

AGENDA
LIGNITE RESEARCH COUNCIL MEETING
GRANT ROUND LRC (108)

Tuesday, November 18, 2025 - 1:30 p.m. (CT)

Bismarck State College – National Energy Center of Excellence Room #335
1200 Schafer St., Bismarck, ND 58501

I. Call to Order – Jonathan Fortner

Introduction of New Lignite Research Council Committee Members:

- Representative Anna Novak (ND Legislature Representative)
- Senator Keith Boehm (ND Legislature Representative)

Introduction of New NDIC Staff Member Presented by Jordan Kannianen:

- Carmen Devney

II. Approval of Minutes

LRC Grant Round, May 7, 2025 – Jonathan Fortner

- ACTION ITEM: Approval of Minutes

III. Updates

- Project Management and Financial Report – Jordan Kannianen

IV. Presentation of Proposals:

Project 108A

- Introduced by Jordan Kannianen
- R&D and EPP overview, presentation, and continuation – Mike Holmes

LRC-108A: Enhance, Preserve, and Protect the North Dakota Coal Industry

Submitted by: LEC

Principal Investigator: Mike Holmes

Request for: \$3,316,695

Total Project Costs: \$3,316,695

Project Duration: 36 months

- Technical Peer Reviewers' Ratings
- Technical Peer Reviewers' Comments and Applicant's Response
- Summary and Recommendation

Project 108B

- Introduced by Mike Holmes
- Presented by Nolan Theaker

LRC-108B: Pilot Expansion and Testing for Improving Lignite Fuels and REE Processing

Submitted by: UND

Principal Investigator: Nolan Theaker

Request for: \$1,100,000

Total Project Costs: \$2,200,000

Project Duration: 24 months

- Technical Peer Reviewers' Ratings
- Technical Peer Reviewers' Comments and Applicant's Response
- Summary and Recommendation

Project 108C

- Introduced by Mike Holmes
- Presented by Alex Benson

LRC-108C: Efficient Refining of Germanium Metal from Fly Ash-Derived Concentrates

Submitted by: Microbeam

Principal Investigator: Alex Benson

Request for: \$400,000

Total Project Costs: \$1,200,000

Project Duration: 24 months

- Technical Peer Reviewers' Ratings
 - Technical Peer Reviewers' Comments and Applicant's Response
 - Summary and Recommendation
-

V. Voting Process

ACTION ITEM: Voting on Proposals

VI. Executive Committee

- Consideration of including Executive LRC representatives in the Technical Advisor transition and selection.

ACTION ITEM: Technical Advisor Transition Process

VII. Voting Results and Other Business

VIII. 2025/2026 Calendar

- Industrial Commission Meeting: November 25, 2025
- Spring Grant Deadline – April 1, 2025
- Spring LRC Meeting – May 12, 2026

IX. Adjourn

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MEETING MINUTES

LIGNITE RESEARCH COUNCIL – GRANT ROUND 107

Wednesday, May 7, 2025 – 1:30 p.m. (CT)

Bismarck State College NECE Room 335 or Microsoft Teams

LRC VOTING MEMBERS PRESENT:

Jonathan Fortner – Lignite Energy Council, Chairman
Jay Kost – The Falkirk Mining Company
Mike Heger – BNI Energy
Ethan Vaagene – Rainbow Energy Center
Reese Boehm – Nexus Line, LLC
Darcy Neigum – Montana Dakota Utilities Co.
Randy Christmann – North Dakota Public Service Commission
Tom Oakland – North Dakota Commerce
Dave Glatt – NDDEQ
Donn Steffen - Coyote Creek Mine
Trinity Turnbow – Dakota Gasification
Gavin McCollam-Basin Electric Power Company
Brad Zimmerman – Otter Tail Power Company
Todd Porter – North Dakota House of Representatives
Charlie Gorecki - EERC
Dale Patten – North Dakota Senate
Bill Sawyer – ALLETE (on-line)
Joseph Heringer – Land Board
Rita Faut – North Dakota Farm Bureau (on-line)
Brad Hawk-Indian Affairs Commission
Ed Murphy – North Dakota Geological Survey
John Phillips-ND Coal Conversion Counties Assn.

OTHERS PRESENT:

Jordan Kannianen – North Dakota Industrial Commission
Brenna Jessen – North Dakota Industrial Commission
Erin Stieg – North Dakota Industrial Commission
Mike Holmes – Lignite Research Council
Angie Hegre - Lignite Energy Council
Geoff Simon – WDEA
Alison Riter - WDEA
Andy Freidt – Minnkota Power Cooperative
Brad Erickson – North American Coal – Coteau
Jason Laumb - EERC (presenter)
Tony Snyder – EERC (presenter)
Greg Henthorn – AmeriCarbon
Joseph Harris - Bismarck Tribune

I. CALL TO ORDER

Meeting called to order:

Lignite Research Council (LRC) Chairman Jonathan Fortner called the meeting to order at 1:33 p.m. (CT) on May 7, 2025.

Fortner introduced the new LRC appointees to the committee.

New LRC appointees:

- Jonathan Fortner, Lignite Research Council (Research Representative)
- Brad Zimmerman, Otter Tail Power Company (Processing Representative)
- Donn Steffen, Coyote Creek Mine (Mining Representative)
- Darcy Neigum, Montana-Dakota Utilities Company (Processing Representative)
- Ethan Vaagene, Rainbow Energy Center (Processing Representative)
- Trinity Turnbow, Dakota Gasification Company (Processing Representative)
- Reese Boehm, Nexus Line LLC (Transmission Representative)

II. APPROVAL OF MINUTES

Approval of March 17, 2025, LRC Meeting Minutes:

Fortner requested a motion to approve the minutes from the above-listed meeting. Randy Christmann so moved; seconded by John Phillips, motion carried.

III. UPDATES

Program Management & Financial Report:

Jordan Kannianen shared the financial summary for the Lignite Research, Development, and Marketing Program. (A copy of the financial summary is available in the Lignite Research Program files and the meeting packet provided.)

Kannianen displayed a high-level dashboard view summary of all the Industrial Commission-managed funds to the committee. Kannianen shared that the Lignite Research Fund availability as of May 2025, is \$6.5 million, which is the amount available to commit to new projects. Kannianen shared that there are two projects before the committee today with an ask of \$2.9 million.

Kannianen brought forth to the committee the Lignite Research fund cash balance of \$28.9 million with \$22.4 million of that having outstanding project commitments. Kannianen shared that the total of \$6.5 million is uncommitted and available while considering new projects.

