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Energy & Environmental Research Center

UNIVERSITY OF NORTH DAKOTA

15 North 23rd Street — Stop 9018 / Grand Forks, ND 58202-9018 / Phone: (701) 777-5000 Fax: 777-5181
Web Site: www.undeerc.org

March 31, 2010

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

Dear Ms. Fine:

Subject: EERC Proposal No. 2010-0211 Entitled "Partnership for CO_2 Capture – Phase II"

Enclosed please find an original and one copy of the proposal entitled "Partnership for CO_2 Capture – Phase II." Also enclosed is the $100 application fee.

The Energy & Environmental Research Center (EERC) of the University of North Dakota is pleased to submit the subject proposal. 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,

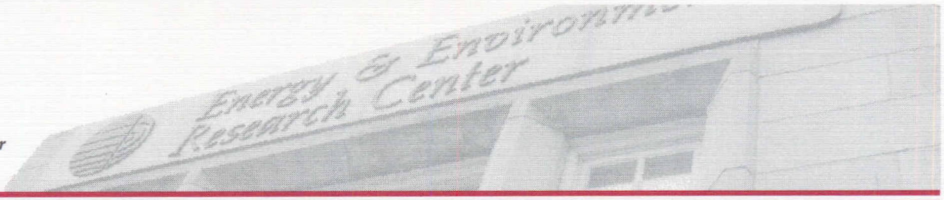
Brandon M. Pavlish
Research Engineer

Approved by:

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

BMP/sah

Enclosures



PARTNERSHIP FOR CO_2 CAPTURE – PHASE II

EERC Proposal No. 2010-0211

Submitted to:

Karlene Fine

North Dakota Industrial Commission
State Capitol
600 East Boulevard Avenue, Department 405
Bismarck, ND 58505-0840

Proposal Amount $150,000

Submitted by:

Brandon M. Pavlish
Jason D. Laumb
John P. Kay
Joshua J. Stanislowski
Scott G. Tolbert

Energy & Environmental Research Center
University of North Dakota
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018

Brandon M. Pavlish, Project Manager

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

March 2010

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PARTNERSHIP FOR CO_2 CAPTURE – PHASE II

ABSTRACT

The overall goal of the Partnership for CO_2 Capture is to identify and help commercialize a range of CO_2 capture technology systems that can be integrated into the electric utility fleet to meet environmental emission constraints and requirements of the CO_2 sequestration. The second phase of the Partnership for CO_2 Capture will involve continuing and new research for the promising technologies identified during Phase I. Phase II will utilize 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. The fuel types considered will include lignite, subbituminous, bituminous, natural gas, petroleum coke, and/or biomass. The test program will deliver information on technical issues and challenges associated with the application of these technologies to the capture of CO_2 from flue gas derived from combustion of selected fuels. A complete systems analysis and economic evaluation of the capture process will be performed as a function of technology type, coal type, and plant configuration to enable industries to make appropriate decisions to retrofit existing plants or build new plants.

The total estimated cost for the Partnership for CO_2 Capture Phase II is \$1,860,000. The Energy & Environmental Research Center (EERC) requested and has secured \$1,460,000 under the EERC's Strategic National Energy Security Solutions (SNESS) Program from the U.S. Department of Energy. The EERC is requesting \$150,000 from the North Dakota Industrial Commission (NDIC) to support the Phase II effort. Cost share from industrial sources has been verbally secured for the remaining balance of \$250,000. Phase II of the Partnership for CO_2 Capture Program is scheduled to be completed in 14 months.

PARTNERSHIP FOR CO_2 CAPTURE – PHASE II

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 of 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 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 the PCO_2C Program 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. The second phase of PCO_2C involves continuing 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.

This program involves the following objectives:

- Phase I Completed Objectives

  - Design, fabricate, and test a high-efficiency, flexible scrubber system to evaluate the performance of several scrubbing solvents in flue gas streams derived from selected fossil fuels, biomass, and blends.
  - Conduct testing of oxygen-fired combustion for selected fuels and blends in one or more of the EERC's existing pilot-scale units combined with the capability to test supercritical, ultrasupercritical, and advanced radiant heat exchangers.
  - Evaluate the performance of other CO_2 capture technologies.
  - Perform systems engineering modeling to examine efficient and cost-effective integration of CO_2 capture technologies in existing and new systems.
  - Management and reporting.
- Phase II Proposed Objectives
  - Evaluate promising and novel technologies identified from Phase I.
  - Develop and implement strategies to overcome or minimize the challenges identified in the Phase I technology evaluations.
  - Develop and implement strategies for more efficient CO_2 capture system integration to reduce energy consumption and cost.
  - Evaluate several approaches for newly developed or existing strategies for system integration.
  - Evaluate evolving or known strategies to mitigate the challenges identified from Phase I.
  - Investigate and/or develop novel approaches for CO_2 capture to demonstrate high-efficiency capture at low cost.
  - Identify the best opportunities for full-scale demonstration of viable CO_2 capture strategies.

- Identify a partner and site to demonstrate promising CO_2 capture technologies at demonstration scale.

This project will evaluate the impact of fuel characteristics on the feasibility of selected CO_2 capture technologies. The fuel types will include lignite, subbituminous, bituminous, natural gas, petroleum coke, and/or biomass. The test program will deliver information on technical issues and challenges associated with the application of these technologies to the capture of CO_2 from flue gas derived from combustion of selected fuels. A complete systems analysis and economic evaluation of the capture process will be performed as a function of technology type, coal type, and plant configuration to enable industries to make appropriate decisions to retrofit existing plants or build new plants. Phase II will utilize 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. The specific tasks to achieve the goals and objectives of the project are listed below:

Phase I

Task 1. Postcombustion Test System(s) Design, Construction, and Implementation (completed during Phase I)

  a. Flexible CO_2 capture systems

  b. Flexible flue gas cleanup and conditioning system

Task 2. Oxygen-Fired Retrofit (completed during Phase I)

Task 3. Conduct CO_2 Capture Technology Testing (completed during Phase I)

Task 4. Systems Engineering and Design (completed during Phase I)

Task 5. Management and Reporting (Phases I and II)

Phase II

Task 6. Evaluation of Promising and Novel Technologies

Task 7. Strategic Studies

Task 8. Commercial Partner-Specific Testing – Emerging Technologies

PROJECT DESCRIPTION

The proposed project is 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 to be tested in pilot-scale systems at the EERC may include solvent scrubbing, oxygen-fired combustion, and other technologies such as gas separation membranes (GSMs).

The overall goal of this project is to demonstrate a range of CO_2 capture technologies while achieving high reductions in SO_x, NO_x, particulate, mercury, and other gas constituents to meet environmental emission constraints and requirements of the CO_2 capture technologies. The technologies will be evaluated on a variety of flue gases derived from the combustion of lignite, subbituminous coal, bituminous coal, and biomass. In addition, other flue gases such as those derived from the combustion of fuel gas-derived gasification and natural gas utilization systems will also be considered for testing. The technologies chosen for evaluation under this project will be based on the results obtained from Phase I.

OBJECTIVES

The overall goal of Phase II is to further develop promising technologies toward demonstration and commercialization. In order for this to happen, the program will focus on developing and demonstrating a range of CO_2 capture technologies while achieving high reductions in SO_x, NO_x, particulate, mercury, and other gas constituents as required by CO_2 capture technologies. The technologies will be evaluated on a variety of flue gases derived from the combustion of lignite, subbituminous coal, bituminous coal, and biomass. In addition, other flue gases such as those derived from the combustion of fuel gas-derived gasification and natural gas utilization systems will also be considered for testing. The end result of the program is focused on 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.

