Energy & Environmental Research Center
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www.undeerc.org

March 30, 2021

Ms. Karlene Fine
Executive Director
ATTN: Lignite Research Program
North Dakota Industrial Commission
600 East Boulevard Avenue
State Capitol, 14th Floor
Bismarck, ND 58505-0840

Dear Ms. Fine:

Subject: EERC Proposal No. 2021-0136 Entitled "Williston Basin CORE-CM Initiative"

The Energy & Environmental Research Center (EERC) is pleased to submit this request for cost-share funding from the Lignite Research, Development and Marketing Program (LRDMP) for the Williston Basin CORE-CM Initiative. This proposal is contingent on the project being selected for funding by the U.S. Department of Energy (DOE), and the anticipated date for selection notification by DOE is April 2021. If awarded, the EERC and a coalition of nearly 30 partners will drive the expansion and transformation of using coal and coal-based resources within the Williston Basin to produce rare-earth elements, critical minerals, and nonfuel carbon-based products.

Enclosed please find an original and one copy of the subject proposal along with a check for $100. The EERC, a research organization within the University of North Dakota, an institution of higher education within the state of North Dakota, is not a taxable entity; therefore, it has no tax liability.

This transmittal letter represents a binding commitment by the EERC to complete the project described in this proposal. If you have any questions, please contact me by telephone at (701) 777-5153, by fax at (701) 777-5181, or by e-mail at terickson@undeerc.org.

Sincerely,

DocuSigned by:
Tom Erickson
D4A0828A1B244CE...

Thomas A. Erickson
Director for Exploratory Research & Intellectual Property & Technology Commercialization

Approved by:

DocuSigned by:
Erin M. O'Leary, for
3C56131ED6AA4FF...

Charles D. Gorecki, CEO
Energy & Environmental Research Center

TAE/rlo

Enclosures

Lignite Research, Development and Marketing Program

North Dakota Industrial Commission

Application

Project Title: Williston Basin CORE-CM Initiative

Applicant: University of North Dakota Energy & Environmental Research Center

Principal Investigator: Thomas A. Erickson

Date of Application: March 30, 2021

Amount of Request: $750,000

Total Amount of Proposed Project: $2,450,000

Duration of Project: 20 months

Point of Contact (POC): Thomas A. Erickson

POC Telephone: (701) 777-5153

POC E-Mail: terickson@undeerc.org

POC Address:

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

TABLE OF CONTENTS

ABSTRACT

The University of North Dakota (UND) Energy & Environmental Research Center (EERC), with nearly 30 coalition team members, is proposing to lay the foundation of a new industry in the Williston Basin focused on producing rare-earth elements (REEs), critical minerals (CMs), and nonfuel carbon-based products (CBPs) from Williston Basin coals. The UND EERC proposal entitled "Williston Basin CORE-CM Initiative" was submitted to the U.S. Department of Energy (DOE) in December 2020, with an anticipated date for selection of April 2021.

Objective: The goal of the Williston Basin CORE-CM Initiative is to lay the foundation for a new industry, as well as drive the expansion and transformation of the existing coal and coal-based resources industry in the Williston Basin to produce REEs, CMs, and CBPs.

Expected Results: The Williston Basin CORE-CM Initiative is a three-phase effort, with this proposal comprising the first phase. Phase 1 is focused on gathering and assessing the existing available data for REEs, CMs, and CBPs in the Williston Basin, identifying data gaps that need to be filled, and developing the strategies necessary to move forward with demonstrations along the entire supply chain.

Duration: 20 months (June 1, 2021 – January 31, 2023).

Total Project Cost: The total value of the currently scoped project is $2,450,000. This proposal requests a total of $750,000 from the North Dakota Industrial Commission (NDIC) Lignite Research, Development and Marketing Program (LRDMP). DOE will provide $1,500,000. Project partners North American Coal and BNI Energy will each provide $75,000, and Minnkota Power Cooperative and Basin Electric Power Cooperative will each provide $25,000.

Participants: DOE, NDIC LRDMP, and a coalition of nearly 30 partners, including UND EERC, Institute for Energy Studies, and Nistler College; Pacific Northwest National Laboratory; North Dakota State University; Montana Tech University; and numerous state and industry partners.

PROJECT SUMMARY

Through the creation of the Williston Basin CORE-CM (carbon ore, rare earth, and critical minerals) Initiative, the University of North Dakota (UND) Energy & Environmental Research Center (EERC) will form and lead a diverse and experienced coalition team of nearly 30 partners as shown in Figure 1, encompassing all value chain segments, focused on laying the foundation for a new industry for the Williston Basin and expanding the use of coal and coal-based resources to produce rare-earth elements (REEs), critical minerals (CMs), and nonfuel carbon-based products (CBPs) in the Williston Basin. REEs have become a critical topic within the United States as they are used extensively in modern electronics, batteries, and other materials, with the majority of REEs being imported from China. The Williston Basin is centered in western North Dakota with portions reaching into South Dakota, Montana, and Canada. The primary development to date of Williston Basin lignite coal has been in North Dakota, with the coal resources being used by a series of power facilities for electricity generation.

	Mining	Coal Utilities	Research/ Academic Institutions/ Mining Schools	State Geological Surveys	Mineral Processing	Manufacturing	Business/ Financial	CORE-CM Cooperation
Core Research Team								
UND Energy & Environmental Research Center			X					
UND Institute for Energy Studies			X					
UND Nistler College of Business & Public Administration			X					
Pacific Northwest National Laboratory			X				X	
North Dakota State University			X				X	
Montana Tech University			X					
Critical Materials Institute (Ames)					X			
Project Partners								
NDIC Lignite Research Program	X	X					X	
North American Coal	X				X			
BNI Energy	X	X						
Minnkota		X						
Basin Electric Cooperative		X						
Northrup Grumman						X		
General Atomics					X	X		
North Dakota Geological Survey				X				
South Dakota Geological Survey				X				
North Dakota Department of Commerce							X	
Semplastics					X	X		
Lignite Energy Council	X	X						
Western Dakota Energy Association	X	X				X	X	
North Dakota Governor's Office				X			X	
Specialty Chemical & Materials Manufacturing					X	X		
U.S. Geological Survey				X				
Wyoming School of Energy Resources CORE-CM Team								X
Illinois Geological Survey CORE-CM Team								X
U of Alaska CORE-CM Team								X
U of Utah CORE-CM Team								X

EERC TE59573.AI

Figure 1. Coalition team members.

This effort is the first phase of a much larger program as defined by the U.S. Department of Energy (DOE). As shown in Figure 2, the first phase is intended to lay the foundation by assembling the existing information, identifying information gaps, developing strategies to move the opportunity forward, and initiating outreach. Phase 2 will focus on filling any remaining information gaps and initiating the overall strategy developed in Phase 1. Phase 3 will implement the outlined strategy developed in Phases 1 and 2, launching the development of the new industry within the Williston Basin. The federal funding expected for each phase is also shown in Figure 2. The coalition team has extensive experience and expertise in lignite coal, REE and CM analysis, REE and CM extraction and enrichment, and developing nonfuel CBPs. Additionally, the EERC has a long history of bringing together regional and national stakeholders to tackle critical and complex topics, involving large partnerships in the Williston

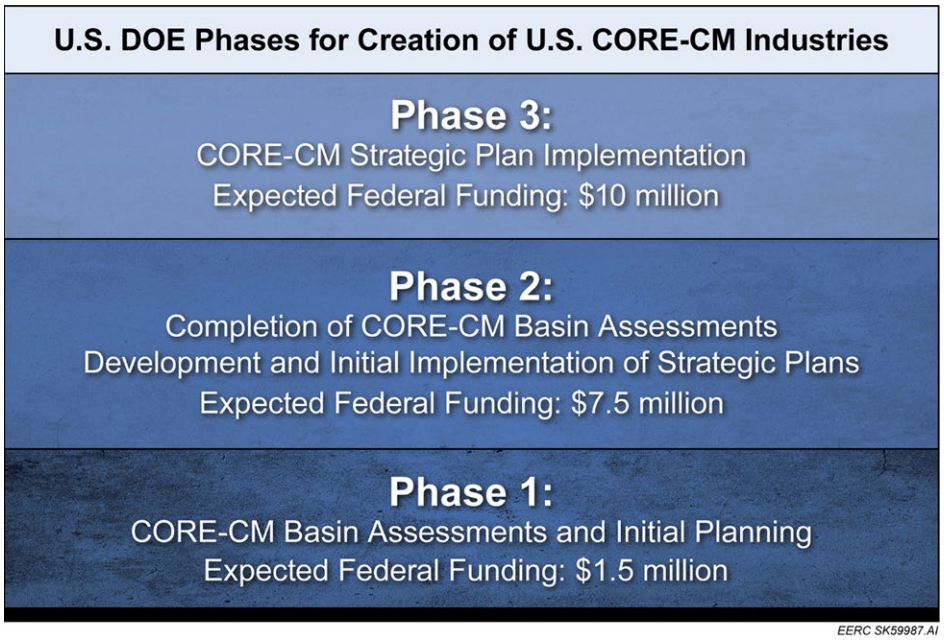

Figure 2. U.S. DOE phases for creation of U.S. CORE-CM industries.

Basin. The coalition team includes research organizations, state entities, coal producers, mineral processers, business and financial partners, end users, policy experts, and more to guide future opportunities in the Williston Basin.

A preliminary analysis for the Williston Basin opportunity, utilizing the energy sustainability model developed at the EERC, shows that a fully developed REE industry could contribute $500 million in state revenues yearly based on an excise tax alone. This is based on extraction from existing coal and coal by-product mining and could grow larger with broader mining specifically for REEs. The goal of the Williston Basin CORE-CM Initiative is to set the stage for future expansion and transformation of coal and coal-based resource utilization within the Williston Basin for the production of REEs, CMs, and nonfuel CBPs. To achieve this, the Williston Basin CORE-CM Initiative will 1) assess the existing information available for resource characterization, waste streams, and technologies, and identify options for business development, innovation centers, and stakeholder engagement; 2) identify the gaps where additional research and technology development are necessary; 3) create a series of strategies to provide a

pathway for future phases of development allowing the Williston Basin to reach its full economic potential; and 4) initiate stakeholder engagement.

PROJECT DESCRIPTION

The EERC will form and lead the diverse and experienced coalition team of nearly 30 partners, encompassing all segments of the REE/CM/CBP value chain, focused on laying the foundation for a new industry in the Williston Basin by expanding and transforming the use of coal and coal-based resources to produce REEs, CMs, and nonfuel CBPs. The Williston Basin CORE-CM Initiative will harness coalition team experience and Williston Basin resources and infrastructure to develop a new industry that will catalyze economic growth and job creation in the region and enhance national and economic security as well as support the existing coal and coal-based resource industry. The proposed work constitutes the first phase of a long-term program to enhance and transform the use of coal and coal-based resources within the Williston Basin.

Objectives: The goal of the project is to set the stage for future expansion and transformation of coal and coal-based resource utilization within the Williston Basin to produce REEs, CMs, and nonfuel CBPs. The objectives are to 1) assess the existing information available for resource characterization, waste streams, and technologies, and identify options for business development, innovation centers, and stakeholder engagement; 2) identify the gaps where additional research and technology development are necessary; 3) create a series of strategies to provide a pathway for future phases of development; and 4) initiate stakeholder engagement.

Methodology: The EERC and project partners will assess existing information, identify information gaps, and develop plans that will drive future phases of REE/CM/CBP development within the Williston Basin. These plans, when combined, will create the long-term strategy to advance this tremendous opportunity for the Williston Basin. The primary deliverables/plans to be developed within this effort (as defined by DOE) include the following:

- Initial basinal assessment – to determine the existing characterization information available.
- Characterization and data acquisition plan – to create a geological model of the Williston Basin and fill any gaps that exist in the characterization data.
- Waste stream reuse plan – to determine the availability and potential for producing CORE-CM materials from existing waste streams.
- Basinal strategies for infrastructure, industries, and business assessment – to examine the existing resources to support all segments of a new industry and those that will be needed.
- Technology assessment, development, and field testing plan – to assess existing technologies at all levels of development and begin to plan for potential implementation across the entire chain of technologies required.
- Technology innovation center plan(s) – to create partnerships between industry, technology providers, financial groups, innovators, and others to accelerate the development of a new industry.
- Stakeholder outreach and education plan – to educate and inform the broad range of stakeholders in the region to aid in advancing this opportunity.

The CORE-CM Initiative work will be accomplished through seven tasks.

Task 1.0 – Project Management, Planning, and Reporting. The EERC will manage and direct the project in accordance with the scope of work to meet all technical, schedule, and budget objectives and requirements. Interim and final reports will summarize the activities of the project and will include key findings, results, and lessons learned.

Task 2.0 – Assessment of CORE-CM Resources. Existing Williston Basin REE and CM data will be compiled and coupled with detailed stratigraphic data. Machine learning algorithms will be applied to identify correlations between REE and CM occurrence and stratigraphy within the Williston Basin. This information will be used to develop an initial geologic information system (GIS)-based geologic model,

identify data gaps, and help target promising locations for additional sample collection and analysis in a future project phase.

2.1 – Data Survey and Acquisition. Existing REE and CM characterization data throughout the Williston Basin will be collected and compiled from the following material types: 1) coal (lignite) beds, leonardite deposits, and sedimentary layers associated with coal beds; 2) coal combustion products (CCPs); 3) coal mine refuse; 4) coal-related acid mine drainage (where present); and 5) other materials including shale deposits, gasifier char material, and oil and gas produced water. Data sources will include the results of analyses performed by coalition team members, including the North Dakota Geological Survey (publications in progress), South Dakota Geological Survey, and U.S. Geological Survey, as well as data and information available in the literature.[1,2,3] The data will be compiled into a database format conducive to developing the geologic model (as discussed in Subtask 2.2) and conducting machine learning analyses which will help in targeting promising formations.

2.2 – Geologic Model Development. A GIS-based geologic model of the coal-bearing Williston Basin strata will be constructed using available data including stratigraphic sequence information from the North Dakota Industrial Commission (NDIC) and National Coal Resources Data System (NCRDS) and data compiled in Subtask 2.1. The geologic model will be constructed to leverage its use in predicting REE and CM resources in future phases.

2.3 – Identification of Data Gaps. Data gaps will be assessed to identify what key CM species are missing from the existing characterization data. CM species will be targeted or excluded based on the various

[1] Zygarlicke, C.J., Folkedahl, B.C., Nyberg, C.M., Feole, I.K., Kurz, B.A., Theaker, N.L., Benson, S.A., Hower, J., and Eble, C.F., 2019. Rare-earth elements (REEs) in U.S. coal-based resources: sampling, characterization, and round-robin interlaboratory study: Final Report Prepared for National Energy Technology Laboratory Cooperative Agreement No. DE-FE0029007, 180 pp.

[2] Murphy, E.C., Moxness, L.D., Kruger, N.W., and Maike, C.A., 2018, Rare earth element concentrations in the Harmon, Hanson, and H lignites in Slope County, North Dakota: North Dakota Geological Survey, Report of Investigation No. 119, 46 p.