For the Lignite Research Fund, Kannianen provided a cumulative view of the fund. Since the program's inception in 1987, 261 cumulative projects have been funded. Each of those projects brings private capital and private match back to the state of North Dakota. That private match has equaled \$2.8 billion project value that has been invested in the state of ND, thanks to projects approved through this program. Currently, there are 20 active projects.

In addition, Kannianen shared the 2023-2025 biennium appropriation and forecasted income. Sharing a graphic showing the Lignite research fund money coming from the Coal Severance Tax, Coal Conversion Tax, Research Tax, and formula funding from Oil Production and Extraction Taxes, showing a total of \$18.5 million through the course of the biennium. Of which \$16.7 million to date.

The financial data was emailed before the meeting to the LRC members.

R&D Overview

Holmes provided an overview of current and historical efforts under the Lignite Research, Development & Marketing Program. He highlighted several long-standing technical challenges that

have been successfully addressed through past research investments, noting the importance of the Lignite Industry Technology Roadmap in guiding priorities and ensuring alignment with industry needs.

He reviewed the portfolio of active projects, outlining the range of technology areas currently supported by the program. These include environmental improvements, operational reliability, value-added products, carbon management, and next-generation coal utilization initiatives. Holmes emphasized that the active portfolio reflects strong collaboration among industry, universities, and state partners.

Holmes also presented the funding status for active projects, summarizing total program commitments and the distribution of state and industry cost-share. He noted that projects continue to leverage significant non-state funding, underscoring the value and competitiveness of the program.

IV. CONSIDERATION OF PROJECTS – MIKE HOLMES

LRC-107A: Development of Next-Generation Carbon Capture Technologies for Efficiency Improvement and Cost Reduction

Submitted by: EERC

Principal Investigator: Tony Snyder

Request for: \$1,462,500

Total Project Costs: \$6,095,833

Project Duration: 1 year

The EERC is proposing the first year of a five-year project to augment their existing carbon dioxide test systems as part of efforts to reduce costs, mitigate risks, and accelerate the deployment of cost-effective commercial-scale carbon capture systems. The EERC has received funding from the DOE and industry support, providing the leveraging of NDIC project funding. The current evaluations of commercial readiness have identified uncertainties in equipment needs and economic challenges. This project would work toward addressing these areas before large commercial investments are made.

Holmes shared that all three reviewers recommended funding. The proposal received an average score of 222.3 out of 250. Holmes stated this project is a great fit for the LRP, as part of the pursuit of carbon capture, utilization and storage (CCUS) options for North Dakota's lignite industry. Commercial applications are challenged by technical and economic risks that the extended project could address. Holmes shared that the funding would be subject to the Technical Advisor participating in the project reviews and reviews the project management plan with the project team. The project leverages state funding by obtaining funding from the DOE and industry. Holmes stated the conflicts of interest included EERC, North American Coal, and BNI.

Jason Laumb and Tony Snyder from EERC presented on behalf of the applicant.

A copy of the PowerPoint presentation is available in the LRP files.

LRC-107B: Commercial Plant Design Optimization: Lignite to Critical Carbon Materials

Submitted by: AmeriCarbon

Principal Investigator: Greg Henthorn

Request for: \$1,499,653

Total Project Costs: \$2,999,653

Project Duration: 1 year

Holmes shared AmeriCarbon is proposing a one-year project to complete the engineering design for a first-of-a-kind commercial facility to convert ND lignite into ECO-Pitch™ for use in carbon materials. Their technology would make coal tars and pitch for use in production of graphite, asphalt binder, and other carbon materials. They are evaluating the opportunity for an initial plant in McLean County, ND. The proposed work builds on pilot-scale operations, prior engineering design, and previous NDIC-supported Research. The end goal is to position AmeriCarbon and its partners to proceed with the execution phase of the project, pending investment and standard contingencies.

Holmes shared that all three of the technical reviewers recommended funding, and the proposal received an average score of 233.3 out of 250. The project would leverage state funding through funding from the project participants. Holmes stated that AmeriCarbon is proposing to optimize their commercial design as they move toward commercial application in North Dakota. Their technology would make coal tars and pitch for use in production of graphite, asphalt binder, and other carbon materials. The technology could provide spin-off manufacturing opportunities in the state, and would integrate well with rare earth and critical mineral opportunities, as well as other emerging market opportunities for North Dakota lignite. This project would provide 50% match with in-kind funding from AmeriCarbon and in-kind cost services from North American Coal.

Holmes shared that the funding would be subject to the Technical Advisor participating in the project reviews and reviews the project management plan with the project team. Holmes stated the conflicts of interest include North American Coal-Falkirk Mine.

Greg Henthorne presented on behalf of the applicant.

A copy of the PowerPoint presentation is available in the LRP files.

A motion to waive the conflict of interest for members was made by Charlie Gorecki and seconded by Dale Patton; the motion carried.

V. Voting Process – Ballots distributed, returned and tabulated.

VI. RESULTS

LRC-107A: Development of Next-Generation Carbon Capture Technologies for Efficiency Improvement and Cost Reduction

Submitted by: EERC

Fund: 21

Do Not Fund: 0

Abstain: 0

LRC-107B: Commercial Plant Design Optimization: Lignite to Critical Carbon Materials

Submitted by: AmeriCarbon

Fund: 21

Do Not Fund: 0

Abstain: 0

VII. LEGISLATIVE OVERVIEW

HB 1592 – LRC Policy Bill Overview

Report by Jonathan Fortner

Fortner provided an overview of HB 1592 and its proposed updates to the Lignite Research Council (LRC) statutes. He reviewed updated legislative findings reflecting current lignite industry impacts, including revised production, employment, and economic figures, and noted the added language affirming the state's role in defending the continued development and use of lignite.

He summarized changes to LRC appointments, confirming that all members would continue to be appointed by the Governor from a list provided by the Lignite Energy Council, and outlined the updated membership categories. Governance amendments include election of a chair and vice chair, establishment of a seven-member Executive Committee, and a requirement that the Council meet at least twice annually.

Fortner noted that the LRC will continue to recommend grants and other funding actions to the Industrial Commission, and that gubernatorial appointees serve at the Governor's pleasure. Legislative members would receive statutory per diem.

He reviewed amendments guiding the selection of independent technical reviewers based on expertise and experience.

Fortner concluded with provisions granting the Industrial Commission authority to retain a technical advisor, adopt necessary policies, and maintain financial records, along with confidentiality protections for proprietary information and the identities of technical reviewers and LRC recommending members.

