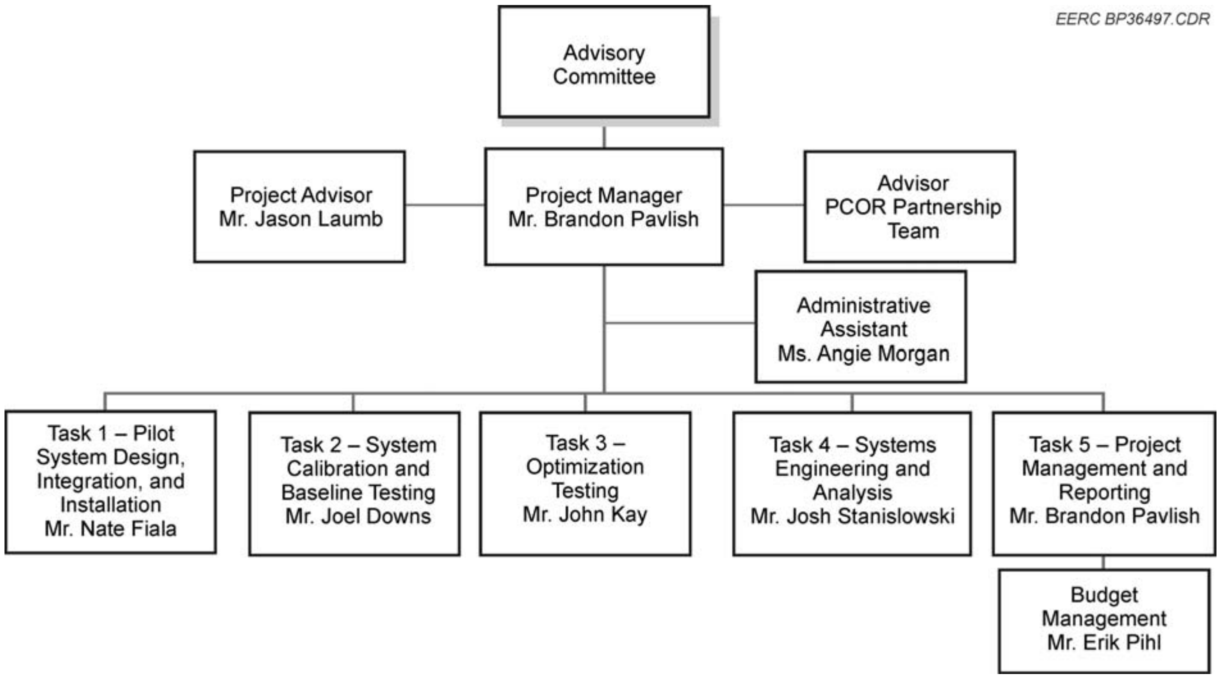

Figure 9. Overview of the project management structure.

BUDGETED COSTS

The EERC is requesting $50,000 from the NDIC to support this effort. The total estimated cost for this project is $1,935,156. The EERC has requested and secured $1,530,000 through the EERC's Strategic National Energy Security Solutions (SNESS) Program from DOE. The remaining cost share of $355,156 required to complete the program will consist of funding through a consortium of industrial participants in the form of cash and noncash cost share. Of the cost share, NSG is proposing to provide noncash cost share in the amount of $164,253 (Appendix B). Of this amount, $42,683 has been identified in the budget and the remaining $121,570 will undergo further cost analysis to determine an appropriate value. Initiation of the proposed work is contingent upon the execution of a mutually negotiated agreement or modification to an existing agreement between the EERC and each of the project sponsors. If project funding cannot be secured through the current industrial consortium members, this would delay the start of the project until new consortium members can be found, but the EERC does not anticipate this will be a problem. A detailed budget and budget notes for the proposed project can be found in Appendix E.

MATCHING FUNDS

The total cost for the project is estimated to be $1,935,156. A proposal has been submitted to DOE requesting $1,530,000. The remaining $312,473 will be requested from industry participants in the form of cash and noncash cost share. NSG is proposing to provide noncash cost share in the amount of $164,253. Of this amount, $42,683 has been identified in the budget and the remaining $121,570 will undergo further cost analysis to determine an appropriate value. The funding requested from NDIC is $50,000.

TAX LIABILITY

The EERC does not have an outstanding tax liability owed to the state of North Dakota or any of its political subdivisions.

CONFIDENTIAL INFORMATION

This proposal contains confidential material that is proprietary to the technology company that is supporting this project. The confidential material is supplied in Appendix B.

REFERENCES

1. Metz, B.; Davidson, O.; Coninik, H.; Loos, M.; Meyer, L. *IPCC Special Report Carbon Dioxide Capture and Storage Technical Summary*; ISBN 92-9169-119-4 (accessed June 15, 2006).

2. Chen, S.G.; Lu, Y.; Rostam-Abadi, M. *Carbon Dioxide Capture and Transportation Options in the Illinois Basin*; Report for U.S. Department of Energy Contract No. DE-FC26-03NT41994 (Oct 1, 2003–Sept 30, 2004).

3. U.S. Environmental Protection Agency. Greenhouse Gas Inventory Sector Analysis, 2004. www.yosemite.epa.gov (accessed June 2006).

4. Rostam-Abadi, M.; Chen, S.; Lu, Y. Assessment of Carbon Capture Options for Power Plants. Presented at the 4th Annual Conference on Carbon Capture & Sequestration, Alexandria, VA, May 2005.

5. Pavlish, B.M.; Jones, M.L. The CO_2 Capture Workshop. Presented at Air Quality VII: An International Conference on Carbon Management, Mercury, Trace Substances, SO_x, NO_x, and Particulate Matter, Arlington, VA, Oct 26–29, 2009.