In order to achieve the overall goal of this project, several specific objectives have been identified:

- Evaluate promising technologies identified from Phase I.
- Develop and implement strategies to overcome or minimize the challenges identified in the Phase I technology evaluations.
- Develop and implement strategies for more efficient CO_2 capture system integration to reduce energy consumption and cost.
- Evaluate several approaches for newly developed or existing strategies for system integration.
- Evaluate evolving or known strategies to mitigate the challenges identified from Phase I.
- Investigate and/or develop novel approaches for CO_2 capture to demonstrate high-efficiency capture at low cost.
- Identify the best opportunities for full-scale demonstration of viable CO_2 capture strategies.
- Identify a partner and site to demonstrate promising CO_2 capture technologies at demonstration scale.

In order to complete the objectives, four tasks have been developed and are as follows:

Task 5 – Management and Reporting (continued from Phase I)

Task 6 – Evaluation of Promising and Novel Technologies

Task 7 – Strategic Studies

Task 8 – Commercial Partner-Specific Testing – Emerging Technologies

APPROACH

Postcombustion efforts will involve design modifications of a flexible CO_2 capture system that was designed and constructed under Phase I. Several CO_2 capture technologies 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 a nearly pure stream of CO_2 ready to be dehydrated and compressed.

Postcombustion tests will involve both solvent-based technologies and solid sorbent or other promising technologies that are identified. Oxy-firing may also be considered if the project team has an interest in further evaluation of that technology. The working group will be used to identify technologies for testing.

The final task is a systems engineering analysis to model and understand the different technology integration scenarios under consideration for use with CO_2 capture. Aspen will be the primary tool and will be used with other engineering calculations and data collected during demonstration testing. This analysis will be used to determine the economic and technical feasibility of using different fuels when CO_2 capture is considered. These system engineering studies will also be used to help modify the flexible scrubbing systems discussed above.

WORKPLAN

In order to accomplish the goals and objectives of Phase II, four tasks will be performed. Tasks 1–4 were accomplished in Phase I. Task 5 will continue to facilitate the management of this phase. Tasks 5 –8 are described in more detail below.

Task 5 – Management and Reporting

This task continues to focus on ensuring the overall success of the project. Quarterly progress reports will continue to be provided a month after the end of each calendar quarter. A draft final report for Phase II tasks will be submitted for U.S. Department of Energy (DOE) and North Dakota Industrial Commission (NDIC) for comments by June 30, 2011. A final report incorporating DOE and NDIC comments will be submitted by August 31, 2011.

Task 6 – Evaluation of Promising and Novel Technologies

Task 6 includes the research needed to develop strategies to mitigate technology issues discovered during Phase I, as well as work on improved efficiency and system integration for the promising technologies identified during the previous evaluations. Task 6 is subdivided into three main subtasks discussed below:

1. CO_2 Capture Strategy Development – This subtask will involve the creation of a working group consisting of experts in the areas of combustion, emission control, and system integration. The main focus of the group will be to identify potential ways to improve CO_2 capture system integration, performance, and strategies for minimizing or eliminating technology issues. The working group may consist of industrial sponsors, EERC personnel, DOE, NDIC, and other industrial contacts with knowledge in the focus area. The group will meet on a regular basis utilizing conference calls and/or net meetings. The main resource for this group will be the results generated from the Phase I test results as well as the group's extensive professional experience. The ideas generated from this working group will be evaluated using process simulation software, and if warranted, the strategies will be evaluated on the pilot-scale systems fabricated in Phase I.

2. Systems Engineering – This subtask is the systems engineering activity, which will involve the following three activities:
   - Strategy Development Evaluation – Aspen Plus will be used as the primary tool utilizing the theoretical CO_2 capture models created during Phase I. These models will be modified when possible to reflect the ideas generated from the CO_2 capture strategy development working group. The models will be built to determine how the concepts will improve energy consumption, capture efficiency, and overall capture cost. The overall deliverable of this preliminary assessment is to determine if the concepts are feasible for implementation at the pilot scale. If they are deemed feasible theoretically, the next step will be to generate data at the pilot scale. These data will then be analyzed, and the models will be verified. The models developed in Aspen Plus can be directly imported into the Aspen Icarus Process Evaluator (IPE) for economic analysis and feasibility studies. IPE provides a vast database of costing information that is updated on a regular basis by AspenTech. The results obtained from IPE will be compared to current literature and to other models where applicable, including the Integrated Environmental Control Model. The cost of each technology will be reported on several different bases, including cost per ton of CO_2 removed, cost per kilowatt hour, and annualized capital and operating costs.
   - CO_2 Capture Technology Evaluation – This subtask will consist of a preliminary evaluation of the novel CO_2 capture technologies developed and/or investigated during Task 7: Strategic Studies. Again, Aspen Plus will be used as the primary tool used for evaluation using the theoretical CO_2 capture models that were created during Phase I. These models will be modified based on the information gathered during Task 7. The overall goal of this subtask will be to generate the necessary

information to preliminarily assess these novel technologies. The models will be used to predict energy penalties and the costs associated to capture CO_2 from a combustion system. Other technologies evaluated during Phase II will also have a part in this subtask.

- System Modification Design – This subtask will involve designing the necessary components for any system modifications needed to evaluate the strategies developed during the Strategy Development Evaluation subtask. Design will involve the specific sizing of equipment. Aspen Plus will be used where appropriate to design piping, pumps, heat exchangers, and other equipment needed for the system. Aspen will also be utilized to perform mass and energy balances around the cleanup and capture systems. Where Aspen is not appropriate, other models or standard engineering calculations will be applied as needed.

3. Pilot-Scale Testing of CO_2 Capture Technologies – This subtask will involve the pilot-scale testing necessary to evaluate/demonstrate the concepts and technologies developed or chosen for evaluation for the other tasks of the program. There are approximately 10 weeks of pilot-scale testing set aside to evaluate several technologies and strategies for implementation. The pilot-scale testing will utilize the existing equipment fabricated during Phase I of the program and/or other systems fabricated for the novel technologies developed during Phase II. The testing will involve advanced solvents, solid sorbents, other novel technologies, and further oxy-fired testing.

Task 7 – Strategic Studies

To meet the established goals for CO_2 capture from coal-based power systems, major advances in performance will be required. This will require technology advances in separation techniques and overall system integration. All of these areas are progressing in parallel, and they can often be codependent. Technology needs and obstacles can be influenced by scientific and engineering advancements in related areas, materials development, governmental policies, economic drivers, public perceptions, and other external drivers. A technology has to be integrated into a complete system to be of optimal value, including all aspects of CO_2 capture, compression, transport, and sequestration. The strategic studies task is directed at maintaining the awareness of the external factors through small paper studies and bench-scale development of technologies.

The proposed strategic studies task for Phase II of the PCO_2C Program comprises two primary areas. The first area of focus will include systems engineering to evaluate technology integration opportunities for CO_2 capture systems. The second area focuses on the development of novel CO_2 capture technologies. These novel technologies will include advanced solvents, solid sorbents, or other advanced technologies.