[3] Kruger, N.W., Moxness, L.D., and Murphy, E.C., 2017, Rare earth element concentrations in Fort Union and Hell Creek Strata in western North Dakota: North Dakota Geological Survey, Report of Investigation No. 117.

parent resource materials in the Williston Basin. The gap analysis results will be used to target additional coal, coal-related sediment, and CCP locations for sampling and for specific CM analyses.

2.4 – Development of R&D Plan to Fill Data Gaps. The results of the data gap assessment will be used to develop a characterization and data acquisition plan for sampling efforts in a future phase. Whereas the data gap analysis will be based heavily on the geologic factors that are likely to influence the occurrence of CMs in certain parent material types, the research and development (R&D) plan will rely on the results generated in Task 5.0 and include factors such as the practical, logistical, and/or economic potential of the parent material to be mined and/or collected as well as the potential extractability of the CMs from the parent material. These data will be provided in the initial basinal resource assessment.

Task 3.0 – Assessment for Reuse of Waste Streams. The coalition team will work with federal, state, and local entities to identify potential waste streams available and appropriate for reuse in developing the Williston Basin production of REEs, CMs, and nonfuel CBPs. A preliminary waste stream reuse plan will be developed through the following subtasks.

***3.1 – Identification of Federal, State, and Local Partners*.** The coalition team will contact and work with multiple agencies at the federal, state, and local level to acquire the necessary information. Discussions will focus on ensuring accessibility of the relevant information and, where appropriate, that it is able to be cross-refenced to other source data. The agencies contacted will include project partners as well as other entities.

3.2 – Compilation of Data Sets. A database of resources that may be available in each state for use in advancing technologies for REEs, CMs, and CBPs will be compiled. The database will be searchable and include waste stream identification (chemical and physical), potential use in respective technologies, volume of waste, associated costs, regulatory issues, location, and enabling technologies to bring to commercialization as well as other information to evaluate the materials' potential.

3.3 – Identification of Data Gaps. Once the potential waste streams have been identified and compiled into a searchable database, an analysis of the potential waste streams that could be processed with technologies aimed at REE, CM, and CBP production within the basin will be performed. Data gaps will be identified where adequate characterization and/or quantification of the waste streams is not available as well as where technology performance for extraction/recovery is not understood. From this initial assessment, a hierarchy of best potential waste streams will be developed. Limited chemical analyses on minimal samples may be required to assist in verifying cost and process validity.

3.4 – Development of R&D Plan to Fill Data Gaps. Based on the data gaps identified, a plan will be developed to characterize and quantify waste streams where current information is not adequate. This may include laboratory and small-scale pilot testing where appropriate. Results of this subtask will be presented in the initial waste stream reuse plan.

Task 4.0 – Strategies for Infrastructure, Industries, and Business. The current infrastructure and businesses that could support a new REE, CM, and CBP industry in the Williston Basin will be identified and a high-level economic impact and a critical industry gap analysis conducted. This task is focused on examining all the links necessary in a complete supply chain to support the development of this industry.

4.1 – Identification of Existing Basinal Infrastructure. Any limitations in the capacity of the existing infrastructure will be identified. The region's infrastructure (roads, rail, industries), abundant natural resources (mining, natural gas, electricity), and history of exporting both raw and refined commodities will be catalogued and assessed for their potential to support the development of carbon-based minerals and REEs. Development of tight oil production in the Bakken provides additional insight and bolsters existing basinal infrastructure.

4.2 – Identification of Businesses/Industries. Existing and potential businesses/industries that may use CMs as well as those industries that may provide extraction and enrichment capabilities will be

identified. Potential strategic partners, resource customers, and specific end-use purchasers of materials generated in this region will be identified.

4.3 – Analysis of Value Chain Segments. The results of the prior subtasks will be compiled along with a high-level analysis of all the existing and potential components along the entire value chain from mining to end-product utilization. The analysis will include the availability of infrastructure, industries, regulatory environment, financial institutions, markets, and more.

4.4 – Infrastructure and Supply Chain Gap Identification. Gaps identified in infrastructure and supply chains that have become evident during assessments made in previous subtasks will be compiled into the results of the basinal strategies for infrastructure, industries, and business assessment. Discussions with potential customers and the economic assessment will identify locations/markets/needs and distances from potential resources in the Williston Basin. An analysis of data gaps will then be completed.

Task 5.0 – Technology Assessment, Development, and Field Testing. This task will focus on technology assessment and identification of suitability criteria for each technology class for further field testing/demonstration, if needed.

5.1 – Technology Discovery. Technology assessment efforts will begin with a technology discovery phase where a combination of literature review and a request for information to technology providers will be used to gather many potential REE, CM, and CBP technologies for evaluation. These efforts will not be selective to feedstock type. Specific items of information required from each technology include 1) feedstock requirements and target products, 2) current state of the technology (scale) and intellectual property holder (if any), 3) flow diagram of the process with estimated flow rates and/or economic landscape of the technology, and 4) intended usage/deployment mechanism for the technology (small modular plants, large centralized). These technology descriptions will be fed into a sortable database.

5.2 – Technology Evaluation – Current State of the Technology. Technology assessment will occur by determining/aggregating technology performance information, current state of development, feedstock applicability for the technologies, and available economics. Additional performance assessments will be developed utilizing Aspen Plus, METSIM, and engineering costing methods for each process as available, and a cost-to-utilize for each resource will be developed. This is aimed to take the form of a GIS-based modeling algorithm for cost to extract/utilize a resource and is overlaid among the REE, CM, and CBP data generated in Tasks 2.0 and 3.0.

5.3 – Technology Assessment, Development, and Field Testing Plan. Using the technologies identified in Subtask 5.2, an initial technology assessment, development, and field testing plan will be created for future phases. This plan will identify areas within the basin accessible for testing and with suitably based feedstocks for technology validation.

Task 6.0 – Technology Innovation Centers. A detailed and comprehensive plan to create a Technology Innovation Center (TIC) for the Williston Basin will be developed. A TIC is intended to bring together industry, regulators, technology developers, and others to help accelerate the development of the industry as a whole. We anticipate creating one or more TICs based on the outcomes of information gaps identified in Task 2.0; the technology needs related to waste streams in Task 3.0, supply chain in Task 4.0, technology commercialization in Task 5.0; and education and outreach in Task 7.0.

6.1 – Identify Potential TIC Areas. Based on the preliminary results from Tasks 2.0–5.0, key topics that would benefit from the creation of a TIC will be identified (such as a TIC around ore refinement and purification). One or more TIC areas will be identified based on the initial assessment.

6.2 – Creation of TIC Plans. Based on the identified TIC areas, plans will be developed to create the public–private partnership. This effort will be led by the EERC with support from a smaller core group of advisors relevant to the TIC area(s). The initial TIC plan will include the TIC organizational structure, governance, and prospective participants.

Task 7.0 – Stakeholder Education and Outreach. Education and outreach activities will inform and educate CORE-CM stakeholders of project learnings through regular correspondence and meetings. Stakeholders will include current coalition team members; potential future members of the coalition team; and other interested parties including legislators, entrepreneurs, general public, and others. These activities will facilitate knowledge sharing and support for program goals.

7.1 – Stakeholder Identification and Engagement. Stakeholders with interest in the activities and assets of the Williston Basin across economic, governmental, and academic sectors will be identified and engaged. This will include seeking out existing resources and synergies with other R&D projects that are relevant to the CORE-CM Initiative and potential partners integral to the education and training of technicians; middle-skills workers; and science, technology, engineering, and math (STEM) professionals. One stakeholder engagement meeting will be held to launch the effort and provide initial networking opportunities. Stakeholders will be invited to participate in advisory capacities to develop the outreach and education plans—including workforce training and education strategies—as well as for other project tasks.

7.2 – Stakeholder Education and Outreach Plan Development. An outreach and education plan will be developed to support CORE-CM economic development activities. The plan will incorporate best practices from previous EERC research projects and identify target audiences, articulate messaging, define materials, delineate engagement strategies, and establish a process to track and gauge outreach effectiveness. The initial stakeholder outreach and education plan will lay the groundwork for workforce training and education for technicians, middle-skills workers, and STEM professionals.

7.3 – Initial Plan Implementation. Key outreach materials will be developed and deployed to encourage audience understanding and engagement. An informative website and engaging documents will describe the CORE-CM Initiative and explain what REEs, CMs, and CBPs are, their significance to national security and economy, and more. A project-focused event booth and single-page fact sheets will be used

at targeted meetings and regional networking events to describe the initiative's key aspects to stakeholders and potential partners.

Anticipated Results: The Williston Basin CORE-CM Initiative will lay the foundation to develop a new industry as well as play a vital role in expanding and transforming the use of coal and coal-based resources within the Williston Basin. As the first phase of an anticipated three-phase program, this phase will create an overall strategy comprising a series of discrete plans to guide the next steps of development. These plans include 1) an initial basinal assessment; 2) a characterization and data acquisition plan; 3) a waste stream reuse plan; 4) results of the basinal strategies for infrastructure, industries, and business assessment; 5) a technology assessment, development, and field testing plan; 6) TIC plan(s); and 7) a stakeholder outreach and education plan.

Facilities: The EERC employs a multidisciplinary staff of about 220 and occupies a research complex consisting of 254,000 square feet of laboratories, fabrication facilities, technology demonstration facilities, and offices. It has large meeting facilities as well as capabilities to host remote meetings if needed. The EERC houses eight laboratories with extensive analytical capabilities.

Resources: Collectively, the coalition team has significant experience characterizing potential CM resources in various Williston Basin deposits and/or waste streams. Over 2400 samples have been previously analyzed for REE content, and UND has laboratory equipment for analyzing additional samples, if needed, including an inductively coupled plasma (ICP)–optical emission spectrophotometer and an ICP–mass spectrometer.

Techniques to Be Used, Their Availability and Capability: The techniques to be used and their capabilities are described in the methodology section. The CORE-CM Initiative will harness the knowledge of the diverse coalition team through collaboration, meetings, reports, etc., to assess the opportunity and solve technical and nontechnical challenges. The initiative will leverage existing REE data for resources and mining, processing, and upgrading technologies.

Environmental and Economic Impacts While Project Is under Way: The proposed scope of work will have minimal environmental impact. This effort consists primarily of data compilation, analysis, and dissemination by the EERC and coalition team members, with limited sample characterization and analysis at UND laboratories. Economic impacts will also be minimal during this project phase; however, as opportunities are identified, the CORE-CM Initiative has the potential to create large economic benefits to North Dakota and the Williston Basin region.

Ultimate Technological and Economic Impacts: The ultimate impacts of the proposed CORE-CM Initiative have the potential to be enormous, including expanded support for the existing coal industry as well as establishing a new North Dakota industry. The existing coal industry supports over 3600 direct jobs, provides over $70 million in state tax revenue, and has an overall economic impact of $1.8 billion. Supporting and strengthening the current lignite industry has the potential to save significant jobs and regional and state revenues, especially in the event of a future carbon tax or cases where other social or economic impacts are felt. A future REE industry has the potential to provide significant revenue to the state through employment opportunities and state and regional excise and sales taxes. Based on Version 1.0.2 of the North Dakota energy sustainability model developed at the EERC, a fully developed REE industry itself could contribute $500 million per year in state taxes based on an excise tax alone.

Why the Project Is Needed: The production of REEs is of critical importance to the national security of the United States. A REE industry, along with CMs and CBPs, would strengthen and support the existing North Dakota coal industry, provide an additional revenue stream and employer in North Dakota, and reduce the country's dependence on REE and CM imports.

STANDARDS OF SUCCESS

The success of this project will be measured by advancing to Phase 2 of the DOE program, resulting in further development of this opportunity in the Williston Basin. To accomplish this, we must successfully 1) acquire the information necessary for initial assessment, 2) identify information gaps, and 3) develop

plans to drive the future opportunity forward. Products that together will create the overall strategy to move into Phase 2 include the 1) initial basinal assessment; 2) characterization and data acquisition plan; 3) waste stream reuse plan; 4) results of the basinal strategies for infrastructure, industries, and business assessment; 5) technology assessment, development, and field testing plan; 6) TIC plan(s); and 7) stakeholder outreach and education plan.

BACKGROUND/QUALIFICATIONS

The coalition team includes nearly 30 partners across all value chain segments, including over 70 years of experience in supporting coal development and utilization within the Williston Basin. A complete list of the coalition team members can be found in Figure 1 and letters of support are included in Appendix A. The core research members of the coalition team will be responsible for the day-to-day research being performed. All of the partners will provide advisory guidance in the areas noted, and the following have also provided cash cost share: North American Coal, BNI Energy, Minnkota Power Cooperative, and Basin Electric Power Cooperative. The CORE-CM teams from University of Alaska, University of Utah, Illinois Geological Survey, and Wyoming School of Engineering have also provided letters of their interest in collaborating on this effort. Additionally, letters are included from U.S. Senator Hoeven, U.S. Senator Cramer, and U.S. Representative Armstrong on the importance of this program for future development of the Williston Basin.

Thomas Erickson, EERC Director for Exploratory Research & Intellectual Property & Technology Commercialization, will serve as Principal Investigator (PI). Mr. Erickson has over 30 years of experience in coal research and has extensive project management and leadership experience. Prior to his current position, Mr. Erickson was CEO of the EERC and led a multidisciplinary team of over 200 researchers. He holds a master's degree in Chemical Engineering, has led the development of advanced analytical techniques for coal characterization, and was the initial project manager (PM) for the Plains CO_2 Reduction (PCOR) Partnership within the DOE National Energy Technology Laboratory (NETL) Regional

Carbon Sequestration Partnership Initiative. Other key personnel were chosen for their roles because they have successfully managed similar work. Key personnel are listed in Table 1, and resumes of key personnel are provided in Appendix B.

Table 1. Key Personnel Roles

Key Personnel	Role(s)	Key Personnel	Role(s)
Thomas Erickson	PI; Tasks 1.0 and 7.0 lead	Nolan Theaker, UND IES	Task 5.0 colead
Bethany Kurz	Task 2.0 lead	Chad Wocken	Task 6.0 lead
Bruce Folkedahl	Task 3.0 lead and Task 5.0 colead	John Harju	Project advisor
Jason Laumb	Task 4.0 lead		

The EERC has extensive experience in understanding, sampling, characterizing, and processing lignite coal for a wide variety of applications. From the earliest existence of the EERC in the 1950s, a significant component of its work has been on Williston Basin lignite coal. More recently, the EERC has successfully led numerous programs that bring together regional stakeholders to advance new concepts. One of the most successful programs is the PCOR Partnership. Similar to the vision of the CORE-CM Initiative, the PCOR Partnership, over the course of 15+ years, has advanced the concept of carbon capture, utilization, and storage from a regional assessment to commercial demonstration (e.g., Project Tundra in North Dakota). The EERC has also led and/or participated in numerous projects within the last few years focused on REE/CM characterization, extraction, and concentration of REEs/CMs and the production of graphene and carbon-based building materials in conjunction with Semplastics.

