April 4, 2005

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

Dear Ms. Fine:

Subject: EERC Proposal No. 2005-0227, "Activated Carbon Production from North Dakota Lignite"

Enclosed are the original and seven copies of the subject proposal. The goal of this project is to determine the feasibility of a commercial process for carbon production from North Dakota lignite. Research by the Energy & Environmental Research Center has shown that activated carbon prepared from North Dakota lignite could perform as well as commercially available carbon-based sorbent for mercury control. Also enclosed is the $100 application fee.

If you have any questions or comments, please contact me by phone at (701) 777-5177 or by e-mail at sbenson@undeerc.org.

Sincerely,

Steven A. Benson, Ph.D.
Senior Research Manager

SAB/krg

Enclosures

c/enc: Harvey Ness, Lignite Research Council

ACTIVATED CARBON PRODUCTION FROM NORTH DAKOTA LIGNITE

EERC Proposal No. 2005-0227

Submitted to:

Ms. Karlene Fine

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

Proposal Amount: $250,000

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April 2005

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ACTIVATED CARBON PRODUCTION FROM NORTH DAKOTA LIGNITE

ABSTRACT

The goal of this Energy & Environmental Research Center (EERC) project is to develop information to determine the feasibility of a commercial process for carbon production from North Dakota (ND) lignite. This project will scale up preparation of ND lignite from bench- to pilot-scale to produce activated carbons for use as advanced mercury control sorbents and in other applications. The work will evaluate selected methods to produce activated carbons from ND lignites using conditions established at a bench scale. These methods include a pilot-scale rotary kiln, a multihearth furnace, a fluidized bed furnace, and a transport reactor furnace. A preliminary evaluation of the different methods will identify the preferred reactors for testing at the pilot scale. The resulting carbons will be characterized to determine their surface area and physicochemical surface characteristics. These results will be compared to sorbents that have shown good mercury capture efficiency in power plant flue gases. In addition, the best carbons will be modified with known methods and exposed to flue gas that contains mercury vapors. This will provide information for the development of more effective and lower-cost sorbents to control elemental mercury emissions from combustion systems firing low-chlorine ND lignite coals. A task is also proposed to perform a market assessment and conceptualize a commercial activated carbon production facility in North Dakota.

The project is scheduled for 9 months with a total cost of $770,000, of which $270,000 is requested from the U.S. Department of Energy. Industry partners will provide $250,000 in cash; $250,000 is requested from the North Dakota Industrial Commission.

ACTIVATED CARBON PRODUCTION FROM NORTH DAKOTA LIGNITE

PROJECT SUMMARY

Since 1991, carbon use in the United States for gas- and liquid-phase cleanup has grown consistently with gross domestic product growth. At the same time, imports of Chinese carbon doubled from 1996 to 2001 to 57 million pounds. U.S. demand is expected to rise to about 450 million pounds in 2006, due to increased use in environmental applications. These estimates do not include the potential new market for mercury control. Additional significant growth in the demand for carbon is anticipated as a result of the need to control the emission of mercury from coal-fired power plants. Activated carbon injection (ACI) upstream of particulate control devices such as a fabric filter (FF) (baghouse) or electrostatic precipitators (ESP) is showing significant promise for controlling mercury emissions. For activated carbons to be successful, they must effectively sorb elemental (Hg^0) and oxidized (Hg^{2+}) forms of mercury. Testing at the Energy & Environmental Research Center (EERC) has shown that activated carbon (AC) sorbents prepared from Fort Union lignites performed as well as the commercial sorbent NORIT America DARCO® FGD in bench-scale evaluations for mercury control (1). These capabilities were verified particularly in a low-acid flue gas stream, as a long-term sorbent, and as an elemental mercury oxidant, indicating their effectiveness in the challenging case of removing mercury from flue gases from lignite-fired boilers. This means that sorbents from North Dakota (ND) lignite could compete in the market for carbon sorbent injection technology, the most mature technology for mercury control from coal-fired power plants, from which the U.S. Environmental Protection Agency (EPA) has mandated a reduction of mercury emissions. On March 15, 2005, the EPA issued the first federal rule to permanently cap and reduce mercury

emissions from coal-fired power plants (a power plant is defined as an electrical generating facility that provides >25 MW_e) (2).

The projected annual cost for activated carbon sorption of mercury in a duct injection system is significant. For an untreated activated carbon, the carbon-to-mercury weight ratios of 3000–18,000 (gram of carbon injected per gram of mercury in flue gas) have been estimated to achieve 90% mercury removal from a coal combustion flue gas containing 10 $\mu g/Nm^3$ of mercury (3). More efficient carbon-based sorbents enhanced for mercury control could enable lower carbon-to-mercury weight ratios to be used, thus reducing the operating costs of carbon injection. The United States has about 320 GW_e of coal-fired capapcity. It is estimated that with the more efficient carbons, carbon injection-to-mercury removal rates of 500:1–1000:1 can be achieved. The potential sorbent cost is estimated at $0.30–$0.50/lb for the untreated sorbent and $0.5–$0.8/lb for the enhanced sorbent. Based on these estimates, the potential market for carbon-based sorbents for mercury control is expected to be $100 million or more annually.

The goal of this EERC project is to develop information to determine the feasibility of a commercial process for carbon production from ND lignite. This would be the basic carbon that can be improved by sorbent-enhancement agents or by chemically treating the carbon prior to injection. The objectives of the project include the following: 1) examine viable options for producing activated carbon sorbents from lignite; 2) scale up the carbon activation process of Fort Union lignite coals from laboratory fixed-bed to pilot-scale production; 3) determine the surface area, physiochemical surface characteristics, and flue gas-surface interactions of prepared carbons and compare to bench-scale and other carbons; and 4) develop a design for commercial implementation of an activated carbon production facility in North Dakota.

In order to meet these objectives, the research plan will produce activated carbon in the pilot-scale reactors, examine chemical and physical characteristics of the prepared carbons, assess the potential mercury sorbent and activated carbon markets, and prepare a design for a commercial activated carbon plant.

PROJECT DESCRIPTION

Goals and Objectives

The goal of this EERC program is to develop information to determine the feasibility of a commercial process for activated carbon mercury sorbent production from ND lignite. The objectives of the project include the following: 1) examine viable options for producing activated carbon sorbents from lignite; 2) scale up the carbon activation process of Fort Union lignite coals from laboratory fixed-bed to pilot-scale production; 3) determine the surface area, physiochemical surface characteristics, and flue gas-surface interactions of prepared carbons and compare to bench-scale and other carbons; and 4) develop a design for commercial implementation of an activated carbon production facility in North Dakota.

Work Plan

The research will be carried out in four tasks.

Task 1 – Pilot-Scale Optimization and Production

Optimization of Activated Carbon Production. This activity will assess the application of various methods to produce activated carbons. Activated carbon production involves two main steps: 1) carbonization—driving out volatiles to obtain the fixed carbon portion of the coal, and 2) activation—partial gasification with steam or carbon dioxide to open the pore structure and create the surface area. Various types of reactors are used in the commercial production of activated carbon. These methods include rotary kilns, multihearth furnaces, fluidized beds, and transport reactors. Rotary kilns and multihearth furnaces are the most widely used for commercial production of activated carbon. The use of fluidized-bed reactors and transport reactors may provide the opportunity to utilize finer raw material and streamline the production method.

After a preliminary evaluation of the different methods, tests will be conducted at the bench-scale level with selected methods to produce activated carbons over a range of operating conditions. This project will examine the key factors that influence the production of optimum activated carbon: temperature, residence time, oxygen content, and steam content. These factors will be varied to determine the proper operating conditions to produce a commercially competitive activated carbon sorbent. The operating variables for the activation step to be evaluated may include solids residence time, temperature, and activation gas composition. These will be optimized by parametric testing, using a statistically designed matrix. Expected ranges for the process variables are presented in Table 1.

Table 1. Optimization Ranges for Carbonization and Activation Parameters

Parameter	Carbonization	Activation
Solids Residence Time, min	60–240	30–60
Temperature, °C	400	750–850
Process Gas	N_2	Steam in N_2
Process Gas Rate, mole/mole °C	Achieve carbonization temperature	Achieve activation temperature and steam/carbon ~ 1
Additional Oxygen/Air	Trace	Trace

Preliminary evaluations of the lignites will include proximate and ultimate analysis and determination of primary inorganic constituents using x-ray fluorescence spectroscopy (XRF). After the results from the bench-scale materials are obtained, tests will be conducted for selected conditions at the pilot scale. Following gas flow modifications to the rotary kiln system at the EERC, a limited number of scoping tests will be performed on one Fort Union lignite to verify production of a suitable char intermediate. Additional pilot-scale tests for both the carbonization and activation steps will be conducted using a rotary kiln, a multihearth furnace, and a fluidized-bed reactor. The pilot-scale furnaces are available through a carbon vendor, a multihearth system manufacturer, as well as at the EERC. These systems are capable of producing activated carbons at approximately 20–75 lb/hr. Activation products will be evaluated for fixed- and volatile-carbon content, and iodine number (an estimate of surface area). In addition, fixed-bed testing will be conducted for mercury capture for the various sorbents under simulated low-acid flue gas conditions.