VIII. OTHER BUSINESS

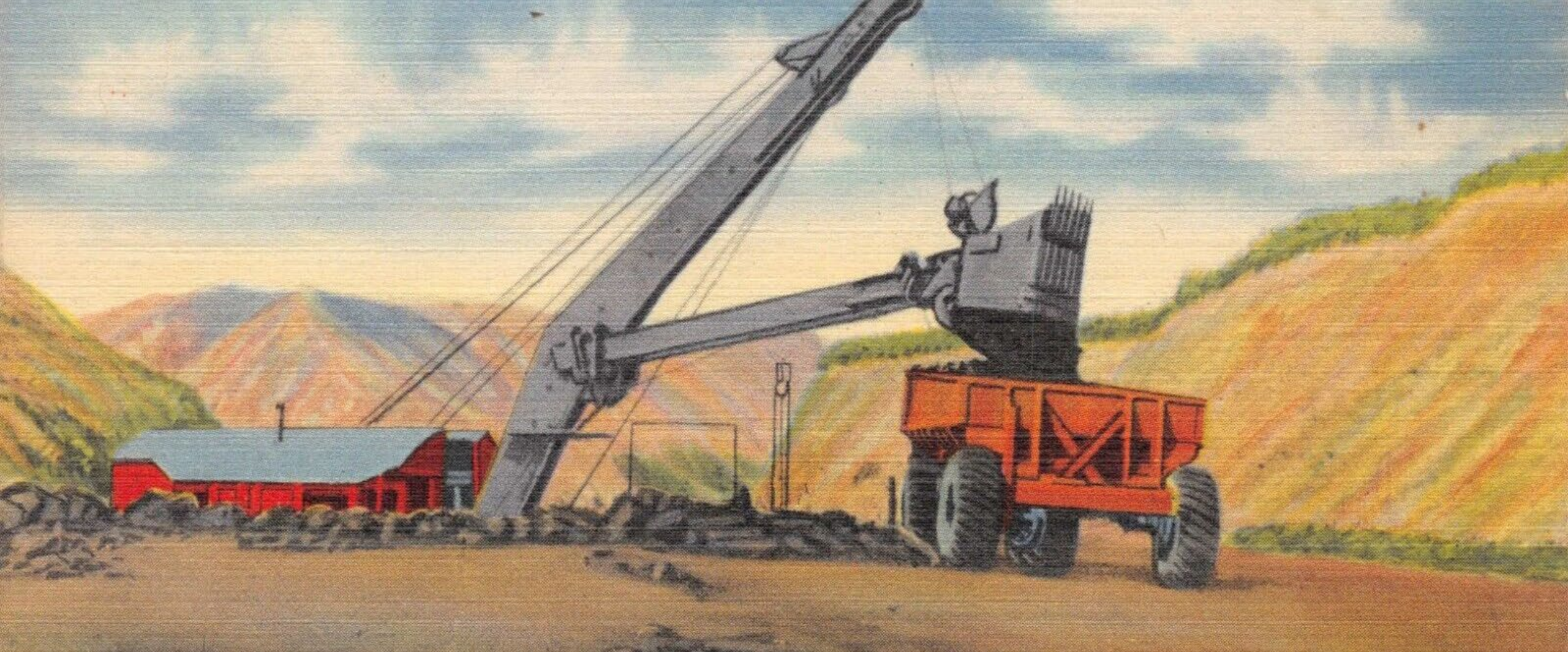
Fortner announced that the next North Dakota Industrial Commission meeting, where these recommendations will be considered, is scheduled for May 22, 2025.

Fortner reminded the group that the fall grant application deadline is October 1, 2025, and the next LRC meeting is scheduled for November 18, 2025.

IX. ADJOURNMENT

There being no further business, Fortner requested a motion to adjourn the LRC meeting. Jay Kost so moved, seconded by Joe Heringer. The motion carried.

Angie Hegre, recording secretary



LIGNITE RESEARCH PROGRAM PROJECT MANAGEMENT REPORT

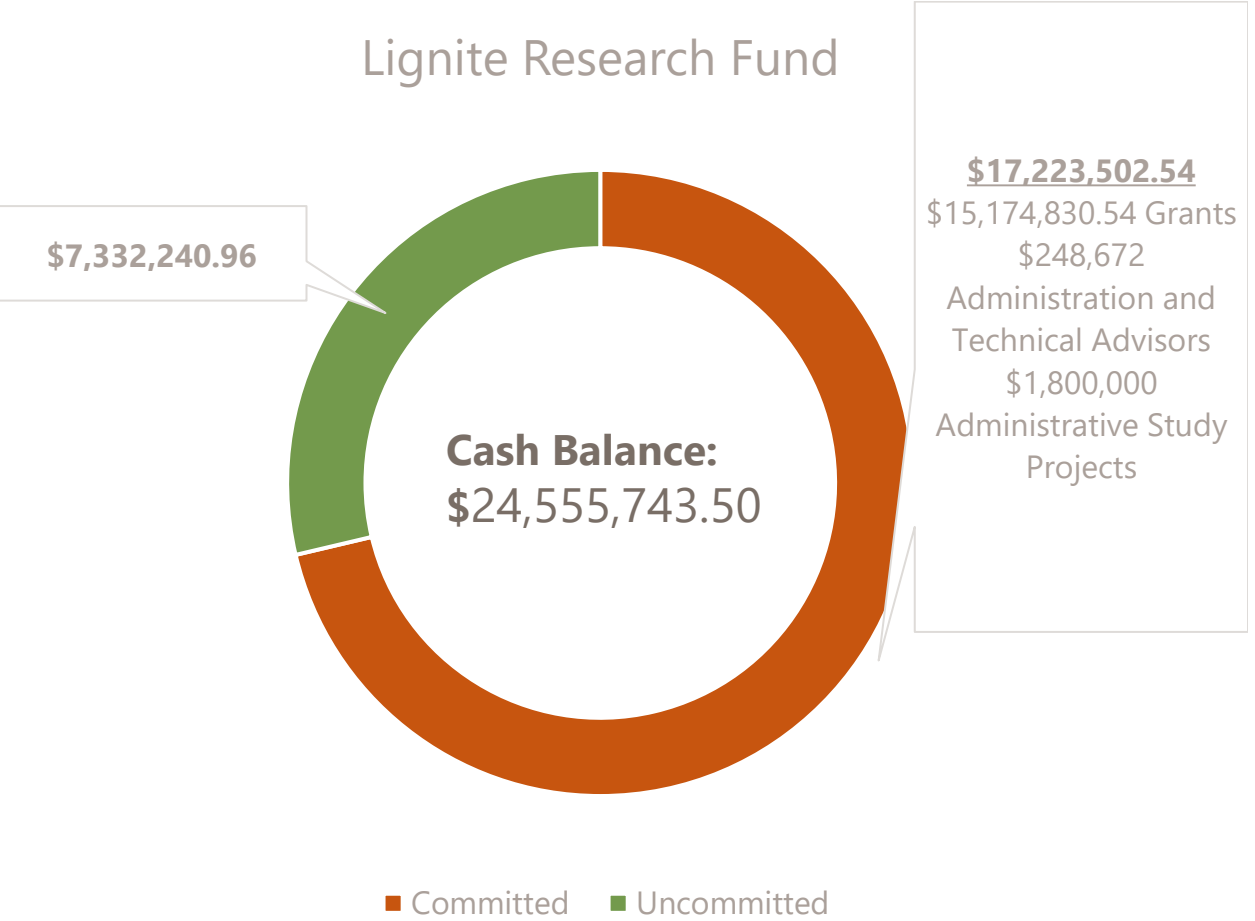
Jordan Kannianen, Deputy Executive Director, NDIC