The UND Institute for Energy Studies (IES) has been conducting REE and CM extraction research from coal-based materials for 4 years and has been involved in conventional and novel processes ranging in scale from proof-of-concept to pilot demonstrations. IES has specific expertise in the available extraction mechanisms for REE from coal-based materials, specifically on the mode of occurrence within the material and identifying nontraditional ore bodies and/or associations. Additional support is provided by the following research groups: Pacific Northwest National Laboratory, which will aid in

technology evaluation in Task 5.0; UND Nistler College of Business & Public Administration and North Dakota State University (NDSU), which will assist with Task 4.0; Montana Tech University, which will support Tasks 2.0 and 5.0; and the Critical Materials Institute at Ames Laboratory, which will support Task 5.0.

VALUE TO NORTH DAKOTA

Advancement of a REE industry from Williston Basin coal in North Dakota has the potential to support and strengthen the existing coal industry and develop a new industry in North Dakota, providing employment opportunities and regional and state revenues. This first phase of a longer-term effort will provide the basis to move forward and develop the strategy further resulting in significant investment in the Williston Basin by DOE. As noted previously, this industry, fully developed could provide $500 million in state tax revenues alone.

MANAGEMENT

The EERC manages over 200 contracts a year, with over 1330 clients in 53 countries. Systems are in place to ensure that projects are managed within budget, schedule, and scope. Mr. Erickson will oversee the entire program, including integration of tasks, collaboration with stakeholders, and organization of meetings. The task leads are shown in Table 1. Regular meetings will be scheduled to provide updates on research activities and discuss the direction of future activities.

TIMETABLE

This effort is proposed as a 20-month program (June 1, 2021 – January 31, 2023). Figure 3 summarizes the preliminary program timetable. Additional timetable detail will be developed as the program evolves.

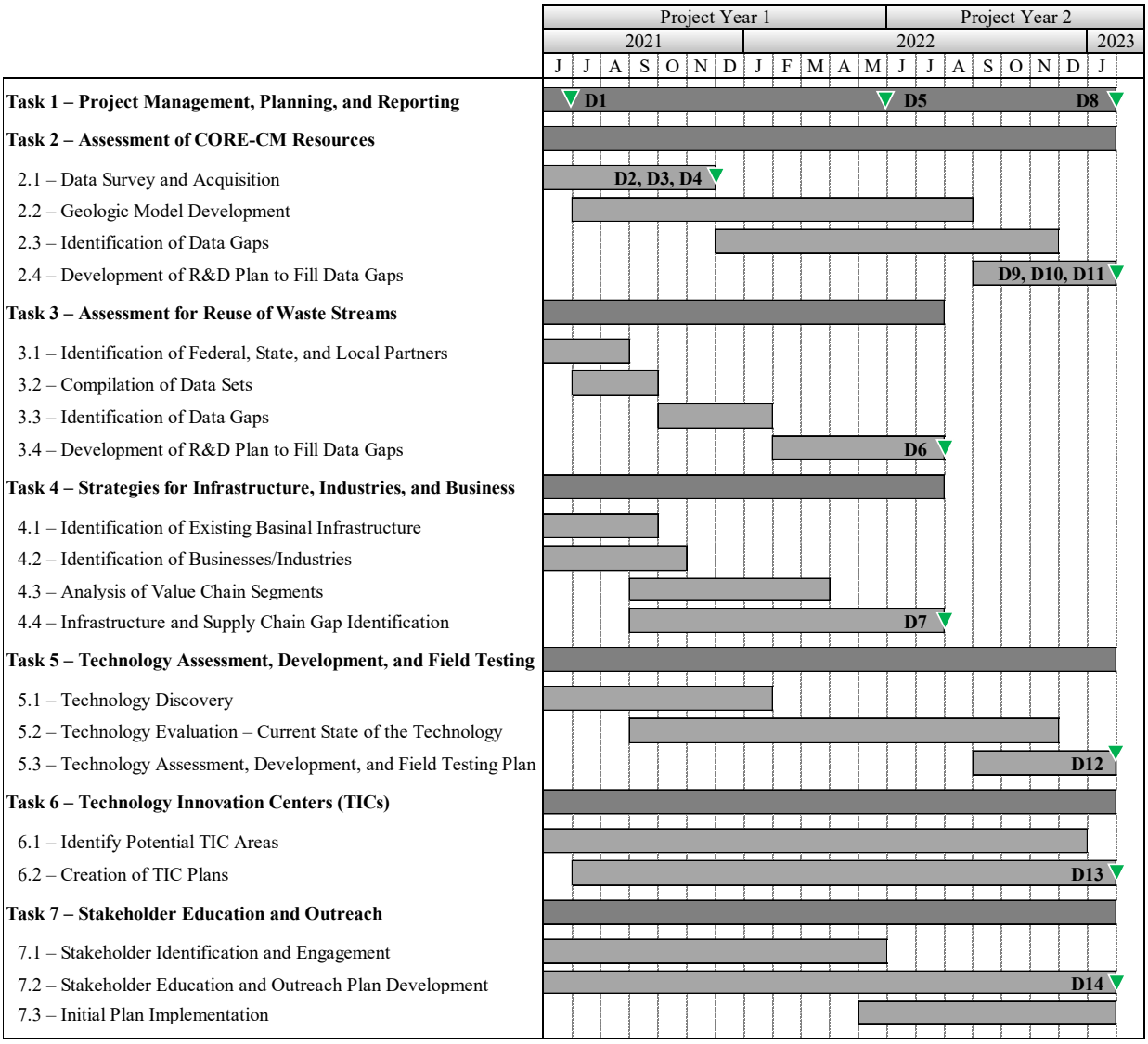

Figure 3. Preliminary timetable.[4]

[4] Deliverables are prescribed by DOE. If sites are accessed in the Subtask 2.1 data acquisition, D2 is required. Resource characterization and location data must be submitted to the Energy Data Exchange (EDX) REE researcher database in a provided template in D3. Geological sample data must be submitted to the NETL REE Sedimentary (REE-SED) assessment in D4 to aid in the development of a method to predict the occurrence of promising REE-bearing deposits. Resource samples must be provided to NETL in D11.

BUDGET AND MATCHING FUNDS

The estimated cost for the proposed effort is $2,450,000; however, the table below only lists $2,385,000. The reason for this discrepancy is that although DOE will be providing $1,500,000 total for this effort, once awarded, only $1,435,000 will be given to the EERC, and the remaining $65,000 will be given directly to our partner Pacific Northwest National Laboratory, in accordance with DOE procedure. $750,000 of cash cost share is requested from the Lignite Research Council's Lignite Research, Development and Marketing Program. North American Coal and BNI Energy will provide cost-share funding in the amount of $75,000 each. Minnkota Power Cooperative and Basin Electric Power Cooperative will provide cost-share funding in the amount of $25,000 each. Letters of commitment for the cost-share providers can be found in Appendix A. Budget notes can be found in Appendix C. If less funding is available than requested, changes to the scope will be considered.

Table 2. Budget Breakdown

Project Associated Expense	NDIC Share (Cash)	DOE Share (Cash)	Commercial Share (Cash)	Total Project
Labor	$ 485,462	$ 831,143	$ 124,920	$ 1,441,525
Travel	$ -	$ 16,792	$ -	$ 16,792
Supplies	$ 408	$ 18,281	$ -	$ 18,689
Subcontractor - MT Tech	$ -	$ 39,941	$ -	$ 39,941
Subcontractor - NDSU	$ -	$ 29,969	$ -	$ 29,969
Communications	$ 156	$ 1,614	$ 80	$ 1,850
Printing & Duplicating	$ 2,050	$ 1,075	$ -	$ 3,125
Food	$ 1,375	$ -	$ -	$ 1,375
Laboratory Fees & Services				
Analytical Research Lab	$ -	$ 12,809	$ -	$ 12,809
Graphics Services	$ 5,650	$ 17,420	$ -	$ 23,070
Technical Software Fee	$ -	$ 2,183	$ -	$ 2,183
Engineering Services Fee	$ 1,587	$ 1,200	$ -	$ 2,787
Freight	$ -	$ 500	$ -	$ 500
Total Direct Costs	$ 496,688	$ 972,927	$ 125,000	$ 1,594,615
Facilities & Administration	$ 253,312	$ 462,073	$ 75,000	$ 790,385
Total Project Costs	$ 750,000	$ 1,435,000	$ 200,000	$ 2,385,000

TAX LIABILITY

The EERC, a department within UND, is a state-controlled institution of higher education and is not a taxable entity; therefore, it has no tax liability to the state of North Dakota or any of its political subdivisions.

CONFIDENTIAL INFORMATION

This proposal has no confidential information.

APPENDIX A

LETTERS OF SUPPORT

Department of Energy

Pacific Northwest Site Office
P.O. Box 350, K9-42
Richland, Washington 99352

December 08, 2020

21-PNSO-F008

Dr. Steven Ashby, Director
Pacific Northwest National Laboratory
Battelle Memorial Institute
Pacific Northwest Division
Richland, Washington 99354

Dear Dr. Ashby:

CONTRACT NO. DE-AC05-76RL01830 – ANNOUNCEMENT NO. DE-FOA-0002364 – PNNL NO. 77967

PNNL will be submitting a proposal entitled, "WILLISTON BASE CORE-CM INITIATIVE." Authorization is granted for PNNL to participate in the proposed effort. The work proposed for the Laboratory is consistent with or complementary to the missions of the Laboratory, will not adversely impact execution of the DOE assigned programs at the Laboratory, and to the best of my knowledge will not place the Laboratory in direct competition with the domestic private sector.

In the event this work is to be funded under DOE's Strategic Partnership Projects program, the DOE legal authority to perform this work is the Atomic Energy Act of 1954, as amended (42 United States Code 2011 et seq.). Further, DOE O 481.1E indicates FFRDCs are eligible to respond to solicitations as long as they do not involve head-to-head competition.

Sincerely,

Melanie P. Fletcher
Contracting Officer

Department of Energy

Office of Science

Ames Site Office

December 3, 2020

Dr. Adam Schwartz, Director
Ames Laboratory
Iowa State University
Ames, Iowa 50011-3020

Dear Dr. Schwartz:

SUBJECT: AMES LABORATORY PARTICIPATION UNDER THE DEPARTMENT OF ENERGY, OFFICE OF FOSSIL ENERGY (FE), CARBON ORE, RARE EARTH AND CRITICAL MINERALS (CORE-CM) INITIATIVE FOR U.S. BASINS, FUNDING OPPORTUNITY ANNOUNCEMENT NO. DE-FOA-0002364

Authorization is granted for the Ames Laboratory to submit or participate in a proposal in response to the subject financial assistance opportunity or other solicitation. The work proposed for Ames Laboratory is consistent with or complementary to the missions of the Laboratory and will not adversely impact execution of the current DOE assigned programs at the Ames Laboratory, and will not place the laboratory in direct competition with the domestic private sector.

Ames Laboratory is managed and operated by Iowa State university for the Department of Energy (DOE) under prime contract no. DE-AC02-07CH11358. All work conducted by Ames Laboratory is subject to the terms and conditions of this contract. It must be clear that no additional terms and conditions, including any specific flow down requirements to subcontractors, are accepted by the action of the Ames Laboratory submitting a proposal or participating as a member in a proposal under the subject financial assistance opportunity or other solicitation. In rare instances, additional terms and conditions may be considered by DOE on a case-by-case basis but must be reviewed and approved by DOE before an award or funding is accepted by DOE and/or Ames Laboratory.

Any membership agreement (or similar document) or Intellectual Property Management Plan that may be created for the collaboration (as part of the application or at a later date) must be submitted to the DOE Ames Site Office for review before it is agreed to by the Laboratory.

If Ames Laboratory is expected to receive any direct DOE program funding, the DOE sponsor must follow the requirements under DEAR 970.5211-1 Work Authorization and DOE Order 412.1A. Again, no additional terms and conditions are accepted by Ames Laboratory under a DOE funding action.

Should you have any questions concerning this authorization please contact me at 630-252-2080 or via email at marlene.martinez@science.doe.gov.

Sincerely,

Marlene E. Martinez
Contracting Officer

cc:
J. Krennrich, Ames
B. Pieper, Ames
M. Schlosser, Ames

NDSU NORTH DAKOTA STATE UNIVERSITY

Letter of Intent

Dec 4, 2020

North Dakota State University is pleased to submit an application to:
Department of Energy / University of North Dakota

Title:
Opportunities for CORE-CM in Williston Basin

Proposed Performance Period:	06/01/2021 - 01/31/2023
NDSU Proposal Reference #:	NOV0004341
NDSU Principal Investigator:	Dean A Bangsund
Department:	AES Agribusiness & Appld Econ
PI email address:	D.Bangsund@ndsu.edu
Direct Cost:	$20,668.00
Indirect Cost:	$9,301.00
Total Requested US Dollars	$29,969.00
Committed Cost Share in US Dollars:	$0.00

This proposal has been institutionally reviewed and approved by the appropriate administrative and programmatic officials. Should this proposal be selected for funding, NDSU reserves the right to negotiate an award with terms and conditions that are appropriate for a public institution of higher education and consistent with NDSU's policies.

NDSU's institutional administrative information is available at https://www.ndsu.edu/research/for_researchers/proposal_development/institutional_information/ NDSU DUNS: 80-3882299 NDSU EIN #: 45-6002439

Any award that results from this application should be in the legal name of the North Dakota State University emailed to ndsu.research@ndsu.edu or sent to the address below. Please call 701.231.8045 if further assistance is required. For technical questions, please contact NDSU's PI.

Sincerely,

Jill Mackenzie

Proposal & Award Officer

SPONSORED PROGRAMS ADMINISTRATION
NDSU Dept 4000 | PO Box 6050 | Fargo ND 58108-6050 | 701.231.8045 | Fax 701.231.8098 | ndsu.research@ndsu.edu

Shipping address: Research 1, 1735 NDSU Research Park Drive, Fargo ND 58102

MONTANA
TECHNOLOGICAL UNIVERSITY

December 11, 2020

Mr. John Harju
Vice President for Strategic Partnerships
Energy & Environmental Research Center
15 North 23rd St, Stop 9018
Grand Forks, ND 58202-9018

Dear Mr. Harju:

Montana Technological University is please to submit a sub-award proposal titled "Phase 1 Basinal Assessment of CORE-CM Resources" for inclusion in your grant application to the US Department of Energy (DOE FOA DE-FOA-0002364). Jay Gunderson is the Montana Tech principal investigator for this project. This sub-award proposal has been administratively approved and support is requested for two years (7/1/2021-2/28/2023) in the amount of $39,941 federal funds.

Montana Tech will work on tasks 2 and 5 as outlined in the attached scope of works from Jay Gunderson and Jerome Downey.

If this proposal is successful, Montana Tech will ensure compliance with all pertinent federal regulations and policies. The sub recipient agreement should be between the University of North Dakota and Montana Tech.

