Energy & Environmental Research Center
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March 31, 2023

Mr. Reice Haase
Deputy Executive Director
ATTN: Lignite Research Program
North Dakota Industrial Commission
600 East Boulevard Avenue
State Capitol, 14th Floor
Bismarck, ND 58505-0840

Dear Mr. Haase:

Subject: EERC Proposal No. 2023-0144 Entitled "Williston Basin CORE-CM Initiative – Continued Assessment"

The Energy & Environmental Research Center (EERC) of the University of North Dakota is pleased to submit the subject proposal. The ACH transaction number is 252060 for the $100 application fee. The EERC is committed to completing the project as described in the proposal if the Commission makes the requested grant.

If you have any questions, please contact me by telephone at (701) 777-4580 or by email at jkay@undeerc.org.

Sincerely,

DocuSigned by:
John Kay
6E1D21EBB3594A6...
John P. Kay
Principal Engineer Emissions
and Carbon Capture

Approved by:

DocuSigned by:
Tami Votava
E7468BBB3DE440E...
Charles D. Gorecki, CEO
Energy & Environmental Research Center

JPK/bjr

Attachment

Lignite Research, Development and Marketing Program

North Dakota Industrial Commission

Application

Project Title: Williston Basin CORE-CM Initiative – Continued Assessment

Applicant: University of North Dakota Energy & Environmental Research Center

Principal Investigator: John P. Kay

Date of Application: April 1, 2023

Amount of Request: $1,050,000

Total Amount of Proposed Project: $2,100,000

Duration of Project: 16 months

Point of Contact (POC): John P. Kay

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POC Email: jkay@undeerc.org

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

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ABSTRACT

The University of North Dakota (UND) Energy & Environmental Research Center (EERC) is continuing to lay the foundation for 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. This has been an ongoing effort since October 2021, with the U.S. Department of Energy (DOE) award of the "Williston Basin CORE-CM Initiative," also supported by the North Dakota Industrial Commission (NDIC) Lignite Research, Development and Marketing Program (LRDMP). DOE will be providing an additional $500,000 to the program for continued characterization of carbon ore, ash, and waste streams within the basin, expected to be in place by June 1, 2023, along with project partners BNI Energy (BNI) and North American Coal Company (NACCO) providing $500,000 and $50,000 in-kind cost share, respectively. **Objective:** The goal of the additional funding is to collect current, field-derived data through sampling and identifying areas that show potential for the development of 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:** This program is the first phase of an expected DOE-funded three-phase effort. Phase 1 is focused on gathering and assessing data for REEs, CMs, and CBPs in the Williston Basin and identifying gaps and developing strategies necessary to move forward with demonstrations along the entire supply chain.

Duration: 16 months (June 1, 2023 – September 30, 2024)

Total Project Cost: The total value of this continued effort is $2,100,000. The proposal requests a total of $1,050,000 from NDIC LRDMP. DOE will provide $500,000. Project partners BNI and NACCO will provide $500,000 and $50,000 of in-kind costs share, respectively.

Participants: DOE, NDIC LRDMP, BNI, and NACCO, along with continued input from the original coalition of nearly 30 partners, formed under the formation of the program in 2021.

PROJECT SUMMARY

Through the creation of the Williston Basin CORE-CM (carbon ore, rare earth, and critical minerals) Initiative in 2021, the University of North Dakota (UND) Energy & Environmental Research Center (EERC) formed and continues to lead a diverse and experienced coalition team of nearly 30 partners, 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 products to produce rare-earth elements (REEs), critical minerals (CMs), and nonfuel carbon-based projects (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.

This effort is the first phase of an expected much larger program as defined by the U.S. Department of Energy (DOE). As shown in Figure 1, 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 1. 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

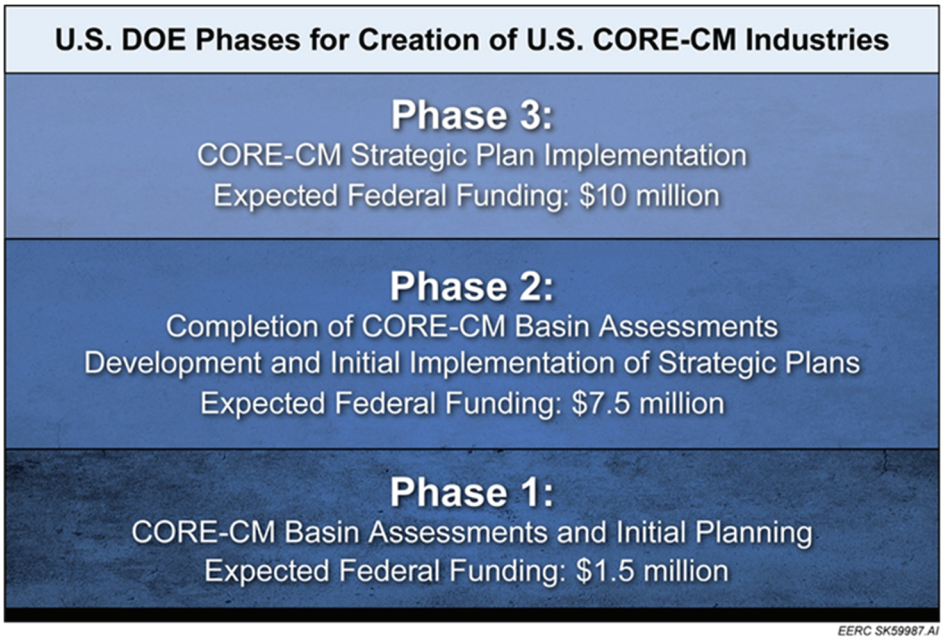


Figure 1. DOE phases for creation of the U.S. CORE-CM industries.

partnerships in the Williston 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.

At the onset of this program, one of the Williston Basin CORE-CM Initiative's goal was to compile existing data and information on REE and CM content within the Williston Basin, identifying gaps and developing plans to drive future DOE phases. However, through this exercise, DOE has recognized that much of the existing data throughout the United States was not collected using modern methods of evaluation and analysis, calling into question its accuracy. Therefore, for all 13 existing CORE-CM programs, DOE is providing additional funds and time extension to collect new samples and analyze them for REE and CM content. Building upon the opportunity, the Williston Basin CORE-CM Initiative desires to expand upon the original goals of the DOE CORE-CM program by 1) further assessment of the Williston Basin resource for coal and waste streams; 2) providing an additional business development assessment; and 3) continuing stakeholder engagement.