6. Ho, M.; Allison, G.; Wiley, D. Factors Affecting the Cost of Capture for Australian Lignite Coal-Fired Power Plants. The University of New South Wales (accessed Oct 2009).

7. Offen, G. EPRI. Personal communication to NSG (2008).

APPENDIX A

DESCRIPTION OF EERC COMBUSTION TEST FACILITY

DESCRIPTION OF EERC COMBUSTION TEST FACILITY

COMBUSTION TEST FACILITY (CTF)

Research programs have been under way at the Energy & Environmental Research Center (EERC) for more than 30 years to study ash fouling of boiler heat-transfer surfaces in coal-fired utility boilers. A 550,000-Btu/hr pulverized coal (pc) pilot plant test furnace was constructed in 1967 to evaluate the influence of variables, including ash composition, excess air, gas temperature, and tube wall temperatures on ash fouling. Results from this work have shown a strong correlation between ash characteristics, boiler operating parameters, and degree of fouling.

The research capabilities of the CTF have been enhanced over the years and expanded to provide information on a wide range of combustion-related issues. To achieve a wide range of operating conditions, the refractory-lined furnace may be fired at a rate sufficient to achieve a furnace exit gas temperature (FEGT) as high as 2500°F. Most tests are performed with the FEGT maintained at approximately 2000°–2200°F. Research applications of this pilot-scale combustion equipment have included the following:

- Determine ash-fouling rates and strength, composition, and structure of fouling deposits for coals of all rank.
- Determine the effectiveness of ash-fouling additives.
- Apply sophisticated analytical methods to characterize input coal, ash, and deposits.
- Correlate coal and ash properties with deposit growth rates and strength development.
- Evaluate the combustion characteristics of coal–water fuels, biomass fuels, municipal solid waste, and petroleum coke.
- Determine fly ash collection properties of various fuels by electrostatic precipitation or fabric filtration using a pulse-jet baghouse, including high-temperature applications.
- Evaluate the slagging potential and slag corrosion in a simulated wet-bottom firing mode.
- Perform flame stability tests for comparing a particular fuel at full load and under turndown conditions.
- Evaluate fouling, slagging, and electrostatic precipitator (ESP) performance for blends of bituminous and subbituminous coals.
- Evaluate the combustion properties of petroleum coke, alone and in blends with subbituminous and lignite coals.

- Evaluate sorbent injection for SO_x control, and assess integrated particulate and SO_x–NO_x control.

The CTF is fully instrumented to provide online analysis of the flue gas. Three flue gas-sampling ports are available. Flue gas concentrations of O_2, CO_2, and SO_2 are obtained simultaneously at the furnace exit and stack. Emissions of CO and NO_x are obtained at the furnace exit. System O_2, CO, and CO_2 analyzers are manufactured by Rosemount; the SO_2 analyzers are manufactured by DuPont and Ametek; and NO_x is measured with a Thermoelectron chemiluminescent analyzer. All system temperatures, pressures, and flue gas analyses are recorded continuously to chart recorders and the system's computer-controlled data acquisition system.

Coal is pulverized remotely in a hammer mill pulverizer to a size of 70% less than 200 mesh (75 µm). The coal is then charged to a microprocessor-controlled weight loss feeder from a transport hopper. Combustion air is preheated by an electric air heater. The pc is screw-fed by the gravimetric feeder into the throat of a venturi section in the primary air line to the burner. Heated secondary air is introduced through an annular section surrounding the burner. Heated tertiary air is added through two tangential ports located in the furnace wall about 1 ft above the burner cone. The percentages of the total air used as primary, secondary, and tertiary air are usually 10%, 30%, and 60%, respectively. An adjustable-swirl burner, which uses only primary and secondary air with a distribution of approximately 15% and 85%, respectively, is used during flame stability testing. Flue gas passes out of the furnace into a 10-in.-square duct that is also refractory-lined. Located in the duct is a vertical probe bank designed to simulate superheater surfaces in a commercial boiler. The fouling probes are constructed of 1.66-in.-o.d. Type 304 stainless steel pipe cooled to a surface metal temperature of 1000°F (or other specified temperature) with steam. Deposit strength can be assessed by laboratory determinations using a drop impactor technique and by scanning electron microscopy (SEM). The drop impactor technique provides a calculated measurement of deposit strength, taking into account the conditions under which the test was performed. SEM point count provides a point-by-point analysis of the deposit. These data can be used to calculate the viscosity of each data point that can be related to deposit strength.

After leaving the probe bank duct, the flue gas passes through a series of water-cooled heat exchangers before being discharged through either an ESP or pulse-jet baghouse. Wet flue gas desulfurization (WFGD), a spray dryer, and selective catalytic reduction (SCR) are available and can also be installed as back-end controls on the unit. The test furnace has numerous ports that permit observation of the probes and the furnace burner zone during the test run. These ports can also be used for installation of additional test probes, auxiliary measurements, photography, or injection of additives. Figure A-1 shows a schematic of the unit.