Negotiations should be directed to:

Dr. Beverly K. Hartline
Vice Chancellor for Research
1300 West Park Street
Butte, MT 59701
grants@mtech.edu

Sincerely,

Dr. Beverly K. Hartline
Vice Chancellor for Research
1300 West Park Street
Butte, MT 59701
grants@mtech.edu
406-496-4453

Scope of Work – Montana Bureau of Mines and Geology (MBMG)

The Montana Bureau of Mines and Geology (MBMG) was established in 1919 with a mandate to collect and publish information on Montana's geology to promote orderly and responsible development of Montana's energy, groundwater, and mineral resources. The MBMG provides these services to the public and a variety of constituents within the private sector, as well as federal, state, and local governments.

The MBMG Coal Program has existed since the 1960s. Past research includes many USGS cooperative programs – from drilling and coal resource assessments in the 1970s and 1980s (CRO/CDP program), gathering/interpreting coal stratigraphic and geochemical data (NCRDS program), to more recent coal availability and coal resource assessments (NCRA program). The MBMG is also involved in coalbed methane research and monitoring, groundwater monitoring in coal spoils, and issues related to coal mine reclamation. The MBMG is well-positioned to assist EERC with the CORE-CM resource assessment of the Williston Basin.

The MBMG's scope of work will address elements of the "Phase 1 Basinal Assessment of CORE-CM Resources" (DOE FOA DE-FOA-0002364, p. 15) for the Montana portion of the Williston Basin (MT-WB).

Specific tasks to be completed:

- Review existing literature for previous and ongoing work that characterizes the occurrence, distribution, and concentration of REE and CM in coal, coal by-products, and associated sediments in the MT-WB.

- Review MBMG and USGS coal quality databases (and potentially others) to identify available coal/sediment trace element analyses. Ensure each data record with trace element data has location and stratigraphic information. The MBMG also has hundreds of paper records containing coal geochemical analyses from drill hole and mine samples that have not been digitized. These will be assessed and added to the MBMG database where appropriate.

- Based on literature and data review, identify the location and distribution of known and potential CORE-CM resources available from coalbeds, associated sediments, and coal mine waste streams (coal combustion, coal refuse, and acid mine drainage). Estimate volumes of each resource where feasible.

- Compile information and data for building a geologic model. Potential information/data may include: published structure maps, geologic cross-sections and depositional models; collecting geophysical logs for geologic interpretation and control; and compiling coal stratigraphic data (e.g. NRCDS). Mutually establish a suitable format for incorporating relevant geospatial data (geological and geochemical) into the Williston Basin geologic model.

- Identify gaps in existing data and formulate an R&D plan that fills those gaps to more accurately characterize the basin's CORE-CM resource potential. Data acquisition will focus on additional coal and sediment sampling and trace element analyses to identify promising coalbeds and sediments for REE and CM content.

Scope of Work – Metallurgical and Materials Engineering Department, Montana Technological University

Metallurgical and Materials Engineering (M&ME) Faculty have extensive expertise in minerals beneficiation, extractive (chemical) metallurgy, and process engineering. Our experience base includes research and process development projects that include metallurgical processing for value metal recovery from coal, shale, fly- and bottom-ash and other carbonaceous matter. Department faculty also have recent relevant experience with rare earth elements (REE) and other critical metals (CM). Accordingly, we are well-positioned to substantively contribute to Task 5 as outlined by UND.

Specific tasks to be completed:

- Coordinate and collaborate with MBMG in the review and assessment of historic analytical and characterization data and determine streams that exhibit sufficient prospects for economic REE and CM recovery.

- Identify data gaps related to the mode of occurrence of REE and CM in coal and coal-derived by-product and waste streams that will necessitate more extensive chemical and mineralogical characterization in order to assess potential of the various streams as feedstock for REE and CM extraction and recovery.

- Assess the applicability of state-of-the-art and emerging physical beneficiation, thermal processing, and/or aqueous processing technologies for REE and CM extraction the selected streams.

- Develop a process and field testing plan for the relevant beneficiation and extraction technologies that will generate the requisite technical information to scale the technologies for commercial implementation.

INDUSTRIAL COMMISSION OF NORTH DAKOTA

LIGNITE RESEARCH, DEVELOPMENT AND MARKETING PROGRAM

Governor,
Doug Burgum
Attorney General,
Wayne Stenehjem
Agriculture Commissioner,
Doug Goehring

December 1, 2020

John Harju
Vice President for Strategic Partnerships
Energy & Environmental Research Center
15 North 23rd St, Stop 9018
Grand Forks, ND 58202-9018

Dear John,

The North Dakota Industrial Commission (NDIC) Lignite Research Program (LRP) is pleased to provide our support for the Williston Basin CORE CM Initiative led by the Energy & Environmental Research Center (EERC). Pending final approval by the LRP and NDIC, we would be happy to provide $750,000 in cash cost-share. We have significant experience in the advancement of coal technologies and are willing to serve as an advisor, as appropriate, to advance the intent of the project.

North Dakota's LRP is a multi-million dollar state/industry partnership that concentrates on practical research and development projects that provide the opportunity to preserve and enhance development of our state's abundant lignite resources. The NDIC LRP has significant experience in the development of new technologies and methodologies to advance the valuable lignite coal resources within the Williston Basin. Our private sector partners have significant experience in the mining, processing, combustion, and conversion of coal for power and valuable chemicals.

The utilization of our vast state lignite resources for the production of rare earth elements, critical minerals or non-fuel coal based products fits within our plans for the future of the Williston Basin. Our partners represent many of the members of the value chains necessary to advance this new industry in the Williston Basin.

We look forward to working with the EERC and the other partners and regional stakeholders on this critical project for North Dakota's future.

Sincerely,

Mike Holmes
Director and Technical Advisor
Lignite Research Development and Marketing Program

December 12, 2020

Mr. John Harju
Vice President for Strategic Partnerships
Energy & Environmental Research Center
15 North 23rd St, Stop 9018
Grand Forks, ND 58202-9018

Dear ~~Mr. Harju:~~ John,

The North American Coal Corporation (NACoal) is pleased to provide our support for the Williston Basin CORE CM Initiative led by the Energy & Environmental Research Center (EERC). In addition to $75,000 of direct financial support, we are also delighted to serve as advisors to the project where appropriate. For planning purposes, we plan to split that contribution equally between 2021 and 2022. Please note that this commitment is contingent on the selection of EERC's proposal by DOE, and the negotiation of mutually acceptable terms and conditions for all parties.

NACoal operates surface mines that produce coal, aggregates, and other valuable minerals throughout the United States. We operate one of the largest dragline fleets in the world and control over 160,000 surface acres and nearly two billion tons of coal and other minerals. Within the Williston Basin we operate the Freedom Mine, the Falkirk Mine, and the Coyote Creek Mine—serving multiple electrical generation units and the Great Plains Gasification facility.

The production of additional products from our vast resources is of significant interest to NACoal and we look forward to supporting this project.

Sincerely,

The North American Coal Corporation

David Straley

Director, External Affairs

PHONE (701) 355-5500

BNI energy
AN ALLETE COMPANY

www.bnienergy.com

December 15, 2020

John Harju
Vice President for Strategic Partnerships
Energy & Environmental Research Center
15 North 23rd St, Stop 9018
Grand Forks, ND 58202-9018

Dear John,

BNI Energy is pleased to provide our support for the Williston Basin CORE CM Initiative led by the Energy & Environmental Research Center (EERC). In addition to $75,000 in support, we agree to serve as advisors to the project where appropriate.

BNI Energy is a subsidiary of ALLETE Inc., a diversified energy company. BNI Energy, headquartered in Bismarck North Dakota, evolved from a native North Dakota Company, BNI Coal, (formerly Baukol-Noonan), founded in Northwest North Dakota in 1930. BNI Energy has a rich history of responsible energy production in North Dakota exemplified by its BNI Coal mining operations near Center North Dakota and its partnerships to advance transformational coal technologies. BNI Energy is focused on value added energy services and infrastructure solutions that balance environmental and the energy needs of consumers. The company is leveraging its talent, experience and solid track record to advance sustainable solutions in North Dakota.

The production of additional products from our coal resources is of significant interest to BNI. BNI is pleased to commit $75,000 to the Williston Basin CORE CM Initiative led by the EERC and serve as advisors to the project subject to negotiations of mutually acceptable terms and conditions.

Sincerely,

Wade Boeshans
President and General Manager

Minnkota Power
COOPERATIVE
A Touchstone Energy® Cooperative

5301 32nd Ave S
Grand Forks, ND 58201-3312
Phone 701.795.4000
www.minnkota.com

December 4, 2020

John Harju
Vice President for Strategic Partnerships
Energy & Environmental Research Center
15 North 23rd St, Stop 9018
Grand Forks, ND 58202-9018

Dear John,
Minnkota Power Cooperative is pleased to provide our support for the Williston Basin CORE CM Initiative led by the Energy & Environmental Research Center (EERC). In addition to $25,000 in support, we agree to serve as advisors to the project where appropriate.

Minnkota Power Cooperative is a not-for-profit generation and transmission cooperative headquartered in Grand Forks, North Dakota. Minnkota provides power to 11 member owned cooperatives in North Dakota and Minnesota serving nearly 135,000 customers and over 34,000 square miles. The primary source of electricity for Minnkota is the Milton R. Young station using Williston Basin lignite coal, located near Center, North Dakota. Minnkota is also leading the development of Project Tundra which would become North America's largest carbon capture plant with options for direct carbon utilization and sequestration within the Williston Basin.

Minnkota is interested in this project for it's potential to provide additional value to its existing operations.

Sincerely,

Mac McLennan
President & CEO

BASIN ELECTRIC POWER COOPERATIVE
A Touchstone Energy® Cooperative

December 8, 2020

John Harju
Vice President for Strategic Partnerships
Energy & Environmental Research Center
15 North 23rd St, Stop 9018
Grand Forks, ND 58202-9018

Dear John,

Basin Electric Power Cooperative (BEPC) is pleased to provide our support for the Williston Basin CORE CM Initiative led by the Energy & Environmental Research Center (EERC). In addition to $25,000 in support, contingent on award, we agree to serve as advisors to the project where appropriate.

BEPC is a not-for-profit generation and transmission cooperative incorporated in 1961 to provide supplemental power to a consortium of rural electric cooperatives. We utilize a diverse energy portfolio including coal, gas, oil, distributed, and renewable energy, including wind power. BEPC is consumer owned by 140 member cooperative systems serving 3 million electric customers. By end of year 2020, Basin Electric will operate 5,189 megawatts (MW) of wholesale electric generating capability and have 7,003 MW of capability within its resource portfolio. BEPC owns and operates the Antelope Valley Station and Leland Olds Station in North Dakota, operating on Williston Basin lignite coal. BEPC subsidiary Great Plains Gasification also utilizes Williston Basin lignite coal for the production of synthetic natural gas and other commodity chemicals.

Basin Electric is interested in this project for its potential to provide additional value to its existing operations.

Sincerely,

Gavin McCollam
Gavin McCollam (Dec 8, 2020 08:18 CST)

Gavin McCollam
Vice President, Engineering and Construction
Basin Electric Power Cooperative

December 1, 2020

Mr. Tom Erickson
Director of State Energy Research Center & Intellectual Property/
Technology Commercialization

UND EERC
15 N 23rd Street
Grand Forks, ND 50203

Dear Mr. Erickson:

Subject: EERC Proposal "Williston Basin CORE CM Initiative" in Response to DE-FOA-0002364

Northrop Grumman Corporation (NGC) is pleased to provide this letter of support for the EERC's proposal focused on the production of rare earth elements (REE), critical minerals (CM), and non-fuel carbon based products from the Williston Basin. Limited to non-proprietary information, Northrop Grumman will serve in an advisory role for this effort based on our knowledge and experience in end-products containing these materials and our knowledge of the defense and security industry.

Northrop Grumman is leading developer of technologies for use in space, aeronautics, defense and cyberspace. We have over 90,000 employees using science, technology and engineering to create and deliver advanced systems, products and services. The availability of domestic sources for REEs and CMs is of importance to the customers we serve and for the products we provide.

We welcome the opportunity to serve in an advisory role on this critically important topic.

Sincerely,

Recoverable Signature

X Michael Fridolfs

Michael Fridolfs

Signed by: ZZMichael S. Fridolfs (B00822)

Mike Fridolfs
Director, Grand Sky

GENERAL ATOMICS

December 16, 2020

Mr. Thomas Erickson
Director of Exploratory Research and Intellectual Property and Technology Commercialization
Energy & Environmental Research Center
15 North 23rd St, Stop 9018
Grand Forks, ND 58202-9018

Re: Letter of Support for the Energy & Environmental Research Center Williston Basin CORE CM Initiative Proposal in Response to DOE DE-FOA-0002425

Dear Mr. Erickson:

The purpose of this letter is to confirm General Atomics' support for the Williston Basin CORE CM Initiative led by the Energy & Environmental Research Center (EERC).

General Atomics is a privately held U.S. company actively involved in the design, development and manufacturing of advanced technology systems for defense and energy applications. General Atomics' products include unmanned aerial and underwater systems, advanced maritime and space systems and next-generation nuclear technologies. Many of General Atomics' products include rare-earth containing components and therefore General Atomics supports initiatives aimed at the domestic production capability for rare earth elements and critical minerals in the U.S. In addition, an affiliate of General Atomics is a major shareholder in Rare Element Resources Ltd., which holds the Bear Lodge rare earth project in Wyoming and is developing and demonstrating rare earth processing technologies.

Should funding be awarded, General Atomics is prepared to serve in an advisory role, given its experience in rare earth element extraction and understanding of end products using rare earth elements and critical minerals. General Atomics is particularly interested in this project, and other projects like it, to ensure secure, domestic sources of these critical materials for its products and national security.

General Atomics looks forward to the opportunity to work with EERC on this initiative.

Sincerely,

Ken Mushinski
Vice President

3550 GENERAL ATOMICS COURT, SAN DIEGO, CA 92121-1122 PO BOX 85608, SAN DIEGO, CA 92186-5608 (858) 455-3000

NORTH Dakota | Mineral Resources
Be Legendary.™

November 27, 2020

Mr. Tom Erickson
Director of State Energy Research Center & Intellectual Property/Technology Commercialization
UND EERC
15 N 23rd Street
Grand Forks, North Dakota 58202-9018

Dear Mr. Erickson:

Subject: EERC Proposal "Williston Basin CORE CM Initiative" in Response to DE-FOA-0002364

The North Dakota Geological Survey (NDGS) is pleased to provide this letter in support of the above referenced proposal focused on the exploration of producing rare earth elements (REEs), critical minerals (CMs), and nonfuel carbon-based products from Williston Basin lignite coal. We are pleased to serve in an advisory role to this effort to guide the acquisition of relevant data in the North Dakota portion of the Williston Basin and to guide future sample collection.

The state of North Dakota has several active mines producing coal for the production of power via combustion, as well as fertilizer and synthetic natural gas production. As a compliment to the existing uses of coal, the NDGS has been aggressively studying the presence of REEs and CMs from Williston Basin coal and their potential for recovery. We have also worked with the EERC and the Institute of Energy Studies at UND to acquire and analyze hundreds of samples for CM content.