Additional lignite samples (up to three containing varying levels of constituents) will be carbonized and activated at conditions as determined to be optimum for the test reactor of choice for the first lignite to provide insight into the effect of varying coal composition on the activation process. The resulting activated carbon sorbents will also be evaluated for carbon content, iodine number, and mercury capture.

AC Production and Pilot-Scale Testing for Hg Capture. Based on the parameters established in the optimization subtask, 100- to 200-lb lots of carbon will be produced for testing mercury removal either in a slip-stream baghouse for mercury control at a candidate lignite-fired utility site or in the EERC's Particulate Test Combuster (PTC). The EERC has several current and pending research projects that include slipstream testing at a full-scale utility. The PTC would combust a selected ND lignite, with sorbent injected upstream of the ESP. Selected sorbent enhancements could also be tested, including the addition of the EERC's sorbent enhancement additives to enhance their ability to capture mercury. In either case, the level of mercury control will be compared to results obtained in past testing with other commercially available sorbents.

As an additional proof-of-concept step, one set of larger-scale demonstration carbonization and activation tests will be performed using ND lignite at a kiln vendor's production facility. The vendor facility will be a rotary kiln system with a 42-in ID tube, 45 ft long and a production rate of 50–100 lb/hr. The process will involve a carbonization step followed by an activation step. The activation step will be conducted in the rotary kiln, but the parameters obtained for the process conditions are directly transferable to the design and sizing of either a multihearth furnace or a rotary kiln for the full-scale production process. The goal for the test will be to produce approximately three 500-lb batches of activated carbon from a ND lignite. All produced carbons will be characterized for surface area and mercury reactivity at the bench-scale. The best carbon(s) will be tested either in the slip-stream baghouse or PTC as described above.

Task 2 – Sorbent Properties Investigations

The main objective of this task is to understand the properties of carbon sorbents from ND lignite prepared under various applications.

Physical and Chemical Characteristics. The surface area and physicochemical characteristics of the carbon will be examined. Based on past studies, both the surface area and the chemistry of the surface of the activated carbon have a major impact on the ability of the carbon to capture mercury. The methods will include the determination of the iodine number;

selected samples will be examined using x-ray photoelectron spectroscopy to determine the chemical characteristics of the surface of the carbon.

Aging and Stability Studies. The effects of aging and storage conditions on the stability of activated carbons, especially sorbents for enhanced mercury capture, have not been well characterized, although they obviously affect the long-term quality of the product. The effects of storage conditions, including time, temperature, and exposure to oxygen, will be investigated. Samples stored under varying conditions will be analyzed for mercury reactivity using the bench-scale screening apparatus and XPS analysis, both of which can be correlated to previous activity studies. Ten bench-scale screenings and XPS analyses are anticipated.

Task 3 –Conceptual Design of a Commercial Plant Producing Activated Carbon from Fort Union Lignite

Market Assessment. Assessment of the market environment involves understanding and determining the market potential before the technology is ready for market. The market development will coincide with the technology development. Evaluation of the marketplace and commercial potential facilitate market-driven research and development. The market assessment will be interactive and draw upon the expertise of the technical researchers here at the EERC and of industry experts. The process will include following activities:

- Industry Structure and Market Overview – One of the key elements of the market/industry overview is quantifying market size of the primary and any potential secondary markets for activated carbon.
- Competitive Analysis – This will describe the competitors and position within the market. The competitive analysis is the basis for market segmentation.

- Market Opportunities and Challenges – This activity will also describe the feasibility of developing new markets based on activated carbon production in North Dakota and the potential impacts. Topics to address include transportation and economies of scale. In addition to identifying the barriers, potential solutions will also be addressed, such as niche marketing.
- Supply and Demand – Determine the current and future demands for carbon and compare to available supply from domestic as well as global sources.
- Recommendations for Marketing Strategies – Summarize competitive advantages for use in planning. Marketing mix, product positioning, and launch/market entry strategies will be addressed.

Preparation of a Conceptual Design. The final activity under this task will use test results from Tasks 1 and 2 to prepare a design and economics of a commercial plant located within North Dakota to produce activated carbon from ND lignite. The design will include the integration of lignite-derived activated carbon production with a power plant. An important aspect of the project will be to reduce capital and operating costs for a commercial activated carbon production plant so that it can be competitive in the global market, particularly with Far Eastern carbon. To achieve this objective, the project will examine the synergy of a carbon plant collocated with a power plant. Significant synergy is anticipated, particularly with respect to coal handling, storage infrastructure, and the availability of low-cost coal at the power plant. Additional synergy may emerge as a result of integrating process steps with existing equipment at the power plant, such as flue gas handling and air pollution control. The target cost is $0.20/lb for the activated carbon production to compete with production from Asian plants

Task 4 – Management and Reporting

This task will involve coordination of all project activities, reporting, and communication between project participants and partners. Reporting will consist of meetings with partners and project participants, monthly reports, a final report, and presentation of results at a national scientific meeting.

DELIVERABLES

Information for determining the feasibility of a commercial process for carbon production from ND lignite will result from the proposed research. Specific anticipated results include:

- A method for making activated carbon from ND lignite coals in a pilot-scale rotary kiln, including a set of optimized parameters.
- A quantity of activated carbon from ND lignite sufficient for demonstration of mercury control in a slipstream of a coal-fired power plant in the region.
- An evaluation of the effects of aging and storage conditions on sorbent surface chemistry and mercury reactivity.
- A market research report that includes industry and market overview, competitive analysis, identification of market opportunities and challenges, and recommended market strategies.
- A conceptual design of a commercial plant located within North Dakota to produce activated carbon from ND lignite.
- Presentation of the results at a technical conference, to project sponsors, and to the U.S. Department of Energy (DOE).
- Quarterly and final reports detailing the progress and results of the research.

The proposed research will be carried out using the EERC's Process Chemistry and Development Laboratory (PCDL), a pilot-scale rotary kiln system, and the Mercury Research Laboratory (MRL). Coal characteristics analysis will be performed in the EERC Fuels and Natural Materials Analytical Laboratories. XPS analysis will be performed at Evans PHI in Eden Prairie, Minnesota.

Additional test reactors, including a rotary kiln, are available for production quantities at an activated carbon vendor facility. The vendor facility has a rotary kiln system with a 42-in ID, 45-ft long tube, and a production rate of 50–100 lb/hr. Pilot-scale facilities have also been identified at multihearth manufacturers and may be employed on the project.

The PCDL has facilities for the development and analysis of different types of product and by-product streams. These analyses provide the data necessary for the calculation of material balances, conversions, and product qualities for engineering projects at the EERC. Equipment is in place for ashing, solubility testing, numerous American Society for Testing and Materials (ASTM) standard tests, coal cleaning, and a variety of general and specialized analytical testing, including wet-chemical testing.

The EERC pilot-scale rotary kiln system includes a sealed, indirectly electrically heated rotary kiln with a nominal heated zone of 6-in diameter, 5 feet long; three-zone temperature control to 1000°C; inert atmosphere operating conditions; rotation from 1 to 5 rpm; internal screw-fed auger; and variable inclination to 5°. The kiln has produced char from –1/4-inch ND lignite at feed rates of 4.5 kg/hr (10 lb/hr).

The MRL specializes in bench-scale systems studying mercury, SO_x/NO_x, catalysts, sorbents, and related work. Two bench-scale systems capable of simulating flue gas conditions such as temperature, particulate loadings, air-to-cloth ratios, and various gas concentrations (e.g.,

SO_2, O_2, CO, CO_2) are used. The MRL has mercury continuous emission monitors (CEMs) to perform bench-scale mercury-screening activities. The PCDL and MRL have over 10 years of experience developing and screening potential sorbents and filter materials, evaluating catalyst materials, and performing SO_x/NO_x in flue gas research.

Evans PHI provides analytical services using highly specialized surface analysis instrumentation. XPS, also known as electron spectroscopy for chemical analysis, is the most widely used surface analysis technique because of its relative simplicity in use and data interpretation. Evans PHI has instrumental analysts and technical support engineers with several years of experience and continuous training on the latest surface analysis equipment and techniques.

Environmental impacts of the research will be minimal. Technological and economic impacts of the ultimate product could be substantial in terms of elemental mercury control from lignite-fired combustion systems. EPA determined that mercury emissions from power plants pose significant hazards to public health and must be reduced. EPA has announced mercury control regulations that mandate coal-fired power plants to reduce mercury emissions by 21% by 2010 and 69% by 2018 based on the current estimate of 48 tons (2). ACI is the most mature technology available for mercury control. Development of a process to make sorbent capable of effective elemental mercury control will be extremely beneficial to lignite production facilities in providing sorbent and to combustion facilities in meeting the imminent regulations.

STANDARDS OF SUCCESS

The success of the project will be based on the ability to provide information to determine the feasibility of a commercial process for carbon production from ND lignite. One tangible measure will be the ability of the rotary kiln to produce an effective mercury control sorbent derived from ND lignite. At a minimum, effective mercury control is defined as providing mercury capture and oxidation as well as DARCO® FGD in the EERC bench-scale screening apparatus under low-acid simulated flue gas conditions. An enhanced mercury control sorbent produced from ND lignite in the rotary kiln should provide good mercury control in the bench-scale screening apparatus at the onset of the test i.e., providing the same or better mercury capture as the DARCO® FGD but exhibiting no induction period.

