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

December 29, 2010

Ms. Karlene Fine
Executive Director
North Dakota Industrial Commission
State Capitol – 14th Floor
600 East Boulevard Avenue, Department 405
Bismarck, ND 58505-0840

Dear Ms. Fine:

Subject: EERC Proposal No. 2011-0137

The Energy & Environmental Research Center (EERC) of the University of North Dakota is pleased to submit the subject proposal to the North Dakota Industrial Commission Renewable Energy Program. The EERC is committed to completing the project as described in this proposal if the Commission makes the requested grant.

Enclosed please find an original and one copy of the proposal entitled "Trace Element Measurements During Biomass Gasification." Also enclosed is the $100 application fee.

The EERC is a research organization within the University of North Dakota, an institution of higher education within the state of North Dakota. The EERC is not a taxable entity; therefore, it has no tax liability.

Initiation of the proposed work is contingent upon the execution of mutually negotiated agreements or modifications to existing agreements between all participating sponsors.

If you have any questions, please contact me by telephone at (701) 777-5337 or by e-mail at nlentz@undeerc.org.

Sincerely,

Nicholas B. Lentz
Research Scientist

Approved by:

Dr. Gerald H. Groenewold, Director
Energy & Environmental Research Center

NBL/hmv

Enclosures

Renewable Energy Program

North Dakota Industrial Commission

Application

Project Title: Trace Element Measurements During Biomass Gasification

Applicant: Energy & Environmental Research Center

Principal Investigator: Nicholas B. Lentz

Date of Application: December 29, 2010

Amount of Request: $250,000

Total Amount of Proposed Project: $500,000

Duration of Project: 12 months

Point of Contact (POC): Nicholas B. Lentz

POC Telephone: (701) 777-5337

POC Email: nlentz@undeerc.org

POC Address: 15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018

TABLE OF CONTENTS

ABSTRACT

As the industrial sector prepares to comply with future greenhouse gas emission requirements, many are considering biomass fuels as an option to either reduce CO_2 emissions or to meet renewable fuel mandates. By November of 2011, the U.S. Environmental Protection Agency will be finalizing National Emission Standards for Hazardous Air Pollutants for utility and industrial boilers, which include regulations on biomass fuels. In order to ensure compliance with these upcoming regulations, additional measurements are needed to better understand and characterize emissions during the gasification of biomass fuels. Standard flue gas measurement methods have had mixed results in syngas reducing environments. Limited data exists on trace element emissions in gasification systems that utilize biomass as a fuel (1).

Objective:

This project will provide trace element emission data while applying advanced measurement techniques for the gasification of biomass fuels available in North Dakota.

Expected Results:

Results include 1) quantitation of trace element emissions during the gasification of wood and switchgrass biomass fuels, 2) application and further development (as needed) of the multi element sorbent trap method under reducing environments while gasifying North Dakota biomass, 3) a final report that presents data and findings, and 4) dissemination of key results and findings at conferences.

Duration:

12 months

Total Project Cost:

$250,000 – Requested from North Dakota Industrial Commission Renewable Energy Program
$250,000 – Provided from U.S. Department of Energy-funded Center for Biomass Utilization®
$500,000 – Total Project Cost

Participants:

North Dakota Industrial Commission and the Energy & Environmental Research Center's U.S. Department of Energy-funded Center for Biomass Utilization

PROJECT DESCRIPTION

Objectives:

The overall goal of this project is to characterize trace element emission data from biomass-derived syngas. The objectives include the following:

- Identify challenges associated with syngas trace element measurement
- Characterize trace element emissions from switchgrass-derived syngas
- Characterize trace element emissions from wood-derived syngas
- Determine the accuracy of the Energy & Environmental Research Center (EERC)-developed multi element sorbent trap (ME-ST) method for syngas sampling

Methodology:

The proposed scope of work for this project will be divided into the following tasks.

Task 1. Installation of Sample Ports and Required Sampling Supplies. This initial task will involve getting the existing EERC pilot-scale gasifier set up for trace element sampling. Additional ports dedicated for trace element sampling will be installed before the stack and after the quench pots in order to accurately measure the trace elements that would exit the stack.

During Task 1, the switchgrass and wood fuel from a North Dakota source will be selected and shipped to the EERC. Once at the EERC, the fuels will be prepared to predetermined specifications to ensure a smooth and consistent feed rate into the gasifier.

Task 2. Characterize Trace Element Emissions from Switchgrass-Derived Biomass. Trace element measurements will be performed during the gasification of switchgrass-derived syngas. The test run for this task focuses on the collection of trace element data from an EERC pilot-scale fluidized-bed gasifier while feeding a North Dakota switchgrass. Trace element data will be collected using both U.S. Environmental Protection Agency (EPA) M29 and the ME-ST method. The two methods will sample at the same location and time duration to ensure an accurate comparison between the two different methods. The sampling location will be before the stack and after the quench pots in order to accurately measure the trace elements that would exit the stack. At least 6 EPA M29 samples and 12 ME-ST samples will be collected during Task 2. All sampling will be performed during steady-state conditions.

In addition to the trace element data, key operational data pertaining to the performance at the gasifier and pollution control systems will be collected during the gasification of the biomass fuel.

Task 3. Characterize Trace Element Emissions from Wood-Derived Syngas. Trace element measurements will be made during the gasification of wood-derived syngas. The test run for this task focuses on the collection of trace element data from an EERC pilot-scale fluidized-bed gasifier while feeding a North Dakota wood. Trace element data will be collected using both EPA M29 and the ME-ST

method. The two methods will sample at the same location and time duration to ensure an accurate comparison between the two different methods. The sampling location will be before the stack and after the quench pots in order to accurately measure the trace elements that would exit the stack. At least 6 EPA M29 samples and 12 ME-ST samples will be collected during Task 3. All sampling will be performed during steady-state conditions

In addition to the trace element data, key operational data pertaining to the performance at the gasifier and pollution control systems will be collected during gasification of the biomass wood.