Task 8 – Commercial Partner-Specific Testing – Emerging Technologies

The Emerging Technologies task allows flexibility in the program for meeting critical DOE and industry needs as they arise. The EERC will work with industry stakeholders to identify critical research needs in CO_2 capture and system integration. These tasks are expected to mature during the first 6 months of this proposed task. Each new task will be required to contain the appropriate commercial cost share and will require written approval by the DOE Contracting Officer's Representative (COR).

DELIVERABLES/MILESTONES

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

- Results from testing CO_2 capture systems
- The strategies developed for increased efficiency and reduced cost
- Analysis results of evaluating system integration approaches

- Results from the development of novel technologies
- Advanced model simulations
- CO_2 capture feasibility studies
- CO_2 capture economic sensitivity analysis

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

- Information on mechanisms of CO_2 capture and its integration into overall systems.
- Increased results of CO_2 emissions and capture potential for promising capture technologies.
- Performance and cost data for various CO_2 capture technologies to assist in developing an overall capture strategy. Data available will be directly applicable to coals and plants that are part of this project.
- 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 report.

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 (UNFCCC), 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 (IEA) 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 sources of anthropogenic CO_2 are fossil-fueled power plants, automobile engines, and furnaces used in residential and commercial buildings. Ninety-seven percent of anthropogenic CO_2 emissions come from energy-related tasks (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

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 (4)

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 1.

Several types of processes have been or are being developed to separate and remove CO_2 from a flue gas stream. Figure 2 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% monoethanolamine (MEA) solution incorporating additives to control corrosion and (oxidative and thermal) degradation. Greater than 20 commercial plants ranging in size from 5 to 400 tons CO_2/day.

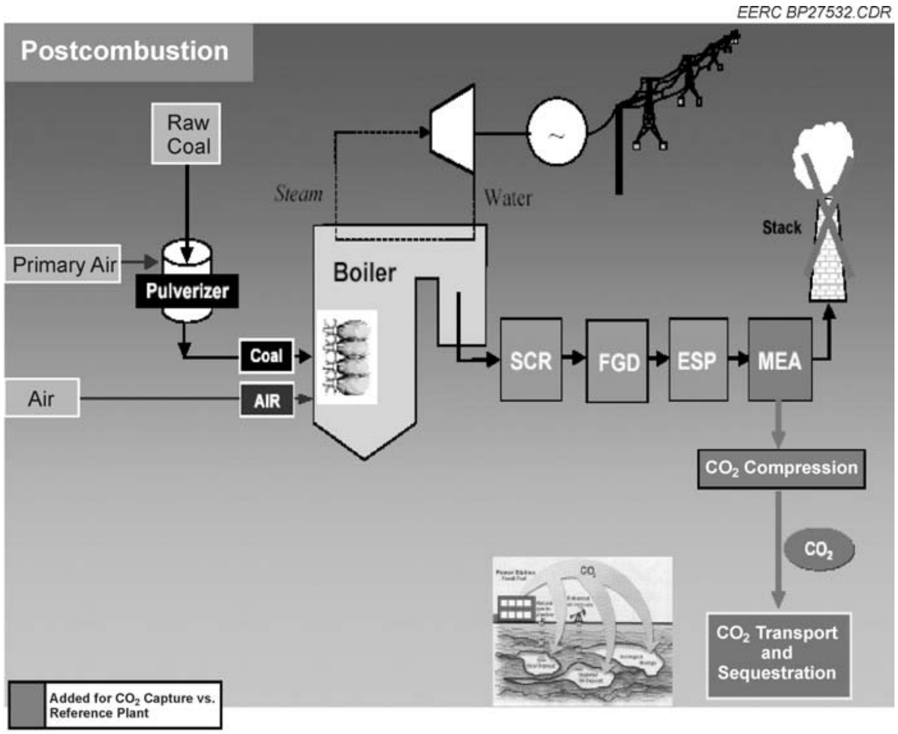


Figure 1. Schematic for postcombustion CO_2 capture (5).

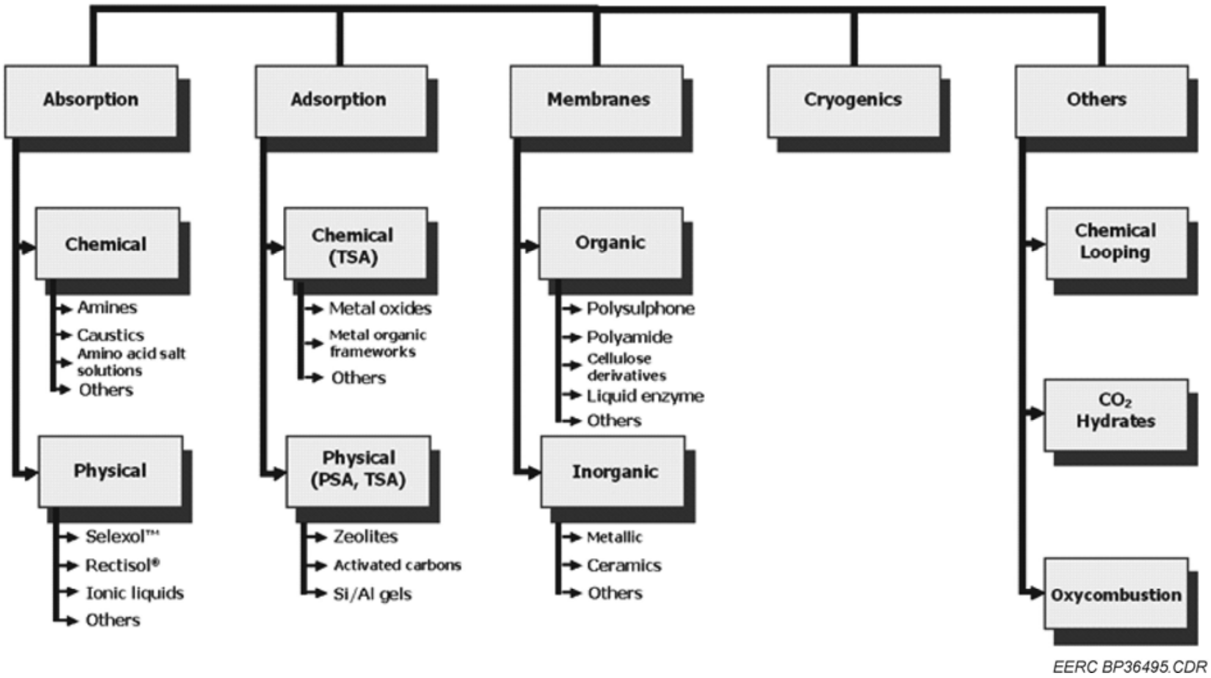


Figure 2. CO_2 capture and separation technology types.

i. ABB-Lummus Global

- 15%–20% MEA solution. Four commercial plants ranging in size from 150 to 850 tons CO_2/day.

ii. Mitsubishi Heavy Industries

- KS-1 – sterically hindered amines. Two commercial plants: ~210 and 30 ton CO_2/day.

iii. Cansolv

- Mixture of amines. Commercial plant case study at NSC (Japan).

iv. HTC Pure Energy

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

v. DOW/Alstom Power

- Advanced amine process.

vi. Hitachi

- Proprietary mixture of amines.

vii. Huntsman Chemical

- Proprietary mixture of amines with bench- and small-pilot-scale data.

viii. 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 (AEP) Demonstration, We Energies pilot plant and other slipstream demonstrations.