PROJECT DESCRIPTION

The EERC will continue to 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 has harnessed coalition team experience and Williston Basin resources and infrastructure to begin the development of 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 additional focus on aspects of 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 updated project remains the same, which 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 have been updated to 1) generate new information for resource characterization and waste streams, with a focus on BNI Energy (BNI) mine property; 2) enhance existing business development conducted under the original program, focusing on job creation and specifics of supply chain potential; and 3) continue stakeholder engagement through informative webinars, and provide annual in-person meetings to expand upon the highly successful Critical & Rare-Earth Elements Symposium, held on October 11, 2022.

Methodology: Building upon this opportunity, the Williston Basin CORE-CM Initiative wants to expand upon the characterization of BNI mining operations, continued collaboration with exploration being performed by the North Dakota Geological Survey (NDGS), provide more examination of fly ash as a potential source of REEs and CMs, and continue to develop plans that will drive future phases of REE/CM/CBP development within the Williston Basin. The Williston Basin CORE-CM Initiative has been

performing work through seven tasks. The continued work under this proposal will be conducted under several subtasks, denoted by italics.

Task 1.0 – Project Management, Planning, and Reporting. The EERC manages and directs the project in accordance with the scope of work to meet all technical, schedule, and budget objectives and requirements. Interim and final reports summarize the activities of the project and include key findings, results, and lessons learned. *Additional information gathered will be included in an additional interim report and the final reports. The project team will also be participating in DOE-led Working Groups. The intent of the Working Groups is to share lessons learned across all DOE project awardees as well as aid in the development of best practices manuals.*

Task 2.0 – Assessment of CORE-CM Resources. Existing Williston Basin REE and CM data are being compiled and coupled with detailed stratigraphic data. Machine learning algorithms are being applied to identify correlations between REE and CM occurrence and stratigraphy within the Williston Basin. *Using continued funding, additional sampling will be conducted to gather new samples across the basin to further refine REE and CM occurrence and to assist BNI and North American Coal Company (NACCO) with insight into the potential for their resources to be an economic source for REEs and CMs. Throughout 2023 and 2024, BNI and NACCO will be evaluating their minable resources for upcoming production. Drill core samples from these assessments will be provided to the project for analytical analysis for REE and CM content. It is expected that BNI will select between 30–60 drill cores for this assessment. Additionally, in conjunction with NDGS and based upon its guidance, additional drill core will be obtained and analyzed from locations in western North Dakota and around the current mines in North Dakota to further clarify REE and CM concentrations at selected sites. It is expected to obtain roughly 18–24 drill cores under this continued effort.* This information is being used to develop an initial geologic information system (GIS)-based geologic model, identifying data gaps and helping target promising locations for additional sample collection and analysis in a future project phase.

***Task 2.1 – Data Survey and Acquisition*.** Existing REE and CM characterization data throughout the Williston Basin are being 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. The data are being 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. *Results from additional drill cores will be included in this subtask.*

***Task 2.2 – Geologic Model Development*.** A GIS-based geologic model of the coal-bearing Williston Basin strata is being 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 (*including additional drill cores*). The geologic model is being constructed to leverage its use in predicting REE and CM resources in future phases.

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

***Task 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 is based heavily on 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 is working 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 is being developed through the following subtasks.

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

Task 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 is being 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.

Task 3.3 – Identification of Data Gaps. Once the potential waste streams are 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.

Task 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 are being 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.

Task 4.1 – Identification of Existing Basinal Infrastructure. Any limitations in the capacity of the existing infrastructure are being identified. The region's infrastructure (roads, rail, industries), abundant natural resources (mining, natural gas), and history of exporting both raw and refined commodities are being 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.

Task 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 are being identified. Potential strategic partners, resource customers, and specific end-use purchasers of materials generated in this region are being identified. *Additional discussion to refine potential businesses will be conducted as analytical results from Task 2.0 clarify potential within the Williston Basin.*

Task 4.3 – Analysis of Value Chain Segments. The results of the prior subtasks are being 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 includes the availability of infrastructure, industries, regulatory environment, financial institutions, markets, and more. *A key question remaining from the current funding will be further investigated: what value chain segments are most probable in the near and long term for the basin? Unlike other industries that begin with extraction from the ground, there is*

minimal required geographic concentration of activities. In such a situation, North Dakota could look to insert itself into the value chain at any or, potentially, all stages. There are several factors, typical to most economic development discussions in North Dakota and elsewhere, creating headwinds for this activity:

1) *Labor force availability*
2) *Investment capital*
3) *Regulatory hurdles*

Task 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 are being compiled into the results of the basinal strategies for infrastructure, industries, and business assessment. Discussions with potential customers and the economic assessment identify locations/markets/needs and distances from potential resources in the Williston Basin. An analysis of data gaps will then be completed. *Additional analysis developing job creation potential within the Williston Basin will be conducted under this proposal. Additional conversation will also take place with potential users identified with previous funding.*

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

Task 5.1 – Technology Discovery. Technology assessment efforts 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 and 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.

Task 5.2 – Technology Evaluation – Current State of the Technology. Technology assessment is occurring by determining/aggregating technology performance information, current state of development, feedstock applicability for the technologies, and available economics. Additional performance assessments are being developed using Aspen Plus, METSIM, and engineering costing methods for each process as available, and a cost-to-utilize for each resource is being 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.

***Task 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 identify 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 is being 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.

Task 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 are being identified (such as a TIC around ore refinement and purification).

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

Task 7.0 – Stakeholder Education and Outreach. Education and outreach activities inform and educate CORE-CM stakeholders of project learnings through regular correspondence and meetings. Stakeholders 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 facilitate knowledge sharing and support for program goals.

Task 7.1 – Stakeholder Identification and Engagement. Stakeholders with interest in the activities and assets of the Williston Basin across economic, governmental, and academic sectors are being identified and engaged. This includes 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 was held to launch the effort and provide initial networking opportunities.

Task 7.2 – Stakeholder Education and Outreach Plan Development. An outreach and education plan is being developed to support CORE-CM economic development activities. The plan incorporates best practices from previous EERC research projects to 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 lays the groundwork for workforce training and education for technicians, middle-skills workers, and STEM professionals.