Anticipated Results:

The anticipated results will characterize and quantify trace element data from the gasification of North Dakota switchgrass and wood. The ME-ST method will be applied toward the analysis of biomass fuels and gasification systems. The results will also identify any challenges with EPA M29 as well as the ME-ST method. The results will also compare the data obtained with the ME-ST method to the data collected with EPA M29.

Facilities and Resources:

The majority of work for this project will be conducted at the EERC in Grand Forks, North Dakota. Since its founding in 1949, 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. The main EERC facilities, with 245,000 square feet of technology demonstration facilities, fuel preparation facilities, analytical laboratories, and office space, are located on the southeast corner of the University of North Dakota (UND) campus. State-of-the-art laboratory- and pilot-scale equipment is available for evaluating various fuels, including coal, biomass, and refuse-derived fuel. The following gasifier, fuel preparation facilities, and laboratories within the EERC will be utilized in this project.

High-Pressure Fluidized-Bed Gasifier. This system has been designed according to American Society of Mechanical Engineers (ASME) B31.3 process piping code specifications. The internal reactor dimensions are based upon the existing operational continuous fluidized-bed reactor (CFBR) that currently operates up to a maximum operating pressure (MOP) of 1.0 MPa (150 psig). The reactor was designed with the capability to operate at a MOP of 6.9 MPa (1000 psig) at an operational temperature of 843°C (1550°F), 4.5 MPa (650 psig) at an operational temperature of 917°C (1650°F), and 2.0 MPa (300 psig) at an operational temperature of 1800°F. This system was also designed to be externally electrically heated. The 2500-lb 316H stainless steel flanged connections at the top and bottom of the reactor are limited to a maximum operating temperature of 677°C (1250°F) for a MOP of 6.9 MPa (1000 psig), 732°C (1350°F) for a MOP of 4.5 MPa (650 psig), and an operational temperature of 816°C (1500°F) for a MOP of 2.0 MPa (300 psig). This system is instrumented with thermocouples in all key locations to monitor that operating temperatures of the material are not exceeding their design limitations.

A design drawing of the reactor is shown in Figure 1. The feed system uses a K-tron® loss-in-weight feeder that was installed inside of a pressure vessel capable of 6.9-MPa (1000-psig) operation. This

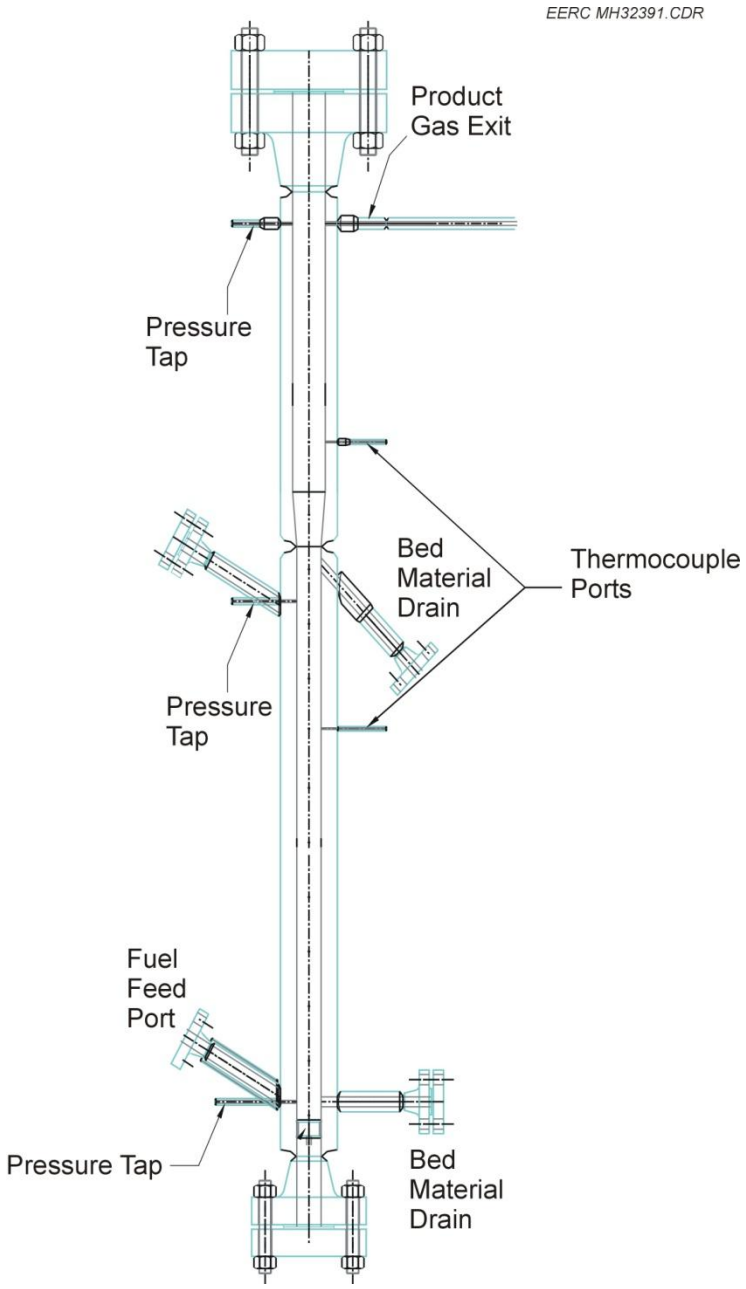

Figure 1. Design drawing of the pressurized fluidized-bed gasification reactor.

system will allow an instantaneous measurement of the fuel feed rate to the gasification system to which it is connected. The feed system electronic controls are interfaced to a data acquisition system that allows for local or remote computer control of the fuel feed rate. Hopper weights along with feed rates are recorded by the data acquisition system and can be displayed and trended as required.