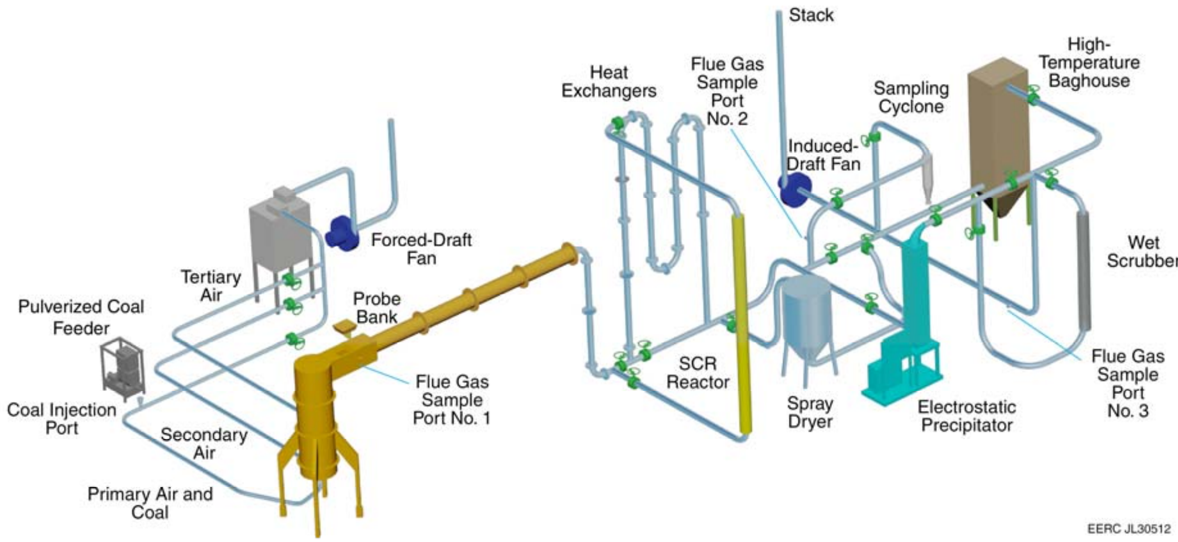

Figure A-1. CTF and auxiliary systems.

APPENDIX C

RESUMES OF KEY PERSONNEL

BRANDON M. PAVLISH
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15 North 23rd Street, Stop 9018, Grand Forks, North Dakota 58202-9018 USA
Phone: (701) 777-5065, Fax: (701) 777-5181, E-Mail: bpavlish@undeerc.org

Principal Areas of Expertise
Mr. Pavlish's principal areas of interest and expertise include management of and technical direction for multidisciplinary science and engineering research teams focused on a wide range of integrated energy and environmental technologies. Specific program areas of interest include clean and efficient use of low-grade fuels, development of advanced power systems, gas separation technologies, carbon dioxide sequestration, activated carbon technologies, and emission control related to mercury, sulfur, and particulates. Projects emphasize a cradle-to-grave approach from resource assessment to optimum utilization systems, to minimization of emissions, and to waste management featuring by-product utilization. Currently, Mr. Pavlish is managing several large projects dealing with the evaluation and demonstration of CO_2 capture technologies focusing on increasing integration and efficiency to push technologies into the commercial marketplace.

Qualifications
B.S., Chemical Engineering, University of North Dakota, 2006.

Professional Experience
2008–Present: Research Manager, EERC, UND. Mr. Pavlish's responsibilities include managing projects in the areas of gas separation technologies, carbon dioxide sequestration, activated carbon technologies, and emission control, including preparing proposals, establishing and maintaining contacts with industry and government organizations, managing staff and project activities, designing and conducting experiments, performing calculations and interpreting data, leading the preparation of technical reports and papers, and presenting research at national and international conferences and in other venues.

2006–2008: Research Engineer, EERC, UND. Mr. Pavlish's responsibilities included preparing proposals, interacting with industry and government organizations, researching literature, designing and conducting experiments as a principal investigator, performing calculations and interpreting data, writing technical reports and papers, managing projects, and presenting information. Activities ranged from project management to field testing management at full-scale power plants, to pilot-scale studies, to laboratory investigations that examined both fuel and system characteristics and their impacts on overall technology performance. Projects focused on Hg control technology evaluation and CO_2 capture development and feasibility.

2002–2006: Student Engineer, EERC, UND. Mr. Pavlish's responsibilities included the following:

– Performed a broad range of engineering functions including literature research, conducting experiments (lab- and bench-scale testing), pilot-scale testing, sampling and sample tracking, tracking project activities, data reduction, writing and presenting technical results, proposal writing, presenting at conferences, and preparation of technical papers and project reports.
– Specific EERC intern/coop experience in hydrogen involved the preparation of the hydrogen short course, literature searches, ChemCad simulations related to hydrogen production, hydrogen production via ethanol + water, and catalyst reactions.
– During intern/coop at the EERC, was involved in numerous projects focused on emission control. The primary focus of the work completed during this time was mercury control technologies and included pilot- and bench-scale testing, data reduction, proposal writing, technical reporting, and presentation.

Professional Memberships
American Institute of Chemical Engineers

Publications and Presentations
Has coauthored numerous publications.

JOHN P. KAY
Research Manager
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Principal Areas of Expertise
Mr. Kay's principal areas of interest and expertise include applications of scanning electron microscopy (SEM), x-ray diffraction (XRD), and x-ray fluorescence (XRF) techniques to the analysis of coal, fly ash, biomass, ceramics, high-temperature specialty alloys, and biological tissue. He is also interested in computer modeling systems, high-temperature testing systems, and gas separation processes and is a FLIR Systems, Inc.-certified infrared thermographer. He is currently involved in field testing site management and sampling techniques for mercury control in combustion systems.

Qualifications
B.S., Geological Engineering, University of North Dakota, 1994.
Associate Degree, Engineering Studies, Minot State University, 1989.