2. Adsorption (solid sorbents)
    a. Research Triangle Institute (RTI) international dry carbonate process
    b. ADA-ES carbon-based amine-enriched sorbents
    c. NETL amine-enriched sorbents
    d. Süd-Chemie
    e. TDA
    f. Metal Organic Frameworks (MOFs)
    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 [RITE])
    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 3 is a flow sheet 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 (PSA) is also used, but the CO_2-rich stream may have significant residual fuel value that makes it attractive for in-plant use.

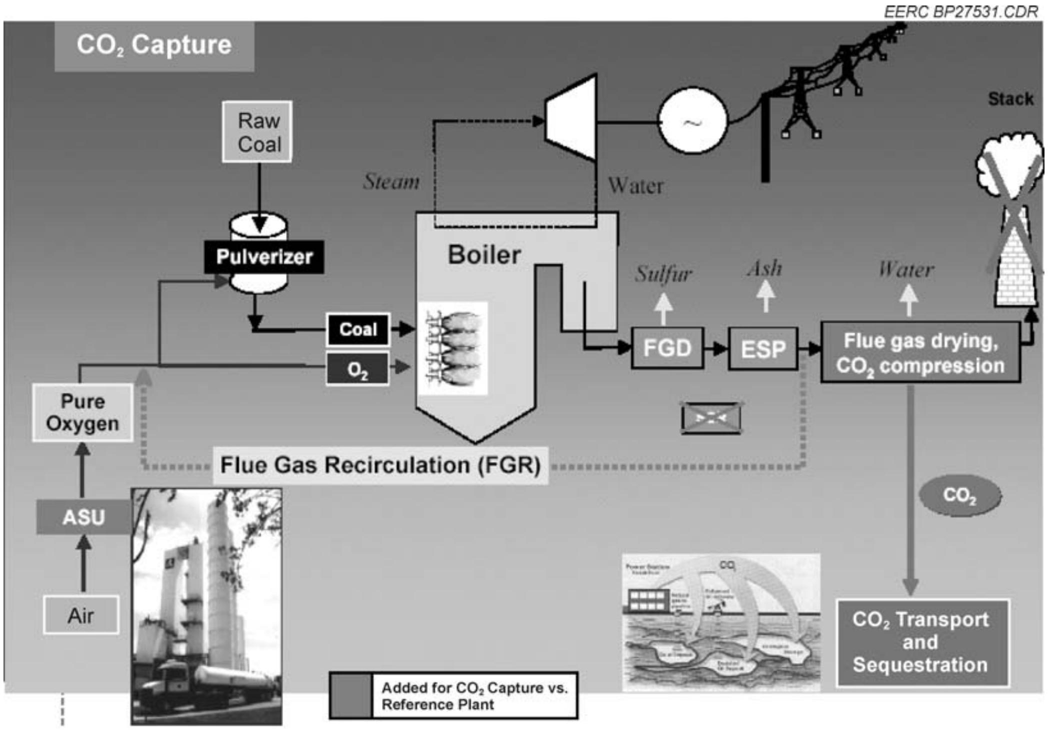


Figure 3. Schematic of an oxygen combustion system (5).

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 (ECBM) 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 (EOR) 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.

Oxygen combustion has several advantages. 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 (ASU) 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 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 pulverized coal (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, 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 solvents can do in terms of decreasing the costs of capturing CO_2. Figure 4 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 5. This is accomplished by designing a solvent with favorable thermodynamics. Discovery of favorable kinetics can reduce capital cost significantly. 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 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"

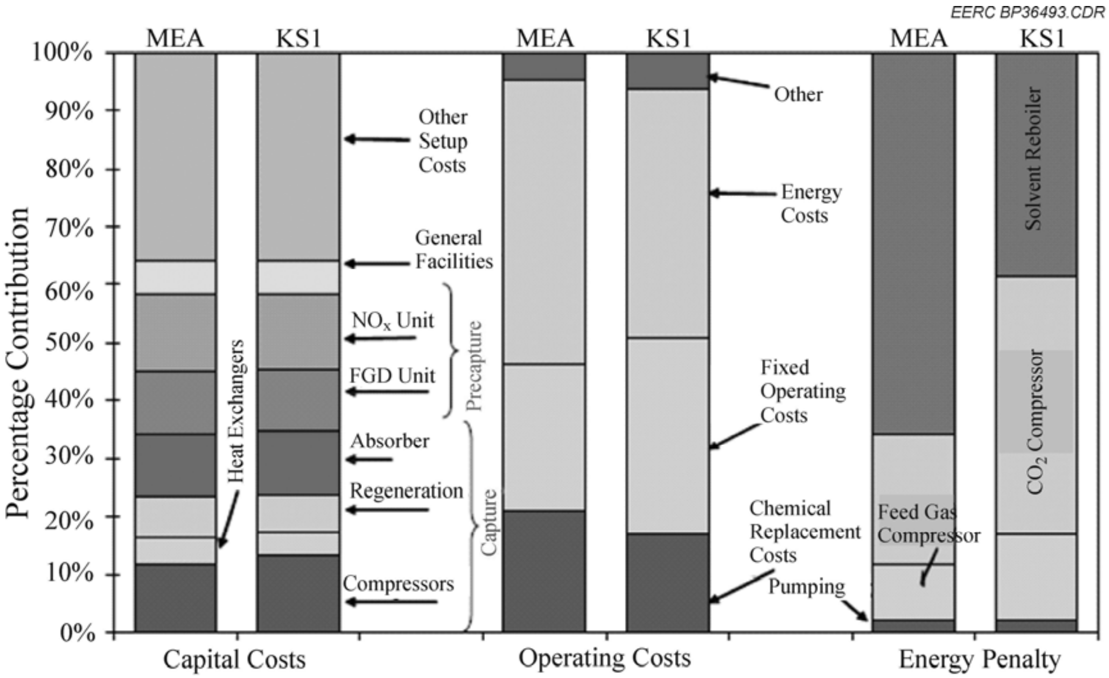


Figure 4. Capital and operating costs and estimates of energy penalties for both MEA and KS1 solvents.