Additionally, two sets of three (six total) water-cooled quench pots were designed and built for condensing moisture and organics from the gas stream. These quench pots have been designed for

operation up to 1000 psig. This design has been very effective in the removal of organics and moisture while not becoming plugged. Either water or a cooled glycol and water mixture is circulated through the outer jacket of each quench pot to cool the product gas down.

Fuel Preparation Facility. The EERC has conducted numerous resource assessments on a variety of biomass types, including wheat straw, rice straw, alfalfa, flax straw, animal manures or litter, corn stover, switchgrass, beet tailings, potato residues, hybrid poplar, sunflower hulls, municipal solid waste, sewage sludge, paper mill sludge, lignin from cellulosic ethanol processing, and many types of wood residue. The fuel preparation facility includes a walk-in trailer for biomass hauling and temporary storage; a batch autoclave that operates up to 2200 psi; a 7.5-ton/day coal or biomass continuous process development unit; and complete fuel-handling, crushing, shredding, and chipping preparation facilities for developing and testing process methods for fuel preparation.

Analytical Research Laboratory. The Analytical Research Laboratory (ARL) is equipped for routine and specialized analyses of inorganic and organic constituents, which are performed using state-of-the-art instrumental procedures as well as classical wet chemistry. Established analytical techniques allow for the chemical characterization of a variety of environmental and biological sample types, including fossil fuels, biomass, combustion by-products, geologic materials, fine particulate matter, groundwater, wastewater, fish tissue, and plant materials. Particular attention is directed toward major, minor, and trace element chemical analysis. Major instrumentation includes VG PQ ExCell inductively coupled plasma mass spectrometer (ICP–MS) with collision cell technology, Perkin Elmer Optima 2100 inductively coupled plasma atomic emission spectrometer (ICP–AES), CETAC M6000A cold-vapor atomic absorption spectrometer (CVAAS) mercury analyzer, PS Analytical Millennium Merlin cold-vapor atomic fluorescence spectrometer (CVAFS), PS Analytical Millennium Excalibur hydride generation atomic fluorescence spectrometer (HGAFS), Varian Spectra AA-880Z graphite furnace atomic absorption spectrometer (GFAAS), Mitsubishi TOX-100 chlorine analyzer with oxidative hydrolysis microcoulometry, and Dionex ISC3000 ion chromatograph (IC) with conductivity detection.

Fuels and Materials Research Laboratory. The Fuels and Materials Research Laboratory (FMRL) is an integrated and fully equipped laboratory designed for testing of fuel quality parameters. The laboratory provides support for many EERC research programs. In addition to performing standard ASTM fuel testing such as proximate and ultimate analyses and heating value, the FMRL provides a wide variety of other testing: surface area determination, laser particle sizing, dry- and wet-sieve analysis, and ash fusion. Major and minor equipment includes Leco TGA-701 analyzer – for the determination of moisture, volatile matter, and ash analysis; Leco TruSpec CHN analyzer, for the determination of carbon, hydrogen, and nitrogen, which is part of the ultimate analysis for fuels; Leco TruSpec sulfur analyzer; Leco AC-350 isoperibol calorimeter to determine heating values in fuels; Malvern 2600 particle-size analyzer, to detect particles in the range of 0.5 to 564 μm; fusibility furnace for coal and coke ash to predict the deformation properties of the ash; facilities for sieving, grinding, and sample preparation. The lab utilizes a variety of equipment to prep samples for analysis, including several types of grinders, pulverizers, and a Hosokawa Micron Powder System unit for typical combustion preparation. Physical tests are also performed, including wet-sieve analysis, dry-sieve analysis, and bulk density.

Techniques to Be Used and Their Availability and Capability:

The two trace element techniques that will be used in the proposed work are EPA Method 29 and an EERC-developed sorbent trap method referred to as ME-ST. EPA Method 29 is a well-established analysis method for trace metal emissions from combustion sources. Detection limits for EPA M29 are shown in Table 1. The EERC has years of experience with EPA M29 sampling and analysis and is confident that the test can be completed as proposed.

While EPA M29 is a reference method, it has proven to be difficult to implement under gasification conditions and is expensive. Consequently, a simpler, more cost-effective method is needed. The ME-ST method is currently being developed at the EERC as an alternative to EPA M29 and has provided very encouraging results to date. The method is a sorbent trap-based method and does not require any solvents in the field. This will reduce costs by not having to transport and prepare solvents in the field and will also reduce sample biases due to contaminated solvents. Recent unpublished data demonstrated that the ME-ST method produced data similar to EPA M29 data during a pilot-scale combustion test (2). Based on initial data, it is anticipated that ME-ST detection limits will be equivalent or better than EPA M29.

Environmental and Economic Impacts While Project Is Under Way:

The use of the EERC pilot-scale gasifier has minimal impacts because of the pollution control devices that are used. The use of the filter vessel, quench pots, and stack thermal oxidizer reduce emissions to

Table 1. EPA M29 Detection Limits Using ICP-AES or GFAAS

Element	Front Half: Probe and Filter, µg/m^3	Back Half: Impingers 1–3, µg/m^3	Back Half: Impingers 4–6, µg/m^3	Total Train, µg/m^3
Antimony	0.7	0.4		1.1
Arsenic	0.3	0.1		0.4
Barium	0.5	0.3		0.8
Beryllium	0.05	0.03		0.08
Cadmium	0.02	0.01		0.03
Chromium	0.2	0.1		0.3
Cobalt	0.2	0.1		0.3
Copper	1.4	0.7		2.1
Lead	0.2	0.1		0.3
Manganese	0.2	0.1		0.3
Mercury	0.06	0.3	0.2	0.56
Nickel	3.6	1.8		5.4
Phosphorus	18	9		27
Selenium	0.5	0.3		0.8
Silver	1.7	0.7		2.4
Thallium	0.2	0.1		0.3
Zinc	0.5	0.3		0.8

below compliance levels. The use of reagents and chemicals needed during this project will be properly handled and disposed of according to UND's waste disposal management system.