November 2025

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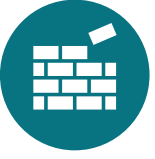
LIGNITE RESEARCH FUND BALANCE

NOVEMBER 2025



Funding Source:

- \$8.5 million coal severance and conversion taxes
- \$10 million oil and gas taxes



261 Cumulative Projects



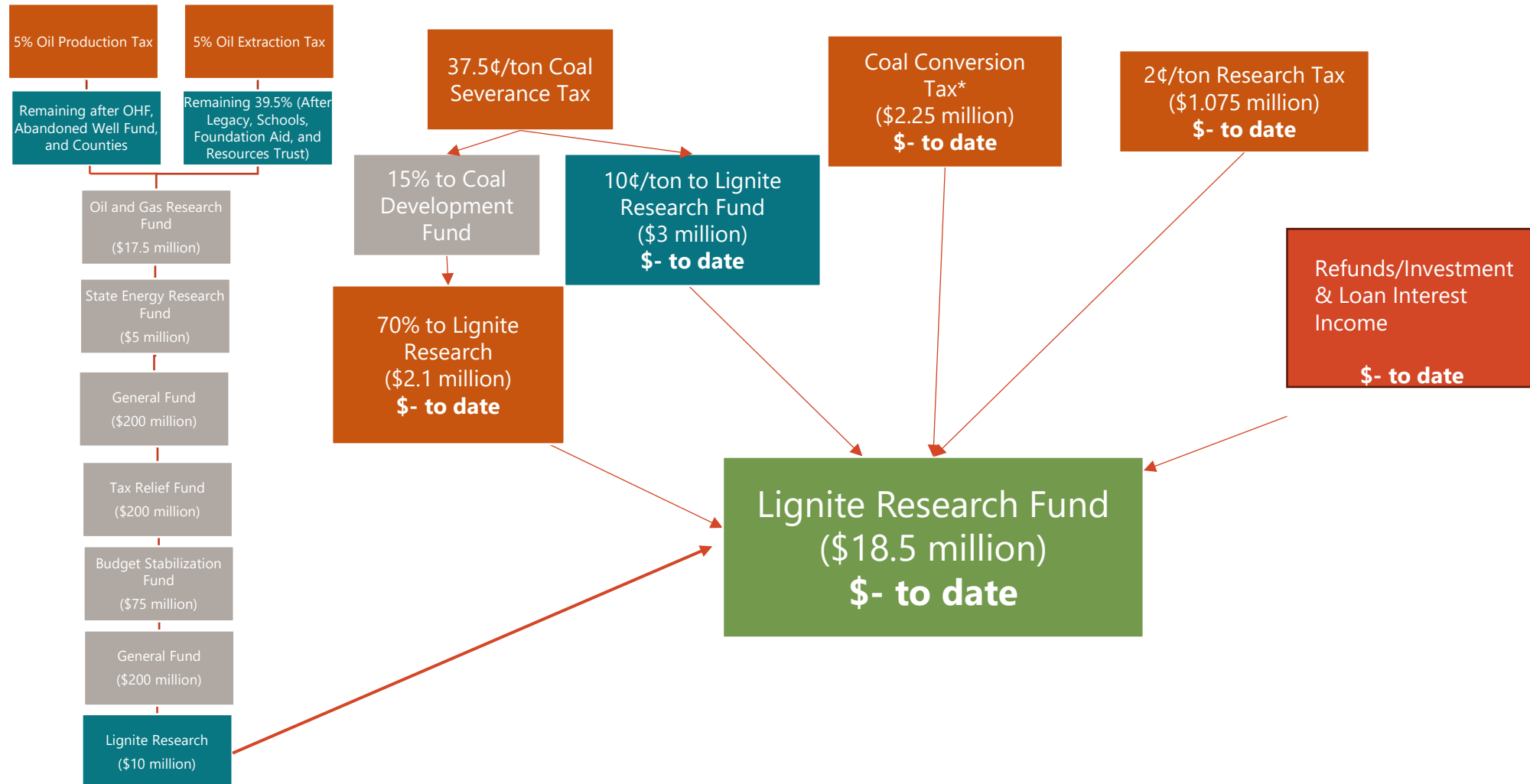
16 Active Projects



Cumulative Value:

- \$183.1 million granted
- \$2.8 billion project value

2025-2027 BIENNIUM APPROPRIATION AND FORECASTED INCOME



Enhance, Preserve and Protect the North Dakota Lignite Industry



**Project Management
Research & Development
Environmental & Legal Support
Power Markets & Transmission Strategies**

January 1, 2026 – December 31, 2028



Prepared by
The Lignite Energy Council
1016 E. Owens Avenue
Bismarck, North Dakota 58501



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Enhance, Preserve and Protect Project Project Management, Research & Development, Environmental & Legal Support, Power Markets & Transmission Strategies

ABSTRACT

The Enhance, Preserve and Protect Project (EPP) continues to build on the ongoing commitment and cooperation among government agencies, elected leadership and the lignite industry to ensure the long-term viability of the North Dakota lignite industry. The project began as the result of an extensive analysis by leaders of the Lignite industry focused on the state of the industry in North Dakota, as well as the coal industry nationwide. Early analysis concluded that federal legislative and regulatory policy moved in a direction which jeopardized the future development of North Dakota's vast lignite resources and created great uncertainty regarding the viability of existing lignite generation plants. The regulatory environment continues to be dynamic, and the EPP project will continue to work with industry and regulators so that North Dakota can make the best use of our vast lignite resource into the future.