Professional Experience
2005–Present: Research Manager, EERC, UND. Mr. Kay's responsibilities include the management and supervision of research involving the design and operation of bench-, pilot-, and demonstration-scale equipment for development of clean coal technologies. The work also involves the testing and development of fuel conversion (combustion and gasification) and gas cleanup systems for the removal of sulfur, nitrogen, particulate, and trace elements.

1994–2005: Research Specialist, EERC, UND. Mr. Kay's responsibilities included conducting SEM, XRD, and XRF analysis and maintenance; creating innovative techniques for the analysis and interpretation of coal, fly ash, biomass, ceramics, alloys, high-temperature specialty alloys, and biological tissue; managing the day-to-day operations of the Natural Materials Analytical Research Laboratory; supervising student workers; developing and performing infrared analysis methods in high-temperature environments; and performing field work related to mercury control in combustion systems.

1993–1994: Research Technician, Agvise Laboratories, Northwood, North Dakota. Mr. Kay's responsibilities included receiving and processing frozen soil samples for laboratory testing of chemical penetration, maintaining equipment and inventory, and training others in processing techniques utilizing proper laboratory procedures.

1991–1993: Teaching Assistant, Department of Geology and Geological Engineering, UND. Mr. Kay taught Introduction to Geology Recitation, Introduction to Geology Laboratory, and Structural Geology. Responsibilities included preparation and grading of assignments and administering and grading class examinations.

1990–1992: Research Assistant, Natural Materials Analytical Laboratory, EERC, UND. Mr. Kay's responsibilities included operating an x-ray diffractometer and interpretation and manipulating XRD data, performing software manipulation for analysis of XRD data, performing maintenance and repair of the XRD machine and sample carbon coating machine, preparing samples for XRD and SEM analysis, and performing point count analysis on the SEM.

Professional Memberships
ASM International
American Ceramic Society
Microscopy Society of America

Publications and Presentations
Has authored or coauthored numerous publications.

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Principal Areas of Expertise
Mr. Stanislowski's principal areas of interest and expertise include fossil fuel combustion for energy conversion with emphasis on trace element control, gasification systems analysis, combustion and gasification pollution control, and process modeling. He has extensive experience with process engineering, process controls, and project management. He has a strong background in gauge studies, experimental design, and data analysis.

Qualifications
B.S., Chemical Engineering, University of North Dakota, 2000.
Six Sigma Green Belt Certified, August 2004.

Professional Experience:
2008–Present: Research Manager, EERC, UND, Grand Forks, North Dakota. Mr. Stanislowski manages projects in the areas of gasification, gas cleanup, hydrogen production, liquid fuel production, and systems engineering.

2005–2008: Research Engineer, EERC, UND, Grand Forks, North Dakota. Mr. Stanislowski's areas of focus included mercury control technologies and coal gasification. His responsibilities involved project management and aiding in the completion of projects. His duties included design and construction of bench- and pilot-scale equipment, performing experimental design, data collection, data analysis, and report preparation. He also worked in the areas of low-rank coal gasification, warm-gas cleanup, and liquid fuels production modeling using Aspen Plus software.

2001–2005: Process Engineer, Innovex, Inc., Litchfield, Minnesota.

- Mr. Stanislowski was responsible for various process lines including copper plating, nickel plating, tin–lead plating, gold plating, polyimide etching, copper etching, chrome etching, and resist strip and lamination. His responsibilities included all aspects of the process line including quality control, documentation, final product yields, continuous process improvement, and operator training. He gained extensive knowledge of statistical process control and statistical start-up methodology. Mr. Stanislowski was proficient with MiniTab statistical software and utilized statistical analysis and experimental design as part of his daily work.

- Mr. Stanislowski designed and oversaw experiments as a principal investigator; wrote technical reports and papers, including standard operating procedures and process control plans; presented project and experimental results to suppliers, customers, clients, and managers; created engineering designs and calculations; and performed hands-on mechanical work when troubleshooting process issues. He demonstrated the ability to coordinate activities with varied entities through extensive project management and leadership experience.

1998–2000: Student Research Assistant, EERC, UND. Mr. Stanislowski worked on a wide variety of projects, including data entry and programming for the Center for Air Toxic Metals® (CATM®) database, contamination cleanup program development, using aerogels for emission control, and the development of a nationwide mercury emission model.

Publications and Presentations
Has coauthored several publications.

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Principal Areas of Expertise

Mr. Fiala’s principal areas of interest and expertise include CO_2 capture technologies, gas turbine heat transfer and aerodynamics, computational fluid dynamics (CFD) and combustion process modeling, and hydrogen fuel technology.

Qualifications

M.S., Mechanical Engineering, University of North Dakota, 2007.
B.S., Mechanical Engineering, University of North Dakota, 2005.

Professional Experience

2006–Present: Research Engineer, EERC, UND. Mr. Fiala’s work focuses on emission control, including mercury capture and CO_2 capture, and hydrogen fuel research.

2005–2007: Graduate Research Assistant, Department of Mechanical Engineering, UND. Mr. Fiala’s responsibilities included investigating the influence of turbulence and Reynolds number on turbine vane aerodynamics losses, secondary flows, and wake growth; analyzing both external and internal heat-transfer characteristics; and investigating turbine blade trailing-edge geometry, developing both laboratory and communication skills.

2002–2003: Microbiology Laboratory Assistant, EERC, UND. Mr. Fiala’s responsibilities included researching information on anaerobic bacteria by-products, including from hydrogen production; setting up, performing, recording, and cleaning up experiments using various laboratory equipment; and preparing solutions in an anaerobic environment.

2002–2002: Research Engineer Assistant, EERC, UND. Mr. Fiala’s responsibilities included researching technologies used to clean up nuclear waste sites, specifically in the deactivation and decommissioning (D&D) focus area, and updating a working database of technologies and vendors using Microsoft Access.