We look forward to serving as an advisor on this critically important project to support the development of additional industries in the Williston Basin.

Sincerely,

Edward C. Murphy
State Geologist

600 E Boulevard Ave – Dept 405 | Bismarck, ND 58505-0840 | PHONE: 701-328-8000 | FAX: 701-328-8010 | dmr.nd.gov/ndgs

Department of
Environment and Natural Resources
Geological Survey Program
414 East Clark Street
Akeley-Lawrence Science Center
Vermillion, SD 57069

December 14, 2020

Mr. Tom Erickson
Director of State Energy Research Center & Intellectual Property/Technology Commercialization
UND EERC
15 N 23rd Street
Grand Forks, ND 50203

Re: EERC Proposal "Williston Basin CORE CM Initiative" in Response to DE-FOA-0002364

Dear Mr. Erickson:

The South Dakota Geological Survey is pleased to provide this letter in support of the above referenced proposal focused on the exploration of producing rare earth elements, critical minerals, and non-fuel carbon-based products from Williston Basin lignite coal. The state of South Dakota has deposits of lignite coal beds within the Williston Basin and we are very interested in the future potential of rare earth elements and critical minerals that may be contained in these coal deposits.

We are pleased to serve in an advisory role to this effort to guide the acquisition of relevant data in the South Dakota portion of the Williston Basin and to guide future sample collection.

Sincerely,

Tim Cowman

Tim Cowman
State Geologist

NORTH Dakota | Commerce
Be Legendary.™

November 20, 2020

Tom Erickson
Director of State Energy Research Center & Intellectual
Property/Technology Commercialization
UND EERC
15 N 23rd Street
Grand Forks, ND 50203

Dear Mr. Erickson:

Subject: EERC Proposal "Williston Basin CORE CM Initiative" in Response to DE-FOA-0002364

The North Dakota Department of Commerce is pleased to submit this letter in support of the Energy and Environmental Research Center's proposal to the solicitation noted above. Additionally, we are pleased to support this proposal in an advisory role, if funded.

The support and advancement of new industries for the State of North Dakota is one of our primary jobs at the North Dakota Department of Commerce. Over the last few years, we have been pursuing the development of lignite coal industries for the recovery of rare earth elements, critical minerals, or non-fuel carbon based products within the Williston Basin recognizing that they would have a tremendous impact on catalyzing additional economic development and creating new jobs.

The North Dakota Department of Commerce works with industrial partners from all over the world identifying opportunities within the state. Over the last ten years, we have provided significant support for the growth of the Bakken oil industry. We are very familiar with the infrastructure and business challenges associated with the rapid growth of new industries and our insight and experience would be helpful to the coalition team to understand how the growth of new coal-based industries could be supported within our State and region.

We look forward to supporting this initiative in the future.

Sincerely,

Shawn Kessel
Interim Commissioner

1600 E Century Avenue, Suite 2 | P.O. Box 2057 | Bismarck, ND 58502
PHONE: 701-328-5300 | TOLL FREE: 1-866-4DAKOTA | ND RELAY TTY: 1-800-366-6888 | VOICE: 1-800-366-6889 |
NDCommerce.com

Semplastics

December 2, 2020

Mr. John Harju
Vice President for Strategic Partnerships
Energy & Environmental Research Center
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018

Subject: Support for EERC's Williston Basin CORE-CM Initiative

Dear Mr. Harju,

This letter is in response to the Energy & Environmental Research Center's request for participation in the subject proposed project, for which a proposal is being submitted to the U.S. Department of Energy (DOE).

Developing and introducing new materials into the marketplace is a point of emphasis for Semplastics. As such Semplastics has recently won several DOE awards for utilization of lignite coal and coal byproducts in developing new composite materials. These novel and high performing composites will help to expand and transform the use of coal and coal-based resources to produce high-value, nonfuel, Carbon-Based Products (CBP) as part of our next generation of domestic U.S. materials. Realizing this potential would enable the U.S. to establish and advance a new CBP industry. Participation in the proposed project will only help to further advance this nascent technology and much needed domestic resource development.

We hope that DOE gives careful consideration to this project, as there is a significant need for projects that promote the continued use of coal in new industries coupled with production of the associated Critical Materials as a National Security issue. Again, we express our interest in and support of the proposed project and look forward to working with the project team.

Sincerely,

William Easter

CEO

269 Aulin Avenue, Suite 1003, Oviedo, FL 32765 (407) 353-6885

Lignite Energy Council

December 1, 2020

John Harju
Vice President for Strategic Partnerships
Energy & Environmental Research Center
15 North 23rd St, Stop 9018
Grand Forks, ND 58202-9018

Dear John,
The Lignite Energy Council (LEC), headquartered in Bismarck, North Dakota is pleased to support the Williston Basin CORE CM Initiative. The LEC and its member partners have significant experience in the development of the Williston Basin and we would be happy to serve in an advisory capacity to support this initiative as necessary.
The primary objective of the Lignite Energy Council is to maintain a viable lignite coal industry and enhance development of the region's lignite coal resources for use in generating electricity, synthetic natural gas and valuable byproducts. Members of the Lignite Energy Council include mining companies, major users that use lignite to generate electricity, synthetic natural gas and other valuable byproducts, and businesses that provide goods and services to the lignite industry.

The development of additional products from Williston Basin lignite coals is central to focus on maintaining a viable lignite coal industry.

Sincerely,

Jason Bohrer
President and CEO
Lignite Energy Council

WESTERN DAKOTA ENERGY ASSOCIATION

December 9, 2020

Mr. Tom Erickson
Director of State Energy Research Center & Intellectual Property/Technology Commercialization
UND EERC
15 N 23rd Street
Grand Forks ND 50203

Subject: EERC Proposal "Williston Basin CORE CM Initiative" in Response to DE-FOA-0002364

Dear Mr. Erickson:

The Western Dakota Energy Association, an organization representing the interests of cities, counties and school districts impacted by oil, gas and coal development, is pleased to provide this letter in support of the Energy & Environmental Research Center's proposal cited above. If funding is obtained, WDEA would welcome the opportunity to continue our support of this project in an advisory capacity.

The members of our association have for decades appreciated the many positive impacts that the lignite coal industry has had on our region. More recently, we have been witnessing new opportunities and challenges brought on by expansion and development of the Bakken oil industry.

The prospect of creating new economic opportunities from existing lignite coal resources by extracting rare earth elements, critical minerals and producing carbon-based products is one of the areas that we as an organization are continually monitoring. We have front-line knowledge of the existing business and infrastructure serving the existing coal and oil industries, and those components capable of supporting new business opportunities. We would be delighted to serve as part of this coalition and to serve in an advisory role to advance this exciting new opportunity.

We look forward to working with the EERC in the future to advance this initiative.

Sincerely,

Geoff Simon
Executive Director

Western Dakota Energy Association
1661 Capitol Way, Bismarck ND 58501
www.ndenergy.org • 701-527-1832

NORTH Dakota | Governor Doug Burgum

Be Legendary.™

11/20/2020

Mr. Tom Erickson
UND EERC
15 N 23rd Street
Grand Forks, ND 50203

RE: Support Letter for EERC Proposal "Williston Basin CORE CM Initiative" in Response to DE-FOA-0002364

Please accept this letter of support for the Energy & Environmental Research Center's proposal to the solicitation noted above.

The development of new uses for the vast resources of lignite coal found within the Williston Basin is of strategic interest not only to the State, but also the entire nation. Nearly 4000 MW of mine-to-mouth lignite-fired power plants currently operate within the borders of the state, with over 800 years of lignite supply at the current consumption rate. The development of industries for the recovery of rare earth elements, critical minerals, or non-fuel carbon-based products within the Williston Basin would not only catalyze additional economic development and create new jobs, but also reduce our reliance on foreign sources for these products. No other nation can produce these products in a cleaner, environmentally friendlier manner than we can in the United States.

Over the last ten years, the State of North Dakota has supported a tremendous growth of our energy industry. EERC has been a globally recognized leader in addressing the technical and business challenges associated with this rapid growth. Their insight and experience would be a strategic asset to the coalition team as these new markets are developed.

Please accept our gratitude for your consideration of our participation in this opportunity. It is only through innovations like this proposed project that we will solve our greatest energy challenges for future generations.

Regards,

Doug Burgum
Governor

Current Lighting Solutions, LLC
Specialty Chemicals & Materials Manufacturing

William E. Cohen, Ph. D.
Specialty Materials Business Leader

1975 Noble Road
Cleveland, OH 44139 USA
T +1 216 462 4592
M +1 216 570 3873
bill.cohen@gecurrent.com

December 14, 2020

Mr. John Harju
Vice President for Strategic Partnerships
Energy & Environmental Research Center
15 North 23rd St, Stop 9018
Grand Forks, ND 58202-9018

Re: Support for EERC's Williston Basin CORE-CM Initiative

Current Lighting Solutions, LLC (Current) Specialty Chemicals & Materials Manufacturing is pleased to provide our support for the Williston Basin CORE-CM Initiative led by the Energy & Environmental Research Center (EERC). In addition to $50,000 of in-kind support, we agree to serve as advisors to the project where appropriate.

Current's inorganic materials manufacturing facility is located in Cleveland, Ohio and is ISO 9001:2015 Certified with over 70 years of plant operations as a global Center of Excellence for the Lighting Industry. Under the General Electric Company until 2019, the plant manufactured many of the necessary specialty chemicals and phosphors needed for manufacturing traditional lighting products including incandescent, halogen, high-intensity discharge, and fluorescent lamps for GE's lighting products plants around the globe. Today the facility continues its focus on the R&D, pilot production, and bulk production of inorganic materials to manufacture premium specialty products, including legacy lighting chemicals, LED phosphors, specialty luminescent materials, specialty paints/coatings, and rare earth materials which serve a broad range of markets. We are pleased to provide our experience in value-added manufacturing and are interested in the development of technologies to extract rare earth elements for use in manufacturing processes.

Sincerely,

William E. Cohen, Ph.D.
Specialty Materials Business Leader

United States Department of the Interior

U.S. GEOLOGICAL SURVEY
Central Energy Resources Science Center
Box 25046, MS 939
Denver, CO 80225

December 9th, 2020

Bethany Kurz
Assistant Director for Integrated Analytical Solutions
Energy & Environmental Research Center (EERC)
University of North Dakota
Grand Forks, ND 58202

Dear Ms. Kurz:

I approve the participation of Brian N. Shaffer, Supervisory Geologist, Central Energy Resources Science Center (CERSC), U.S. Geological Survey, on the U.S. Department of Energy, Carbon Ore, Rare Earth and Critical Minerals (CORE-CM) Initiative for U.S. Basins, DE-FOA-0002364 grant proposal entitled "Williston Basin CORE-CM Initiative."

If the grant is awarded, the CERSC would support Brian's role as scientific expert and USGS point of contact for this activity. Brian's work would be conducted in collaboration with your organization to investigate the distribution of rare earth and critical elements in coal and coal by-products in the Williston Basin. This work benefits ongoing activities in the CERSC related to assessing domestic energy resources and supports the USGS mission to understand and assess the Nation's energy resources for the public. Brian's current work on compiling a geologic database for the lignite beds in the Williston Basin, as well as correlating lignite beds in the Paleocene Fort Union Formation on a regional basis and identifying areas that may have potential for economic development of lignite resources supports this proposed Williston Basin initiative.

Please be advised that this letter is not a commitment of Government resources but is written in support of a proposed collaboration and the project's scientific and scholarly activities related to the mission of the USGS Energy Resources Program. The USGS is a Federal agency and is subject to Federal laws and regulations. Should the grant be awarded, the USGS has legal authorities that allow for collaboration and prosecution of projects with your organization. These authorities include 43 USC § 36c and 15 USC § 3710a. Subject to the negotiation of a mutually acceptable agreement based on one of these authorities, the USGS agrees to provide the support as stated in this letter.

Thank you for the opportunity to participate in this collaborative effort.

Sincerely,

OFORI PEARSON
Digitally signed by OFORI PEARSON
Date: 2020.12.09 08:46:53 -07'00'

Ofori N. Pearson, Ph.D.
Director (Acting), Central Energy Resources Science Center

cc: Brian N. Shaffer
James J. Sander

UNIVERSITY OF WYOMING
School of Energy Resources
Dept. 3012, 1000 E. University Ave., Laramie, WY 82071-2000
(307) 766-6879 • fax (307) 766-6701 • www.uwyo.edu/ser

December 8, 2020

Mr. John Harju
Vice President for Strategic Partnerships
Energy & Environmental Research Center
15 North 23rd St, Stop 9018
Grand Forks, ND 58202-9018

Re: Collaboration with EERC's Williston Basin CORE CM Initiative

This letter is in support of future collaboration with the EERC with their efforts, if awarded, for their Williston Basin CORE CM Initiative in response to DOE FOA 0002364. The Wyoming School of Energy Resources is also responding to this same solicitation with a focus on the Powder River Basin and if we are awarded, we intend to collaborate with the EERC. As specifically expressed by DOE, collaboration between awarded institutions is encouraged and advised. The form of collaboration will depend on the activities carried out and their relation to both institutions' efforts. Potential areas of collaboration may include stakeholder education and outreach material development, technology identification, and the applicability of analytical techniques for future analysis.

We look forward to collaborating with the EERC if we are both successful in our awards.

Sincerely,

Scott Quillinan
Director of Research and Communications
Director Center for Economic Geology Research
School of Energy Resources
University of Wyoming

ILLINOIS

PRAIRIE RESEARCH INSTITUTE

Illinois State Geological Survey
615 E. Peabody Drive
Champaign, IL 61820

December 7, 2020

Mr. John Harju
Vice President for Strategic Partnerships
Energy & Environmental Research Center
15 North 23rd St, Stop 9018
Grand Forks, ND 58202-9018

Re: Collaboration with EERC's Williston Basin CORE CM Initiative

This letter is in support of future collaboration with the EERC with their efforts, if awarded, for their Williston Basin CORE CM Initiative in response to DOE FOA 0002364. The Illinois State Geological Survey is also responding to this same solicitation with a focus on the Illinois Basin and if we are awarded, we intend to collaborate with the EERC. As specifically expressed by DOE, collaboration between awarded institutions is encouraged and advised. The form of collaboration will depend on the activities carried out and their relation to both institutions' efforts. Potential areas of collaboration may include stakeholder education and outreach material development, technology identification, and the applicability of analytical techniques for future analysis.

We look forward to collaborating with the EERC if we are both successful in our awards.

Sincerely,

Steve Whittaker
Director Energy & Minerals
Illinois State Geological Survey

UNIVERSITY OF ALASKA FAIRBANKS
Institute of Northern Engineering

Brent J Sheets
Director
Petroleum Development Lab
907-750-0650
Bjsheets2@alaska.edu
www.pdl.uaf.edu

December 11, 2020

Thomas Erickson, Director
State Energy Research Center
University of North Dakota

Dear Dr. Erickson:

We are very interested in and support the proposed collaboration between the Technology Innovation Centers of Alaska, Utah, and North Dakota. If each area of interest is awarded a Department of Energy's CORE-CM program Phase I Cooperative Agreement, then we commit to meeting on a quarterly basis.