Since some of the activities are scientific investigation as opposed to a field-testing exercise, the achievement of these goals will be measured by appropriate scientific and engineering standards. Results of commercial significance will be rapidly patented so that the findings can be released to consortium members and the general public as appropriate. The detailed model(s) developed and improved as a result of the project will be disseminated, and the adoption and subsequent use of these models by the EERC, consortium members, and the public will be noted. Although the latter will occur after conclusion of the project, the records will show that the project was successful.

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. Table 2 outlines project QC. Specific to the measurement and control of mercury emissions, the following quality parameters have been defined.

Table 2. Project Quality Measures

QA/QC Control Measure	Purpose/Clarification
EERC QMS, including *Quality Manual* and quality policy and procedures	Ensure organizationwide compliance with QMS and applicable regulations, codes, and protocols based on ISO9000 standards. Authorized and supported by EERC management.
Project-Independent QA Manager at the EERC (David Brekke)	Assist research managers to plan QA for projects, does reviews and random audits for compliance assurance.
Perform Hg Mass Balance with Values 100% ± 20%	Determine total amount of Hg to be accounted for and determine removal rates.
EERC Expertise in Analytical Methods and CEM Sampling for Hg	Understand potential problems that can occur, troubleshoot, ability to get valid data under difficult conditions.
Hg CEM Calibrations Daily, at least; if target not met, may require that additional calibration or maintenance be done and repeat QA/QC check	PS Analytical: sample clean air drawn through carbon trap followed by injecting known Hg standard. This procedure is done four times to determine scatter (internal QA/QC EERC standard is that $R^2 = 0.999$).
Chain-of-Custody Procedures	Ensure integrity of samples at all steps, including sample identification, analysis, and storage.
Interim Team Audit	Use expertise of team members to ensure consistent quality, double-check analytical systems.
Team direction by Consortium and DOE	Ensure that communication issues and problems are addressed to ensure objectives of project are attained.
Quarterly Conference Calls (or as needed)	Ensure effective communications between all team members, address developing issues, resolve problems.
Information Transfer via FTP Site	Allows efficient transfer of data between team members.

The most important aspect of QA/QC is the expertise of the team conducting sorbent testing and spectroscopic measurements. EERC research personnel are highly trained and experienced, having conducted hundreds of sampling tests. In addition, EERC team members are considered experts in the operation of Hg CEMs, which are still considered to be in the developmental phase. The EERC has successfully demonstrated these instruments for 2 weeks or longer at 60 different power plants over the past 6 years. The EERC has actively used these instruments in bench-, pilot-, and full-scale tests for over ten years.

BACKGROUND

Since 2001, there has been growth in the use of carbon for gas and liquid phase cleanup such as flue gas desulfurization, water and waste remediation treatments. Carbon derived from lignite is being used in novel ways to clean dioxins from scrap-metal smelters in Europe. In the United States, the imports of carbon from China have doubled from 1996 to 2001 to 57 million pounds. Activated carbon use has grown steadily and is projected to total 450 million pounds in 2006.

Significant additional growth in the demand for carbon is anticipated as a result of the need to control the emission of mercury from coal fired power plants. Activated carbon injection upstream of a particulate control device such as an FF (baghouse) or ESP is showing significant promise for controlling mercury emissions (4). For activated carbons to be successful, they must effectively sorb Hg^0 and Hg^{2+}. Testing at the EERC compared activated carbon sorbents prepared from Fort Union lignites to the commercial sorbent NORIT America's DARCO® FGD (1). The DARCO® FGD is derived from Texas lignites. Typically, Texas lignites have higher ash contents than ND lignites. The ND lignites have high levels of alkali and alkaline earth elements that are organically associated. During carbonization and activation, these elements catalyze gasification resulting in improved pore structure in the resulting activated carbon. In bench-scale evaluations of mercury control capabilities in a low-acid flue gas stream, the ND lignite derived activated carbon performed as well as the DARCO® FGD both as a long-term sorbent and as an elemental mercury oxidant. This means that sorbents from ND lignite could compete in the market for carbon sorbent injection technology, the most mature technology for mercury control from coal-fired power plants, from which EPA has mandated a reduction of mercury emissions.

On March 15, 2005, the EPA issued a federal rule to cap and reduce mercury emissions from coal-fired power plants permanently (2). The rule is a market-based cap and trade program (Section 111 of the Clean Air Act) and is similar to the program in place for SO_2. The rule is to be administered in two phases. The first phase places a cap of 38 tons of mercury beginning in 2010. The second phase sets a final cap of 15 tons by 2018. Currently, the estimate of total mercury emitted from coal-fired power plants is 48 tons; therefore, the reduction is 21% and 69%, respectively.

With the implementation of the Clear Air Interstate Rule (CAIR) (5), to reduce emissions of SO_2 and NO_x in the eastern 28 states, it is expected that the initial phase of Clean Air Mercury Rule will partially meet the mercury emission reductions required via co-benefit expected from the additional wet scrubbers and SCR systems that will be installed. However, a cap of 15 tons will require additional mercury specific controls at many power plants. Also, states are moving forward separately, and in several cases with more stringent mercury emission reductions and earlier timetables than Federal standards.

For trading purposes, the EPA has established allocations for each state, the District of Columbia, and Indian Reservations based on their share of the total heat input from coal. These were then adjusted to reflect coal rank and existing air pollution control equipment. For allocation purposes coals were subcategorized as bituminous, subbituminous, lignite, integrated gasification combined cycle, and coal refuse. The total 2010–2017 state allocation is 38 tons and 2018 and thereafter, 15 tons. Each state will be free to decide if it wishes to participate in the trading program.

In addition to the cap and trade program new coal-fired sources will have additional mercury requirements as part of the New Source Performance standard (6). The requirements have been subcategorized as follows.

- Bituminous Units – 21 x 10^{-6} lb/MW-hr
- Subbituminous Units
  - Wet FGD – 42 x 10^{-6} lb/MW-hr
  - Dry FGD – 78 x 10^{-6} lb/MW-hr
- Lignite Units – 145 x 10^{-6} lb/MW-hr
- IGCC Units – 20 x 10^{-6} lb/MW-hr
- Coal Refuse Units – 1.4 x 10^{-6} lb/MW-hr

Specific to North Dakota, the 2010 cap will be 1.564 tons and 0.617 tons beginning in 2018 (7). These caps include the current coal-fired utilities as well as any new units that may be installed during this time frame. The ND lignite industry has been proactive in helping to developing new mercury control technologies in preparation for these regulations. Tests are currently underway at several ND power plants by the EERC, Babcock & Wilcox, and URS, with support from industry, the North Dakota Industrial Commission, EPRI, and DOE.

The projected annual cost for activated carbon sorption of mercury in a duct injection system is significant. For an untreated activated carbon, the carbon-to-mercury weight ratios of 3000–18,000 (gram of carbon injected per gram of mercury in flue gas) have been estimated to achieve 90% mercury removal from a coal combustion flue gas containing 10 µg/Nm^3 of mercury (3). More efficient carbon-based sorbents enhanced for mercury control could enable lower carbon-to-mercury weight ratios to be used, thus reducing the operating costs of carbon injection. The United States has about 320 GW_e of coal-fired capapcity. It is estimated that with the more efficient carbons, carbon-injection-to-mercury-removal rates of 500:1–1000:1 can be achieved. The potential sorbent cost is estimated to be \$0.30–0.50/lb for the untreated sorbent and \$0.5 to 0.8/lb for the enhanced sorbent. Based on these estimates, the potential market for carbon-based sorbents for mercury control is expected to be upwards of \$100 million annually.

Current production and use of activated carbon is illustrated in Figure 1. Activated carbon can be produced from a wide range of raw materials that includes coal, wood, and biomass materials. These materials are heat treated with steam to produce activated carbon. The carbons that are currently used include powdered and granular carbons. These components are used to remove contaminants from liquid and gas phase streams. The spent carbons are either disposed or regenerated.

The growth in the demand for activated carbon is shown in Figure 2. A significant increase is projected for 2006, not including any of the carbon used for mercury control. The market opportunity for the use of activated carbon for mercury control is the 315 GW_e of coal-fired power plant capacity in the United States. The mercury emissions reduction anticipated as a

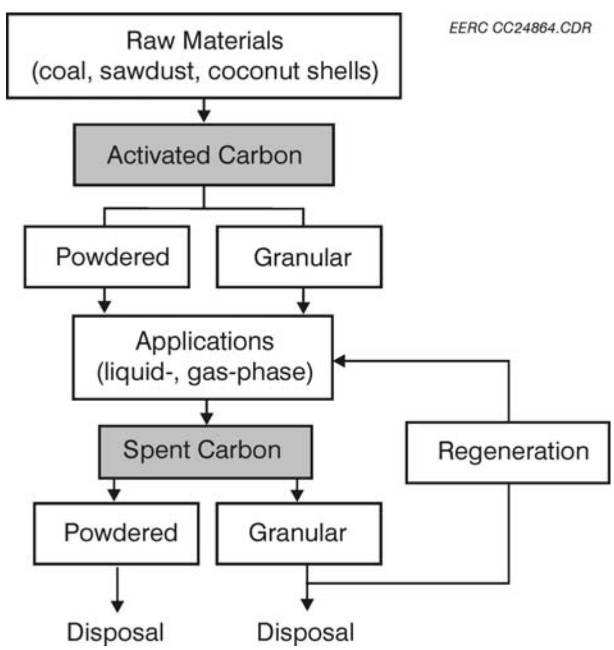

Figure 1. Flow diagram of the current production and use of activated carbon.