Professional Memberships

American Society of Mechanical Engineers
Tau Beta Pi

Publications and Presentations

Has coauthored several publications.

JOEL G. DOWNS
Research Specialist
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, ND 58202-9018 USA
Phone (701) 777-5000, Fax (701) 777-5181, E-Mail: jdowns@undeerc.org

Principal Areas of Expertise
Mr. Downs' principal areas of interest and expertise include coal combustion and CO_2 capture technologies, Fischer−Tropsch (FT) catalyst development, process simulation, mathematical modeling, design of experiments, and statistical analysis of data.

Qualifications
B.S., Chemical Engineering, University of North Dakota, May 2010.
M.S., Mathematics, University of North Dakota, 2007.
B.S., Mathematics, University of North Dakota, 2005.
Proficient in the use of Aspen Tech, ChemCad, Visual Basic, Mathematica, Linux, and Fortran.

Professional Experience
2010 –present: Research Specialist, EERC, UND. Mr. Downs' work focuses on coal combustion, CO_2 capture technologies, and FT catalysis. Responsibilities include performing data reduction and analysis for CO_2 capture experiments, preparing experimental plans and technical reports, creating CO_2 capture process simulations using Aspen Tech software, and developing new FT catalysts.

2009: Student Research Engineer, EERC, UND. Mr. Downs' work focused on coal combustion and CO_2 capture technologies. Responsibilities included performing data reduction and analysis for CO_2 capture experiments, preparing experimental plans and technical reports, creating CO_2 capture process simulations using Aspen Tech software. He also performed experimental work to determine the feasibility of using hydrothermal dewatering of coal for CO_2 reduction.

2008: Process Engineer Internship/Coop, American Crystal Sugar Company, East Grand Forks, Minnesota. Mr. Downs' work focused on improving the East Grand Forks factory and sugar-making process. He created a heat exchanger-tracking spreadsheet to improve heat exchanger maintenance, performed process modeling using the SUGARS software package, and managed the construction of a seal water piping project.

2005–2007: Graduate Teaching Assistant, Department of Mathematics, UND. Mr. Downs taught sections of College Algebra, Applied Calculus, and Precalculus.

2003: Advanced Undergraduate Research Award Recipient, North Dakota EPSCoR, Department of Physics, UND. Mr. Downs performed an independent research project in which he wrote a computer program to simulate an asteroid search using predetermined patterns, compiled research data, and presented his work at a North Dakota EPSCoR conference.

Professional Memberships
Tau Beta Pi
Phi Beta Kappa
Alpha Lambda Delta Honor Society
American Institute of Chemical Engineers
American Mathematical Society

Publications and Presentations
Has coauthored several publications.

JASON D. LAUMB
Senior Research Manager
Energy & Environmental Research Center (EERC) University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, ND 58202-9018 USA
Phone (701) 777-5114, Fax (701) 777-5181, E-Mail: jlaumb@undeerc.org

Principal Areas of Expertise
Mr. Laumb's principal areas of interest and expertise include biomass and fossil fuel conversion for energy production, with an emphasis on ash effects on system performance. He has experience with trace element emissions and control for fossil fuel combustion systems, with a particular emphasis on air pollution issues related to mercury and fine particulates. He also has experience in the design and fabrication of bench- and pilot-scale combustion and gasification equipment.

Qualifications
M.S., Chemical Engineering, University of North Dakota, 2000.
B.S., Chemistry, University of North Dakota, 1998.

Professional Experience
2008–Present: Senior Research Manager, EERC, UND. Mr. Laumb's responsibilities include leading a multidisciplinary team of 30 scientists and engineers whose aim is to develop and conduct projects and programs on power plant performance, environmental control systems, the fate of pollutants, computer modeling, and health issues for clients worldwide. Efforts are focused on the development of multiclient jointly sponsored centers or consortia that are funded by government and industry sources. Current research activities include computer modeling of combustion/gasification and environmental control systems, performance of selective catalytic reduction technologies for NO_x control, mercury control technologies, hydrogen production from coal, CO_2 capture technologies, particulate matter analysis and source apportionment, the fate of mercury in the environment, toxicology of particulate matter, and in vivo studies of mercury-selenium interactions. Computer-based modeling efforts utilize various kinetic, systems engineering, thermodynamic, artificial neural network, statistical, computation fluid dynamics, and atmospheric dispersion models. These models are used in combination with models developed at the EERC to predict the impacts of fuel properties and system operating conditions on system efficiency, economics and emissions.

2001–2008: Research Manager, EERC, UND. Mr. Laumb's responsibilities include supervising projects involving bench-scale combustion testing of various fuels and wastes; supervising a laboratory that performs bench-scale combustion and gasification testing; managerial and principal investigator duties for projects related to the inorganic composition of coal, coal ash formation, deposition of ash in conventional and advanced power systems, and mechanisms of trace metal transformations during coal or waste conversion; and writing proposals and reports applicable to energy and environmental research.

2000–2001: Research Engineer, EERC, UND. Mr. Laumb's responsibilities included aiding in the design of pilot-scale combustion equipment and writing computer programs that aid in the reduction of data, combustion calculations, and prediction of boiler performance. He was also involved in the analysis of current combustion control technology's ability to remove mercury and studying the suitability of biomass as boiler fuel.