Early project work included development of a technology development roadmap under the guidance of the lignite industry. This roadmap will continue to be updated as needed to guide technology development required for lignite conversion systems. The EPP Project will focus on preserving and enhancing the existing lignite industry while at the same time providing continued technical support to activities under the Advanced Energy Technology Program which focuses on new opportunities to capitalize on North Dakota vast lignite resources. The State of North Dakota and lignite industry continue to benefit from the EPP project, as they supply energy to regional residents and industry, while strengthening the economy through creating and sustaining jobs and clean, low-cost reliable electricity.

Project Objectives

One of the primary objectives of the EPP Project is to preserve and protect the existing lignite fleet in North Dakota. The Project also continues to look to the future and assist the state and industry in understanding where the "new" opportunities are for this abundant resource in the future. Finally, the Project will continue to explore new avenues to develop value-added opportunities for lignite and its combustion byproducts. Options include rare earth elements and critical minerals that exist in significant quantities in the lignite found in North Dakota, using excess process heat within the plant and to add value to adjacent industry, development of building materials and carbon materials from lignite, and carbon dioxide used for enhanced oil recovery, to name a few. Value-added opportunities will also include demand side technologies that can consume off-peak electricity, such as electric vehicles and data centers.

To achieve the EPP Project objectives the EPP Project team will develop and implement research & development, environmental and legal support, and power markets and transmission strategies. These strategies will include addressing technology challenges for existing plants to achieve compliance with regulations and to discover new and innovative ways to use lignite and its byproducts in order to ensure the future of lignite in

North Dakota for years to come. Additionally, the EPP Project team will enhance the partnership with the state by working with state agencies and officials to understand the legal and economic implications of legislative and regulatory initiatives on the lignite industry, one of North Dakota's largest industries. The Project team will also monitor the progress of current and future Advanced Energy Technology projects and eliminate any potential duplication of efforts among these activities, thereby maximizing value for the State of North Dakota. Strategic studies will be performed to better understand the value of technology developments, provide critical information for the State on the commercial potential of emerging markets, evaluate the economics associated with technologies and the lignite industry, and the impacts of outside factors on the industry and North Dakota.

Key personnel involved in the management of the Enhance, Preserve and Protect Project are Angie Hegre, LEC Research and Development Program Manager and EPP Project Manager; Mike Holmes, LEC Executive Vice President of Research and Development, EPP Principal Investigator, lead of EPP R&D and strategic study efforts, and Technical Advisor to the NDIC; and Jonathan Fortner, LEC President, EPP Project Policy Advisor and Environmental management and power markets lead for the EPP project. The EPP Project team will work together with consultants who have research & development, environmental, legal, power markets, and transmission technical expertise to complete the project activities.

The EPP Project is seeking \$3,316,695 from the North Dakota Industrial Commission (NDIC) over a period of 36 months (January 1, 2026 – December 31, 2028).

BACKGROUND

A. State Policy

In 1991, the North Dakota Legislative Assembly enacted legislation creating the Lignite Research, Development and Marketing Program and declaring that:

“...it is an essential governmental function and public purpose to assist with the development and wise use of North Dakota's vast lignite resources by supporting a lignite research, development, and marketing program that promotes economic, efficient, and clean uses of lignite and products derived from lignite in order to maintain and enhance development of North Dakota lignite and its products; preserve and create jobs involved in the production and utilization of North Dakota lignite; ensure economic stability, growth, and opportunity in the lignite industry; and maintain a stable and competitive tax base for our state's lignite industry for the general welfare of North Dakota.....” (NDCC § 54-17.05-01)

In the past the North Dakota Legislative Assembly has appropriated funding from the Lignite Research Fund for the purpose of contracting services that will focus on the preservation of existing jobs and production as well as the growth of the lignite industry. The NDIC, with policy advice and funding recommendations from the Lignite Research Council, has administered this program. As guidance to the NDIC for the use of the nonmatching funding, the Legislature stated that:

“...Moneys appropriated pursuant to this section may ... be used for the purpose of contracting for nonmatching studies and activities in support of the Lignite Vision 21 Project; for litigation that may be necessary to protect and promote the continued development of lignite resources; for nonmatching externality studies and activities in externality proceedings; or other marketing or environmental activities that assist with marketing of lignite-based electricity and lignite-based byproducts...” (Chapter 14, Section 11, 2011 ND Session Laws)

During the 2017 North Dakota Legislative Assembly, the State approved an additional \$3 million from the Strategic Infrastructure and Improvements Fund for supporting the Advanced Energy Technology (AET) projects directed at late-stage evaluation of technologies under consideration for commercial application in North Dakota. In the 2019 North Dakota Legislative Assembly, the State approved an additional \$10 million and that was made continuous in the 2021 Assembly. The AET program allows expansion of projects to include technological solutions for existing plants, including carbon capture and low carbon options.

An amendment to Contract LMFS-22-43 to meet the legislative intent of Section 17 of House Bill 1014 passed by the Sixty-eighth Legislative Assembly of North Dakota and to remove Transmission Authority base funding, which was appropriated directly to the Commission by the Sixty-eighth Legislative Assembly. The Commission voted to accept the recommendation of the Lignite Research Council and authorize the amendment to Contract LMFS-22-43 on July 28, 2023.

In the 2025 legislative session, the enrolled version of Senate Bill 2014 updated that section of law:

SECTION 13. LIGNITE RESEARCH, DEVELOPMENT, AND MARKETING PROGRAM - LIGNITE MARKETING FEASIBILITY STUDY - REPORT TO THE SEVENTIETH LEGISLATIVE ASSEMBLY. 1.

Pursuant to the continuing appropriation under section 57-61-01.6, up to \$4,500,000 from the lignite research fund may be used for the purpose of contracting for an independent, nonmatching lignite marketing feasibility study or studies that determine those focused priority areas where near-term, market-driven projects, activities, or processes will generate matching private industry investment and have the most potential of preserving existing lignite production and industry jobs or that will lead to increased development of lignite and its products and create new lignite industry jobs and economic growth for the general welfare of this state. Moneys designated under this section also may be used for the purpose of contracting for nonmatching studies and activities in support of advanced energy technology and other technology development programs; for litigation that may be necessary to protect and promote the continued development of lignite resources; for nonmatching externality studies and activities in externality proceedings; or other marketing, environmental, or transmission activities that assist with marketing of lignite-based electricity

and lignite-based byproducts. Moneys needed for the purposes stated in this section are available to the industrial commission for funding projects, processes, or activities under the lignite research, development, and marketing program.

2. The industrial commission shall report to the appropriations committees of the seventieth legislative assembly on the amounts spent pursuant to this section.