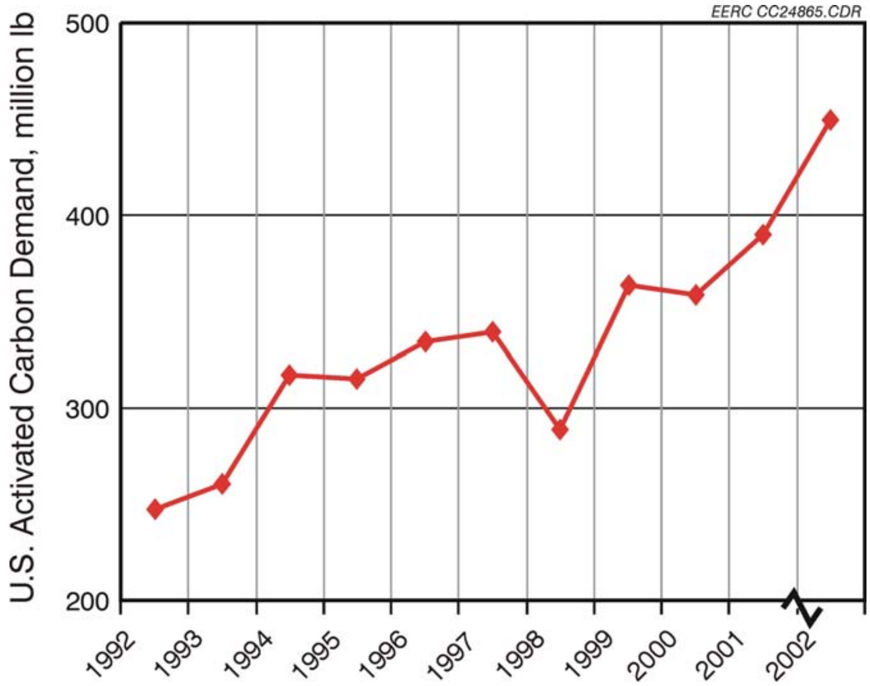

Figure 2. Demand for activated carbon in the United States.

result of the EPA rule is a reduction from 48 tons to 38 tons by 2010. We estimate that 30% of coal-fired power plants will use ACI for mercury. Based on the expected amounts of activated carbon required for mercury reduction, we estimate the market size for activated carbon for mercury control to be about 150,000 tpy. This is compared with the current U.S. consumption of activated carbon for other applications at 225,000 tpy, suggesting a significant increase in the demand for the activated carbon industry.

Previous investigations examined the ability to produce activated carbons from four Fort Union lignites for use as mercury sorbents (1). Activated carbons were prepared from relatively high-sodium (4–9 wt% Na_2O on an ash basis) lignites because the high sodium contents catalyze the gasification reactions producing a highly porous activated carbon. The activated carbons were produced by carbonization at 400°C (752°F) in nitrogen followed by steam activation at 750°C (1382°F) and 800°C (1472°F) in nitrogen. Iodine numbers (mg I_2/g sorbent) for the lignite-based activated carbons ranged from 320 to 440 as compared to 524 for the DARCO® FGD.

The lignite-based activated carbons, were tested in a thin-film, fixed-bed, bench-scale reactor using a simulated lignitic flue gas consisting of nominally 10 µg/Nm^3 Hg^0, 6% O_2, 12% CO_2, 15% H_2O, 580 ppm SO_2, 120 ppm NO, 6 ppm NO_2, and 1 ppm HCl in N_2. All of the lignite-based activated (750°C, 1382°F) carbons required a 30- to 45-minute conditioning period in the simulated lignite flue gas before they exhibited good mercury sorption capacities and Hg^0 oxidation potentials (>90% Hg^{2+}).

The Fort Union Lignite Activated Carbon (800°C, 1472°F) and DARCO® FGD were selected for additional testing in a 580-MJ/hr (550,000-Btu/hr) pulverized coal-fired unit based on the sorbent screening results (reactivity and capacity), physical properties (particle size and surface area), and cost (1). The Fort Union Lignite Activated Carbon activated at 800°C (1472°F) and DARCO® FGD were effective in capturing Hg.

QUALIFICATIONS

The EERC of the University of North Dakota is one of the world's major energy and environmental research organizations. Since its founding in 1949 as the U.S. Bureau of Mines Robertson Lignite Research Laboratory, the EERC has conducted research, testing, and evaluation of fuels, combustion, and gasification technologies; emission control technologies; ash use and disposal; analytical methods; groundwater; waste-to-energy systems; and advanced environmental control systems. Today's energy and environmental research needs typically require the expertise of a total-systems team that can focus on technical details while retaining a broad perspective. The EERC team has more than four 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 mine land reclamation settings.

The future of North Dakota energy production depends upon developing connections between energy and the environment that will allow the extraction of sufficient energy and other resources from our environment in a manner that does not jeopardize its integrity and stability.

The EERC has been a leader in mercury research for several years and is viewed as an expert in the field. In recent years, EERC researchers have been in the forefront of advancing the understanding of mercury chemistry, measurement, transformations, solid–gas interactions, and the development of control technologies.

VALUE TO NORTH DAKOTA

A major challenge facing ND lignite-fired power plants is the control of mercury emissions. The mercury species in combustion flue gases produced from ND lignite plants is primarily elemental and much more difficult to control than oxidized mercury forms. Preliminary testing at the EERC showed that activated carbon sorbents prepared from ND lignites performed as well as the commercial sorbent NORIT America DARCO® FGD in bench-scale evaluations of mercury control capabilities in a low-acid flue gas stream, both as a long-term sorbent and an elemental mercury oxidant. This means that sorbents from ND lignite could compete in the market for carbon sorbent injection technology, the most mature technology for mercury control from coal-fired power plants. This project aims to develop a mercury sorbent production facility in North Dakota which could provide an additional market for ND lignite, effectively control the emissions of mercury during the combustion of ND lignites, and aid in maintaining and potentially increasing the use of lignite for power generation in the future.

MANAGEMENT

Dr. Steven A. Benson will be the EERC Project Manager responsible for oversight of the project. Dr. Benson has more than 25 years in coal utilization and environmental control technologies and has managed numerous projects involving government and industry participants. Principal Investigators Dr. Edwin S. Olson, Ms. Charlene Crocker, Mr. Mark Musich, and Dr. Sheila Hanson will assist with project tasks. Dr. Olson has more than 40 years of experience in carbon and coal structure and reactivity, mercury analysis, emission, adsorption chemistry, coal liquefaction, and gasification catalysis. Ms. Crocker has 10 years of experience in mercury and chlorine analysis and measurement in coal combustion and sorbent development. Mr. Musich has 10 years of experience in low-rank coal beneficiation and gasification. Dr. Hanson has 12 years of experience in market research. Dr. Michael Jones will serve as technical advisor to the project. Experienced EERC technicians will assist them.

Resumes of key personnel are included in Appendix A.

PROJECT TIMETABLE

The project will be initiated upon receipt of DOE funding and approval of the project by the NDIC. It is anticipated that the proposed work will be carried out over 9 months.

Task Name	M1	M2	M3	M4	M5	M6	M7	M8	M9
Task 1. Pilot-Scale Optimization and Production									
Optimization of Activated Carbon Production									
AC Production and Pilot-Scale Testing for Hg Capture									
Task 2. Sorbent Properties Investigations									
Physical and Chemical Characteristics									
Aging and Stability Studies									
Task 3. Conceptual Design									
Task 4. Management and Reporting									
Monthly Progress Reports									
Final Project Report									

BUDGET

The budget outlining the costs for the project is enclosed. The total cost of the project is $770,000.

The EERC is requesting NDIC to commit $250,000 of funding to this project. Once we have NDIC's commitment, we will submit the proposal to DOE, requesting approval of its share of the funding.

Three items are required from NDIC for inclusion in our proposal to DOE.

- A formal commitment to the project. This can be a letter of commitment, a purchase order, or a signed contract.
- A biographical sketch or resume for NDIC's project manager and/or key technical contributor.
- A short description of NDIC.

MATCHING FUNDS

The total cost of the project is $770,000. Cost-share funding to be requested from the EERC–DOE Jointly Sponsored Research Program is $270,000. Funding requested from NDIC is $250,000. Cash funding from industry partners is anticipated to total $250,000.

TAX LIABILITY

None of the participants in this research proposal have outstanding tax liabilities to the state of North Dakota.

CONFIDENTIAL INFORMATION

No confidential information is included in the proposal.