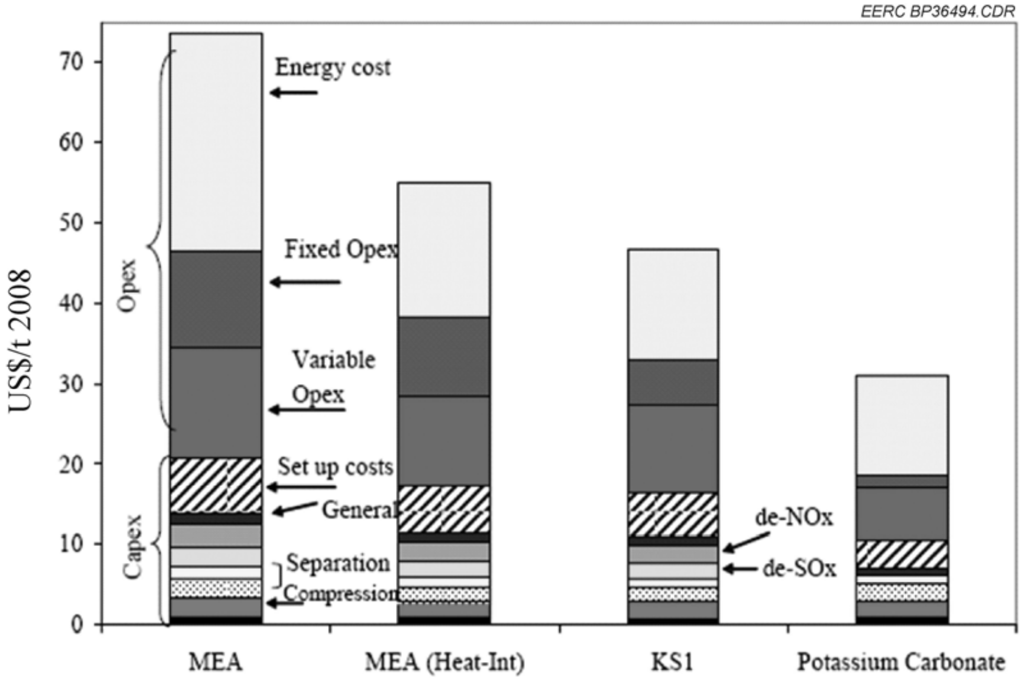


Figure 5. CO_2 capture cost breakdown.

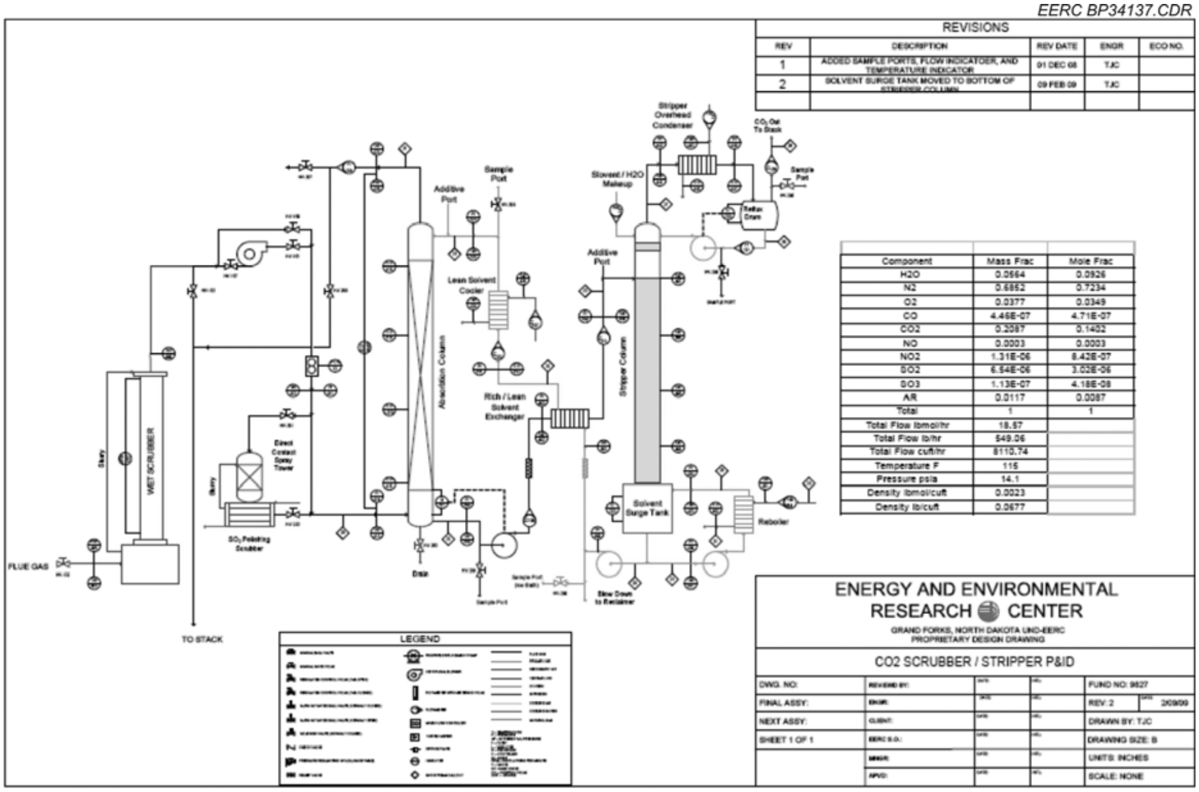
approach for capturing CO_2; several CO_2 capture technologies will need to be used on a site-by-site evaluation. Further cost reductions can be realized if capital equipment costs can be decreased. This can be accomplished by increasing the mass-transfer rate between the CO_2 and the liquid solvent.

Phase I Accomplishments

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 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 6.

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, see Appendix A). 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 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



REVISIONS				
REV	DESCRIPTION	REV DATE	ENGR	ECO NO.
1	ADDED SAMPLE PORTS, FLOW INDICATOER, AND TEMPERATURE INDICATOR	01 DEC 08	TJC	
2	SOLVENT SURGE TANK MOVED TO BOTTOM OF STRIPPER COLUMN	09 FEB 09	TJC	

Component	Mass Frac	Mole Frac
H2O	0.0564	0.0926
N2	0.6852	0.7234
O2	0.0377	0.0349
CO	4.46E-07	4.71E-07
CO2	0.2087	0.1402
NO	0.0003	0.0003
NO2	1.31E-06	8.42E-07
SO2	6.54E-06	3.02E-06
SO3	1.13E-07	4.18E-08
AR	0.0117	0.0087
Total	1	1
Total Flow lbmol/hr	18.57	
Total Flow lb/hr	549.06	
Total Flow cuft/hr	8110.74	
Temperature F	115	
Pressure psia	14.1	
Density lbmol/cuft	0.0023	
Density lb/cuft	0.0677	

Figure 6. P&ID of the solvent absorption/stripper system designed during Phase I.

and a suite of gas cleanup systems that include electrostatic precipitators, fabric filtration, selective catalytic reduction, 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 7 shows a P&ID of the oxygen-fired retrofit system.