Task 7.3 – Initial Plan Implementation. Key outreach materials are being developed and deployed to encourage audience understanding and engagement. An informative website and engaging documents

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 have been used at targeted meetings and regional networking events to describe the initiative's key aspects to stakeholders and potential partners. *To date, three webinars have been conducted to inform stakeholders and the general public on topics as explained above. Under this proposal, additional webinars targeted toward topics relevant to concerns in developing REE and CM supply chain segments within the Williston Basin will be conducted. It is anticipated that an additional five webinars will be planned. On October 11, 2022, the Critical & Rare-Earth Elements Symposium was held in Bismarck, North Dakota to provide an in-person platform to meet and discuss REE and CM potential in the Williston Basin. It provided an opportunity for legislators, regulators, industry, researchers, and the general public to collaborate in an open forum. Under this proposal, the symposium would also be held in the fall of 2023 and in late summer of 2024 to disseminate data, information, and analysis collected under the CORE-CM Program.*

Anticipated Results: The Williston Basin CORE-CM Initiative will establish 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 that comprises 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 275 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 Underway: 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.

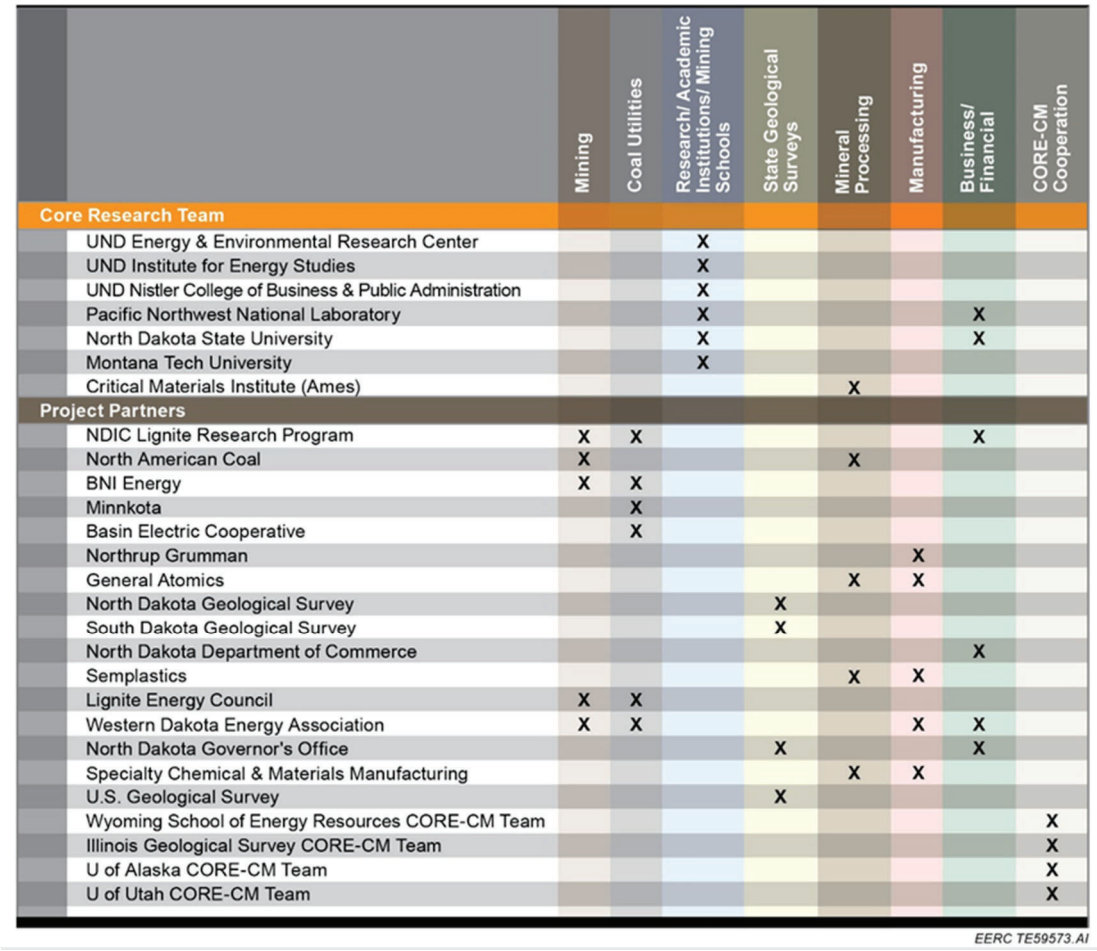
Why the Project Is Needed: The production of REEs is of critical importance to the national security of the United States. A REE industry, along with CMs and CBPs, would strengthen and support the existing North Dakota coal industry, provide an additional revenue stream and employer in North Dakota, 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 1) the 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. Information presented through discussions, webinars, and the symposium has already been successful in highlighting the potential of REEs and CMs within the Williston Basin.

BACKGROUND/QUALIFICIATIONS

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 2, and letters of support are included in



	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

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Figure 2. List of coalition team members.

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: NDIC, NACCO, BNI, Minnkota Power Cooperative, and Basin Electric Power Cooperative. Under this proposal for additional funding, BNI is providing in-kind cost share and DOE is also providing funding.

John Kay, EERC Principal Engineer, serves as principal investigator (PI). Mr. Kay has over 28 years of experience in coal research and has extensive project management and leadership experience. He has led the development of advanced analytical techniques for coal characterization and was the project manager (PM) for the Partnership for Plains CO_2 Capture (PCO_2C) Program. 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)
John Kay	PI; Task 1	Nolan Theaker, UND Institute for Energy Studies (IES)	Task 5 colead
Todd Brasel	Task 2 lead	Charlene Crocker	Task 7 lead
Bruce Folkedahl	Tasks 3 and 7 lead and Task 5 colead	John Harju	Project advisor
Jason Laumb	Task 4 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 Plains CO_2 Reduction (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.

UND 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. In addition to the members named above, the coalition team has an extensive group of cooperating partners and cost-share providers.

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. Kay 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 16-month program (June 1, 2023 – September 30, 2024). Figure 2 summarizes the preliminary program timetable. Additional timetable detail will be developed as the program evolves.