Ultimate Technological and Economic Impacts:

The information collected from this project will provide key trace element data during the gasification of North Dakota biomass. The ME-ST method development will provide a significant technological contribution toward the advancement of trace element measurements in reducing environments while at the same time reducing the costs associated with trace element sampling. The reduced costs associated with sampling are significant because of the upcoming National Emission Standards for Hazardous Air Pollutants rules that apply to both industrial and utility boilers/gasifiers, regardless of fuel type.

Why the Project Is Needed:

This project is needed because of the lack of trace element emission data in gasification systems, especially when biomass is used as the feedstock. While EPA M29 works well for combustion systems, reducing gases such as H_2S, CO, and H_2 rapidly deplete the oxidizing solvents in the impingers, thereby decreasing the effectiveness of the method (3). This report also concludes that there is a need for the development of sampling techniques for use in a reducing environment. The proposed work seeks an alternative method that does not utilize solvents. This method offers a significant advantage over M29 and is anticipated to provide accurate trace element data from gasification systems.

The measurement data collected in the proposed work and the development of the ME-ST method will allow entities gasifying biomass and other fuels the tools that they need to accurately measure trace element emissions and ensure compliance with upcoming emission regulations.

STANDARDS OF SUCCESS

The standards of this project will include the report that will be generated and presentation of the results. Since little work has been done regarding trace element emissions resulting from the gasification of biomass, dissemination of the results at meetings and conferences will aid in getting the data out to a large audience and have an impact on the utilization of biomass in industrial systems.

The key industries in North Dakota that will benefit from the results of this project are the gasification industry, both utility and small industrial users. The development of the ME-ST method will offer a reliable, cost-effective trace element measurement method to ensure accurate measurements in reducing environments and compliance with upcoming emission regulations. Presenting the data at conferences will provide gasification and biomass users in North Dakota and the rest of the United States with key information regarding trace element emissions. The collection of biomass syngas trace element data and development of new measurement methods in reducing environments will likely lead to greater confidence in the use of biomass in North Dakota and will result in newly created jobs by expanding the industry.

BACKGROUND/QUALIFICATIONS

The EERC is one of the world's major energy and environmental research organizations. Since its founding in 1949, 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. The EERC has established working relationships with nearly 1100 clients in 51 countries and all 50 states, including federal and state agencies, universities, coal companies, utilities, research and development firms, equipment vendors, architecture and engineering firms, chemical companies, and agricultural products companies. The EERC emphasizes true working partnerships among private industry, government agencies, academic institutions, and the research community. Thus the EERC is committed to a partnership team approach for energy and environmental technologies.

The Centers for Renewable Energy and Biomass Utilization are a designated Center of Excellence located at the EERC. The Centers conduct critical research, development, demonstration, and commercial deployment of technologies utilizing biomass, wind, solar, geothermal, and hydroelectric energy sources. Under the Center for Biomass Utilization® (CBU®), the EERC offers the most comprehensive approach to biomass conversion research.

PERSONNEL/MANAGEMENT

Dr. Nicholas Lentz, Research Scientist, will serve as the project manager for this project and will be responsible for pilot-scale test runs and subsequent data reduction. His areas of expertise and interest include the identification and development of new analytical methods for the advancement of elemental analysis in biological tissues and nonbiological samples, including coal and coal by-products; analysis for combustion flue gas, fuel oil, and biowaste; and experimental design and analysis related to control technologies to remove mercury and other elements from combustion systems. Dr. Lentz is particularly interested in applying analytical techniques from various research sectors to the energy and environmental sectors to develop more sensitive methods that are robust and applicable across a wide variety of applications. He is currently involved in mercury and trace metal work at the pilot and bench scale and has been involved in full-scale field demonstrations of mercury control technologies.

John Pavlish, Senior Research Advisor, will serve as the principal investigator for this project. Mr. Pavlish's principal areas of interest and expertise include air toxic issues; HAPs with special emphasis on mercury; coal combustion processes and power plant system performance, including economic and feasibility analyses; advanced emission control technologies; gasification; and energy conversion systems. He has over 25 years of experience with advanced combustion systems, with expertise in regulatory issues regarding air toxics (especially mercury), international consulting, and research into advanced emission control technologies. Mr. Pavlish has led several large projects across North America and has overseen complex programs that orchestrate several disciplines of

research toward a common goal of understanding and remediating mercury and other trace metal issues.

Ms. Lucinda Hamre, Research Specialist, will provide assistance to Dr. Lentz in day-to-day management and technical support. Ms. Hamre's principal areas of expertise include technical and management support for emission control research for coal-fired power systems. She has been involved in ongoing research projects for public and private entities, which have been primarily focused on mercury control. For the past 6 years, Ms. Hamre has assisted with the management of the CATM® Program and has been involved in several projects from bench-scale testing through full-scale demonstrations of emerging mercury control technologies and assists in technology transfer research and community outreach programs and publication development.

Dr. Lentz will serve as project manager for this project. He will have the overall responsibility for the contract and will communicate regularly with all project sponsors and participants. He will also be responsible for contractual reporting to the North Dakota Industrial Commission (NDIC) Renewable Energy Program (REP) and CBU. Other members of the project management team will include John Pavlish and Lucinda Hamre. Resumes of key personnel are enclosed in Appendix A.