1998–2000: SEM Applications Specialist, Microbeam Technologies, Inc., Grand Forks, North Dakota. Mr. Laumb's responsibilities included gaining experience in power system performance including conventional combustion and gasification systems; a knowledge of environmental control systems and energy conversion technologies; interpreting data to predict ash behavior and fuel performance; assisting in proposal writing to clients and government agencies such as NSF and DOE; preparing and analyzing coal, coal ash, corrosion products, and soil samples using SEM/EDS; and modifying and writing FORTRAN, C+ and Excel computer programs.

Professional Memberships
American Chemical Society

Publications and Presentations
Has coauthored numerous professional publications.

APPENDIX D

LETTER OF SUPPORT

BASIN ELECTRIC
POWER COOPERATIVE

1717 EAST INTERSTATE AVENUE
BISMARCK, NORTH DAKOTA 58503-0564
PHONE: 701-223-0441
FAX: 701-557-5336

March 30, 2010

Mr. Brandon M. Pavlish
Research Manager
Energy & Environmental Research Center
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018

Subject: Energy & Environmental Research Center Proposal to the NDIC Solicitation Entitled "Evaluation of Novel Technologies for CO_2 Capture"

Dear Mr. Pavlish:

This letter is in response to the Energy & Environmental Research Center's request for support in the proposed subject proposal to be submitted under the North Dakota Industrial Commission's (NDIC's) April solicitation.

Basin Electric Power Cooperative has a particular interest in this program because we own and operate several units that utilize coal as a means to produce electricity. Our company has a critical need to identify CO_2 capture options that are both technically and economically feasible for implementation at a commercial scale. Coal will continue to play a major role in meeting energy demands well into the 21st Century. This program's research is ensuring that coal can be utilized as cleanly and efficiently as possible in existing facilities as well as with emerging technologies. We recognize, based on the currently available CO_2 capture technology data, that there is a need for the understanding and further development of technologies that can provide CO_2 capture technologies that are efficient and economically acceptable.

Basin Electric is pleased to offer support in the form of a letter of interest, recognizing that the research provided by this project will help to determine the best available technologies to efficiently and economically capture CO_2 from existing coal-fired power stations.

We hope that NDIC gives careful consideration to this project as there is a significant need for data applicable to lignite coal, data which we believe this project will provide. Again, we express our interest of the proposed project and look forward to seeing the project move forward with support from NDIC.

Sincerely,

Wayne Backman
Senior Vice President, Generation

rle/dz

APPENDIX E

BUDGET AND BUDGET NOTES

EVALUATION OF NOVEL TECHNOLOGIES FOR CO_2 CAPTURE
NDIC
PROPOSED PROJECT START DATE: 7/1/10
EERC PROPOSAL #2010-0210

SUMMARY BUDGET

CATEGORY		Rate	PROJECT TOTAL Hrs	PROJECT TOTAL Cost	INDUSTRY SHARE Hrs	INDUSTRY SHARE Cost	NDIC SHARE Hrs	NDIC SHARE Cost	NON-CASH COST SHARE Hrs	NON-CASH COST SHARE Cost	DOE SHARE Hrs	DOE SHARE Cost
LABOR												
Pavlish, B.	Project Manager	$ 33.31	905	$ 30,147	275	$ 9,160	50	$ 1,666	-	$ -	580	$ 19,321
Kay, J.	Principal Investigator	$ 40.08	440	$ 17,635	40	$ 1,603	-	$ -	-	$ -	400	$ 16,032
Stanislowski, J.	Principal Investigator	$ 36.78	440	$ 16,183	105	$ 3,862	-	$ -	-	$ -	335	$ 12,321
Fiala, N.	Principal Investigator	$ 27.99	525	$ 14,695	40	$ 1,120	35	$ 980	-	$ -	450	$ 12,595
Downs, J.	Principal Investigator	$ 20.00	510	$ 10,200	100	$ 2,000	-	$ -	-	$ -	410	$ 8,200
Laumb, J.	Project Advisor	$ 51.19	220	$ 11,263	119	$ 6,092	-	$ -	-	$ -	101	$ 5,171
--------------	Senior Management	$ 70.17	417	$ 29,261	97	$ 6,807	73	$ 5,122	-	$ -	247	$ 17,332
--------------	Research Scientists/Engineers	$ 38.29	3,821	$ 146,305	250	$ 9,573	87	$ 3,331	-	$ -	3,484	$ 133,401
--------------	Research Technicians	$ 25.08	664	$ 16,653	124	$ 3,110	90	$ 2,257	-	$ -	450	$ 11,286
--------------	Technology Dev. Mechanics	$ 29.23	2,840	$ 83,014	2,440	$ 71,322	160	$ 4,677	-	$ -	240	$ 7,015
--------------	Technical Support Services	$ 20.02	195	$ 3,904	35	$ 701	-	$ -	-	$ -	160	$ 3,203
				$ 379,260		$ 115,350		$ 18,033		$ -		$ 245,877
Escalation Above Base			6%	$ 22,755		$ 6,920		$ 1,082		$ -		$ 14,753
TOTAL DIRECT HRS/SALARIES			10,977	$ 402,015	3,625	$ 122,270	495	$ 19,115	-	$ -	6,857	$ 260,630
Fringe Benefits - % of Direct Labor - Staff		54%		$ 217,088		$ 66,026		$ 10,322		$ -		$ 140,740
TOTAL FRINGE BENEFITS				$ 217,088		$ 66,026		$ 10,322		$ -		$ 140,740
TOTAL LABOR				$ 619,103		$ 188,296		$ 29,437		$ -		$ 401,370
TRAVEL				$ 11,733		$ -		$ -		$ -		$ 11,733
EQUIPMENT > $5000				$ 28,000		$ -		$ -		$ -		$ 28,000
SUPPLIES				$ 13,047		$ 2,847		$ 1,474		$ -		$ 8,726
SUBRECIPIENT – NEUMAN SYSTEMS GROUP				$ 699,994		$ -		$ -		$ -		$ 699,994
COMMUNICATION - PHONES & POSTAGE				$ 700		$ 50		$ 25		$ -		$ 625
PRINTING & DUPLICATING				$ 1,350		$ 20		$ -		$ -		$ 1,330
FOOD				$ 1,500		$ -		$ -		$ -		$ 1,500
OPERATING FEES & SVCS												
Fuels & Materials Research Lab.				$ 9,249		$ -		$ -		$ -		$ 9,249
Analytical Research Lab.				$ 15,582		$ -		$ -		$ -		$ 15,582
Combustion Test Svcs.				$ 65,455		$ -		$ -		$ -		$ 65,455
Fuel Prep. and Maintenance				$ 7,208		$ -		$ -		$ -		$ 7,208
Graphics Support				$ 3,558		$ -		$ -		$ -		$ 3,558
Shop & Operations Support				$ 4,395		$ 4,081		$ 314		$ -		$ -
TOTAL DIRECT COST				$ 1,480,874		$ 195,294		$ 31,250		$ -		$ 1,254,330
FACILITIES & ADMIN. RATE - % OF MTDC			VAR	$ 411,599	60%	$ 117,179	60%	$ 18,750	60%	$ -	50%	$ 275,670
TOTAL PROJECT COST - US DOLLARS				$ 1,935,156		$ 312,473		$ 50,000		$ 42,683		$ 1,530,000