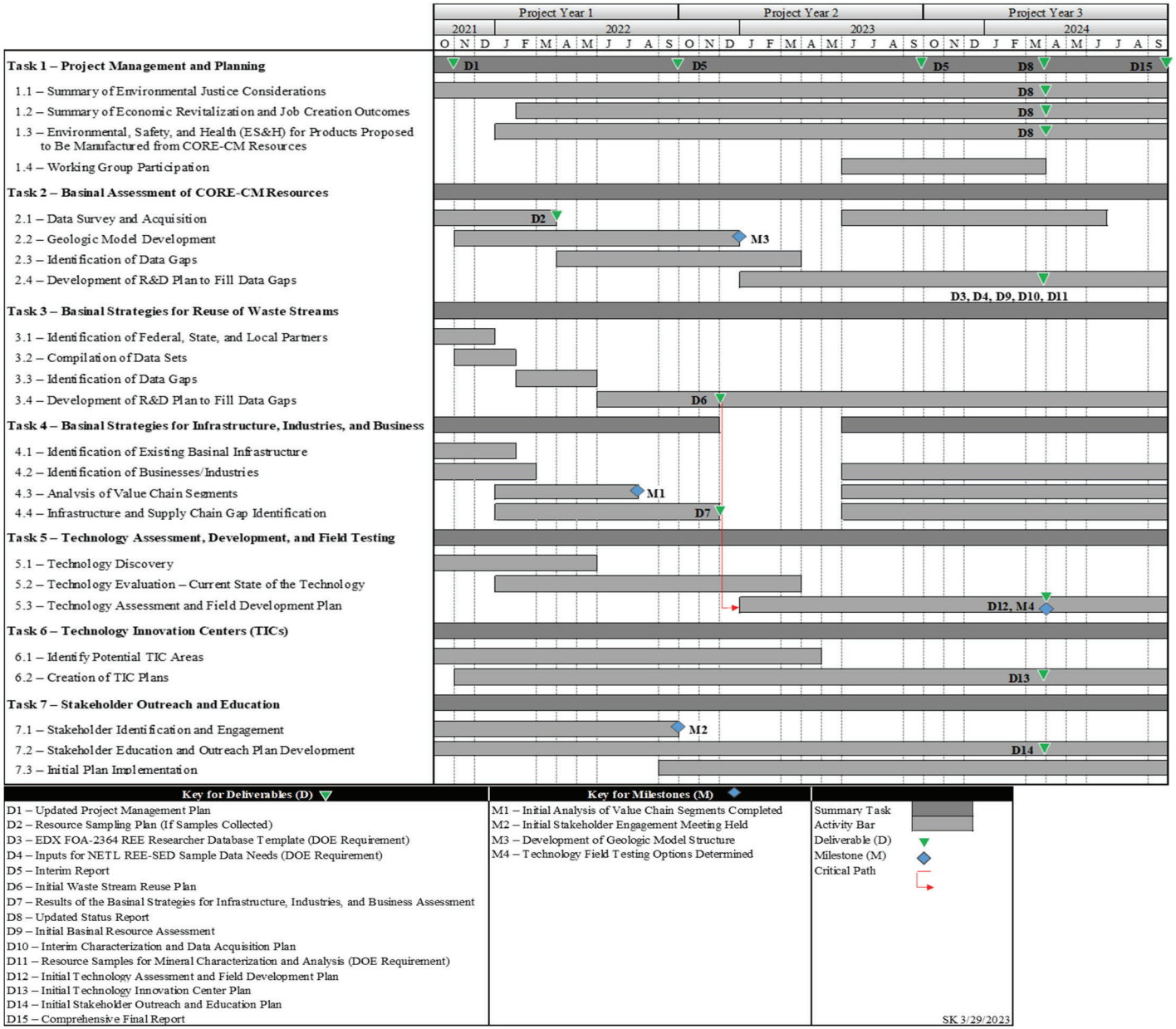

Figure 2. Preliminary timetable.

BUDGET AND MATCHING FUNDS

The estimated cost for the proposed effort is $2,100,000. The budget breakdown is given in Table 2. $1,050,000 of cash cost share is requested from NDIC's Lignite Research, Development and Marketing Program. BNI will provide in-kind cost-share funding in the amount of $500,000, with NACCO providing in-kind cost-share funding in the amount of $50,000. A letter of commitment for the cost share provided by BNI and NACCO 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. $125,000 of this cash cost-share request will be used to match the existing DOE Williston Basin CORE-CM Initiative, which is planned to end March 31, 2024. Deliverables for this program at that time will be delivered to NDIC's Lignite Research, Development and Marketing Program as interim reports with a final comprehensive report at the end of the project, September 30, 2024.

Table 2. Budget Breakdown

Project Associated Expense	NDIC Share (Cash)	DOE Share (Cash)	Total Project
Labor	$172,000	$265,374	$437,374
Travel	$18,937	$18,360	$37,297
Supplies	$0	$500	$500
Subcontractor - NDSU	$20,000	$0	$20,000
Communications	$100	$100	$200
Printing & Duplicating	$119	$108	$227
Food	$10,620	$0	$10,620
Rents & Leases - Bismarck State College	$5,000	$0	$5,000
Fee - Field Driller (TBD)	$320,000	$0	$320,000
Laboratory Fees & Services			
Natural Materials Analytical Research Lab	$14,943	$1,600	$16,543
Analytical Research Lab	$124,851	$39,446	$164,297
Document Production Services	$8,841	$1,533	$10,374
Engineering Services Fee	$555	$2,914	$3,469
Outside Lab	$572	$1,191	$1,763
Total Direct Costs	$696,538	$331,126	$1,027,664
Facilities & Administration	$353,462	$168,874	$522,336
Total Cash Requested	**$1,050,000**	**$500,000**	**$1,550,000**
In-Kind Cost Share			
BNI Energy	$500,000	$0	$500,000
North American Coal	$50,000	$0	$50,000
Total In-Kind Cost Share	**$550,000**	**$0**	**$550,000**
Total Project Costs	**$1,600,000**	**$500,000**	**$2,100,000**

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

North American COAL

March 28, 2023

Mr. John Kay
Principal Engineer
Energy & Environmental Research Center
University of North Dakota
15 N 23rd Street, Stop 9018
Grand Forks, ND 58201

Subject: Energy & Environmental Research Center Proposal "Williston Basin CORE-CM Initiative – Continued Assessment" Submitted to the Lignite Research Council (LRC).

Dear Mr. Kay:

North American Coal is excited for the opportunity to partner with the Energy & Environmental Research (EERC) team to support the critically needed characterization work to develop nascent resource estimates of rare-earth elements and other critical minerals (REE-CM) in North Dakota coals.

The overall goal of the project is to characterize lignite coal-bearing sequences to determine abundance and association of REE-CM that can be used to optimize the recovery of REE-CM extraction and concentrating processes. In this project, the EERC will work with North American Coal to collect samples from North American Coal mines and the EERC will analyze the samples and determine the abundance of REE-CM in major and minor coal seams. The project will begin in the summer of 2023 and go through the summer of 2024.

If awarded, North American Coal will participate in the proposed effort by 1) working with the EERC to provide samples for analytical characterization at the EERC and 2) provide industry and subject matter expertise pertaining to mining practices and industry insight into the techno-economic opportunities and key technical barriers limiting the economical production of REE-CM. North American Coal is prepared to commit to providing samples and technical and advisory support of this project to support the proposed testing at an estimated value of US$50,000.