Internal project review meetings will be scheduled to ensure that all analytical activities in this project are completed in a timely manner according to the project schedule. Quarterly reports will be prepared for project sponsors with updated results as well as a final report at project completion. Information will also be disseminated through presentations at conferences.

TIMETABLE

Table 2 outlines the schedule of project activities.

Table 2. Schedule of Project Activities

	Month											
Activity	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
Initiate and Finalize Contract	◄►											
Fuel Acquisition and Preparation			◄►	◄►								
Task 1				◄►	◄►							
Task 2						◄►	◄►					
Task 3								◄►	◄►			
Data Reduction				◄	─	─	─	─	─	─	─	►
Interim/Quarterly Reports			*X*			*X*			*X*			*X*
Final Report to Project Sponsors												*X*

BUDGET

Project Associated Expense	NDIC Share	CBU Share (Cash)
Total Direct Salaries	$ 54,109	$ 61,387
Total Fringe	$ 29,219	$ 33,149
Total Labor	$ 83,328	$ 94,536
Travel	$ 2,183	$ 5,885
Supplies	$ 7,072	$ 7,928
Communication	$ 100	$ 110
Printing & Duplicating	$ 100	$ 109
Food	$ 200	$ -
Operating Fees and Services	$ 63,267	$ 59,217
Total Direct Costs	$ 156,250	$ 167,785
Total Indirect Costs (F&A)	$ 93,750	$ 82,215
Total Project Cost	$ 250,000	$ 250,000

The total estimated cost for the proposed scope of work is $500,000. The EERC is requesting $250,000 from the NDIC REP, with the remaining amount of $250,000 provided in cost share by the U.S. Department of Energy (DOE)-funded CBU. This budget is necessary to adequately address the proposed tasks in this project. The scope of work developed for the overall project cost assumes funding is approved by both parties. The CBU funding has been awarded to the EERC; however, approval from DOE is necessary to ensure the project scope of work falls within the objectives of the DOE–CBU goals before formally committing dollars to the project. Initiation of the proposed work is contingent upon the execution of mutually negotiated agreements or modifications to existing agreements between the EERC and each of the participating sponsors. A detailed budget, accompanying budget notes, and letter of commitment are enclosed in Appendix B.

CONFIDENTIAL INFORMATION

No confidential information is included in this proposal.

PATENTS/RIGHTS TO TECHNICAL DATA

The ME-ST method is already progressing through the patent process. The rights to technical data generated will be held jointly by the EERC and project sponsors.

STATUS OF ONGOING PROJECTS (IF ANY)

Applicant has not received any previous funding.

REFERENCES

1. Wetherold, B.; Orr, D.; Maxwell, D. A Comparison of Gasification and Incineration of Hazardous Wastes. Final Report for the U.S. Department of Energy Contract No. 99.803931.02, March 30, 2010.

2. Unpublished Center for Air Toxic Metals® data.

3. Erickson, T.A.; Brekke, D.W.; Botros, P.E. *Assessment of HAPs Emissions from Advanced Power Systems*; Final Report for the U.S. Department of Energy Contract No. DE-AC21-92MC28016; 1996.

APPENDIX A

RESUMES OF KEY PERSONNEL

DR. NICHOLAS B. LENTZ
Research Scientist
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) 777-5337, Fax: (701) 777-5181, E-Mail: nlentz@undeerc.org

Principal Areas of Expertise

Dr. Lentz's principal areas of expertise are the identification and development of new analytical methods for the advancement of elemental analysis in biological tissues and nonbiological samples, including coal and coal by-products; analysis for combustion flue gas, fuel oil, and biowaste; and experimental design and analysis related to control technologies to remove mercury and other elements from combustion systems.

Qualifications

Ph.D., Analytical Chemistry, Iowa State University, Ames, Iowa.
B.S., Chemistry, Bemidji State University, Bemidji, Minnesota.

Proficient in the use of Word, Excel, and PowerPoint.

Professional Experience

2007–Present: Research Scientist, EERC, UND. Dr. Lentz's responsibilities include identification and development of new analytical methods required for the advancement of elemental analysis in biological tissues and nonbiological samples including coal and coal by-products, as well as analysis for combustion flue gas, fuel oil, and biowaste. His work also involves experimental design and analysis related to control technologies to remove mercury and other elements from combustion systems. Dr Lentz manages a portfolio of ongoing measurement research projects by serving as a program area manager for the EERC's Center for Air Toxic Metals® Program.

2002–2007: Research Assistant, Iowa State University, Ames, Iowa. Dr. Lentz's responsibilities included performing chemical research in pursuit of a graduate degree.

2005–2006: Teaching Assistant, Iowa State University. Dr. Lentz's responsibilities included teaching three physical chemistry laboratory sections, grading laboratory reports and problem sets, recording scores and helping to prepare final examinations, and maintaining three lab instruments.

2002–2003: Teaching Assistant, Iowa State University. Dr. Lentz's responsibilities included teaching general chemistry recitations and laboratory sections, proctoring exams and recording scores, grading of homework and examinations, and conducting weekly office hours at the chemistry help center.

2001–2002: Lab Assistant, Bemidji State University. Dr. Lentz's responsibilities included preparing samples and standards for general chemistry labs, performing quality control checks on

undergraduate laboratories, collecting hazardous waste from laboratories and filling out necessary manifest forms, and organizing and taking inventory of all chemicals used in the stockroom.

2001–2001: Undergraduate Researcher, Bemidji State University. Dr. Lentz's responsibilities included collecting water samples from Lake Bemidji and the Mississippi River for ion chromatograph analysis as well as analyzing fuel samples for the Petroleum Products Research Laboratory.