The purpose of the quarterly meetings will be for identifying common research needs, to spark scientific collaborations between our faculty, encourage early application of new findings across basins, and share outreach and education materials.

Nothing in our collaboration will reduce the autonomy of each basin-focused TIC. The purpose of this collaboration is to identify areas of mutual interest, and to create synergies built from our common goals. We expect this collaboration to grow during Phase 2, as described in the FOA, since Phase 1 will largely be concerned with establishing research plans. As a group, we will establish a more formal collaborative structure during our initial meeting, and refine that relationship throughout Phase 1 of the award.

While each basin has its own unique characteristics, there will be similarities in the technology, innovation, and workforce development needs and opportunities. Our hope is that, by building a collaborative framework across these basins, that we will enhance the networking capabilities, stakeholder engagement, and educational innovations; and by doing so, to leverage NETL 's investment in our respective TICs.

We are delighted to support the University of North Dakota's proposal in response to this DOE research campaign.

Sincerely,

Brent J Sheets

THE UNIVERSITY OF UTAH

December 8, 2020

Thomas Erickson
Director of the State Energy Research Center
University of North Dakota

Dear Tom:

We are very interested in and support the proposed collaboration between the Technology Innovation Centers of Alaska, Utah, and North Dakota. If each area of interest is awarded a Department of Energy's CORE-CM program Phase I Cooperative Agreement, then we commit to meeting on a quarterly basis.

The purpose of the quarterly meetings will be for identifying common research needs, to spark scientific collaborations between our faculty, encourage early application of new findings across basins, and share outreach and education materials.

Nothing in our collaboration will reduce the autonomy of each basin-focused TIC. The purpose of this collaboration is to identify areas of mutual interest, and to create synergies built from our common goals. We expect this collaboration to grow during Phase 2, as described in the FOA, since Phase 1 will largely be concerned with establishing research plans. As a group, we will establish a more formal collaborative structure during our initial meeting, and refine that relationship throughout Phase 1 of the award.

While each basin has its own unique characteristics, there will be similarities in the technology, innovation, and workforce development needs and opportunities. Our hope is that, by building a collaborative framework across these basins, that we will enhance the networking capabilities, stakeholder engagement, and educational innovations; and by doing so, to leverage NETL 's investment in our respective TICs.

We are delighted to support the University of North Dakota's proposal in response to this DOE research campaign.

Best regards,

Michael L. Free
Chair, Department of Mining Engineering
Professor, Department of Materials Science & Engineering

APPENDIX B

RESUMES OF KEY PERSONNEL

THOMAS A. ERICKSON
Director for Exploratory Research and Intellectual Property and Technology Commercialization
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, North Dakota 58202-9018 USA
701.777.5153 (phone), 701.777.5181 (fax), terickson@undeerc.org

Principal Areas of Expertise
Mr. Erickson's principal areas of interest and expertise include innovative energy technologies, technology development and commercialization, development and protection of intellectual property, program management, and partnering and collaborative relations.

Qualifications
M.S., Chemical Engineering, University of North Dakota, 1990.
B.S., Chemical Engineering, University of North Dakota, 1988.

Professional Experience
August 2019–Present: Director for Exploratory Research and Intellectual Property (IP) and Technology Commercialization, EERC, UND. Mr. Erickson leads research on emerging topics and pioneering technologies that support North Dakota's energy industry and benefit the environment through the State Energy Research Center (SERC), which provides a platform for developing impactful technologies in North Dakota and is driven by the state's future needs, challenges, and opportunities. Mr. Erickson also oversees the development and protection of IP and the commercialization of EERC-developed technologies.

2014–July 2019: CEO, EERC, UND. Mr. Erickson led a multidisciplinary science, engineering, and support team of more than 200 people focused on research and development (R&D) leading to demonstration and commercialization of innovative energy and environmental technologies. Mr. Erickson oversaw efforts to address energy and environmental issues through strategic initiatives focused on clean coal technologies; oil and gas industry technologies; carbon capture, utilization, and storage; energy and water sustainability; air toxics and fine particulate control; water management strategies; global climate change; waste utilization; hydrogen technologies; and contaminant cleanup.

2011–2014: Associate Director for Business, Operations, and Intellectual Property, EERC, UND. Mr. Erickson's responsibilities included support for EERC research programs, coordination with senior research managers and associate directors in the preparation of proposals, coordination of facility improvements, and overall direction of facility and safety requirements as well as development and enhancement of strategic collaborative relationships with EERC clients, protection relevant intellectual property, and advancement of EERC-developed technologies into the commercial marketplace.

1999–2011: Associate Director for Research, EERC, UND. Mr. Erickson was responsible for the direction and management of programs related to integrated energy and environmental system development. The research, development, and demonstration programs involve fuel quality effects on power system performance, advanced power systems development and demonstration, renewable energy systems and resources, alternative fuel production systems, hydrogen production technologies, computational modeling, advanced materials for power systems, and analytical methods for the characterization of materials.

1994–1999: Senior Research Manager, Engineering and Modeling Technologies, EERC, UND. Mr. Erickson was responsible for the management and operation of the Engineering and Modeling Technologies group, including personnel and budget planning, management of process and product modeling of combustion and gasification processes, and research related to toxic substance emissions during coal utilization.

1992–1994: Research Manager, Fuels and Materials Science, EERC, UND. Mr. Erickson was responsible for the organization and management of personnel and budgets, process and product modeling of combustion and gasification processes, and qualitative and quantitative analysis of coal and ash systems.

1991–1992: Supervisor, Analytical Research, EERC, UND. Mr. Erickson was responsible for the organization and management of personnel and budgets for the Inorganic Analytical Research laboratory, quantitative and qualitative analysis of coal and its combustion products, and process modeling of transformations during combustion and gasification.

1990–1991: Research Engineer, Combustion Studies, EERC, UND. Mr. Erickson was responsible for the quantitative and qualitative analysis of coal and its combustion products to model and predict transformations during combustion.

1989–1990: Research Specialist II, Energy and Mineral Research Center, UND. Mr. Erickson was responsible for the operation and maintenance of a scanning electron microscope/ microprobe and supervision of student employees.

1988–1989: Research Specialist I, Energy and Mineral Research Center, UND. Mr. Erickson was responsible for the operation and maintenance of a vertically orientated, laminar-flow (drop-tube) furnace.

Relevant Publications

Steadman, E.N.; Erickson, T.A.; Folkedahl, B.C.; Brekke, D.W. Coal and Ash Characterization: Digital Image Analysis Application. In *Inorganic Transformations and Ash Deposition During Combustion*; American Society of Mechanical Engineers: New York, 1992; pp 147–164.

Zygarlicke, C.J.; Ramanathan, M.; Erickson, T.A. Fly Ash Particle-Size Distribution and Composition: Experimental and Phenomenological Approach. In *Inorganic Transformations and Ash Deposition During Combustion*; ASME: New York, 1992; pp 525–544.

O'Keefe, C.A.; Erickson, T.A. Quantitative XRF Analysis of Coal After Successive Leachings. *Adv. X-Ray Anal.* **1994,** *37*, 735–739.

Erickson, T.A.; Ludlow, D.K.; Benson, S.A. Fly Ash Development from Sodium, Sulfur, and Silica During Coal Combustion. *Fuel* **1992**, *71* (1), 15–18.

Erickson, T.A. State Energy Research Center (SERC) – Driving North Dakota's Energy Future. Presented to ND Legislative Assembly Energy Development and Transmission Committee (EDTC), Bismarck, ND, Jun 2, 2020.

Erickson, T.A. Overview of the Energy & Environmental Research Center (EERC). Presented to the ND Legislative Assembly EDTC, Grand Forks, ND, Oct 16, 2014.

Erickson, T.A. Future of Energy in North Dakota. Presented at Marketplace for Entrepreneurs, Grand Forks, ND, Jan 16, 2008.

Erickson, T.A. Regional Carbon Sequestration Partnerships: Plains CO_2 Reduction Partnership. Presented at Western Governors' Association North American Energy Summit, April 2004.

Synergistic Activities

- UND College of Engineering & Mines Executive Board member, 2016.
- Lignite Research Council member, 2015.
- Technical Director, International Conference on Air Quality VI, 2007.
- Technical Coordinator, 19th International Western Fuels Symposium: Lignite, Brown, and Subbituminous Coals, 2004.
- Technical Coordinator, 18th International Low-Rank Fuels Symposium, 2003.

DR. BRUCE C. FOLKEDAHL
Senior Research Engineer, Critical Materials
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, North Dakota 58202-9018 USA
701.777.5243 (phone), 701.777.5181 (fax), bfolkedahl@undeerc.org

Principal Areas of Expertise

Dr. Folkedahl's principal areas of interest and expertise include combustion and gasification processes; biomass to fuels and chemicals; development of methodologies to mitigate the effects of inorganic components on the performance of combustion, gasification, and air pollution control systems; and fuel inorganic transformations and deposition and development of predictive models to assess these processes. Dr. Folkedahl has been responsible for the development of two novel water minimization technologies for use in power generation systems. He is also interested in the study and development of high-temperature materials for aggressive environments.

Qualifications

Ph.D., Materials Science and Engineering, Pennsylvania State University, 1997.
B.S., Computer Science, University of North Dakota, 1990.

Professional Experience

2001–Present: Sr. Research Engineer, Critical Materials Lead, EERC, UND. Dr. Folkedahl's responsibilities include studies of rare-earth element (REE) and critical materials (CMs) extraction and purification from coal and coal combustion products (CCPs) and traditional source materials for REEs and CMs; combustion and gasification in conjunction with electricity generation; fundamental mechanisms of ash deposition, fouling, and fine particulate and aerosol formation and emission during combustion; and corrosion and development of high-temperature materials to withstand aggressive combustion environments.

2000–2001: Product Manager, 3M Industrial Mineral Products Division, Little Rock, Arkansas. Dr. Folkedahl's responsibilities included managing a crushing and screening business unit 24-hr/day, 7-day/week manufacturing operation, including hiring, training, and directing 40 employees; managing a $12,000,000 annual budget; forecasting budgets; developing and implementing cost reduction plans; and developing automated labor-reducing equipment and routines.

1999–2000: Senior Product Engineer, 3M Industrial Mineral Products Division, St. Paul, Minnesota. Dr. Folkedahl's responsibilities included developing ceramer-coated roofing granules, developing automated dry powder-handling system for slurry-making process, investigating the mechanism of fluorine alkalinity reduction and coating enhancement in roofing granules, and investigating mechanisms of rust formation in mild steel storage tanks for roofing granules.

1994–1998: Graduate Assistant, Pennsylvania State University, University Park, Pennsylvania. Dr. Folkedahl's responsibilities included proctoring and grading exams and teaching lab classes. Thesis work consisted of development of a neural network model of inorganic ash viscosity in high-temperature systems; development of an image analysis program to identify graphitizability of cokes; and statistical cluster analysis of the chemical composition of ash deposits in electrical generation boilers.

1989–1999: Research Scientist, EERC, UND. Dr. Folkedahl's projects and responsibilities included corrosion studies of high-temperature alloys, modeling of slag and silicate material viscosities, and crystallization studies of coal. Other responsibilities included design, development, and maintenance of analytical software; development and implementation of new analysis techniques; and operation and performance analysis with x-ray diffraction, x-ray fluorescence, scanning electron microscopy, and processing and manipulation of raw data.

Relevant Publications

Hower, J.C.; Eble, C.F.; Dai, S.; Folkedahl, B.C.; Feole, I. Coal Geology – Lanthanides. Basic Concepts and Case Studies. In *Rare Earth Elements in Coal and Coal Byproducts*; in press.

Wang, Y.; Tang, Y.; Hurley, J.P.; Guo, X.; Finkelman, R.B.; Folkedahl, B.C.; Butler, S.K.; Azenkeng, A. Size Distributions and Chemistry of Inorganic Particles in Residues Produced from Two Commercial Entrained-Flow Coal Gasification Plants in China. Abstract presented at the 2020 International Pittsburgh Coal Conference.

Folkedahl, B.C.; Nyberg, C.; Addleman, R.; Theaker, N. Economic Extraction and Recovery of REEs and Production of Clean Value-Added Products from Low-Rank Coal Fly Ash. Presented at the 2019 Annual Project Review Meeting for Crosscutting, REE, Gasification, and Transformation Power Generation, Pittsburgh, PA, 2019.

Folkedahl, B.C.; Stanislowski, J.J. Regional Impacts of Carbon Capture and Sequestration (CCS). Presented at 34th Annual International Brotherhood of Boilermakers, MOST Tripartite Alliance Conference, 2019.

Laumb, J.D.; Folkedahl, B.C.; Zygarlicke, C.J. Characteristics and Behavior of Inorganic Constituents. In *Combustion Engineering Issues for Solid Fuel Systems*; Elsevier: Burlington, MA, 2008; pp 133–170.

Steadman, E.N.; Erickson, T.A.; Folkedahl, B.C.; Brekke, D.W. Coal and Ash Characterization: Digital Image Analysis Application. In *Inorganic Transformations and Ash Deposition During Combustion*; Benson, S.A., Ed.; American Society for Mechanical Engineers: New York, March 10–15, 1992; pp 147–164.

Martin, C.L.; Folkedahl, B.C.; Dunham, D.J.; Kay, J.P. Application of Liquid Desiccant Dehumidification to Amine-Based Carbon Capture Systems. *Int. J. Greenhouse Gas Control* **2016,** *54*, 557–565.

Folkedahl, B.C.; Snyder, A.C.; Strege, J.R.; Bjorgaard, S.J. Process Development and Demonstration of Coal and Biomass Indirect Liquefaction to Synthetic Iso-Paraffinic Kerosene. *Fuel Process. Technol.* **2011,** *92*, 1939–1945.

Folkedahl, B.C. End-Product Applications and Gas Cleanup Technology. Preworkshop Tutorial: Fundamentals of Gasification, Biomass '09 Workshop, Grand Forks, ND, July 14, 2009.

Synergistic Activities

- Led successful multi-institution program to develop methods to extract REEs from low-rank coal (LRC) ash, producing viable process with potential to produce REE concentrates suitable for sale to REE-refining operations.
- Led development and execution of sampling plan to collect and analyze +600 coal and CCP samples for REE content characterization focused on LRCs, with results delivered on time and on budget.
- Developed proprietary automated analysis process to analyze coal and CCPs for REE content using image analysis techniques.
- Led development of sampling and analysis plan for coal and CCPs at North Dakota minemouth power plant, including leading collaboration with mine personnel to identify specific fuel properties of

interest for testing based on drill core sample analysis data and well logs and employing full stream elemental analyzers (PGNAA) for coal selection.

- Vast experience in μm and sub-μm materials characterization/measurement and methods development to control very fine particles in challenging combustion environments, including understanding chemical interactions of inorganics in coals and their combustion by-products, leading to understanding of aerosol generation in these environments.