On behalf North American Coal, we all look forward to working with the EERC on this promising project.

Sincerely,
THE NORTH AMERICAN COAL CORPORATION

Carroll L. Dewing
Vice President – Operations

MH

North American Coal
5340 Legacy Drive, Suite #300
Plano, TX 75024
972.448.5400 | Direct 701.323.3392
NACoal.com | carroll.dewing@nacco.com

BNI coal
A BNI ENERGY COMPANY

Mike Heger
General Manager
BNI Coal

March 21, 2023

Mr. John Kay
Principal Engineer
Energy & Environmental Research Center
University of North Dakota
15 N 23rd Street, Stop 9018
Grand Forks, ND 58201

Dear Mr. Kay:

Subject: Energy & Environmental Research Center Proposal "Williston Basin CORE-CM Initiative – Continued Assessment" Submitted to the Lignite Research Council (LRC).

BNI Coal, LTD (BNI), a subsidiary of BNI Energy Inc., is developing North Dakota's abundant lignite energy resource. At the Center Mine, BNI mines and reclaims about 200 acres a year to supply lignite coal to fuel the nearby Milton R. Young Generation Station. BNI has earned a reputation for industry leadership in delivering exceptional customer value. This reputation is supported by the values that we live every day.

BNI Coal is excited for the opportunity to partner with the Energy & Environmental Research (EERC) team to support the critically needed characterization work to develop nascent resource estimates of rare-earth elements and other critical minerals (REE-CM) in North Dakota coals. This work is needed to begin to evaluate the potential of a new industry in North Dakota of mining, extracting, and processing these REE-CM.

The overall goal of the project is to characterize lignite coal-bearing sequences to determine abundance and association of REE-CM that can be used to optimize the recovery of REE-CM extraction and concentrating processes. In this project, the EERC will work with BNI to collect drill core samples from BNI mines to analyze the samples and determine the abundance of REE-CM in major and minor coal seams (waste coal) and associated sediments. This information will be used to provide insight into the potential for lignite materials to be an economic source of REE-CM. The project will cover mine core drilling in both summer of 2023 and 2024.

If awarded, BNI will participate in the proposed effort by 1) working with the EERC to provide core drilling samples for analytical characterization at the EERC and 2) provide industry and subject matter expertise pertaining to mining practices and industry insight into the techno-economic opportunities and key technical barriers limiting the economical production of REE-CM. BNI is prepared to commit to providing samples and technical and advisory support of this project to support the proposed testing at an estimated value of US$500,000.

On behalf of BNI, we all look forward to working with the EERC on this promising project.

Sincerely,

Mike Heger
General Manager, BNI Coal

APPENDIX B

RESUMES OF KEY PERSONNEL

JOHN P. KAY
Principal Engineer, Emissions and Carbon Capture Group Lead
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, North Dakota 58202-9018 USA
701.777.4580, jkay@undeerc.org

Principal Areas of Expertise

Mr. Kay's principal areas of interest and expertise include rare-earth element (REE) and critical mineral (CM) availability in the Williston Basin and applications of solvents for removing CO_2 from gas streams to advance technology with a look toward transformational concepts and techno-economic assessments. He has 2 years of experience managing a multimillion-dollar REE/CM project and 12 years of experience in field testing site management and sampling techniques for hazardous air pollutants and mercury control in combustion systems, along with 10 years of experience utilizing scanning electron microscopy (SEM), x-ray diffraction (XRD), and x-ray fluorescence (XRF) techniques to analyze coal, fly ash, biomass, ceramics, and high-temperature specialty alloys. He is also interested in computer modeling systems and high-temperature testing systems.

Education and Training

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

Research and Professional Experience

2011–Present: Principal Engineer, Emissions and Carbon Capture Group Lead, EERC, UND. Mr. Kay's responsibilities include management of CO_2 separation research related to bench-, pilot-, and demonstration-scale equipment for the advancement of technology. This also includes the development of cleanup systems to remove SO_x, NO_x, particulate, and trace elements to render flue gas clean enough for separation. REE and CM concentrations in the Williston Basin, extraction techniques, and development of supply chains for them are also a focus.

2005–2011: Research Manager, EERC, UND. Mr. Kay's responsibilities included the management and supervision of research involving the design and operation of bench-, pilot-, and demonstration-scale equipment for development of clean coal technologies. The work also involved the testing and development of fuel conversion (combustion and gasification) and gas cleanup systems for the removal of sulfur, nitrogen, particulate, and trace elements.

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

methods in high-temperature environments; and performing field work related to mercury control in combustion systems.

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

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

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

Professional Activities
Member, ASM International
Member, American Ceramic Society
Member, Microscopy Society of America

Publications
Mr. Kay has authored or coauthored numerous publications.

TODD A. BRASEL
Principal Geoscience Data and Software Manager
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, North Dakota 58202-9018 USA
701.777.5285, tbrasel@undeerc.org

Principal Areas of Expertise

Mr. Brasel's principal areas of interest and expertise is in geoscience applications and data analysis through the development and management of geoscience applications, database systems, data analysis, and data visualization systems; creating impactful process improvements utilizing data analytic tools and methods; implementing workflow improvements in multiple areas of application and data management; and possessing expert knowledge working with large data sets and geoscience application systems.

Education and Training

B.S., Geology, Oklahoma State University, 1993.

Research and Professional Experience

September 2021–Present: Principal Geoscience Data and Software Manager, EERC, UND. Mr. Brasel's responsibilities include managing information technology; working with contracts staff to procure, manage, and maintain geoscience and other software licenses; developing and maintaining databases; and organizing and managing geoscience data in support of EERC projects.

2015–2020: Exploration Geologist/Analyst, Atalaya Resources, Tulsa, Oklahoma. Mr. Brasel's responsibilities included evaluating new resource plays and potential bolt-on acreage for exploration and production (E&P) startup; developing growth opportunities through land acquisitions and drilling of existing land inventory; developing data analysis methods using data analytics platforms; and providing management of geoscience software applications and internal data management processes. Mr. Brasel managed geoscience applications and data in terms of software (licensing, infrastructure needs, installs, troubleshooting, enhancement request, data imports/exports, end-user training) and data (licensing, geoscience data repositories, data manipulation workflows, process improvements). He created compelling presentations for prospective development opportunities; assisted the land department with leasing, permitting, and surveying activities; led the geologic assessment of areas of interest (AOIs) that resulted in leasing and subsequent sale of assets for six times the purchase amount ($30MM); extended horizontal Tonkawa Sand Play that delivered 20+ drilling prospects to drilling inventory; steered horizontal wells with a 95% success rate; developed data analysis methods for play evaluation using TIBCO Spotfire data analytics platform by filtering large data sets into insightful dashboards; established data governance practices around geoscience mapping and engineering data across all company departments; and established workflows for geoscience and engineering data structure and updates into various systems.