Due to limitations within the University's accounting system, bolded budget line items represent how the University proposes, reports and accounts for expenses. Supplementary budget information, if provided, is for proposal evaluation.

EVALUATION OF NOVEL TECHNOLOGIES FOR CO_2 CAPTURE
EERC PROPOSAL #2010-0210

DETAILED BUDGET - TRAVEL

RATES USED TO CALCULATE ESTIMATED TRAVEL EXPENSES

DESTINATION	AIRFARE	LODGING	PER DIEM	CAR RENTAL	REGIST.
Unspecified Destination (USA)	$ 950	$ 175	$ 71	$ 75	$ 525
Morgantown, WV (via Pittsburgh, PA)	$ 900	$ 125	$ 46	$ 65	$ -

PURPOSE/DESTINATION	NUMBER OF TRIPS	NUMBER OF PEOPLE	NUMBER OF DAYS	AIRFARE	LODGING	PER DIEM	CAR RENTAL	MISC.	REGIST.	TOTAL
Conference/Unspecified Dest. (USA)	1	2	3	$ 1,900	$ 700	$ 426	$ 225	$ 120	$ 1,050	$ 4,421
Client Visit/Unspecified Dest. (USA)	1	2	3	$ 1,900	$ 700	$ 426	$ 225	$ 120	$ 1,050	$ 4,421
Review Meeting/Morgantown, WV (Pittsburgh, PA)	1	2	3	$ 1,800	$ 500	$ 276	$ 195	$ 120	$ -	$ 2,891
TOTAL ESTIMATED TRAVEL - ALL ACTIVITIES										$ 11,733

DETAILED BUDGET - EQUIPMENT

Fabricated Equipment	$COST
Piping, fittings	$ 3,000
Valves	$ 10,000
Control Systems	$ 12,000
Misc.	$ 1,500
Shipping	$ 1,500
Total Estimated Cost: Connection of NSG System	$ 28,000

EVALUATION OF NOVEL TECHNOLOGIES FOR CO_2 CAPTURE
EERC PROPOSAL #2010-0210

DETAILED BUDGET - EERC RECHARGE CENTERS

		PROJECT	
Fuels & Materials Research Lab.	Rate	#	$Cost
BTU	$74	25	$ 1,850
Moisture %	$66	25	$ 1,650
Proximate Ultimate	$209	25	$ 5,225
Subtotal			$ 8,725
Escalation		6%	$ 524
Total Fuels & Materials Research Lab			$ 9,249

Analytical Research Lab.	Rate	#	$Cost
Miscellaneous (Sample)	$49	300	$ 14,700
Subtotal			$ 14,700
Escalation		6%	$ 882
Total Analytical Research Lab.			$ 15,582

Combustion Test Services	Rate	#	$Cost
Combustion Test Facility (CTF) (Hourly)	$95	650	$ 61,750
Subtotal			$ 61,750
Escalation		6%	$ 3,705
Total Combustion Test Services			$ 65,455

Fuel Preparation & Maintenance	Rate	#	$Cost
Fuel Preparation & Maintenance (Hourly per piece of equip)	$34	200	$ 6,800
Subtotal			$ 6,800
Escalation		6%	$ 408
Total Fuel Prep. & Maintenance			$ 7,208

Graphics Support	Rate	#	$Cost
Graphics (hourly)	$61	55	$ 3,355
Subtotal			$ 3,355
Escalation		6%	$ 203
Total Graphics Support			$ 3,558

Shop & Operations Support	Rate	#	$Cost
Technical Development Hours	$1.46	2,840	$ 4,146
Subtotal			$ 4,146
Escalation		6%	$ 249
Total Shop & Operations Support			$ 4,395

BUDGET NOTES

ENERGY & ENVIRONMENTAL RESEARCH CENTER (EERC)

BACKGROUND

The EERC is an independently organized multidisciplinary research center within the University of North Dakota (UND). The EERC receives no appropriated funding from the state of North Dakota and is funded through federal and nonfederal grants, contracts, and other agreements. Although the EERC is not affiliated with any one academic department, university faculty may participate in a project, depending on the scope of work and expertise required to perform the project.