BETHANY A. KURZ
Assistant Director for Integrated Analytical Solutions
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) 777-5050, Fax: (701) 777-5181, E-Mail: bkurz@undeerc.org

Principal Areas of Expertise

Ms. Kurz's principal areas of interest and expertise include geologic and geochemical characterization of subsurface media for carbon storage and/or CO_2-based enhanced oil recovery, produced water and drilling waste management, assessment of high-value materials in coal and produced brine, and resource management related to energy development.

Qualifications

M.S., Hydrogeology, University of North Dakota, Grand Forks, ND, 1998.
B.S., Geochemistry, Bridgewater State University, Bridgewater, MA, 1995.

Professional Experience

July 2018–Present: Assistant Director for Integrated Analytical Solutions, Energy & Environmental Research Center (EERC), UND. Ms. Kurz is responsible for assisting the EERC's leadership team with developing business opportunities and successfully executing research projects related to oil and gas; high-value materials resource assessments; natural resource management; and carbon capture, utilization, and storage. She oversees a multidisciplinary team of scientists and engineers who work in the EERC's applied research laboratories. In that role, she is responsible for ensuring quality assurance/quality control of data and results generated by the EERC's laboratories and integrating those results into applied research efforts conducted by the Subsurface R&D team.

2011–July 2018: Principal Hydrogeologist, Laboratory Analysis Group Lead, EERC, UND. Ms. Kurz oversaw a multidisciplinary team of scientists and engineers and several of the EERC's analytical research laboratories that focus on classical and advanced wet-chemistry analyses; petrochemical, geochemical and geomechanical evaluation of rocks and soils; and advanced characterization of various materials, including metals, alloys, catalysts, and corrosion and scale products.

2002–2011: Senior Research Manager, Water Management and Flood Mitigation Strategies, EERC, UND. Ms. Kurz's responsibilities included project management, technical report and proposal writing, public outreach, and the development of new research focus areas. Research activities included the evaluation of nontraditional water supply sources for municipal and industrial use, flood and drought mitigation, watershed-scale water quality assessments using hydrologic models, and public education and outreach on various water and energy issues.

1998–2002: Research Scientist, Subsurface Remediation Research, EERC, UND. Ms. Kurz's responsibilities included managing and conducting research involving remediation technologies for contaminated groundwater and soils, groundwater sampling and analysis, technical report writing, and proposal research and preparation.

Relevant Publications

Zygarlicke, C.J., Folkedahl, B.C., Nyberg, C.M., Feole, I.K., Kurz, B.A., Theakar, N.L., Benson, S.A., Hower, J., and Eble, C., 2019, Rare-earth elements (REES) in U.S. coal-based resources—sampling, characterization, and round-robin interlaboratory study: Final report for U.S. Department of Energy National Energy Technology Laboratory Cooperative Agreement No. DE-FE0029007, EERC Publication 2019-EERC-09-08, Grand Forks, North Dakota, September.

Synergistic Activities

- Ongoing management and oversight of multiple laboratory-based efforts to characterize and evaluate the critical mineral content of various materials, including coal, organic-rich shale, and Williston Basin formation fluids (including produced water).
- Involvement in current and past projects that entailed the development and execution of sample collection and analysis plans, analytical data compilation, and interpretation of results.
- Extensive experience in collection and analysis of samples derived from sedimentary basin stratigraphic sequences that contain coal, oil, and gas resources.
- Currently oversees projects aimed at understanding the geology and geochemistry of coal- and oil-bearing sequences.

NOLAN THEAKER
Research Engineer
Institute for Energy Studies, College of Engineering & Mines, University of North Dakota
Collaborative Energy Center, Room 246, Stop 8153, Grand Forks, North Dakota 58202-8153
701.777.6298 (phone), nolan.theaker@UND.edu

Qualifications

Ph.D. candidate, Chemical Engineering, University of North Dakota (UND).
M.Eng., Chemical Engineering, University of Louisville, 2017.
B.S., Chemical Engineering, University of Louisville, 2016.

Professional Experience

2017–Present: Research Engineer, Institute for Energy Studies, UND. Responsibilities include high-level innovative research and development of novel concepts for submission of funding proposals. Coordinated and conducted efforts associated with downstream rare-earth element (REE) concentration operations that have resulted in the development of final process flow diagrams. Key contributor on projects related to costing and analysis of REE extraction technologies. Previously co-principal investigator (PI) on bench-scale REE work (DE-FE0027006) and currently co-PI on pilot-scale REE work (DE-FE31835), leading day-to-day research activities on the project.

2016–2017: Research Assistant, University of Louisville Conn Center. Research involved design and operation of multistage electrochemical reactor scheme for efficient production of fuels from CO_2. Developed nanofunctionalized electrocatalysts for improvements in activity and selectivity for targeted reactions in two-phase reaction systems.

2014–2015: Co-Op Engineer, Center for Applied Energy Research (CAER), University of Kentucky. Research involved improvement and operation of a U.S. Department of Energy (DOE) bench-scale CO_2 capture unit in multiple reaction conditions. Evaluation and comparison of catalyst performance in a holistic view for CO_2 capture was conducted, including novel organic and enzymatic catalysts.

Relevant Publications

Park, D., Middleton, A., Smith, R., Laudal, D., Theaker, N., Hsu-Kim, H., Jiao, Y. A Biosorption-based approach for the selective extraction of REEs from coal byproducts. *Separation and Purification Technology*. 2020.

Theaker, N., Rew, B., Laudal, D., Mann, M. Investigation of rare earth element extraction from North Dakota Coal-Related Feed Stocks. 2019 NETL Annual Crosscutting Projects Review Meeting. April 9, 2019. Pittsburgh, PA.

Theaker, N., Laudal, D., Benson, S., Rew, B., Lucky, C. Bench-scale testing update – recovery of rare earth elements from lignite coal. 2019 SME Annual Conference. February 2019. Denver, CO.

Mann, M; Theaker, N.; Rew, B; Benson, S.; Palo, D. Phase 2 Final Technical Report for "Investigation of Rare Earth Element Extraction from North Dakota Coal-Related Feedstocks." Report furnished by University of North Dakota, 2020.

Zygarlicke, C; Folkedahl, B; Nyberg, C; Feole, I; Kurz, B; Theaker, N; Benson, S; Hower, J; Eble, C. "REEs in U.S. Coal-Based Resources: Sampling, Characterization, and Round-Robin Interlaboratory Study." Report furnished by University of North Dakota, 2019.

Synergistic Activities

- Technical lead and co-PI on multiple REE-coal-related projects, including pilot-scale demonstration of UND technology (DE-FE0031835) and conceptual-scale study of a commercial-scale version of a REE extraction from lignite plant (89243320CFE000057).
- Collaborator on bio-related extraction technology from coal-based solutions (with LLNL).

JASON D. LAUMB
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Principal Areas of Expertise

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

Qualifications

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

Professional Experience

September 2019–Present: Assistant Director for Advanced Energy Systems, EERC, UND. Mr. Laumb assists the EERC executive team by providing leadership on projects related to advanced energy systems. Mr. Laumb leads a multidisciplinary team of 25 scientists and engineers developing and conducting projects and programs on power plant performance, environmental control systems, fate of pollutants, and computer modeling for clients worldwide. Efforts focus on development of multiclient jointly sponsored centers and consortia funded by government and industry sources. Current research activities include computer modeling of combustion/ gasification and environmental control systems, performance of selective catalytic reduction technologies for NO_x control, mercury control technologies, hydrogen production from coal, CO_2 capture technologies, aerosol analysis, and fate of mercury in environment. Computer-based modeling efforts utilize various kinetic, systems engineering, thermodynamic, artificial neural network, statistical, computation fluid dynamics, and atmospheric dispersion models. These models are used in combination with models developed at the EERC to predict impacts of fuel properties and system operating conditions on system efficiency, economics, and CO_2 emissions.

2008–August 2019: Principal Engineer, Advanced Energy Systems Group Lead, EERC, UND. Mr. Laumb led a multidisciplinary team of 30 scientists and engineers to develop and conduct projects and programs on power plant performance, environmental control systems, the fate of pollutants, computer modeling, and health issues for clients worldwide. Efforts focused on development of multiclient jointly sponsored centers or consortia funded by government and industry sources. Research activities included computer modeling of combustion/gasification and environmental control systems, performance of SCR technologies for NO_x control, mercury control technologies, hydrogen production from coal, CO_2 capture technologies, particulate matter analysis and source apportionment, the fate of mercury in the environment, toxicology of particulate matter, and in vivo studies of mercury–selenium interactions.

2001–2008: Research Manager, EERC, UND. Mr. Laumb led projects involving bench-scale combustion testing of various fuels and wastes as well as a laboratory that performs bench-scale combustion and gasification testing. He served as principal investigator and managed projects related to the inorganic composition of coal, coal ash formation, deposition of ash in conventional and advanced power systems,

and mechanisms of trace metal transformations during coal or waste conversion and wrote proposals and reports focused on energy and environmental research.

2000–2001: Research Engineer, EERC, UND. Mr. Laumb assisted in the design of pilot-scale combustion equipment and wrote computer programs to aid in the reduction of data, combustion calculations, and prediction of boiler performance. He was also involved in the analysis of combustion control technologies' ability to remove mercury and the suitability of biomass as boiler fuel.

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

Relevant Publications

Laumb, J.D.; Folkedahl, B.C.; Zygarlicke, C.J. Characteristics and Behavior of Inorganic Constituents. In *Combustion Engineering Issues for Solid Fuel Systems*; Elsevier: Burlington, MA, 2008; pp 133–170.

Olson, E.S.; Azenkeng, A. Laumb, J.D.; Jensen, R.R.; Benson, S.A.; Hoffman, M.R. New Developments in the Theory and Modeling of Mercury Oxidation and Binding on Activated Carbons in Flue Gas. In *Air Quality VI: Mercury, Trace, Elements, SO_3, Particulate Matter, and Greenhouse Gases*, Special Issue of *Fuel Process. Technol.* **2009**, *90* (11), 1360–1363.

Pavlish, J.H.; Laumb, J.D.; Benson, S.A., Eds. Air Quality VI: Mercury, Trace Elements, SO_3, Particulate Matter, & Greenhouse Gases; Special Issue of *Fuel Process. Technol.* **2009,** *90* (11), 1327–1434.

Azenkeng, A.; Laumb, J.D.; Jensen, R.R.; Olson, E.S.; Benson, S.A.; Hoffmann, M.R. Carbene Proton Attachment Energies: Theoretical Study. *J. Phys. Chem. A* **2008**, *112*, 5269–5277.

Laumb, J.D.; Cowan, R.M.; Azenkeng, A.; Hanson, S.K.; Heebink, L.V.; Letvin, P.A.; Jensen, M.D.; Raymond, L.J. *Subtask 2.14 – Beneficial Use of CO_2 for North Dakota Lignite-Fired Plants*; Final Report for U.S. Department of Energy National Energy Technology Laboratory Cooperative Agreement No. DE-FC26-08NT43291; EERC Publication 2012-EERC-01-27.

Hanson, S.K.; Azenkeng, A.; Laumb, J.D.; McCollor, D.P.; Pavlish, B.M.; Buckley, T.D.; Botnen, L.S. *Subtask 3.7 – Beneficiated Lignite Market Study*; Final Report for U.S. Department of Energy National Energy Technology Laboratory Cooperative Agreement No. DE-FC26-08NT43291; EERC Publication 2010-EERC-06-09.

Laumb, J.D.; Benson, S.A.; Stanislowski, J.J. *JV Task 75 - Lignite Fuel Enhancement Via Air-Jigging Technology*; Final Report for U.S. Department of Energy National Energy Technology Laboratory Cooperative Agreement No. DE-FC26-98FT40321; EERC Publication 2007-EERC-02-10.

Laumb, J.D.; Stanislowski, J.J. *JV Task 5 – Predictive Coal Quality Effects Screening Tool (PCQUEST)*; Final Report for U.S. Department of Energy National Energy Technology Laboratory Cooperative Agreement No. DE-FC26-98FT40321; EERC Publication 2007-EERC-08-04.

Jensen, R.R.; Benson, S.A.; Laumb, J.D. *Subtask 3.6 – Advanced Power Systems Analysis Tools*; Final Report for U.S. Department of Energy National Energy Technology Laboratory Cooperative Agreement No. DE-FC26-98FT40320; EERC Publication 2001-EERC-08-05.

Laumb, J.D.; Benson, S.A.; Olson, E.S.; Dunham, G.E. Characterization of Coal-Derived Mercury Sorbents. In *Proceedings of the 26th International Technical Conference of Coal Utilization & Fuel Systems*; Clearwater, FL, March 5–8, 2001.

Synergistic Activities

Instructor, EERC Gasification and Ash Behavior Short Courses.
Organizing Committee Member, 5th International Freiberg Conference on IGCC and XtL Technologies.
National Advisory Board for the International Conference on Coal Science & Technology.
Reviewer, *Fuel Processing Technology.*

JOHN A. HARJU
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Principal Areas of Expertise
Mr. Harju's principal areas of interest and expertise include carbon sequestration, enhanced oil recovery, unconventional oil and gas development, waste management, geochemistry, technology development, hydrology, and analytical chemistry, especially as applied to the upstream oil and gas industry.

Qualifications
M.Eng., Petroleum Engineering, University of North Dakota, 2020.
B.S., Geology, University of North Dakota, 1986.

Professional Experience
2002–Present: EERC, UND.
July 2015–Present: Vice President for Strategic Partnerships. Mr. Harju leads efforts to build and grow dynamic working relationships with industry, government, and research entities globally in support of the EERC's mission to provide practical, pioneering solutions to the world's energy and environmental challenges. He represents the EERC regionally, nationally, and internationally in advancing its core research priorities: coal utilization and emissions, carbon management, oil and gas, alternative fuels and renewable energy, and energy–water.

2003–June 2015: Associate Director for Research. Mr. Harju led a team of scientists and engineers building industry–government–academic partnerships to carry out research, development, demonstration, and commercialization of energy and environmental technologies.

2002–2003: Senior Research Advisor. Mr. Harju developed, marketed, managed, and disseminated research programs focused on the environmental and health effects of power and natural resource production, contaminant cleanup, water management, and analytical techniques.

2017–Present: Adjunct Lecturer, Department of Petroleum Engineering, UND.

1999–2002: Vice President, Crystal Solutions, LLC, Laramie, WY. Mr. Harju's firm was involved in commercial E&P produced water management, regulatory permitting and compliance, and environmental impact monitoring and analysis.

1997–2002: Gas Research Institute (GRI) (now Gas Technology Institute [GTI]), Chicago, IL.
2000–2002: Principal Scientist, Produced Water Management. Mr. Harju developed and deployed produced water management technologies and methodologies for cost-effective and environmentally responsible management of oil and gas produced water.