2012–2015: Development Geologist, Apache Corporation, Tulsa, Oklahoma. Mr. Brasel's responsibilities included leading the development of assets in northwest Oklahoma and Texas Panhandle Marmaton Lime Play and Cherokee Lime Play; collaborating with an integrated team of engineers, landmen, and geophysicists to develop fractured carbonate reservoirs; presenting prospects to management for weekly drilling approval meeting; running a multi-rig extended lateral horizontal drilling program, which led to drilling 10 wells throughout the AOI; and preparing annual team budgets for regional management and corporate office. Mr. Brasel drilled the top performing Marmaton Lime well in Ochiltree County, Texas; drilled all wells under budget, which resulted in 25% savings in drilling cost over the life of the project; developed horizontal well planning practices for geologic teams to ensure wells were landed and drilled within the target window, which led to more efficient well planning and better in-zone drilling accuracy; and trained geologists in groups and one-on-one scenarios on Petra geographic information system (GIS) mapping software, which led to more proficient software skills for staff.

2006–2012: Geoscience Applications and Data Manager, WPX Energy, Tulsa, Oklahoma. Mr. Brasel's responsibilities included serving as the Software Account Manager for a multi-office Energy Company that managed the full software life cycle from licensing and implementation to end-user support; interfacing with the IT department and clients to understand business drivers and to ensure solutions were consistent with business needs; advocating for client's technology requirements; and leading software evaluations. He served as project lead for geoscience infrastructure build-out, which included decommissioning servers managed by IBM and designing new systems for E&P geoscience software portfolio, and all project metrics including timeline, downtime, and system requirements were achieved. Mr. Brasel managed full life cycle seismic data management for multiple offices, including inventory database, physical data (tapes and other media), license contracts, processing, data licensing, and infrastructure needs; managed geoscience databases, including well log data (LAS/Raster), core data, directional surveys, and other digital files; designed and implemented geoscience data management workflows that led to improved business processes; provided software support for customers and solicited enhancement request to vendors Voice for Client; and evaluated new technology needs for the geoscience department and implemented technology into the workflows for staff.

1997–2006: Geoscience Applications and Data Analyst, Newfield Exploration, Tulsa, Oklahoma. Mr. Brasel's responsibilities included managing large landmark and Petra databases for geoscience staff; loading well/seismic data, tops data, building cross section, and geologic maps; developing corporate data repositories for LAS, raster images, petrophysical data, and seismic data; providing training resources for geoscience staff that included in-house training and off-site training. He served as project lead for large seismic data inventory management system design and implementation; migrated 12,000 miles of 2D and 500 square miles of 3D tape data to current media standards; built a back-end database and front-end GIS web-based search and retrieval tool to access data more efficiently. Mr. Brasel imported/exported data between geoscience systems; kept systems updated with weekly well data imports from vendor/internal sources; performed data prep/cleaning; improved data management workflows; developed database inventory systems for geoscience assets, including LAS, seismic, checkshot, drilling and completion data, directional surveys, and core meta data; coordinated all vendor in-house training programs for geoscience staff to improve software proficiency and created processes that increased data access, accuracy, completeness, and security for multidiscipline teams.

DR. BRUCE C. FOLKEDAHL
Principal Research Engineer, Critical Minerals
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, bfolkedahl@undeerc.org

Principal Areas of Expertise

Dr. Folkedahl's principal areas of interest and expertise include rare-earth element (REE)/critical materials (CMs) extraction/purification from coal/coal combustion products (CCPs) and traditional source materials for REEs/CMs; development and characterization of coal/ceramic/plastic composites for construction products; combustion/gasification in conjunction with electricity generation; fundamental mechanisms of ash deposition/fouling/fine particulate and aerosol formation/emission during combustion; corrosion/development of high-temperature materials to withstand aggressive combustion; 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.

Education and Training

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

Research and Professional Experience

2001–Present: Principal Research Engineer, Critical Minerals, EERC, UND.

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 and developing automated dry powder-handling system for a slurry-making process.

Publications

Dr. Folkedahl has authored or coauthored numerous professional publications.

JASON D. LAUMB
Director of Advanced Energy Systems Initiatives
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, ND 58202-9018 USA
701.777.5114, jlaumb@undeerc.org

Principal Areas of Expertise

Mr. Laumb's principal areas of interest and expertise include renewable energy, CO_2 capture, techno-economic modeling, extraction of critical materials, environmental control systems, supercritical CO_2 power cycles, and advanced gasification technologies. His experience includes biomass and fossil fuel conversion for energy production, with an emphasis on ash effects on system performance; trace element emissions and control for fossil fuel combustion systems, with a particular emphasis on air pollution issues related to mercury and fine particulates; and design and fabrication of bench- and pilot-scale combustion and gasification equipment.

Education and Training

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

Research and Professional Experience

May 2021–Present: Director of Advanced Energy Systems Initiatives, EERC, UND. Mr. Laumb provides leadership on projects related to advanced energy systems and leads a multidisciplinary team of scientists and engineers working on advanced energy technologies from pollution control to new energy platforms.

September 2019–April 2021: Assistant Director of Advanced Energy Systems, EERC, UND. Mr. Laumb assisted the EERC executive team by providing leadership on projects related to advanced energy systems. Mr. Laumb led a multidisciplinary team of scientists and engineers working on advanced energy technologies from pollution control to new energy platforms. Specific areas of interest included CO_2 capture, techno-economic modeling, environmental control systems, supercritical CO_2 power cycles, and advanced gasification technologies. Research activities focused on low-carbon-intensity power cycles for fossil fuel-fired systems.

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.

Professional Activities
Member, American Chemical Society

Publications
Mr. Laumb has coauthored numerous professional publications.

DR. JOHN A. HARJU
Vice President for Strategic Partnerships
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, North Dakota 58202-9018 USA
701.777.5157, jharju@undeerc.org

Principal Areas of Expertise

Dr. 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.

Education and Training

Ph.D., Petroleum Engineering, University of North Dakota, 2022.
M.Eng., Petroleum Engineering, University of North Dakota, 2020.
B.S., Geology, University of North Dakota, 1986.