INTELLECTUAL PROPERTY

If federal funding is proposed as part of this project, the applicable federal intellectual property (IP) regulations may govern any resulting research agreement. In addition, in the event that IP with the potential to generate revenue to which the EERC is entitled is developed under this agreement, such IP, including rights, title, interest, and obligations, may be transferred to the EERC Foundation, a separate legal entity.

BUDGET INFORMATION

The proposed work will be done on a cost-reimbursable basis. The distribution of costs between budget categories (labor, travel, supplies, equipment, etc.) is for planning purposes only. The project manager may, as dictated by the needs of the work, incur costs in accordance with Office of Management and Budget (OMB) Circular A-21 found at www.whitehouse.gov/omb/circulars. If the Scope of Work (by task, if applicable) encompasses research activities which may be funded by one or more sponsors, then allowable project costs may be allocated at the Scope of Work or task level, as appropriate, to any or all of the funding sources. Financial reporting will be at the total-agreement level.

Escalation of labor and EERC recharge center rates is incorporated into the budget when a project's duration extends beyond the current fiscal year. Escalation is calculated by prorating an average annual increase over the anticipated life of the project.

The cost of this project is based on a specific start date indicated at the top of the EERC budget. Any delay in the start of this project may result in a budget increase. Budget category descriptions presented below are for informational purposes; some categories may not appear in the budget.

Salaries: The EERC employs administrative staff to provide required services for various direct and indirect support functions. Salary estimates are based on the scope of work and prior experience on projects of similar scope. The labor rate used for specifically identified personnel is the current hourly rate for that individual. The labor category rate is the current average rate of a personnel group with a similar job description. Salary costs incurred are based on direct hourly effort on the project. Faculty who work on this project will be paid an amount over their normal base salary, creating an overload which is subject to limitation in accordance with university policy. Costs for general support services such as contracts and intellectual property, accounting, human resources, purchasing, shipping/receiving, and clerical support of these functions are included in the EERC facilities and administrative cost rate.

Fringe Benefits: Fringe benefits consist of two components which are budgeted as a percentage of direct labor. The first component is a fixed percentage approved annually by the UND cognizant audit agency, the Department of Health and Human Services. This portion of the rate covers vacation, holiday, and sick leave (VSL) and is applied to direct labor for permanent staff eligible for VSL benefits. Only the actual approved rate will be charged to the project. The second component is estimated on the basis of historical data and is charged as actual expenses for items such as health, life, and unemployment insurance; social security; worker's compensation; and UND retirement contributions.

Travel: Travel is estimated on the basis of UND travel policies which can be found at www.und.edu/dept/accounts/policiesandprocedures.html. Estimates include General Services Administration (GSA) daily meal rates. Travel may include site visits, field work, meetings, and conference participation as indicated by the scope of work and/or budget.

Equipment: If equipment is budgeted, it is discussed in the text of the proposal and/or identified more specifically in the accompanying budget detail.

Supplies – Professional, Information Technology, and Miscellaneous: Supply and material estimates are based on prior experience and may include chemicals, gases, glassware, nuts, bolts, and piping. Computer supplies may include data storage, paper, memory, software, and toner cartridges. Maps, sample containers, minor equipment, signage, and safety supplies may be necessary as well as other organizational materials such as subscriptions, books, and reference materials. General purpose office supplies (pencils, pens, paper clips, staples, Post-it notes, etc.) are included in the facilities and administrative cost.

Subcontracts/Subrecipients: Not applicable.

Professional Fees/Services (consultants): Not applicable.

Other Direct Costs

Communications and Postage: Telephone, cell phone, and fax line charges are generally included in the facilities and administrative cost. Direct project costs may include line charges at remote locations, long-distance telephone, postage, and other data or document transportation costs.

Printing and Duplicating: Photocopy estimates are based on prior experience with similar projects. Page rates for various photocopiers are established annually by the university's duplicating center.

Food: Food expenditures for project meetings, workshops, and conferences where the primary purpose is dissemination of technical information may include costs of food, some of which may exceed the institutional limit.

Professional Development: Fees are for memberships in technical areas directly related to work on this project. Technical journals and newsletters received as a result of a membership are used throughout development and execution of the project by the research team.

Fees and Services – EERC Recharge Centers, Outside Labs, Freight: EERC recharge center rates for laboratory, analytical, graphics, and shop/operation fees are anticipated to be approved for use beginning July 1, 2009. Only the actual approved rates will be charged to the project.

Laboratory and analytical fees are charged on a per sample, hourly, or daily rate, depending on the analytical services performed. Additionally, laboratory analyses may be performed outside the university when necessary.

Graphics fees are based on an established per hour rate for production of such items as report figures, posters, and/or PowerPoint images for presentations, maps, schematics, Web site design, professional brochures, and photographs.

Shop and operation fees are for expenses directly associated with the operation of the pilot plant facility. These fees cover such items as training, personal safety (protective eyeglasses, boots, gloves), and physicals for pilot plant and shop personnel.

Freight expenditures generally occur for outgoing items and field sample shipments.

Facilities and Administrative Cost: Facilities and administrative (F&A) cost is calculated on modified total direct costs (MTDC). MTDC is defined as total direct costs less individual items of equipment in excess of $5000 and subawards in excess of the first $25,000 for each award. The F&A rate for commercial sponsors is 60%. This rate is based on costs that are not included in the federally approved rate, such as administrative costs that exceed the 26% federal cap and depreciation/use allowance on buildings and equipment purchased with federal dollars.