1998–2000: Program Team Leader, Soil, Water, and Waste. Mr. Harju managed projects and programs related to the development of environmental technologies and informational products related to the North American oil and gas industry; formulated RFPs, reviewed proposals, and formulated contracts;

performed technology transfer activities; and supervised staff and contractors. He served as Manager of the Environmentally Acceptable Endpoints project, a multiyear program focused on rigorous determination of appropriate cleanup levels for hydrocarbons and other energy-derived contaminants in soils. He led GRI/GTI involvement with industry environmental consortia and organizations, such as PERF, SPE, AGA, IPEC, and API.

1997–1998: Principal Technology Manager (1997–1998) and Associate Technology Manager (1997), Soil and Water Quality.

1988–1996: EERC, UND.
1994–1996: Senior Research Manager, Oil and Gas Group. Mr. Harju served as:
- Program Manager for assessment of the environmental transport and fate of oil- and gas-derived contaminants, focused on mercury and sweetening and dehydration processes.
- Project Manager for field demonstration of innovative produced water treatment technology using freeze crystallization and evaporation at oil and gas industry site.
- Program Manager for environmental transport and fate assessment of MEA and its degradation compounds at Canadian sour gas-processing site.
- Program Manager for demonstration of unique design for oil and gas surface impoundments.
- Director of the National Mine Land Reclamation Center for the Western Region.
- Co-PI on project exploring feasibility of underground coal gasification in southern Thailand.
- Consultant to an International Atomic Energy Agency program entitled "Solid Wastes and Disposal Methods Associated with Electricity Generation Fuel Chains."

1988–1994: Research Manager (1994), Hydrogeologist (1990–1994), Research Specialist (1989–1990), and Laboratory Technician (1988–1989).

Relevant Publications

Sorensen, J.A., Heebink, L.V., Gorecki, C.D., Steadman, E.N., Harju, J.A., Kurz, B.A., Wocken, C.A., and Romuld, L., 2020, Bakken Production Optimization Program: Final Report for North Dakota Industrial Commission (NDIC) Contract No G-040-080, EERC Publication 2020-EERC-06-17.

Peck, W.D., Azzolina, N.A., Barajas-Olalde, C., Burton-Kelly, M.E., Kalenze, N.S., Feole, I.K., Glazewski, K.A., Ayash, S.C., Hurley, J.P., Jensen, M.D., Gorecki, C.D., Harju, J.A., Bangsund, D.A., and Cook, B., 2019, Techno-economic assessment of implementing lignite-based CO_2 EOR in North Dakota: Final report for U.S. Department of Energy National Energy Technology Laboratory Cooperative Agreement No. DE-FE0024233, EERC Publication 2019-EERC-04-14.

Leroux, K.M., Klapperich, R.J., Kalenze, N.S., Jensen, M.D., Daly, D.J., Crocker, C.R., Ayash, S.C., Azzolina, N.A., Crossland, J.L., Doll, T.A., Gorecki, C.D., Stevens, B.G., Botnen, B.W., Foerster, C.L., Schlasner, S.M., Hamling, J.A., Nakles, D.V., Peck, W.D., Glazewski, K.A., Harju, J.A., Piggott, B.D., and Vance, A.E. 2018, Integrated carbon capture and storage for North Dakota ethanol production – Phase II: Final report for North Dakota Industrial Commission Contract No. R-034-043, EERC Publication 2018-EERC-07-11.

Romuld, L., Harju, J.A., Russell, C.J., Aulich, T.R., and Steadman, E.N., 2018, EERC–DOE joint program on research and development for fossil energy-related resources: Final report for U.S. Department of Energy Cooperative Agreement No. DE-FC26-08NT43291, EERC Publication 2018-EERC-05-18.

Jensen, M.D., Pei, P., Snyder, A.C., Heebink, L.V., Botnen, L.S., Gorecki, C.D., Steadman, E.N., and Harju, J.A., 2013, A methodology for phased development of a hypothetical pipeline network for CO_2 transport during carbon capture, utilization, and storage: Energy and Fuels, v. 27, p. 4175–4182.

Peck, W.P., Battle, E.P., Grove, M.M., Glazewski, K.A., Riske, J.M., Gorecki, C.D., Steadman, E.N., and Harju, J.A., 2017, Plains CO_2 Reduction (PCOR) atlas (5th ed., rev.): Prepared for U.S. Department of Energy National Energy Technology Laboratory and PCOR Partnership, Grand Forks, North Dakota: Energy & Environmental Research Center, 114 p.

Synergistic Activities

- Member, National Coal Council (appointed 2018).
- Member, National Petroleum Council (appointed 2010).
- Member, DOE Unconventional Resources Technology Advisory Committee (2012–2014).
- Member, Interstate Oil and Gas Compact Commission (appointed 2010).
- Member, Rocky Mountain Association of Geologists.

CHAD A. WOCKEN
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Principal Areas of Expertise

Mr. Wocken's principal areas of research include developing alternative fuel and chemical processes and innovative energy technologies. Currently, he leads projects focused on developing and advancing alternative chemical and fuel production processes at the bench, lab, and pilot scale and optimizing processes associated with oil and gas production and midstream operations. In addition, Mr. Wocken manages a group of researchers and a lab facility containing batch and continuous reactor systems capable of testing a variety of thermochemical processes.

Qualifications

B.S., Chemical Engineering, University of North Dakota, 1994

Professional Experience

2001–Present: EERC, UND.

Assistant Director for Clean Energy Solutions (September 2019–Present). Mr. Wocken leads a multidisciplinary team of engineers and scientists focused on applying scientific principles to address the challenges to energy production. His team's applied research activities include process modeling; engineering studies; and technology evaluation and development at the bench, pilot, and demonstration scale. Mr. Wocken has over 25 years of experience spanning work in oil and gas production, fuel processing, electricity generation, emission control, environmental remediation, and process engineering. Drawing on his engineering training and diverse experience, he enjoys defining problems and developing innovative solutions to promote clean energy solutions.

Principal Engineer, Transformational Energy Group Lead (2015–August 2019); Senior Research Manager (2009–2015); Research Engineer (2001–2009).

<u>Project/Program Management</u>

- Developed a new research program and managed the design and fabrication of a facility to test and evaluate solid-oxide fuel cells with a variety of gaseous fuels including actual syngas produced from the EERC's pilot-scale gasification systems.
- Led a process-modeling team within the EERC's Bakken Production Optimization Program, focused on applying computational modeling expertise to crude oil production processes and addressing emission reduction and gas flaring while also reducing crude oil volatility.
- Directed the EERC's associated gas-flaring mitigation activities, aiding industry partners in their efforts to identify technologies to reduce flaring. These efforts led to the creation of the Flaring Solutions Database, a clearinghouse of business and technology solutions that have the potential to utilize gas at the wellhead and reduce flaring.
- Managed a Defense Advanced Research Projects Agency (DARPA)-funded project that successfully developed technology to produce drop-in-compatible jet fuel for the military from renewable feedstock. Activities included planning work activities, developing and executing a risk-based project

management plan, coordinating activities of five project partners to meet project goals, and communicating with the DARPA project manager.
- Managed the scale-up and design of a 300-barrel/day renewable fuel pilot plant capable of producing specification-compliant jet and diesel fuels from renewable oil feedstock.

Technology Development and Research
- Designed and executed an oil and gas gathering pipeline leak detection demonstration project, resulting in tangible performance improvements for three pipeline operators.
- Conducted a technical and economic assessment of alternative uses for associated gas in an effort to reduce the amount of gas being flared in the Williston Basin. Technologies evaluated included gas-processing operations to recover natural gas liquids, gas-fired power generation, transportation fuel, and traditional petrochemical unit operations.
- Performed a system-level engineering evaluation of integrated algae production at a coal-fired power plant to assess carbon uptake, emission control requirements, relative scale, and the viability of water and waste heat utilization.
- Designed, fabricated, and operated several fixed-catalyst bed reactor systems to evaluate a variety of thermocatalytic processes to produce renewable fuels and chemicals.
- Conducted testing at coal-fired power plants, and developed control technologies to reduce atmospheric emission of particulate matter, mercury, and other contaminants.

1995–2001: Project Engineer, URS/Radian International, Salt Lake City, Utah (1997–2001), and Milwaukee, Wisconsin (1995–1997).

Process Design, Operation, and Optimization
- Designed remediation systems to remove BTEX compounds and chlorinated solvents from groundwater. Project tasks included site evaluation, technology selection, system design, and creation of specifications.
- Performed start-up and long-term operations of groundwater remediation systems. Responsibilities included troubleshooting equipment/system malfunctions, process optimization, writing operations and maintenance manuals, establishing performance verification criteria, defining operational cost, and directing technicians' work.
- Conducted detailed reviews of industrial wastewater treatment systems to identify alternative treatment technologies, process optimizations, and water reuse alternatives.

Construction Oversight
- Provided on-site oversight for several construction projects consisting of mechanical equipment installation, instrumentation and process control, building and road construction, excavation, and underground utility installation. Daily responsibilities included evaluating work for conformance with construction drawings and specifications; coordinating work activities; and facilitating communication between the design firm, client, and contractors.

Project Management
- Served as project manager for several large projects that were completed successfully. Activities included developing cost proposals, managing budget and schedule, equipment and subcontractor acquisition, and maintaining effective communication with the client.

1994–1995: Process Engineer, Archer Daniels Midland, Clinton, Iowa.

Plant Operation

- Supervised operations and personnel at a wet corn mill oil extraction and refining plant. Tasks consisted of prioritizing work activities, scheduling maintenance of process equipment, monitoring product quality, and extensive system troubleshooting and failure analysis.

Relevant Publications

None.

Synergistic Activities

- Member of the project management team that created the iPIPE (intelligent Pipeline Integrity Program), a public–private partnership focused on advancing technologies that improve pipeline integrity and performance. iPIPE is funded through participation fees of commercial pipeline companies and state match from the North Dakota Industrial Commission (NDIC) Oil and Gas Research Program. The EERC supports its partners by managing the consortium, performing technology scouting, and managing a competitive award program that provides matching funds to pipeline leak detection and leak prevention technologies.
- Member of the project management team for BPOP, a public–private partnership focused on improving the efficiency and reducing the environmental impacts of oil and gas production in North Dakota. The consortium is funded through membership fees from oil and gas operators and state match form the NDIC Oil and Gas Research Program. Project activities are executed by EERC researchers, with guidance, participation, and expertise from both industry and state agency partners.

APPENDIX C

BUDGET NOTES

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 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

The applicable federal intellectual property (IP) regulations will govern any resulting research agreement(s). In the event that IP with the potential to generate revenue to which the EERC is entitled is developed under this project, 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.) and among funding sources of the same scope of work is for planning purposes only. The project manager may incur and allocate allowable project costs among the funding sources for this scope of work in accordance with Office of Management and Budget (OMB) Uniform Guidance 2 CFR 200.

Escalation of labor and EERC recharge center rates is incorporated into the budget when a project's duration extends beyond the university's current fiscal year (July 1 – June 30). 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: 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 average rate of a personnel group with similar job descriptions. Salary costs incurred are based on direct hourly effort on the project. Faculty who work on this project may be paid an amount over the normal base salary, creating an overload which is subject to limitation in accordance with university policy. As noted in the UND EERC Cost Accounting Standards Board Disclosure Statement, administrative salary and support costs which can be specifically identified to the project are direct-charged and not charged as facilities and administrative (F&A) costs. Costs for general support services such as contracts and IP, accounting, human resources, procurement, and clerical support of these functions are charged as F&A costs.

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 may include site visits, fieldwork, meetings, and conferences. Travel costs are estimated and paid in accordance with OMB Uniform Guidance 2 CFR 200, Section 474, and UND travel policies, which can be found at http://und.edu/finance-operations (Policies & Procedures, A–Z Policy Index, Travel). Daily meal rates are based on U.S. General Services Administration (GSA) rates unless further limited by UND travel policies; other estimates such as airfare, lodging, ground transportation, and miscellaneous costs are based on a combination of historical costs and current market prices. Miscellaneous travel costs may include parking fees, Internet charges, long-distance phone, copies, faxes, shipping, and postage.

Supplies: Supplies include items and materials that are necessary for the research project and can be directly identified to the project. Supply and material estimates are based on prior experience with similar projects. Examples of supply items are chemicals, gases, glassware, nuts, bolts, piping, data storage, paper, memory, software, toner cartridges, maps, sample containers, minor equipment (value less than $5000), signage, safety items, subscriptions, books, and reference materials. General purpose office supplies (pencils, pens, paper clips, staples, Post-it notes, etc.) are included in the F&A cost.

Subcontract – Montana Technological University (MTU): MTU will subcontract with the EERC to interface with Montana entities and track down appropriate data in support of Task 2 as well as support the technology assessments in Task 5.

Subcontract – North Dakota State University (NDSU): NDSU will subcontract with the EERC to provide technical assistance in Task 4 in determining business boundary gaps and needs.

Communications: Telephone, cell phone, and fax line charges are included in the F&A cost; however, direct project costs may include line charges at remote locations, long-distance telephone charges, postage, and other data or document transportation costs that can be directly identified to a project. Estimated costs are based on prior experience with similar projects.

Printing and Duplicating: Page rates are established annually by the university's duplicating center. Printing and duplicating costs are allocated to the appropriate funding source. Estimated costs are based on prior experience with similar projects.

Food: Expenditures for project partner meetings where the primary purpose is dissemination of technical information may include the cost of food. The project will not be charged for any costs exceeding the applicable GSA meal rate. EERC employees in attendance will not receive per diem reimbursement for meals that are paid by project funds. The estimated cost is based on the number and location of project partner meetings.

Operating Fees: Operating fees generally include EERC recharge centers, outside laboratories, and freight.

EERC recharge center rates are established annually and approved by the university.

Laboratory and analytical recharge fees are charged on a per-sample, hourly, or daily rate. Additionally, laboratory analyses may be performed outside the university when necessary. The estimated cost is based on the test protocol required for the scope of work.

Graphics recharge fees are based on an hourly rate for production of such items as report figures, posters, and/or images for presentations, maps, schematics, Web site design, brochures, and photographs. The estimated cost is based on prior experience with similar projects.

Shop and operations recharge fees cover specific expenses related to the pilot plant and the required expertise of individuals who perform related activities. Fees may be incurred in the pilot plant, at remote locations, or in EERC laboratories whenever these particular skills are required. The rate includes such items as specialized safety training, personal safety items, fall protection harnesses and respirators, CPR certification, annual physicals, protective clothing/eyewear, research by-product disposal, equipment repairs, equipment safety inspections, and labor to direct these activities. The estimated cost is based on the number of hours budgeted for this group of individuals.

Engineering services recharge fees cover specific expenses related to retaining qualified and certified design and engineering personnel. The rate includes training to enhance skill sets and maintain certifications using Webinars and workshops. The rate also includes specialized safety training and related physicals. The estimated cost is based on the number of hours budgeted for this group of individuals.

Technical Software fees cover the use of ASPEN Modelling software to support processing modeling and economics modeling.

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

Facilities and Administrative Cost: The F&A rate proposed herein is approved by the U.S. Department of Health and Human Services and is applied to 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 1 year, as well as subawards in excess of the first $25,000 for each award.