The latest legislation continued the authority to continue this type of work by explicitly authorizing the use of Lignite Research Fund, *“Moneys designated under this section also may be used for the purpose of contracting for nonmatching studies and activities in support of advanced energy technology and other technology development programs; ... for nonmatching externality studies and activities in externality proceedings; or other marketing, environmental, or transmission activities that assist with marketing of lignite-based electricity and lignite-based byproducts.”*

In summary, the North Dakota Legislative Assembly has consistently reaffirmed the importance of lignite to the state’s economy and energy future through sustained policy direction and dedicated funding. From the creation of the Lignite Research, Development, and Marketing Program in 1991 to the expansion of support for advanced energy technologies and the most recent updates in Senate Bill 2014, the Legislature has provided clear authority and resources to preserve existing lignite production, foster innovation, and create new opportunities for jobs and growth. This enduring commitment ensures that lignite remains a cornerstone of North Dakota’s energy strategy while adapting to evolving technological and environmental challenges.

B. Industry Economic Impact, Challenges, and Opportunities

Over the years, lignite producers in North Dakota have maintained a steady annual production level at nearly 30 million tons. North Dakota ranks as one of the top ten coal producing states in the country and as of 2019 is the top lignite mining state in the country.

In 2023, the Lignite Industry employed approximately 3,228 direct workers in all segments of the industry. Direct, indirect, and induced economic effects were estimated to support a total of 12,032 jobs in the state of North Dakota. The lignite industry also supports about \$1 billion in labor income, which represents wages, salaries, benefits, and sole proprietor’s income. The industry also contributes \$2 billion to the state’s gross domestic product, and the industry’s gross business volume was estimated at \$5.5 billion. In addition, industry continues to provide clean, low-cost, reliable electricity that is the cornerstone of our state economy.

After strong growth in the 70s and 80s, the market for electricity produced by North Dakota Lignite reached a plateau. The start-up of the combined heat and power Spiritwood facility near Jamestown in 2014 marked the first new Lignite-based energy conversion facility in

over 20 years. This was a significant milestone considering the challenges facing the lignite industry. These challenges include increasingly stringent federal environmental regulations; carbon dioxide capture, utilization and storage targets; competition from other energy sources; legislative mandates from surrounding states which impact the continued use of lignite-based electric generation and concerns about the adequacy of transmission infrastructure in light of oil and gas development in western North Dakota, as well as constant monitoring of the status of export constraints on the existing transmission system. In addition to limiting sale of lignite fired electricity, transmission constraints can increase the impact of regional wind power on the existing coal units.

Another challenge to the State of North Dakota and the lignite industry is to design a comprehensive program to alter the present “anti-coal” campaign and replace it with a strategy that recognizes the importance of all forms of energy as a way to ensure our nation’s energy security as well as the strategic importance of the many value-added opportunities available through innovations that have been identified. Lignite-based electric generation has been at the heart of North Dakota’s economy for decades, providing low-cost reliable and dispatchable electricity to farmers, ranchers, businesses (large and small) and consumers. If the on-going campaign to eliminate coal is successful, affordable electricity to fuel North Dakota’s future will be a thing of the past. To continue to address this changing landscape the Lignite industry plans to continue the focus on its regulatory / legislative program, as well as enhancing its research and development work. The purpose of the EPP Project is to continue to align industry efforts with the state’s mission to “maintain and enhance development of North Dakota lignite” to strengthen the industry / State partnership. Through this refocused effort, the State of North Dakota will benefit from continued access to low-cost, reliable, and clean energy as well as have the opportunity to see new industries located in ND like Rare Earth and Critical Element extraction to provide critically needed material for numerous 21st Century applications that require these materials. This is one of the many emerging markets with potential for application in North Dakota. Others include construction materials, carbon-based materials, additional fertilizer production, and combined heat and power projects that use the remaining process heat from lignite power plants.

A continually growing focus of the State / Industry partnership has been in solutions for carbon management. North Dakota has a unique opportunity to diversify the products from lignite-fired power plants by adding CO₂ as a commodity. CO₂ captured from lignite-fired power plants could facilitate a second round of oil recovery from the conventional oil fields as well as in the Bakken formation. This would greatly increase the tremendous economic boom experienced over the last decade, resulting in economic activity to the benefit of all North Dakotans. A study performed to evaluate the impact of carbon capture and use in North Dakota oil recovery showed that the impact on employment alone could be as high as 14,000 additional jobs. In the near term, the industry is looking to fund additional geologic storage of CO₂ through a federal incentive (45Q).

PROJECT DESCRIPTION

A. Overall Objectives

The objective of the EPP Project is to protect and extend operation of the existing lignite facilities while at the same time seeking technology solutions for existing plants and new technologies for the future of the North Dakota lignite industry. To achieve the EPP Project objectives, the Lignite Energy Council (LEC), in conjunction with the lignite industry partners, will continue to develop, and implement research and development, environmental and legal support, power markets and transmission strategies that will enhance, preserve, and protect existing facilities and support the future development of North Dakota's lignite resources. The EPP Project team will monitor progress, avoid duplication of services, and maximize value to the State by working with industry, technology developers, federal and state agencies, and other interested parties in finding solutions that will allow the state to maintain existing lignite facilities and to provide for new growth in the lignite industry. Activities and tasks that will be addressed by the EPP Project include:

- Project Management
- Research & Development Studies and Activities
- Environmental Strategies & Legal Support and Activities
- Power Markets & Transmission Strategies and Activities

The project team will work along with consultants who have legal, research & development, environmental, and transmission technical expertise to execute the project. A detailed description of the management organization and qualifications of key personnel are outlined on pages 12 through 13, and the organizational chart is provided in Appendix 3.

B. Statement of Work

The EPP Project team will provide overall program management responsibility for the project. Key personnel identified above will be responsible for completing EPP Project tasks and achieving program objectives. The timeframe for the project is estimated at 36 months (January 1, 2026, to December 31, 2028) with an estimated budget of \$3,316,695. Tasks and timeframes for the project activities are summarized below and outlined in Appendix 2.

Task 1.0: Project Management – 36 months (\$518,915)

The LEC will continue its proven project management system to ensure deliverables are met and value is maximized. This will include close coordination with industry and state stakeholders to address needs in technology development, strategic studies, environmental and legal support, and power market and transmission strategies. Angie Hegre will manage project documentation by compiling results with input from the

Principal Investigator, task leads and subcontracts. Mike Holmes will provide technical oversight across project management, R&D, and environmental/legal support, and Jonathan Fortner will oversee environmental/legal activities and power market strategy. These efforts will be carried out collaboratively, with support from the EERC and other subcontractors.