REFERENCES

1. Pavlish, J.H.; Holmes, M.J.; Benson, S.A.; Crocker, C.R.; Olson, E.S.; Galbreath, K.C.; Zhuang, Y.; Pavlish, B.M. *Mercury Control Technologies for Electric Utilities Burning Lignite Coal, Phase I Bench- and Pilot-Scale Testing*; Final Report for U.S. Department of Energy Environmental Management Contract No. DE-FC26-98FT40321; Energy & Environmental Research Center: Grand Forks, ND, Oct 2003.
2. Standards of Performance for New and Existing Stationary Sources: Electric Utility Steam Generating Units, amended. *Code of Federal Regulations*, Part 60, 63, 72, and 75 Title 40, 2005.
3. Pavlish, J.H.; Sondreal, E.A.; Mann, M.D.; Olson, E.S.; Galbreath, K.C.; Laudal, D.L.; Benson, S.A., Status Review of Mercury Control Options for Coal-Fired Power Plants. *Fuel Process. Technol.* **2003**, *82* (2–3), 89–165.
4. Benson, S.A.; Crocker, C.R.; Galbreath, K.C.; Gunderson, J.R.; :Holmes, M.J.; Laumb, J.D.; Mackenzie, J.M.; Olderbak, M.R.; Pavlish, J.H.; Yan, L.; Zhuang, Y. *Pilot- and Full-Scale Demonstration of Advanced Mercury Control Technologies for Lignite-Fired Power Plants*; Final Report for U.S. Department of Energy National Energy Technology Laboratory Cooperative Agreement No. DE-FC26-03NT41897 and Multiclients; EERC Publication 2005-EERC-02-05; Energy & Environmental Research Center: Grand Forks, ND, Feb 2005.
5. Rule to Reduce Interstate Transport of Fine Particulate Matter and Ozone (Clean Air Interstate Rule); Revisions to Acid Rain Program; Revisions to the NOx SIP Call. *Code of Federal Regulations*, Parts 51, 72, 73, 77, 78, and 96, Title 40, 2005.

6. Standards of Performance for New and Existing Stationary Sources: Electric Utility Steam Generating Units. *Code of Federal Regulations*, Part 60 subpart Da, 63, 72, and 75 Title 40, 2005, Page 23.
7. Office of Air and Radiation US EPA. Technical Support Document for the Clean Air Mercury Rule Notice of Final Rulemaking State and Indian Country Emissions Budgets. http://www.epa.gov/ttn/atw/utility/state_indiancountry_emissionbudgets_oar-2002-0056-6154.pdf (accessed Apr 2005), page 6.

SUMMARY BUDGET

ACTIVATED CARBON PRODUCTION FROM NORTH DAKOTA LIGNITE
MULTI-CLIENT/NDIC/DOE
PROPOSED START DATE: JUNE 15, 2005
EERC PROPOSAL #2005-0277

CATEGORY		**TOTAL HRS**	**TOTAL $COST**	**INDUSTRIAL SHARE HRS**	**INDUSTRIAL SHARE $COST**	**NDIC SHARE HRS**	**NDIC SHARE $COST**	**EERC JSRP SHARE HRS**	**EERC JSRP SHARE $COST**
TOTAL DIRECT LABOR		6,938	$ 228,482	2,588	$ 88,172	3,120	$ 102,388	1,230	$ 37,922
FRINGE BENEFITS - % OF DIRECT LABOR	50%		$ 114,242		$ 44,086		$ 51,194		$ 18,962
TOTAL LABOR			$ 342,724		$ 132,258		$ 153,582		$ 56,884
OTHER DIRECT COSTS									
TRAVEL			$ 24,082		$ -		$ -		$ 24,082
COMMUNICATION - PHONES & POSTAGE			$ 1,847		$ 300		$ 300		$ 1,247
OFFICE (PROJECT SPECIFIC SUPPLIES)			$ 1,442		$ 400		$ 409		$ 633
SUPPLIES			$ 11,100		$ 3,327		$ 3,772		$ 4,001
GENERAL (FREIGHT, FOOD, MEMBERSHIPS, ETC.)			$ 5,000		$ 500		$ 500		$ 4,000
EQUIPMENT > $5000			$ 5,000		$ -		$ -		$ 5,000
FEES			$ 113,735		$ 23,471		$ 1,693		$ 88,571
TOTAL OTHER DIRECT COST			$ 162,206		$ 27,998		$ 6,674		$ 127,534
TOTAL DIRECT COST			$ 504,930		$ 160,256		$ 160,256		$ 184,418
FACILITIES & ADMIN. RATE - % OF MTDC		VAR	$ 265,070	56%	$ 89,744	56%	$ 89,744	47.7%	$ 85,582
TOTAL ESTIMATED COST			$ 770,000		$ 250,000		$ 250,000		$ 270,000

NOTE: Due to limitations within the University's accounting system, the system does not provide for accumulating and reporting expenses at the Detailed Budget level. The Summary Budget is presented for the purpose of how we propose, account, and report expenses. The Detailed Budget is presented to assist in the evaluation of the proposal.

DETAILED BUDGET

ACTIVATED CARBON PRODUCTION FROM NORTH DAKOTA LIGNITE
MULTI-CLIENT/NDIC/DOE
PROPOSED START DATE: JUNE 15, 2005
EERC PROPOSAL #2005-0277

					INDUSTRIAL		**NDIC**		**EERC JSRP**	
		HOURLY	**TOTAL**		**SHARE**		**SHARE**		**SHARE**	
LABOR	**LABOR CATEGORY**	**RATE**	**HRS**	**$COST**	**HRS**	**$COST**	**HRS**	**$COST**	**HRS**	**$COST**
BENSON, S.	PROJECT MANAGER	$ 54.21	240	$ 13,009	100	$ 5,421	100	$ 5,421	40	$ 2,167
CROCKER, C.	PRINCIPAL INVESTIGATOR	$ 28.38	660	$ 18,731	300	$ 8,514	250	$ 7,095	110	$ 3,122
OLSON, E.	PRINCIPAL INVESTIGATOR	$ 46.60	534	$ 24,884	240	$ 11,184	240	$ 11,184	54	$ 2,516
MUSICH, M.	PRINCIPAL INVESTIGATOR	$ 33.30	356	$ 11,855	160	$ 5,328	130	$ 4,329	66	$ 2,198
JONES, M.	PROJECT ADVISOR	$ 53.72	100	$ 5,372	40	$ 2,149	40	$ 2,149	20	$ 1,074
HANSON, S.	RESEARCH SCIENTIST/ENGINEER	$ 30.92	140	$ 4,328	90	$ 2,783	42	$ 1,299	8	$ 246
--------------	SENIOR MANAGEMENT	$ 53.73	333	$ 17,893	-	$ -	333	$ 17,893	-	$ -
--------------	RESEARCH SCIENTIST/ENGINEER	$ 29.47	3,131	$ 92,270	1,638	$ 48,272	811	$ 23,900	682	$ 20,098
--------------	RESEARCH TECHNICIAN	$ 20.07	636	$ 12,764	-	$ -	466	$ 9,353	170	$ 3,411
--------------	TECHNOLOGY DEV. OPER.	$ 20.73	556	$ 11,526	-	$ -	556	$ 11,526	-	$ -
--------------	TECHNOLOGY DEV. MECH.	$ 23.04	132	$ 3,041	-	$ -	132	$ 3,041	-	$ -
--------------	TECHNICAL SUPPORT SERVICES	$ 16.08	120	$ 1,930	20	$ 322	20	$ 322	80	$ 1,286
			6,938	$ 217,603	2,588	$ 83,973	3,120	$ 97,512	1,230	$ 36,118
ESCALATION ABOVE CURRENT BASE		5%		$ 10,879		$ 4,199		$ 4,876		$ 1,804
TOTAL DIRECT LABOR				$ 228,482		$ 88,172		$ 102,388		$ 37,922
FRINGE BENEFITS - % OF DIRECT LABOR		50%		$ 114,242		$ 44,086		$ 51,194		$ 18,962
TOTAL LABOR				$ 342,724		$ 132,258		$ 153,582		$ 56,884
OTHER DIRECT COSTS										
TRAVEL				$ 24,082		$ -		$ -		$ 24,082
COMMUNICATION - PHONES & POSTAGE				$ 1,847		$ 300		$ 300		$ 1,247
OFFICE (PROJECT SPECIFIC SUPPLIES)				$ 1,442		$ 400		$ 409		$ 633
SUPPLIES				$ 11,100		$ 3,327		$ 3,772		$ 4,001
GENERAL (FREIGHT, FOOD, MEMBERSHIPS, ETC.)				$ 5,000		$ 500		$ 500		$ 4,000
EQUIPMENT > $5000				$ 5,000		$ -		$ -		$ 5,000
NATURAL MATERIALS ANALYTICAL RES. LAB.				$ 2,850		$ 2,850		$ -		$ -
FUELS & MATERIALS RESEARCH LAB.				$ 8,022		$ 8,022		$ -		$ -
PARTICULATE ANALYSIS				$ 53,323		$ -		$ -		$ 53,323
PROCESS CHEM. & DEV. LAB.				$ 7,475		$ -		$ -		$ 7,475
FUEL PREP. AND MAINTENANCE				$ 1,059		$ 1,059		$ -		$ -
CONTINUOUS FLUIDIZED-BED REACTOR				$ 3,969		$ 2,540		$ -		$ 1,429
GRAPHICS SUPPORT				$ 1,844		$ -		$ 500		$ 1,344
SHOP & OPERATIONS SUPPORT				$ 1,193		$ -		$ 1,193		$ -
OUTSIDE LAB				$ 9,000		$ 9,000		$ -		$ -
ACTIVATED CARBON PROCESSING FEE				$ 25,000		$ -		$ -		$ 25,000
TOTAL OTHER DIRECT COST				$ 162,206		$ 27,998		$ 6,674		$ 127,534
TOTAL DIRECT COST				$ 504,930		$ 160,256		$ 160,256		$ 184,418
FACILITIES & ADMIN. RATE - % OF MTDC			VAR	$ 265,070	56%	$ 89,744	56%	$ 89,744	47.7%	$ 85,582
TOTAL ESTIMATED COST				$ 770,000		$ 250,000		$ 250,000		$ 270,000