Research and Professional Experience

2002–Present: EERC, UND.
July 2015–Present: Vice President for Strategic Partnerships. Dr. 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. Dr. 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. Dr. 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. Dr. 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. Dr. 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. Dr. 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. Dr. 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).

Professional Activities
Member, National Coal Council (appointed 2018)
Member, National Petroleum Council (appointed 2010)
Member, Mainstream Investors, LLC, Board of Governors (2014–present)
Member, DOE Unconventional Resources Technology Advisory Committee (2012–2014)
Member, Interstate Oil and Gas Compact Commission (appointed 2010)
Member, Rocky Mountain Association of Geologists

Publications
Dr. Harju has authored or coauthored more than 100 professional publications and nearly 300 technical presentations.

CHARLENE R. CROCKER
Senior Research Scientist, Outreach Team Lead
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, North Dakota 58202-9018 USA
701.777.5018, ccrocker@undeerc.org

Principal Areas of Expertise

Ms. Crocker's principal areas of interest and expertise span public outreach and scientific research activities. Public outreach programs have focused on fossil energy transformations, carbon dioxide emissions, recovery of critical minerals and elements from coal and fossil energy waste streams, water quality and use, and fish consumption advisories and include general public and K–12 education and documentary development, writing, and production. Research areas have focused on trace element emissions and control for fossil fuel combustion systems, with a particular emphasis on air pollution issues related to mercury and fine particulates. This includes developing carbon-based mercury control sorbents; mercury and halogens in coal combustion; and airborne particulate matter instrumentation. Ms. Crocker has experience in water quality monitoring, analytical methods, and education; development and implementation of fish consumption surveys; laser-induced breakdown spectroscopy (LIBS); atomic absorption spectroscopy (AAS) (flame; graphite furnace, and hydride generation); inductively coupled plasma (ICP) spectroscopy; trace element analysis of water, coal, and coal by-products; and atomic fluorescence spectroscopy (AFS).

Education and Training

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

Research and Professional Experience

2002–Present: Senior Research Scientist, Outreach Team Lead, EERC, UND. Ms. Crocker's responsibilities include managerial and principal investigator duties for projects related to public outreach and scientific research. With respect to outreach, this included the development of public outreach programs for CO_2 sequestration, water, and fish advisories and the development of CO_2 sequestration public outreach materials, water quality education, and a water-based geoscience education program and outreach activities for middle and high school students. Research responsibilities included projects related to development of sorbents for emission control strategies in fossil fuel-fired energy systems; projects related to environmental management and air quality; collaborating with other scientists on the development of carbon-based flue gas sorbents, particulate matter (PM) sampling, evaluation of bioassessment tools, fish consumption survey development, proposal and report writing, data analysis, presentation of results, and budget tracking; developing PM-sampling protocols; and directing the activities of student assistants. Specific roles and activities include the following:

- Outreach Task Lead for the U.S. Department of Energy (DOE)–North Dakota Industrial Commission (NDIC)-funded Williston Basin CORE-CM (Carbon Ore, Rare Earth Elements,

and Critical Minerals) project. Activities include public outreach materials and messaging development; oversight of annual symposia and webinars; and support for research and fieldwork associated with project activities in the Williston Basin, North Dakota, South Dakota, and Montana.

- Program Coordinator and student supervisor for the EERC Energy Hawks internship program, funded by the State Energy Research Center at the EERC. Activities include development and implementation of an energy literacy syllabus for a multidisciplinary team of graduate and undergraduate students during a 10-week internship; supervision of student activities; and guidance in the development of white papers focused on value-added energy topics for North Dakota.

- Outreach Task Lead for the North Dakota CarbonSAFE Phase III project, funded by DOE, NDIC, Minnkota Power Cooperative, and BNI Energy. Activities include public outreach materials development and support for research and fieldwork associated with permanent CO_2 storage project activities in central North Dakota.

- Outreach Task Lead for DOE-,NDIC-, Red Trail Energy (RTE)-funded Phase III Integrated Carbon Capture and Storage for North Dakota Ethanol Production project. Activities include public outreach materials development and support for research and fieldwork associated with permanent CO_2 storage project activities in Stark County, North Dakota.

- Outreach Task Lead and team member for the North Dakota CarbonSAFE Phase II project, funded by DOE, NDIC, Minnkota Power Cooperative, Basin Electric Power Cooperative, BNI Energy, North American Coal, and ALLETE Clean Energy. Activities include public outreach materials development and support for research and fieldwork associated with permanent CO_2 storage project activities in central North Dakota.

- Outreach Team member for the Wyoming CarbonSAFE Phase II project, funded by DOE, Basin Electric Power Cooperative, et al. Activities include public outreach materials development and consulting for research and fieldwork associated with permanent CO_2 storage project activities in central North Dakota.

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

1993–1994: Research Assistant, EERC, UND. Ms. Crocker's responsibilities included preparing and analyzing ultratrace element samples in inorganic media; performing research on ultratrace element analysis of mercury in air using AFS; and preparing reagents and solutions.

1990: Naturalist, Deep Portage Conservation Reserve, Hackensack, Minnesota. Ms. Crocker's responsibilities included planning and conducting environmental education programs for children and adults; evaluating curriculum; and organizing lending of educational learning stations.

1988–1990: Sanctuary Manager, Wetlands, Pines & Prairie Audubon Sanctuary, Warren, Minnesota. Ms. Crocker's responsibilities included planning and conducting environmental education programs; organizing chapter meetings; publishing the Sanctuary newsletter; and performing administrative tasks.

1988: Park Ranger/Interpreter, Boston Harbor Islands State Park, Boston, Massachusetts. Ms. Crocker's responsibilities included interpreting natural and human history; developing special programs and leading walking tours of the islands; and conducting school programs.

Publications

Ms. Crocker has authored and coauthored over 50 publications.

Nolan L. Theaker

Technical Group Manager – Critical Minerals, Institute for Energy Studies
University of North Dakota, Grand Forks, ND 58202

Education and Training

University of Louisville	Chemical Engineering	B.S. 2016
University of Louisville	Chemical Engineering	M.Eng. 2017
University of North Dakota	Chemical Engineering	Pursuing PhD

Research and Professional Experience

2017-Present Technical Group Manager, UND Institute for Energy Studies.