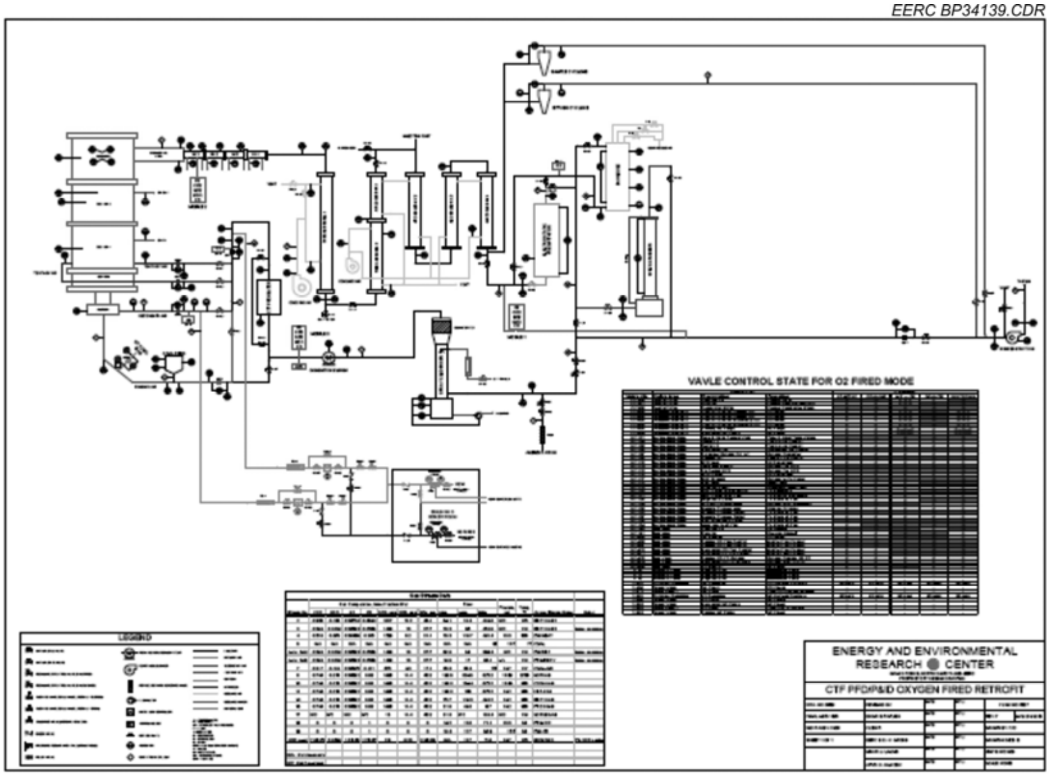


Figure 7. Schematic of oxygen-fired retrofit on the CTF and auxiliary systems.

Task 3 – Conduct CO2 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 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 addresses management and reporting. Its success was demonstrated by the timely and cost-effective accomplishment of contractual deliverables and milestones. Task 5 will continue through the next phase.

QUALIFICATIONS

The EERC is a research facility that operates as a business unit of UND. The EERC has an annual budget of $43.9 million and has worked with nearly 1100 clients in all 50 states and 51 countries. The EERC has a multidisciplinary staff of more than 340 who have expertise and partnerships in a broad spectrum of energy and environmental programs, including over 50 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; conducting field testing and demonstrations; and advanced analysis of materials.

The project manager and principal investigators are many of the same team members who contributed greatly to the successful completion of many tasks in the Phase I project. Details of their qualifications can be found in the enclosed resumes. The EERC has a staff of fabricators from the various crafts and trades (welders, machinists, electricians, instrumentation and controls, etc.) who have extensive talent and experience with all aspects of producing and modifying combustion, gasification, and gas cleanup systems. As a result, it is anticipated that little outsourcing will need to be done and the control of the resource allocation and scheduling can be handled internally. Additionally, quality control is maintained in-house. Many of these people serve dual roles at the EERC, with the fabricators being the operators of the systems when they are complete. This unique situation has resulted in the integration of the fabricator/operators in the early stages of the mechanical design process alongside the engineers and designers. There is a great deal of transparency in the management of projects, so all members of the team feel motivated to contribute.

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.

MANAGEMENT

This project will be executed by the EERC (Table 2), with guidance from the project team made up of the industrial sponsors, NDIC, and DOE. Mr. Brandon Pavlish will be responsible for overall task management and strategic studies. Other task managers have been assigned for each of the tasks discussed above and include Mr. John Kay, Mr. Josh Stanislowski, and Mr. Scott Tolbert. The Plains CO_2 Reduction (PCOR) Partnership team along with Mr. Jason Laumb will serve as project advisors. Figure 8 provides an overview of the project management structure. Resumes for key personnel can be found in Appendix B.

PROJECT SCHEDULE

The proposed tasks for Phase II will take 18 months to complete. An overview of the schedule for the project is shown in Table 3.

BUDGET/MATCHING FUNDS

The EERC is requesting $150,000 from the NDIC to support the PCO_2C Phase II effort. The total estimated cost for Phase II is $1,860,000, of this the EERC has requested and secured $1,460,000 through the EERC’s Strategic National Energy Security Solutions (SNESS) Program from DOE. The remaining $250,000 required to complete the program will consist of funding through a consortium of industrial participants, which has been verbally secured. 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 to happen. Budget information is found in Appendix C. Letters of support appear in Appendix D.

Table 2. Key Personnel

Name	Role	Hours
Brandon Pavlish	Project Manager	1500
John Kay	Principal Investigator	1000
Josh Stanislowski	Principal Investigator	1000
Scott Tolbert	Principal Investigator	550
Jason Laumb	Project Advisor	700

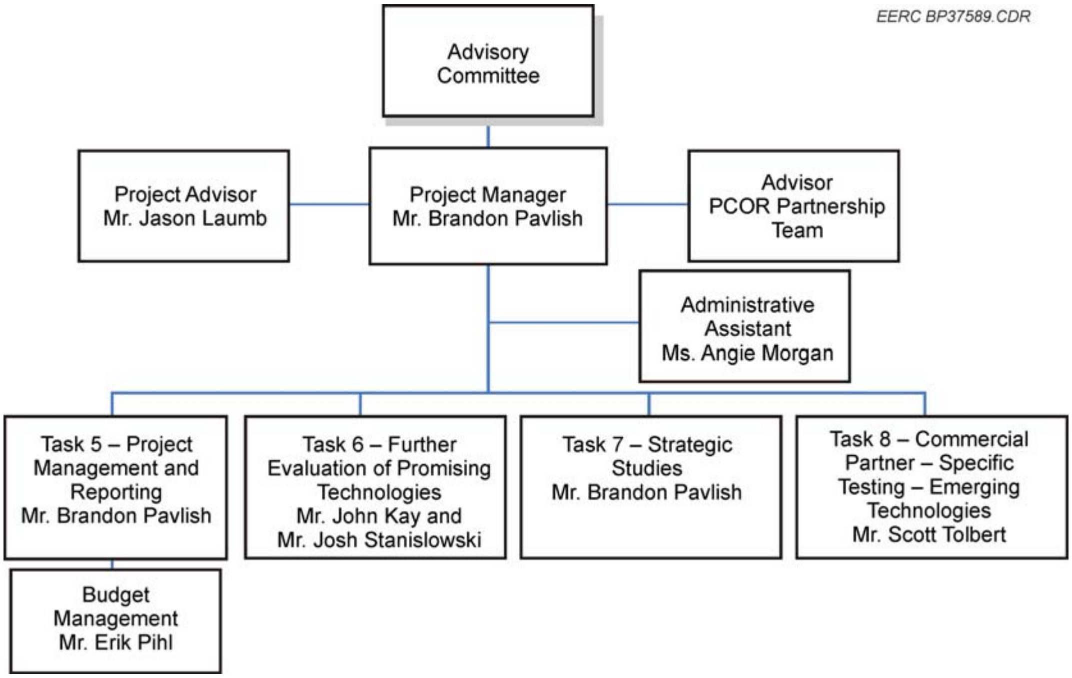


Figure 8. Overview of management structure.

Table 3. Schedule of Tasks

Tasks	Duration
5 – Project Management and Reporting	1–14 months
6 – Further Evaluation of Promising Technologies	1–12 months
7 – Strategic Studies	1–12 months
8 – Commercial Partner-Specific Testing – Emerging Technologies	2–12 months

TAX LIABILITY

The EERC—a research organization within the University of North Dakota, which is an institution of higher education within the state of North Dakota—is not a taxable entity.

CONFIDENTIAL INFORMATION

No confidential information is included in this proposal.

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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 backend 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.