DETAILED BUDGET - FEES

ACTIVATED CARBON PRODUCTION FROM NORTH DAKOTA LIGNITE
EERC PROPOSAL #2005-0277

NATURAL MATERIALS ANALYTICAL RES. LAB.	RATE	TOTAL #	$COST
XRFA	$181	15	$ 2,715
SUBTOTAL			$ 2,715
ESCALATION		5%	$ 135
TOTAL NATURAL MATERIALS ANALYTICAL RES. LAB.			$ 2,850

FUELS & MATERIALS RESEARCH LAB.	RATE	#	$COST
ASH DETERMINATION	$27	6	$ 162
BTU	$47	4	$ 188
MISCELLANEOUS	$76	27	$ 2,052
PROXIMATE ANALYSIS	$52	54	$ 2,808
SULFUR	$45	54	$ 2,430
SUBTOTAL			$ 7,640
ESCALATION		5%	$ 382
TOTAL FUELS & MATERIALS RESEARCH LAB.			$ 8,022

PARTICULATE ANALYSIS	RATE	#	$COST
BENCH SCALE SIMULATOR (PER HOUR)	$117	328	$ 38,376
MERCURY CEM (PER DAY)	$264	47	$ 12,408
SUBTOTAL			$ 50,784
ESCALATION		5%	$ 2,539
TOTAL PARTICULATE ANALYSIS			$ 53,323

PROCESS CHEM. & DEV. LAB.	RATE	#	$COST
MISC (HOURLY)	$51	80	$ 4,080
PREP/GC/CHN	$49	62	$ 3,038
SUBTOTAL			$ 7,118
ESCALATION		5%	$ 357
TOTAL PROCESS CHEM. & DEV. LAB.			$ 7,475

FUEL PREP. & MAINTENANCE	RATE/HR.	#	$COST
FUEL PREP. AND MAINTENANCE (PER EQUIP)	$18	56	$ 1,008
SUBTOTAL			$ 1,008
ESCALATION		5%	$ 51
TOTAL FUEL PREP. & MAINTENANCE			$ 1,059

CONTINUOUS FLUIDIZED-BED REACTOR	RATE/HR.	#	$COST
CONTINUOUS FLUIDIZED-BED REACTOR	$36	105	$ 3,780
SUBTOTAL			$ 3,780
ESCALATION		5%	$ 189
TOTAL CONTINUOUS FLUIDIZED-BED REACTOR			$ 3,969

GRAPHICS SUPPORT	RATE	#	$COST
GRAPHICS (HOURLY)	$45	39	$ 1,755
SUBTOTAL			$ 1,755
ESCALATION		5%	$ 89
TOTAL GRAPHICS SUPPORT			$ 1,844

SHOP & OPERATIONS SUPPORT	RATE	#	$COST
TECHNICAL DEVELOPMENT HOURS	$1.65	688	$ 1,135
SUBTOTAL			$ 1,135
ESCALATION		5%	$ 58
TOTAL SHOP & OPERATIONS SUPPORT			$ 1,193

DETAILED BUDGET - TRAVEL

ACTIVATED CARBON PRODUCTION FROM NORTH DAKOTA LIGNITE
EERC PROPOSAL #2005-0277

RATES USED TO CALCULATE ESTIMATED TRAVEL EXPENSES

DESTINATION	ECON AIRFARE	PER MILE	LODGING	PER DIEM	CAR RENTAL	REGIST.
Unspecified Destination (USA)	$ 900	$ -	$ 150	$ 51	$ 60	$ 525
Minneapolis, MN	$ -	$ 0.31	$ 150	$ 51	$ 60	$ -
Morgantown, WV (via Pittsburgh, PA)	$ 1,200	$ -	$ 100	$ 39	$ 60	$ -
Philadelphia, PA	$ 900	$ -	$ 150	$ 51	$ 60	$ -

	NUMBER OF											
PURPOSE/DESTINATION	TRIPS	PEOPLE	MILES	DAYS	AIRFARE	MILEAGE	LODGING	PER DIEM	CAR RENTAL	MISC.	REGIST.	TOTAL
Conference/Unspecified Dest. (USA)	3	1	0	5	$ 2,700	$ -	$ 1,800	$ 765	$ 900	$ 300	$ 1,575	$ 8,040
Client Meeting/Unspecified Dest. (USA)	3	2	0	2	$ 5,400	$ -	$ 900	$ 612	$ 360	$ 240	$ -	$ 7,512
Sample Analysis/Minneapolis, MN	3	2	700	2	$ -	$ 651	$ 900	$ 612	$ 360	$ 240	$ -	$ 2,763
Review Meeting/Morgantown, WV (Pittsburgh, PA)	1	1	0	3	$ 1,200	$ -	$ 200	$ 117	$ 180	$ 60	$ -	$ 1,757
Site Visit/Philadelphia, PA	1	2	0	5	$ 1,800	$ -	$ 1,200	$ 510	$ 300	$ 200	$ -	$ 4,010
TOTAL ESTIMATED TRAVEL TASK X												$ 24,082

DETAILED BUDGET - EQUIPMENT

DESCRIPTION	$COST
Modifications to the rotary kiln	$ 5,000
TOTAL ESTIMATED EQUIPMENT	$ 5,000

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, or other agreements. Although the EERC is not affiliated with any one academic department, university academic faculty may participate in a project, depending on the scope of work and expertise required to perform the project.

The proposed work will be done on a cost-reimbursable basis. The distribution of costs between budget categories (labor, travel, supplies, equipment, subcontracts) is for planning purposes only. The principal investigator may, as dictated by the needs of the work, reallocate the budget among approved items or use the funds for other items directly related to the project, subject only to staying within the total dollars authorized for the overall program. Escalation of labor and EERC fee rates is incorporated in 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 current escalation rate of 5% is based on historical averages. The budget prepared for this proposal is based on a specific start date; this start date is indicated at the top of the EERC budget or identified in the body of the proposal. Please be aware that any delay in the start of this project may result in an increase in the budget.

Salaries and Fringe Benefits

As an interdisciplinary, multiprogram, and multiproject research center, the EERC employs an administrative staff to provide required services for various direct and indirect support functions. Direct project salary estimates are based on the scope of work and prior experience on projects of similar scope. Technical and administrative salary charges are based on direct hourly effort on the project. 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. For faculty, if the effort occurs during the academic year and crosses departmental lines, the salary will be in addition to the normal base salary. University policy allows faculty who perform work in addition to their academic contract to receive no more than 20% over the base salary. Costs for general support services such as grants and contracts administration, accounting, personnel, and purchasing and receiving, as well as clerical support of these functions, are included in the EERC facilities and administrative cost rate.

Fringe benefits are estimated on the basis of historical data. The fringe benefits actually charged consist of two components. The first component covers average vacation, holiday, and sick leave (VSL) for the EERC. This component is approved by the UND cognizant audit agency and charged as a percentage of direct labor for permanent staff employees eligible for VSL benefits. The second component covers actual expenses for items such as health, life, and unemployment insurance; social security matching; worker's compensation; and UND retirement contributions.

Travel

Travel is estimated on the basis of UND travel policies which can be found at: http://www.und.edu/dept/accounts/employeetravel.html. Estimates include General Services Administration (GSA) daily meal rates. Travel includes scheduled meetings and conference participation as indicated in the scope of work.

Communications (phones and postage)

Monthly telephone services and fax telephone lines are generally included in the facilities and administrative cost. Direct project cost includes line charges at remote locations, long-distance telephone, including fax-related long-distance calls; postage for regular, air, and express mail; and other data or document transportation costs.

Office (project-specific supplies)

General purpose office supplies (pencils, pens, paper clips, staples, Post-it notes, etc.) are provided through a central storeroom at no cost to individual projects. Budgeted project office supplies include items specifically related to the project; this includes duplicating and printing.

Data Processing

Data processing includes items such as site licenses and computer software.

Supplies

Supplies in this category include scientific supply items such as chemicals, gases, glassware, and/or other project items such as nuts, bolts, and piping necessary for pilot plant operations. Other items also included are supplies such as computer disks, computer paper, memory chips, toner cartridges, maps, and other organizational materials required to complete the project.