Task 1.1 Reports - The Program Manager will prepare and submit biannual reports, final reports, and other reports as required to satisfy all contractual requirements. The Program Manager and Principal Investigator will prepare other written and oral presentations as requested or required to achieve the objectives of the EPP Project and communicate the activities. The reporting and presentations will be used to extract value and communicate key findings with the NDIC, other state leaders and industry and the North Dakota Public.

Task 1.2 Advanced Energy Technology Contract Administration – Administration of the Advanced Energy Technology (AET) contracts will continue, and the Principal Investigator will oversee compliance with NDIC conditions imposed in the participants' contracts in addition to the following:

- 1) Review and approval of detailed scopes of work, budget, and milestone charts, progress reports, for each phase of the Advanced Energy Technology participant's activities.
- 2) Review and approval of activities and studies that evaluate cost-effective North Dakota lignite-fueled generation options and promote efficient and clean use of North Dakota lignite.
- 3) Review and approval of activities and studies that maximize efficient use of available state and industry funds and avoid duplication among the technology developers and AET participants, particularly in the generation, environmental, and transmission areas.
- 4) Monitor the continued work on existing AET contracts, allowing these activities to be completed to allow the State of North Dakota to derive the maximum benefit for the work completed in pursuing the objectives of this program.

The Principal Investigator or his designee will meet by conference call or personally with each Advanced Energy Technology participant monthly or as needed to monitor progress and ensure compliance with the NDIC grant conditions.

Task 1.3 Administration and Support Facilities - The LEC will provide the necessary direction, administration, and technical support for the project. The EPP Project team will provide contracts, personnel, and budget supervision throughout the term of the grant. In addition, the EPP team will facilitate communications between the Lignite Research Council, lignite industry, NDIC, North Dakota Legislative Assembly, Congressional delegation, national and regional associations, and other federal and state agencies.

Task 2.0: Research & Development Studies and Activities – 36 months (\$1,188,729)

Research and development is at the heart of enhancing, preserving, and protecting the North Dakota lignite industry and all of the residents and industries across the state that depend on clean reliable and affordable electricity. Early stages have supported spectrum of essential technology developments. Some of the examples include technology support for enhanced mine reclamation, support of early technology developments related to the DGC Poly generation system, development of technology for control of primary pollutants followed by mercury and air toxics, support of the Spiritwood power plant, technology and plans for management and utilization of carbon dioxide, and more recently expanded efforts on developing commercially viable additional uses of North Dakota lignite.

Task 2.0 focuses on advancing innovative strategies and studies to strengthen the role of lignite in North Dakota's energy future. The EPP Project team will pursue efforts that address regulatory compliance, expand value-added uses of lignite, and explore emerging technologies and markets. By combining technical innovation, global collaboration, and targeted research, this task ensures continued progress toward reducing carbon footprints and pursuing the opportunity to utilize CO₂ for Enhanced Oil Recovery (EOR) capturing new economic opportunities and maintaining lignite as a competitive and sustainable energy resource.

Task 2.1 The EPP Project team will engage in activities that include:

- 1) Tailoring criteria pollutant control strategies to meet the regulatory requirements placed on existing and new facilities.
- 2) Identifying new revenue streams based on value-added products from lignite and/ or products produced from regulated emission streams.
- 3) Participation as a global player in groundbreaking research, partnering with lignite interests around the world; and
- 4) Exploring high-risk, high-payoff technology options for the lignite resource.
- 5) Complete strategic studies on topics related to technology, economic impacts, and commercial potential of emerging markets.

This set of activities will maintain an elevated focus on emerging markets and carbon footprint and will be critical to successfully meet the overall goals of the EPP Project.

Task 2.0 Strategic Studies

Strategic studies continue to play an important role within the EPP Program. Recent efforts include the initial report from the Lignite Plant of the Future findings, the Coal Counties Study, an Ash training course, the continuation of the Coal Counties Study with an emphasis on evaluating opportunities for thermal integration, and several key

past studies. Examples of the latter include the evaluation of CCR utilization for North Dakota lignite, which helped address and correct misconceptions about the applicability of the technology, and the study of the sulfur removal potential from DGC's CO₂ to evaluate the potential for North Dakota Enhanced Oil Recovery (EOR) applications.

Looking ahead, future studies will be prioritized based on input from lignite industry stakeholders. Two studies have already been identified for the first year of the project and will serve as initial focal points.

Lignite Plant of the Future – Continued Assessment with EERC – Strategic study for up to \$200,000 to further the assessment of the lignite plant of the future. It will include forecasts for sustained load growth in the region, necessitating retention and development of dispatchable energy resources. A tremendous opportunity exists for the lignite power sector to provide CO₂ for Enhanced Oil Recovery and continue to increase returns from the Bakken oil formation. Some of the challenges to be addressed include additional economic analysis, feasibility studies including integration of emerging markets, exploring incentives for CO₂ capture including use for EOR, increased understanding of capital expenses for new plants and comparisons with alternate sources of generation.

Review of Improvements for ND Lignite Assets – This is a strategic study done by EERC that is up to \$200,000 to evaluate the improvements that can be made to existing ND lignite power generation and utilization facilities. There are many opportunities to expand the value of these facilities. These will be explored and the implications to new source review and other potential regulatory impacts will be evaluated.

Task 2.0 will be managed by the Technical Advisor, currently Mike Holmes. Should a change in the Technical Advisor role occur, the new appointee will be selected with input from the NDIC and the Governor's staff, with the Executive LRC members informed accordingly.

Task 3.0: Environmental Strategies & Legal Support and Activities – 36 months (\$821,645)

Task 3.0 focuses on developing environmental strategies and applying technology-based solutions to address the regulatory challenges facing North Dakota's lignite industry. The project team reviews and analyzes proposed and current federal rules that impact mining operations, power plants, and emerging technologies. This work helps build a strong scientific record to guide future decisions, ensuring strategies are supported by sound data and research. The effort also fosters close coordination with environmental managers, the North Dakota Department of Environmental Quality, and the Attorney General's office to align technical and environmental priorities across the state.

In parallel, the project team works with industry to address key environmental issues such as regional haze, new source performance standards, effluent discharges, air quality improvements, and the management of coal combustion residuals. Technical expertise is applied to evaluate options like carbon dioxide management, advanced monitoring, and carbon capture and storage. Legal assistance supports these activities as needed, particularly when environmental or technology strategies intersect with federal policy and regulatory requirements. By engaging regional and national partners and leveraging subcontractor expertise, Task 3.0 strengthens North Dakota's ability to apply innovative environmental and technology solutions that preserve lignite resources and sustain reliable energy generation.