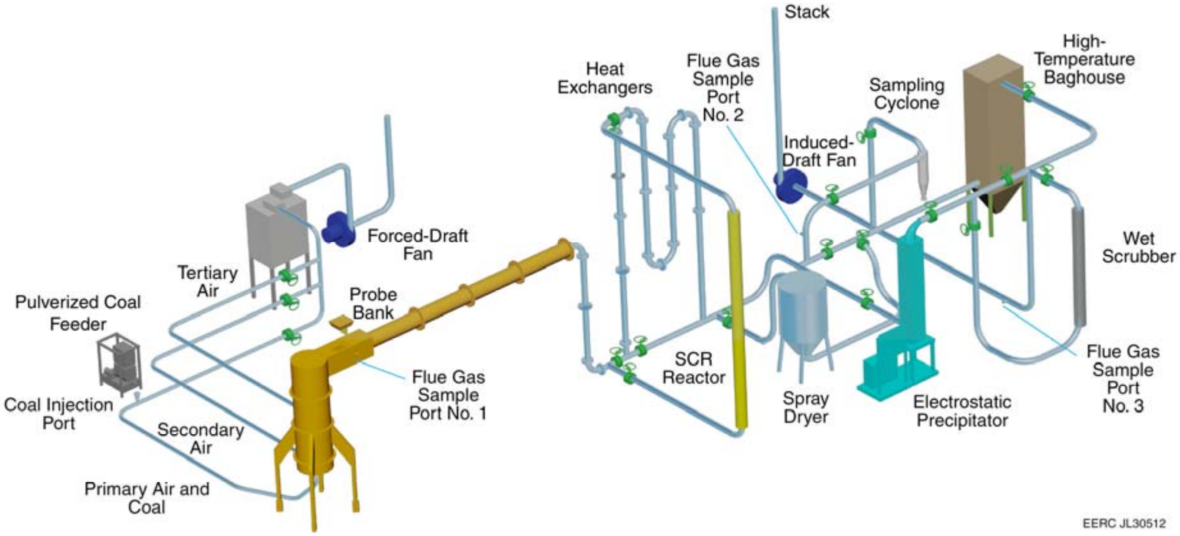

Figure A-1. CTF and auxiliary systems.

APPENDIX B

RESUMES OF KEY PERSONNEL

BRANDON M. PAVLISH
Research Manager
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
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.

JOSHUA J. STANISLOWSKI

Research Manager
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, North Dakota 58202-9018 USA
Phone: (701) 777-5087, Fax: (701) 777-5181, E-Mail: jstanislowski@undeerc.org

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.

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.

JOHN P. KAY

Research Manager
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, North Dakota 58202-9018 USA
Phone: (701) 777-4580, Fax: (701) 777-5181, E-Mail: jkay@undeerc.org

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.

SCOTT G. TOLBERT

Research Manager
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, North Dakota 58202-9018 USA
Phone: (701) 777-5096, Fax: (701) 777-5181, E-Mail: stolbert@undeerc.org

Principal Areas of Interest and Expertise

Mr. Tolbert's principal areas of interest and expertise is in the design, construction, and operation of bench- and pilot-scale equipment for testing various fuel conversion and environmental control processes, advanced multipollutant control and gas cleanup, hydrogen/CO_2 separation, hybrid electric vehicle drive systems, fuel cells, photovoltaics, and electrolyzer technologies. He has worked on design and construction projects involving small-scale combustion and gasification systems as well as gas cleanup systems. He has worked on processes for sulfur control for gasification systems that have been focused on providing a clean gas stream for hydrogen production and utilization. Mr. Tolbert has over a decade of experience with advanced vehicular photovoltaic and proton exchange membrane (PEM) fuel cell energy systems.

Qualifications

M.S., Industrial Technology, University of North Dakota, 1990.
B.S., Industrial Technology, University of North Dakota, 1985.

Professional Experience

2006–Present: Research Manager, EERC, UND, Grand Forks, North Dakota. Mr. Tolbert'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. His work focuses on hydrogen production and utilization.

1990–2006: Assistant Professor, Department of Mechanical Engineering, UND, Grand Forks, North Dakota.

1992–2006: Consultant. Mr. Tolbert provided expertise on electrohydraulic machinery and ISO certifications to Toro Company Inc., Mayo Manufacturing Inc., and Hawkes Manufacturing Inc.

1998–2002: Assistant to the Dean, School of Engineering and Mines, UND, Grand Forks, North Dakota.

1997–2002: System Administrator, Computer-Aided Engineering Network, School of Engineering and Mines, UND, Grand Forks, North Dakota.

1988–1990: Instructor, Department of Mechanical Engineering, UND, Grand Forks, North Dakota.

Professional Memberships
Steering Committee, Upper Midwest Hydrogen Initiative
American Society for Engineering Education (ASEE)
Engineering Design Graphics Division, ASEE
Faculty Advisor, UND Society for Energy Alternatives
UND Student Technology Fee Committee
University Information Technology Council
UND Academic Advising Committee
UND Enrollment Management Summit Group

Publications and Presentations
Has authored or coauthored several publications and presentations.

APPENDIX C

BUDGET AND BUDGET NOTES

PARTNERSHIP FOR CO_2 CAPTURE – PHASE II
NDIC
PROPOSED PROJECT START DATE: 7/1/10
EERC PROPOSAL #2010-0211

BUDGET SUMMARY

CATEGORY			**PROJECT TOTAL**		**INDUSTRY SHARE**		**NDIC SHARE**		**DOE SHARE**	
LABOR		Rate	Hrs	Cost	Hrs	Cost	Hrs	Cost	Hrs	Cost
Pavlish, B.	Project Manager	$ 33.31	1,500	$ 49,966	197	$ 6,563	50	$ 1,666	1,253	$ 41,737
Kay, J.	Principal Investigator	$ 40.08	1,000	$ 40,080	85	$ 3,407	83	$ 3,327	832	$ 33,346
Stanislowski, J.	Principal Investigator	$ 36.78	1,000	$ 36,780	85	$ 3,126	83	$ 3,053	832	$ 30,601
Tolbert, S.	Research Scientist/Engineer	$ 43.20	550	$ 23,760	-	$ -	-	$ -	550	$ 23,760
Laumb, J.	Research Scientist/Engineer	$ 51.19	700	$ 35,833	86	$ 4,402	14	$ 717	600	$ 30,714
--------------	Senior Management	$ 70.17	575	$ 40,347	21	$ 1,474	18	$ 1,263	536	$ 37,610
--------------	Research Scientists/Engineers	$ 38.29	4,829	$ 184,902	584	$ 22,361	560	$ 21,442	3,685	$ 141,099
--------------	Research Technicians	$ 25.08	1,065	$ 26,711	108	$ 2,709	-	$ -	957	$ 24,002
--------------	Technology Dev. Mechanics	$ 29.23	2,990	$ 87,398	600	$ 17,538	500	$ 14,615	1,890	$ 55,245
--------------	Undergrad-Res.	$ 11.26	1,916	$ 21,574	153	$ 1,723	-	$ -	1,763	$ 19,851
--------------	Technical Support Services	$ 20.02	255	$ 5,106	38	$ 760	14	$ 280	203	$ 4,066
				$ 552,457		$ 64,063		$ 46,363		$ 442,031
Escalation Above Base			6%	$ 33,148		$ 3,843		$ 2,782		$ 26,523
TOTAL DIRECT HRS/SALARIES			16,380	$ 585,605	1,957	$ 67,906	1,322	$ 49,145	13,101	$ 468,554
Fringe Benefits - % of Direct Labor - Staff		54.0%		$ 303,878		$ 35,683		$ 26,538		$ 241,657
Fringe Benefits - % of Direct Labor - Undergrad. Research		1.0%		$ 228		$ 18		$ -		$ 210
TOTAL FRINGE BENEFITS				$ 304,106		$ 35,701		$ 26,538		$ 241,867
TOTAL LABOR				$ 889,711		$ 103,607		$ 75,683		$ 710,421
TRAVEL				$ 23,540		$ 2,705		$ -		$ 20,835
EQUIPMENT > $5000				$ 50,000		$ -		$ -		$ 50,000
SUPPLIES				$ 48,950		$ 7,816		$ 522		$ 40,612
COMMUNICATION - PHONES & POSTAGE				$ 1,817		$ 370		$ 20		$ 1,427
PRINTING & DUPLICATING				$ 1,360		$ 165		$ 20		$ 1,175
FOOD				$ 2,000		$ 2,000		$ -		$ -
OPERATING FEES & SVCS										
Fuels & Materials Research Lab.				$ 16,430		$ -		$ -		$ 16,430
Combustion Test Svcs.				$ 145,008		$ 24,168		$ -		$ 120,840
Particulate Analysis				$ 16,642		$ -		$ 16,642		$ -
Fuel Prep. and Maintenance				$ 14,416		$ 14,416		$ -		$ -
Graphics Support				$ 5,497		$ 72		$ 89		$ 5,336
Shop & Operations Support				$ 4,627		$ 929		$ 774		$ 2,924
Outside Lab.				$ 20,000		$ -		$ -		$ 20,000
TOTAL DIRECT COST				$ 1,239,998		$ 156,248		$ 93,750		$ 990,000
FACILITIES & ADMIN. RATE - % OF MTDC			VAR	$ 620,002	60%	$ 93,752	60%	$ 56,250	50%	$ 470,000
TOTAL PROJECT COST - US DOLLARS				$ 1,860,000		$ 250,000		$ 150,000		$ 1,460,000