Instructional/Research

This category includes subscriptions, books, and reference materials necessary to the project.

Fees

Laboratory, analytical, graphics, and shop/operation fees are established and approved at the beginning of the university's fiscal year.

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 overall graphics production such as report figures, posters for poster sessions, standard word or table slides, simple maps, schematic slides, desktop publishing, photographs, and printing or copying.

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

General

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

Membership fees (if included) 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 as well as by the research team directly involved in project activity.

General 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), transportation, rental of facilities, and other items incidental to such meetings or conferences.

Facilities and Administrative Cost

The facilities and administrative rate (indirect cost rate) included in this proposal is the rate that became effective May 11, 2004. Facilities and administrative 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 subcontracts/subgrants in excess of the first $25,000 for each award.

APPENDIX A

RESUMES OF KEY PERSONNEL

DR. STEVEN A. BENSON
Senior Research Manager/Advisor
Energy & Environmental Research Center (EERC)
University of North Dakota (UND)
PO Box 9018, Grand Forks, ND 58202-9018 USA
Phone: (701) 777-5000 Fax: (701) 777-5181
E-Mail: sbenson@undeerc.org

Principal Areas of Expertise
Management of complex multidisciplinary programs focused on solving energy production and environmental problems. Program areas include the development of 1) methodologies to minimize the effects of inorganic components on the performance of combustion/gasification and air pollution control systems; 2) the fate and behavior of air toxic substances in combustion and gasification systems; 3) advanced analytical techniques to determine the chemical and physical transformations of inorganic species in combustion gases; 4) computer-based codes to predict the effects of coal quality on system performance; 5) advanced materials for coal-based power systems; and 6) training programs designed to improve the global quality of life through energy and environmental research activities.

Qualifications
Ph.D., Fuel Science, Materials Science and Engineering, The Pennsylvania State University, 1987.
B.S., Chemistry, Moorhead State University (Minnesota), 1977.

Professional Experience

1999 – Senior Research Manager/Advisor, EERC, UND. Responsible for the direction of projects and programs on the impact of inorganic species on the performance of combustion and associated environmental control systems. Specific areas of focus include the direction of the EPA Center for Air Toxic Metals at the EERC, advanced methods of materials analysis, and application of computer models to energy and environmental issues.

1994 – 1999 Associate Director for Research, EERC, UND. Responsible for the direction of programs related to integrated energy and environmental systems development. EERC research, development, and demonstration programs involve fuel quality effects on power system performance, advanced power systems development/demonstration, computational modeling, advanced materials for power systems, and analytical methods for the characterization of materials. Specific areas of focus included the direction of the EPA Center for Air Toxic Metals at the EERC, ash behavior in combustion and gasification systems, hot-gas cleanup, and analytical methods of analysis. Responsible for identifying research opportunities and the preparation of proposals and reports for clients.

1986 – 1994 Senior Research Manager, Fuels and Materials Science, EERC, UND. Responsible for management and supervision of research on the behavior of inorganic constituents, including air toxic metals during combustion and gasification, hot-gas cleanup (particulate gas-phase species control), fundamental combustion, and analytical methods of inorganic analysis, including SEM and microprobe analysis, Auger, XPS, SIMS, XRD, and XRF. Responsible for identification of research opportunities, preparation of proposals and reports for clients, and publication.

1989 – 1991 Assistant Professor (part-time), Department of Geology and Geological Engineering, UND. Responsible for teaching courses on coal geochemistry, coal ash behavior in combustion and gasification systems, and analytical methods of materials analysis. Taught courses on SEM/microprobe analysis and mineral transformations during coal combustion.

1984 – 1986 Graduate Research Assistant, Fuel Science Program, Department of Materials Science and Engineering, The Pennsylvania State University.

1983 – 1984 Research Supervisor, Distribution of Inorganics and Geochemistry, Coal Science Division, UND Energy Research Center. Responsible for management and supervision of research on the distribution of major, minor, and trace inorganic constituents and geochemistry of coals and ash chemistry related to inorganic constituents and mineral interactions and transformations during coal combustion and environmental control systems.

1980 – 1983 Research Chemist, U.S. Department of Energy (DOE) Grand Forks Energy Technology Center. Performed research on surface and/or chemical analysis and characterization of coal-derived materials by SEM, XRF, and thermal analysis in support of projects involving SO_x, NO_x, and particulate control; ash deposition; heavy metals in combustion systems; coal gasification; and fluidized-bed combustion.

1979 – 1980 Research Chemist, DOE Grand Forks Energy Technology Center. Performed research on the application of such techniques as differential thermal analysis, differential scanning calorimetry, thermogravimetric analysis, and energy-dispersive XRF analysis with application to low-rank coals and coal process-related material. In addition, research was performed on the use of x-ray analysis to measure trace elements in fuels and conversion products.

1977 – 1979 Chemist, DOE Grand Forks Energy Technology Center. Performed analysis on coal and coal derivatives by techniques such as wavelength-dispersive x-ray analysis, argon plasma spectrometry, atomic absorption spectrometry, thermal analysis, and elemental analysis (CHN).

1976 – 1977 Teaching Assistant, Department of Chemistry, Moorhead State University.

Professional Memberships

- The Combustion Institute
- ASME Research Committee on Corrosion and Deposits from Combustion Gases
- American Chemical Society, Fuel Division Member
- Industrial Liaison, American Chemical Society Division of Fuel Chemistry

Publications and Presentations

- Has authored/coauthored over 180 publications and is the editor of six books and Special Issues

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Principal Areas of Expertise
Ms. Crocker's principal areas of interest and expertise include mercury and halogens in coal combustion, developing carbon-based mercury control sorbents, airborne particulate matter instrumentation, water quality monitoring and analytical methods, development and implementation of fish consumption surveys, general public and K–12 education, laser-induced breakdown spectroscopy (LIBS), atomic absorption spectroscopy (AAS) (flame, graphite furnace, and hydride generation), inductively coupled plasma spectroscopy (ICP), trace element analysis of water, coal and coal by-products, and atomic fluorescence spectroscopy (AFS).

Qualifications
B.S., Chemistry, University of North Dakota, 1994
B.A., French, Colby College, Waterville, ME, 1986

Professional Experience

2002 – Research Scientist, Responsibilities include managing projects relating to environmental management and air quality; collaborating with other scientists on development of carbon-based flue gas sorbents, particulate matter (PM) sampling, development of water quality education and CO_2 sequestration public outreach materials, evaluation of bioassesssment tools, fish consumption survey development, proposal and report writing, data analysis, presentation of results, and budget tracking; developing PM sampling protocols; participating in development of a water-based geoscience education program and outreach activities for school children; directing activities of student assistants.

1994 – 2002 Research Chemist, Responsibilities include managing projects relating to environmental management and air quality; collaborating with other scientists on particulate matter (PM) sampling, fish consumption survey development, corrosion of ceramic and alloy materials, coal ash, water purification, and surface decontamination research; proposal and report writing, data analysis, presentation of results, and budget tracking; developing PM sampling protocols; participating in development of a water-based geoscience education program and outreach activities for school children; directing activities of student assistants; developing and implementing analytical methods employing LIBS. Previous duties performed in the Analytical Research Laboratory focused on water quality and energy-related analyses. Responsibilities included preparing and analyzing ultratrace element samples in aqueous and inorganic media using AAS, ICP, and IC; recording and disseminating analytical results and quality control checks;

performing research on ultratrace elemental analysis of mercury using AFS; and preparing reagents and solutions.

1993 – 1994	Research Assistant, EERC, UND. Ms. Crocker's responsibilities included preparing and analyzing ultratrace element samples in inorganic media; performing research on ultratrace element analysis of mercury in air using AFS; and preparing reagents and solutions.
1990	Naturalist, Deep Portage Conservation Reserve, Hackensack, Minnesota. Ms. Crocker's responsibilities included planning and conducting environmental education programs for children and adults; evaluating curriculum; and organizing lending of educational learning stations.
1988 – 1990	Sanctuary Manager, Wetlands, Pines & Prairie Audubon Sanctuary, Warren, Minnesota. Ms. Crocker's responsibilities included planning and conducting environmental education programs; organizing chapter meetings; publishing the Sanctuary newsletter; and performing administrative tasks.
1988	Park Ranger/Interpreter, Boston Harbor Islands State Park, Boston, Massachusetts. Ms. Crocker's responsibilities included interpreting natural and human history; developing special programs and leading walking tours of the islands; and conducting school programs.

Publications and Presentations

Has coauthored several publications

DR. EDWIN S. OLSON
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Principal Areas of Expertise
Dr. Olson's principal areas of interest and expertise include carbon and coal structure and reactivity, mercury sorption, water purification chemistry, enzyme-catalyzed esterification and desulfurization reactions, chromatography, organic trace analysis, mass spectrometry, and organic spectroscopy.

Qualifications
Ph.D., Chemistry and Physics, California Institute of Technology, 1964.
B.A., Chemistry, magna cum laude, St. Olaf College, 1959.