Publications and Presentations
Has coauthored several professional publications.

JOHN H. PAVLISH
Senior Research Advisor
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) 777-5268, Fax: (701) 777-5181, E-Mail: jpavlish@undeerc.org

Principal Areas of Expertise

Mr. Pavlish is a Senior Research Advisor and the Director of the multiyear, multimillion dollar Center for Air Toxic Metals® (CATM®) Program at the EERC. He has over 26 years of experience with advanced and conventional combustion systems to solve operational and environmental problems. His principal areas of interest and expertise include air toxic issues; hazardous air pollutants (HAPs) with special emphasis on mercury; CO_2 capture; and coal combustion process and power plant system performance, including economic and feasibility analyses.

Qualifications

B.S., Mechanical Engineering, North Dakota State University, 1984.
A.A.S., Power and Machinery, University of Minnesota – Crookston, 1979.
P.E., Kansas.

Professional Experience

2000–Present: Center for Air Toxic Metals Director, EERC, UND. Mr. Pavlish is a Senior Research Advisor and the Director of the multiyear, multimillion dollar CATM Program. His responsibilities include developing and managing an array of projects involving air toxic metals (mercury), fuel impacts on energy conversion systems, emission control technologies for power plant applications, biomass utilization, fuel cell applications, and technical and economic evaluations of various advanced emission control and energy conversion systems.

1994–2003: Senior Research Manager, EERC, UND. Mr. Pavlish's responsibilities included managing research programs related to emissions and control of air toxic substances. In an advisory role, Mr. Pavlish provided direction, vision, and technical review of future research programs. His responsibilities also included supervising research on the effects of fuel quality on combustion and gasification system performance; laboratory, pilot, and field testing; planning and performing specific research projects; evaluating the effects of coal quality and ash on power plant performance, generation recovery, steam generator performance and reliability, formation of HAPs, assessment of various control technologies, and flue gas-processing equipment; creating, developing, maintaining, testing, and validating innovative computer programs; identifying research opportunities and writing proposals and reports to meet client needs; and managing budgets and personnel on multiple projects.

1993–1994: Research Manager, Fuels and Materials Science, EERC, UND. Mr. Pavlish's responsibilities included supervising research on the effects of coal quality on coal combustion and gasification system performance; laboratory, pilot, and field testing; planning and

performing specific research projects; evaluating the effects of coal quality and ash on power plant performance, generation recovery, steam generator performance and reliability, formation of HAPs, assessment of various control technologies, and flue gas-processing equipment; creating, developing, maintaining, testing, and validating innovative computer programs; identifying research opportunities and writing proposals and reports to meet client needs; and managing budgets and personnel on multiple projects.

1984–1993: Unit Leader/Systems Engineer, Black & Veatch Engineers–Architects. Mr. Pavlish's responsibilities included providing engineering/technical advice; determining and managing resources; developing and monitoring budgets; developing, overseeing, and maintaining project schedules; conducting formal/informal presentations to clients and at technical conferences; writing the technical scope of work, preparing cost estimates, and providing the supervision and organization of the proposal effort; assisting in the preparation and presentation of appropriate marketing material; planning, performing, and coordinating numerous coal quality impact studies; and creating, developing, maintaining, teaching, and validating innovative computer-based programs for evaluating the impacts that coal/ash constituents have on the combustion process, power plant equipment, overall plant performance, and unit/plant/system generation costs.

1979–1981: Diesel Power Technician, Crookston Implement, Inc., Crookston, Minnesota.

Professional Memberships

U.S. Representative, Mercury Emissions from Coal International Experts Working Group on Reducing Emissions from Coal, in association with the International Energy Agency Clean Coal Centre, 2004–present
United Nations Environment Programme Global Mercury Partnership, Reduction of Mercury Releases from Coal Combustion
Advisory Member, BiNational Strategy Utility Mercury Reduction Committee
Advisory Member, Minnesota Pollution Control Agency Research Advisory Committee
Advisory Member, Minnesota Taconite Mercury Control Advisory Committee
Advisory Member, Advanced Emissions Control Development Program
American Society of Mechanical Engineers
Air & Waste Management Association

Patents, Publications, and Presentations

Has authored and coauthored over 200 publications and presentations and holds several patents.

LUCINDA L. HAMRE
Research Specialist
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) 777-5059, Fax: (701) 777-5181, E-Mail: lhamre@undeerc.org

Principal Areas of Expertise

Ms. Hamre's principal areas of interest and expertise include technical and management support for research focusing on emission control for coal-fired power systems. She has been involved in ongoing research projects for public and private entities, which have primarily focused on mercury control. For the past 6 years, Ms. Hamre has assisted with the management of the EPA-funded Center for Air Toxic Metals® (CATM®) Program, which conducts basic and applied research into the effects of potentially toxic trace metals.

Qualifications

Master's-Level Certificate, Public Administration, North Dakota State University, 2004.
B.S., Technology Assessment and Management, St. Cloud State University, 1998.
B.S., Speech Communication, St. Cloud State University, 1998.
A.A., Prenursing, Willmar Community College, 1989.

Professional Experience

2002–Present: Research Specialist, EERC, UND, Grand Forks, North Dakota. Ms. Hamre's responsibilities include project management activities, including those for the CATM Program, at the EERC and oversight of small research projects. She prepares research reports and assists with the CATM Annual Report; assists with writing peer-reviewed journal articles; develops proposals, tracks budgets and project progress; and assists with contractual and funding issues. In addition, she serves as a liaison between project managers and clients, disseminating information and otherwise keeping sponsors, subcontractors, and other EERC groups informed of project activities. She also develops presentation materials, prepares the CATM Technical Newsletter, and maintains the CATM Web site. Ms. Hamre performs sample and data collection, tracking, and submission of samples for analysis; creates, manipulates, maintains, and archives spreadsheets and databases for data reduction; assists in the development of site-specific test plans and quality assurance/quality control plans; designs graphical tools for presentation of data; and performs literature searches for project-related information; and otherwise assists CATM and researchers in accomplishing project objectives.