Responsibilities include high-level innovative research and development of novel concepts for submission of funding proposals. Coordinated and led efforts associated with downstream rare earth element concentration operations that have resulted in the development of final process flow diagrams and process designs. Principle Investigator to $6.5M pilot-scale REE extraction and concentration project, as well as PI/Co-PI on 7 other proposals, managing up to $10M in total project funds involving pilot-scale design, construction, and operation; resource identification and quantification; engineering-scale economic and engineering analyses; and novel process development and commercialization. Key contributor/PI to multiple proposals involving REE/CM extraction and/or concentration from multiple, conventional and unconventional feedstocks. Proposed efforts associated with coal conversion and value improvement using chemical/thermal methods. Co-PI for project involving CO_2 utilization from coal-derived flue gases.

2016-2017 Research Assistant, University of Louisville Conn Center.

Research involved design and operation of multi-stage electrochemical reactor scheme for efficient production of fuels from CO_2. Developed nano-functionalized electrocatalysts for improvements in activity and selectivity for targeted reactions in two phase reaction systems. Implemented phase-segregation devices for multi-step electrochemical reaction system, with planned production cost below research benchmarks to date.

2014-2015 Co-op Engineer, University of Kentucky CAER.

Research involved improvement and operation of a DOE bench-scale CO_2 capture unit in multiple reaction conditions, including enzymatic and amine-based systems. Evaluation and comparison of catalyst performance in a holistic view for CO_2 capture was conducted, including novel organic and enzymatic catalysts. Implemented system changes for improved user functionality of the system, including development of control systems and equipment selection for easy manual usage.

Publications/Presentations

1. **Theaker, N.**, Strain, J. M., Kumar, B., Brian, J. P., Kumari, S., & Spurgeon, J. M. (2018). Heterogeneously Catalyzed Two-Ctep Cascade Electrochemical Reduction of CO_2 to Ethanol. *Electrochimica Acta, 274*, 1-8. doi:10.1016/j.electacta.

2. 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.

3. Dong, Z; Deblonde, G; Middleton, A; Hu, D; Dohnalkova, A; Kovarik, L; Qafoku, O; Shutthanandan, S; Jin, H; Hsu-Kim, H; **Theaker, N**; Jiao, Y; Park, D. "Microbe Encapsulated Silica Gel Biosorbent for Selective Extraction of Scandium from Coal Byproducts." *Environmental Science and Technology.* 2021.
4. Mann, M; **Theaker, N**; Benson, S; Palo, D. "Investigation of Rare Earth Element Extraction from North Dakota Coal-Related Feedstocks – Final Report". Submitted March 31, 2020.
5. Mann, M., **Theaker, N.**, Ling, A., Haugen, C., Winburn, R., Brewer, J., Benson, S., Benson, A., James, D., Goven, G., Koenig, A, Srinivasachar, S. "Feasibility Study of a One Tonne per day Rare Earth Extraction and Concentration Plant from Low-Rank Coal Resources." Submitted January 28, 2022.
6. **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 9th, 2019. Pittsburgh, PA.
7. **Theaker, N.** "Extraction of Rare Earth Elements from Lignite Coal – Kinetics of Extraction and Bench-Scale Updates." 2019 Annual Society of Mining Engineering" Presented February 2, 2019.
8. Zygarlicke, C; Folkedahl, B; Feole, I; Kurz, B; **Theaker, N**; Benson, S; Hower, J; Eble, C. "Rare-Earth Elements (REEs) in U.S. Coal-Based Resources: Sampling, Characterization, and Round-Robin Interlaboratory Study – Final Report". Submitted September 30th, 2019.
9. Gautam, M; Hofsommer, D. T; **Theaker, N**; Paxton, W. F; Grapperhaus, C. A; Spurgeon, J. M. "The effect of flue gas contaminants on electrochemical reduction of CO2 to methyl formate in a dual methanol/water electrolysis system." Chem Catalysis, 2022.
10. Spurgeon, J; **Theaker, N**; Phipps, C; Uttarwar, S; Grapperhaus, C. A. "A Comparative Technoeconomic Reduction of CO2 with Methanol to Produce Methyl Formate." ACS Sustainable Chemistry & Engineering, 2022.

Patents/Applications:

1. Theaker, Nolan; Laudal, Dan. 2020. Method for Leaching Rare Earth Elements and Critical Minerals from Organically Associated Materials. USA. 63/112,846A, filed Nov. 12, 2020.
2. Theaker, Nolan; Laudal, Dan; Lucky, Christine. 2020. Generation of Rare Earth Elements from Organically-Associated Leach Solutions. USA. 63/112,842A, filed Nov. 12, 2020.

Synergistic Activities

Mr. Theaker's principal area of research interest include energy, fuels, and alternative critical material research. These include developing alternative uses and sources of fuels and valuable materials, both carbon and mineral based, as well as developing new and unconventional sources of energy-critical materials.

APPENDIX C

BUDGET NOTES

BUDGET NOTES

ENERGY & ENVIRONMENTAL RESEARCH CENTER (EERC)

BACKGROUND

The Energy & Environmental Research Center (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.

Equipment: If equipment (value of $5000 or more) is budgeted, it is discussed in the text of the proposal and/or identified more specifically in the accompanying budget detail.

Supplies: 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.

Subcontractor - NDSU: Project partner to provide technical assistance in determining business boundary gaps, provide job creation projections, and collect information on regulatory hurdles. Cost is based on prior experience with similar projects.

Professional Fee: Not applicable.

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: Food will be purchased for the annual symposium in Bismarck. EERC employees in attendance will not receive per diem reimbursement for meals that are paid by project funds. The estimated cost is based on previous experience.

Rents & Leases – Bismarck State College: Facilities will be rented from Bismarck State College for hosting the annual symposium. The estimated cost is based on previous experience.

Fee – Field Drilling (TBD): Field drilling entity, which has not yet been determined, will be utilized to collect drill cores at field locations specified by the project. The estimated cost is based on previous experience.

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

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.

Document production services recharge fees are based on an hourly rate for production of such items as report figures, posters, and/or images for presentations, maps, schematics, website 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.

Geoscience services recharge fees are discipline fees for costs associated with training, certifications, continuing education, and maintaining required software and databases. The estimated cost is based on the number of hours budgeted for this group of individuals.

Software solutions services recharge fees are for development of customized websites and interfaces, software applications development, data and financial management systems for comprehensive reporting and predictive analysis tools, and custom integration with existing systems. The estimated cost is based on prior experience with similar projects.

Field safety fees cover safety training and certifications, providing necessary PPE, and annual physicals. The estimated cost is based on the number of days individuals are budgeted to work in the field.

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.

Cost Share: DOE will be provided $500,000 of cash cost share. BNI Energy will be providing $500,000 of in-kind cost share in the form of providing samples and technical and advisory support. North American Coal Corporation will be providing $50,000 of in-kind cost share in the form of providing samples and technical and advisory support.