Professional Experience

1994 –	Senior Research Advisor, EERC, UND. Novel activated carbons for air and water treatment were designed and tested.
1988 –	President, Universal Fuel Development Associates, Inc. Dr. Olson served as Project Manager for Phase I and II Small Business Innovation Research projects involving water purification, nonaqueous enzymatic solubilization of coal materials, oxygenate synthesis from agricultural materials. and DBP removal from drinking water and for DOE projects involving geotechnical characterizations and fine-particle catalysts for coal liquefaction.
1983 – 1994	Research Supervisor, Fuel Conversion and Process Chemistry Division, EERC, UND. Dr. Olson performed hydrotreating and HDS catalyst, and coal liquefaction, and gasification research and analytical methods development.
1980 – 1983	Research Chemist, Grand Forks Energy Technology Center, U.S. Department of Energy. Dr. Olson developed analytical methods for coal conversion products by GC, MS, HPLC, and NMR and trace organics in air, water, and fly ash.
1968 – 1980	Professor of Chemistry, South Dakota State University. Taught graduate/under-graduate courses in organic, biochemistry, and instrumental analysis. Research in homogeneous catalysts, organic synthesis.
1977	Visiting Professor, University of Notre Dame (summer).

1972 – 1976 Visiting Staff Member, Los Alamos Scientific Laboratory (summers).

Dr. Olson also has experience at the University of California, Los Angeles, Department of Biochemistry, and at Idaho State University, Department of Chemistry.

Publications and Presentations (over 180 total)

- Has authored/coauthored over 180 publications

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Principal Areas of Expertise
Application of systems engineering (SE) and systems analysis methods to the design and assessment of Environmental Management (EM) technologies and systems; development and operation of liquid and solid fuel beneficiation processes including agglomeration, hydrothermal and thermal treatment, chemical and physical cleaning, and gasification.

Qualifications
M.S., Chemical Engineering, University of North Dakota, 1986.
B.S., Chemical Engineering, University of North Dakota, 1983.

Professional Experience (EERC)

1996 – Research Manager, Systems Analysis. Responsibilities include supervision of Systems Analysis personnel; applying software engineering tools for the simulation and economic evaluation of chemical processes; performing critical review of SE studies; applying SE methodology and decision-making tools to the design, development, and implementation of chemical processing technologies and systems.

1991 – 1996 Research Engineer/Supervisor. Responsibilities include experimental design and data evaluation, supervision of beneficiation and briquetting test programs, development of beneficiation processes, analytical and product evaluation techniques, beneficiation personnel supervision, preparation of reports and proposals, and preparation and presentation of papers.

1989 – 1991 Research Engineer, Fuels Beneficiation/Fuels Preparation. Responsibilities included the operation and maintenance of bench- and pilot-scale hydrothermal drying processes; operation of pilot-scale coal cleaning processes; design, performance, and evaluation of beneficiation experiments; report writing; and proposal solicitation.

1988 – 1989 Research Engineer, Mild Gasification. Responsibilities included the design and material specifications for the construction of a 100-lb/hr spout-fluid-bed reactor for the low-temperature gasification of carbonaceous feedstocks.

1987 – 1988 Contract Research Engineer, Great Plains Coal Gasification Company, Beulah, North Dakota. Responsibilities included the operation and maintenance of a demonstration scale sour-gas scrubbing unit for the removal of SO_2, design of test matrices, evaluation of the test data, and preparation of reports.

1986 – 1987 Research Engineer, Hydrogen Production. Responsibilities included the design, construction, and operation of a 40-lb/hr fluidized-bed reactor for the catalytic gasification of carbonaceous feedstocks; data reduction; and report writing.

1986 Engineering Research Technician, Combustion Division. Responsibilities included the operation of pilot-scale pulverized coal and fluidized-bed combustion units.

1985 – 1986 Engineer, EG&G Washington Analytical Services Center, Inc., Grand Forks, North Dakota. Responsibilities included reviewing fluidized-bed combustion test data, isolating and evaluating steady-state performance periods, and performing mass and energy balances for the test periods.

Professional Memberships

- American Institute of Chemical Engineers

Publications and Presentations

- Has coauthored over 50 publications in the area of fuels beneficiation.

Patents

- Musich, M.A.; Potas, T. "Low–Rank Coal Oil Agglomeration Product and Process" U.S. Patent 5 162 050, 1992.

DR. MICHAEL L. JONES
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Principal Areas of Expertise
Dr. Jones' 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 combustion of low-rank fuels, matching of fuel characteristics to system design and operating parameters, development of advanced power systems based on low-rank fuels, fundamentals of combustion, ash deposition in combustion systems, and analysis of inorganic materials. Projects emphasize a cradle-to-grave approach from resource assessment, to optimum utilization systems, to minimization of emissions and waste management featuring by-product utilization.

Qualifications
Ph.D., Physics, University of North Dakota, 1978.
M.S., Physics, University of North Dakota, 1973.
B.S., Physics, Bemidji State University (Minnesota), 1971.

Professional Experience
1994 – Adjunct Assistant Professor, Physics, UND.

1983 – Associate Director, Industrial Relations and Technology Commercialization, EERC, UND. Dr. Jones' responsibilities include planning, staffing, and technical direction of combustion research, including projects in combustion chemistry, ash fouling and slagging, fluidized-bed combustion, coal–water fuels combustion, SO_x/NO_x removal, and particulate removal and characterization. Special emphasis is given to low-rank coal systems; activities range from field testing of full-scale power plants to pilot-scale studies and laboratory investigations that examine both fuel and system characteristics and their impact on overall performance.

1990 – Adjunct Professor, Department of Chemical Engineering, The University of Utah, Salt Lake City, Utah.

1979 – 1983 Grand Forks Energy Technology Center, U.S. Department of Energy. Dr. Jones' responsibilities included technical direction of research and development projects related to combustion technology for low-rank coals, with specific responsibility for fundamental research on pulverized coal combustion. Directed research on new, specialized analytical procedures for determination of inorganics and trace elements in coal and materials derived from coal combustion and conversion processes. Instrumentation included methods Auger/ESCA spectrometer, scanning electron microscope, x-ray diffraction, x-ray fluorescence, argon plasma spectrometer, and atomic absorption spectrometer.

Professional Memberships

- Adjunct Membership, Graduate Faculty, University of North Dakota, 1994
- Chair, ASME Research Committee on Corrosion and Deposits from Combustion Gases
- Utility Advisory Task Force for DOE-FE Study on RCRA Impact on Coal-Fired Utilities
- Sigma Xi – The Scientific Research Society
- Society for Applied Spectroscopy
- The Combustion Institute
- North Dakota Academy of Science

Publications and Presentations

- Has authored or coauthored over 80 publications

DR. SHEILA K. HANSON
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Principal Areas of Expertise

Dr. Hanson's principal areas of interest and expertise include marketing high-tech products, feasibility studies, university–industry relations, and technology transfer.

Qualifications

Ph.D., Research Methodologies with a cognate in Business Administration, University of North Dakota, 2000.
M.S., Research Methodologies, University of North Dakota, 1992.
B.A., Psychology and German, University of North Dakota, 1990.
B.B.A., Marketing, University of North Dakota, 1988.

Professional Experience

2001 – Marketing Research Manager, EERC, UND. Dr. Hanson's responsibilities include conducting marketing research for a variety of industry and government organizations, providing market information for interdisciplinary teams of scientists and engineers, and assisting senior management in commercialization of technologies.

2000 – Assistant Professor, Department of Marketing, UND. Dr. Hanson teaches Marketing Research II and Marketing Foundations.

1998 – 1999 Lecturer, Department of Marketing, UND. Dr. Hanson taught Principles of Marketing.

1997 – 2001 Marketing Director, Center for Innovation, UND. Dr. Hanson's responsibilities included managing the research, analysis, and writing of commercial evaluations and marketing assessments of energy-related technologies for a U.S. Department of Energy grant and researching and writing economic and marketing feasibility studies, business plans, and marketing plans for clients for a variety of products and technologies.

1997 – 1998 Instructor, Department of Educational Foundations and Research, UND. Dr. Hanson taught Statistical Methods.

1996 – Consulting Services. Dr. Hanson has provided focus group, survey research, market planning, and media planning consultation for a broad range of clients, including the Grand Forks Economic Development Corporation, Grand Forks Chamber of Commerce, health care facilities, banks, and retail organizations.

1992 – 1997 Marketing Research Director, Simmons Advertising, Grand Forks, North Dakota. Dr. Hanson's responsibilities included conducting market reviews, focus groups, and survey research for a wide variety of clients, including electric utilities, fast food, banking, and health care facilities; using account planning to develop creative themes for advertising campaigns; and researching, planning, and managing marketing and communications plans and budgets for clients.

1992 – 1997 Media Buyer. Dr. Hanson's responsibilities included performing qualitative and quantitative media analysis and evaluation, evaluating media opportunities and trends, and measuring the effectiveness of media campaigns using Media Management Plus software.

Professional Memberships

- American Academy of Advertising
- Association for Consumer Research
- Academy of Management
- American Marketing Association
- American Advertising Federation

Publications and Presentations

- Has authored and coauthored numerous professional publications