1998–2002: Research Information Associate, Administrative Resources, EERC, UND, Grand Forks, North Dakota. Ms. Hamre provided administrative and technical support to a Senior Research Advisor and associated team members to carry out project activities for field research projects. Ms. Hamre assisted with the preparation of proposals; writing research test plans, journal articles, and reports; and preparing presentation materials. She also assisted researchers with research sample inventory, cataloguing and inventory, data entry, spreadsheet preparation, data interpretation, and other responsibilities as needed. Project management assistance included

interaction with accountants, contract specialists, project sponsors, and other external participants as needed.

1997–1998: Executive/Administrative Clerk, Computer Department, UND Bookstore, Grand Forks, North Dakota. Ms. Hamre provided professional support for University staff and students to procure technical products. She negotiated contracts for technical products with outside vendors, processed receivables for payment, and prepared financial reports. She planned and implemented marketing campaigns, developed marketing materials, and prepared financial reports and projections.

1996–1997: Territory Representative, Devils Lake Journal, Devils Lake, North Dakota. Ms. Hamre's responsibilities included developing new business in a rural sales region for two newspapers, one weekly and one daily, and servicing accounts. She planned and carried out marketing and advertising campaigns, including advertising themes, ad design, customer proof, and layout.

1992–1994: Interim Assistant Director, Higher Education Manufacturing Process Applications Consortium, St. Cloud, Minnesota. Ms. Hamre's responsibilities included providing ongoing direction and support for a $10.6 million grant ($2.5 million federal) for manufacturing improvement by disseminating lean manufacturing engineering principles to company management through front-line employees. This joint venture project included leaders from government, higher education, and private industry. Her responsibilities included project management activities, developing and delivering training in engineering practices, advanced-level technical writing, marketing outreach, conference development, and public relations.

1984–1991: Estimator/Head of Sales Department, Print House, Willmar, Minnesota. Ms. Hamre consulted with government, nonprofits, and private industry to develop and produce marketing campaign materials and printed business materials. She was involved in contract interpretation and negotiation, consultations, and debt collection. In addition, Ms. Hamre's responsibilities included oversight of internal sales people, including training, accounting practices, and planning future staffing needs.

Publications and Presentations
Has authored or coauthored several publications.

APPENDIX B

BUDGET, BUDGET NOTES, AND LETTER OF COMMITMENT

TRACE ELEMENT MEASUREMENTS DURING BIOMASS GASIFICATION
NDIC RENEWABLE ENERGY PROGRAM
PROPOSED PROJECT START DATE: 05/01/2011
EERC PROPOSAL #2011-0137

BUDGET

CATEGORY			TOTAL		NDIC SHARE		FEDERAL SHARE	
LABOR		Rate	Hrs	Cost	Hrs	Cost	Hrs	Cost
Lentz, N.	Project Manager	$ 30.38	360	$ 10,937	160	$ 4,861	200	$ 6,076
Pavlish, J.	Principal Investigator	$ 76.55	270	$ 20,669	125	$ 9,569	145	$ 11,100
Hamre, L.	Principal Investigator	$ 29.90	240	$ 7,176	110	$ 3,289	130	$ 3,887
----------	Senior Management	$ 74.19	144	$ 10,683	21	$ 1,558	123	$ 9,125
----------	Research Scientists/Engineers	$ 39.47	948	$ 37,418	354	$ 13,972	594	$ 23,446
----------	Research Technicians	$ 25.94	183	$ 4,747	-	$ -	183	$ 4,747
----------	Technology Dev. Mechanics	$ 30.94	600	$ 18,564	600	$ 18,564	-	$ -
----------	Technical Support Services	$ 21.50	40	$ 860	10	$ 215	30	$ 645
				$ 111,054		$ 52,028		$ 59,026
Escalation Above Base		4%		$ 4,442		$ 2,081		$ 2,361
TOTAL DIRECT HRS/SALARIES			2,785	$ 115,496	1,380	$ 54,109	1,405	$ 61,387
Fringe Benefits - % of Direct Labor - Staff		54%		$ 62,368		$ 29,219		$ 33,149
TOTAL FRINGE BENEFITS				$ 62,368		$ 29,219		$ 33,149
TOTAL LABOR				$ 177,864		$ 83,328		$ 94,536
OTHER DIRECT COSTS								
TRAVEL				$ 8,068		$ 2,183		$ 5,885
SUPPLIES				$ 15,000		$ 7,072		$ 7,928
COMMUNICATION - LONG DISTANCE & POSTAGE				$ 210		$ 100		$ 110
PRINTING & DUPLICATING				$ 209		$ 100		$ 109
FOOD				$ 200		$ 200		$ -
OPERATING FEES & SVCS								
Fuels & Materials Research Lab.				$ 1,360		$ -		$ 1,360
Analytical Research Lab.				$ 79,319		$ 48,691		$ 30,628
Particulate Analysis				$ 21,135		$ -		$ 21,135
Fuel Prep. and Maintenance				$ 4,784		$ -		$ 4,784
Continuous Fluidized-Bed Reactor				$ 13,603		$ 13,603		$ -
Graphics Support				$ 1,310		$ -		$ 1,310
Shop & Operations Support				$ 973		$ 973		$ -
TOTAL DIRECT COST				$ 324,035		$ 156,250		$ 167,785
FACILITIES & ADMIN. RATE - % OF MTDC			VAR	$ 175,965	60%	$ 93,750	49%	$ 82,215
TOTAL PROJECT COST - US DOLLARS				$ 500,000		$ 250,000		$ 250,000

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.