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.

DETAILED BUDGET - TRAVEL

RATES USED TO CALCULATE ESTIMATED TRAVEL EXPENSES

DESTINATION	AIRFARE	LODGING	PER DIEM	CAR RENTAL	REGIST.
Unspecified Destination (USA) – Conference	$ 950	$ 175	$ 71	$ 75	$ 525
Unspecified Destination (USA) – Meeting	$ 950	$ 175	$ 71	$ 75	$ -

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	4	$ 1,900	$ 1,050	$ 568	$ 300	$ 160	$ 1,050	$ 5,028
Meeting/Unspecified Dest. (USA)	2	2	3	$ 3,800	$ 1,400	$ 852	$ 450	$ 240	$ -	$ 6,742
Conference/Unspecified Dest. (USA)	1	2	4	$ 1,900	$ 1,050	$ 568	$ 300	$ 160	$ 1,050	$ 5,028
Meeting/Unspecified Dest. (USA)	2	2	3	$ 3,800	$ 1,400	$ 852	$ 450	$ 240	$ -	$ 6,742
TOTAL ESTIMATED TRAVEL										$ 23,540

PARTNERSHIP FOR CO_2 CAPTURE – PHASE II
EERC PROPOSAL #2010-0211

DETAILED BUDGET - EQUIPMENT

Fabricated Equipment	$COST
Piping	$ 8,000
Steel	$ 15,000
Analysis Equipment	$ 12,000
Control Systems	$ 5,000
Miscellaneous	$ 10,000
Total Estimated Cost: CO_2 Sequestration System	$ 50,000
Total Equipment	$ 50,000

PARTNERSHIP FOR CO_2 CAPTURE – PHASE II
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DETAILED BUDGET - EERC RECHARGE CENTERS

		PROJECT	
Fuels & Materials Research Lab.	Rate	#	$Cost
Ash Determination	$49	20	$ 980
BTU	$74	20	$ 1,480
CHN	$115	20	$ 2,300
Miscellaneous	$102	20	$ 2,040
Moisture %	$66	20	$ 1,320
Proximate Analysis	$89	20	$ 1,780
Proximate Ultimate	$209	20	$ 4,180
Sulfur	$71	20	$ 1,420
Subtotal			$ 15,500
Escalation		6%	$ 930
Total Fuels & Materials Research Lab.			$ 16,430
Combustion Test Services	Rate	#	$Cost
Combustion Test Facility (CTF) (Hourly)	$95	1,440	$ 136,800
Subtotal			$ 136,800
Escalation		6%	$ 8,208
Total Combustion Test Services			$ 145,008
Particulate Analysis	Rate	#	$Cost
Mercury CEM (Daily)	$314	50	$ 15,700
Subtotal			$ 15,700
Escalation		6%	$ 942
Total Particulate Analysis			$ 16,642
Fuel Preparation & Maintenance	Rate	#	$Cost
Fuel Preparation & Maintenance (Hourly per piece of equip)	$34	400	$ 13,600
Subtotal			$ 13,600
Escalation		6%	$ 816
Total Fuel Prep. & Maintenance			$ 14,416
Graphics Support	Rate	#	$Cost
Graphics (hourly)	$61	85	$ 5,185
Subtotal			$ 5,185
Escalation		6%	$ 312
Total Graphics Support			$ 5,497
Shop & Operations Support	Rate	#	$Cost
Technical Development Hours	$1.46	2,990	$ 4,365
Subtotal			$ 4,365
Escalation		6%	$ 262
Total Shop & Operations Support			$ 4,627

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.

APPENDIX D

LETTERS OF SUPPORT

EERC®
Energy & Environmental Research Center

UNIVERSITY OF NORTH DAKOTA
15 North 23rd Street — Stop 9018 / Grand Forks, ND 58202-9018 / Phone: (701) 777-5000 Fax: 777-5181
Web Site: www.undeerc.org

March 31, 2010

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

Dear Ms. Fine:

Subject: Cost Share for EERC Proposal No 2010-0211, Entitled "Partnership for CO_2 Capture – Phase II"

The Energy & Environmental Research Center (EERC) is conducting complementary research and development efforts under a multi-million 5-year Cooperative Agreement with the U.S. Department of Energy (DOE) entitled "Joint Program on Research and Development for Fossil Energy-Related Resources – Strategic National Energy Security Solutions." Through this joint program, nonfederal entities can team with EERC and DOE in projects that address the goals and objectives of DOE's Office of Fossil Energy.

The proposed project to the North Dakota Industrial Commission (NDIC) entitled "Partnership for CO_2 Capture – Phase II" is a viable candidate for funding under this program. Therefore, the EERC will provide $1,460,000 of cash cost share for the proposed project through its Cooperative Agreement with DOE, and $250,000 from other industry partners, providing that the NDIC commits $150,000 of cash cost share.

Once the EERC has NDIC's commitment to the project, the EERC will submit the scope of work to DOE for its concurrence. Initiation of the proposed work is contingent upon the execution of a mutually negotiated agreement or modification to an existing agreement between EERC and each of the project sponsors. If you have any questions, please contact me by phone at (701) 777-5131 or by e-mail at ghg@undeerc.org.

Sincerely,

Gerald H. Groenewold
Director

GHG/sah

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 "The Partnership for CO_2 Capture: Phase II"

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/dz

Wayne Backman
Senior Vice President, Generation

rle/dz