TRACE ELEMENT MEASUREMENTS DURING BIOMASS GASIFICATION
EERC PROPOSAL #2011-0137

BUDGET - TRAVEL

RATES USED TO CALCULATE ESTIMATED TRAVEL EXPENSES

DESTINATION	AIRFARE	PER MILE	LODGING	MEALS	CAR RENTAL	REGIST.
Unspecified Destination (USA)	$ 900	$ -	$ 200	$ 71	$ 85	$ 575
Bismarck, ND	$ -	$ 0.33	$ 75	$ 25	$ -	$ -
Morgantown, WV (via Pittsburgh, PA)	$ 1,100	$ -	$ 150	$ 46	$ 75	$ -

PURPOSE/DESTINATION	NUMBER OF TRIPS	PEOPLE	MILES	DAYS	AIRFARE	MILEAGE	LODGING	MEALS	CAR RENTAL	MISC.	REGIST.	TOTAL
Conference/Unspecified Dest. (USA)	1	2	-	5	$ 1,800	$ -	$ 1,600	$ 710	$ 425	$ 200	$ 1,150	$ 5,885
NDIC Meeting/Bismarck, ND	1	1	650	2	$ -	$ 215	$ 75	$ 50	$ -	$ 20	$ -	$ 360
DOE Review Meeting/Morgantown, WV (Pittsburgh, PA)	1	1	-	3	$ 1,100	$ -	$ 300	$ 138	$ 225	$ 60	$ -	$ 1,823
TOTAL ESTIMATED TRAVEL												$ 8,068

TRACE ELEMENT MEASUREMENTS DURING BIOMASS GASIFICATION
EERC PROPOSAL #2011-0137

DETAILED BUDGET - EERC RECHARGE CENTERS

Fuels & Materials Research Lab.	Rate	#	$Cost
Moisture %	$67	4	$ 268
Proximate Ultimate	$260	4	$ 1,040
Subtotal			$ 1,308
Escalation		4%	$ 52
Total Fuels & Materials Research Lab.			$ 1,360

Analytical Research Lab.	Rate	#	$Cost
Coal Digestion	$175	4	$ 700
Miscellaneous (Sample)	$53	1,286	$ 68,158
Trace Element Digestion	$39	190	$ 7,410
Subtotal			$ 76,268
Escalation		4%	$ 3,051
Total Analytical Research Lab.			$ 79,319

Particulate Analysis	Rate	#	$Cost
101-A & Bench Scale Method 29/Ontario Hydro	$434	1	$ 434
EPA Method 29/Ontario Hydro	$855	16	$ 13,680
Appendix K/Method 30B	$194	32	$ 6,208
Subtotal			$ 20,322
Escalation		4%	$ 813
Total Particulate Analysis			$ 21,135

Fuel Preparation & Maintenance	Rate	#	$Cost
Fuel Preparation & Maintenance (Hourly/unit equipment)	$46	100	$ 4,600
Subtotal			$ 4,600
Escalation		4%	$ 184
Total Fuel Prep. & Maintenance			$ 4,784

Continuous Fluidized-Bed Reactor	Rate	#	$Cost
Continuous Fluidized-Bed Reactor (Hourly)	$109	120	$ 13,080
Subtotal			$ 13,080
Escalation		4%	$ 523
Total Continuous Fluidized-Bed Reactor			$ 13,603

Graphics Support	Rate	#	$Cost
Graphics (hourly)	$63	20	$ 1,260
Subtotal			$ 1,260
Escalation		4%	$ 50
Total Graphics Support			$ 1,310

Shop & Operations Support	Rate	#	$Cost
Technical Development Hours	$1.56	600	$ 936
Subtotal			$ 936
Escalation		4%	$ 37
Total Shop & Operations Support			$ 973

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 (value of $5000 or more) 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 (value less than $5000), 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 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 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 capital expenditures, such as equipment or software costing $5000 or more with a useful life of greater than one year, as well as 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.

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

December 29, 2010

Ms. Karlene Fine
Executive Director
Attn: Renewable Energy Program
North Dakota Industrial Commission
State Capitol – Fourteenth Floor
600 East Boulevard Avenue
Bismarck, ND 58505

Dear Ms. Fine:

Subject: Center for Biomass Utilization® Commitment for EERC Proposal No. 2011-0137 Entitled "Trace Element Measurements During Biomass Gasification"

This letter is in regard to the cost share to be provided by the Energy & Environmental Research Center (EERC) for the "Trace Element Measurements During Biomass Gasification" proposal submitted to the the North Dakota Industrial Commission Renewable Energy Program (NDIC REP). The EERC will provide $250,000 toward the total project cost of $500,000 under the 2010 U.S. Department of Energy (DOE)-sponsored Center for Biomass Utilization (CBU®) Program. CBU is an ongoing program within the EERC that has been in existence for over 12 years. The funds that are committed toward this project are available now and have been reserved and allocated toward the support of this project.

CBU has a history of funding research projects that involve the development of technologies and tools to advance electricity, heat, and fuel production from renewable resources. The approach and concepts outlined in the proposed project should provide the data and information needed to address critical questions that remain unanswered and allow biomass to play a larger role as greenhouse gas issues are addressed.

I am hopeful that NDIC REP will both view this proposal favorably and look forward to supporting and participating in this project.

If you have any questions, please feel free to contact me by phone at (701) 777-5243, by fax at (701) 777-5181, or by e-mail at bfolkedahl@undeerc.org.

Sincerely,

Bruce C. Folkedahl
Senior Research Manager

BCF/hmv

Enclosures

c: John Hendrikson, EERC
Lucinda Hamre, EERC