Task 3.1 Technical Services Coordination – The EPP Project Team will coordinate industry responses to environmental issues that may jeopardize the future of existing generation facilities as well as the future growth of the North Dakota lignite industry in order to avoid unnecessary cost and duplication and maximize value for the State of North Dakota. The most significant environmental challenges facing existing generation facilities include:

1. Continued efforts by regulatory agencies and environmental groups to impose stringent new regulations which will create significant issues for the continued use of Lignite.
2. Issue between the EPA and the State of North Dakota over modeling protocols and actual emission monitoring data.
3. Supporting the State's regional haze state implementation plan.
4. Utility maximum achievable control technology determinations for various regulations.
5. New source performance standards for existing plants, carbon dioxide management, and the regulation of carbon capture and sequestration and enhanced oil recovery.
6. Regulation of effluent discharges.
7. New standards for particulate matter and ozone.
8. New standards for cooling water intake structures.
9. Development of stream protection rules; and
10. Regulation of coal combustion residuals as hazardous waste and the regulation of the use of coal combustion residuals at mining operations.

The EPP Project team will continue to coordinate and develop environmental strategies to address these challenges during the grant period, including the development of more aggressive partnerships with national and regional organizations with similar concerns regarding the scientific justification and economic impact of the federal regulatory agenda. The Project team will also develop stronger cooperative programming throughout the region to monitor and address actions by agencies and legislatures in surrounding states that may have negative implications for the Lignite industry. As issues develop the EPP Project team will establish individual tasks that identify the issue and necessary actions to be taken and highlight results. These tasks will be included in the project reports.

Task 3.2 Legal Support – Legal assistance, including support and analysis regarding federal and state administrative actions and potential litigation, may be needed on issues resulting from ongoing federal rulemakings or similar state proceedings in North Dakota and other states. The actions listed in Task 3.1 may also warrant legal support. In addition, the ND Transmission Authority may benefit from legal assistance to respond to Federal Energy Regulatory Commission (FERC) proposed rules in addition to rules and policies from Regional Transmission Organizations (RTOs) such as rate tariffs, return on equity, cost allocation, siting, and routing. Legal support may also be needed to help attract developers for the construction of new transmission infrastructure to support a more robust energy industry in North Dakota. The EPP Project team will coordinate these activities.

Task 4.0: Power Markets and Transmission Strategies – 36 months (\$787,406)

Task 4.0: Power Markets and Transmission Strategies support the North Dakota lignite industry by ensuring active participation in regional and national transmission and market planning processes. The LEC provides the North Dakota Transmission Authority and industry with critical demand forecasts, market analysis, and regulatory insights to inform planning and decision-making. A key objective is to maintain a united voice for lignite in stakeholder forums, particularly with the Midcontinent Independent System Operator (MISO) and the Southwest Power Pool (SPP), where LEC advocates for stronger price signals for baseload, dispatchable resources. LEC also partners with consultants to provide expert economic, regulatory, and technical analysis, as well as testimony before RTOs and federal and state regulatory bodies.

Examples of this work include partnering with BARR Engineering to forecast long-term power demand related to oil production and population growth, and working with utilities and the North Dakota Transmission Authority to develop transmission strategies consistent with North Dakota’s “all of the above” energy policy. These efforts demonstrate the type of analysis, coordination, and advocacy the LEC has provided in the past, and will continue to deliver in the future to ensure North Dakota’s energy interests are protected and advanced.

Task 4.1 Midcontinent Independent System Operator (MISO)- LEC staff will engage in the regional electricity market known as MISO to improve generation resource attribute value which is currently not provided in the marketplace. The Lignite Energy Council joined MISO as a member in 2020 to advocate for stronger price signals for baseload, dispatchable resources in the electricity market. In that same year, the Federal Energy Regulatory Commission voted to approve a new stakeholder group to be placed on the MISO Advisory Committee, along with the Planning Advisory Committee (PAC) with an official seat along with voting rights on each committee.

LEC now serves in a leadership position serving as the Chair of the Affiliate Sector, which is one of eleven stakeholder groups with representation and voting rights on the Advisory Committee (AC). LEC's Jonathan Fortner is the Chairman and attends the meetings and provides a voice for coal in the marketplace while also pushing for valuing the attributes that coal possesses in the Midcontinent Independent System Operator (MISO) grid.

To be able to provide tracking coverage of the committee process and in-depth analysis of market activities and proposals, LEC is going to utilize contract support with an energy consulting firm that provides economic, regulatory, and technical analysis and advice to a wide range of energy clients. The firm has been providing analysis of wholesale and retail energy markets and projects and provides a host of analytical and support services for power resources throughout the United States. They provide regulatory support on complex matters and expert testimony at the regional transmission organization (RTO), State, and Federal Energy Regulatory Commission (FERC) level. The firm has expert knowledge of RTOs and maintains an RTO division that is fully dedicated to monitoring and analyzing issues at the RTO level.

Task 4.2 Southwest Power Pool (SPP)- LEC joined SPP in 2021 to advocate for stronger price signals for baseload, dispatchable resources in the electricity market. LEC is a part of the Markets and Operations Planning Committee along with the Membership Committee.

To be able to provide tracking coverage of the committee process and in-depth analysis of market activities and proposals, LEC has contract support for background in rural cooperative electric and electricity market issues.

Task 4.3 Power Demand Forecast- Engage with BARR Engineering to continue to develop power demand forecasting as it relates to the future of North Dakota's electricity generation resources. To help understand the demand for electricity in the growth area in the oil producing counties, along with population growth across the state, the LEC will commission additional studies estimating the growth over the next 20 years.

Task 4.4 Transmission Strategies – The LEC will continue to work with utilities and the NDTA to inform and support development of transmission strategies. Whether the scope of the planning process is national, regional, or state, the Authority will participate to protect North Dakota's interest. The EPP will participate in studies for transmission planning on a regional basis and a national basis as appropriate. Input will be provided that is consistent with North Dakota's policy of "all of the above" energy options.

QUALIFICATIONS

A. Capabilities and Experience

The Lignite Energy Council is a trade organization comprised of 250+ members including major lignite producers who produce a total of 30 million tons annually, the nation's largest

commercial gasification project, and investor-owned utilities and rural electric cooperatives from a multi-state area that generate electricity from lignite serving millions of people from Canada to Texas. For over 30 years, the Lignite Energy Council has maintained a formal partnership with the NDIC to assist with administration of the Lignite Research, Development and Marketing Program and provide technical assistance to the NDIC.

Besides partnering with the NDIC on the development and implementation of the state's research and development program, the Lignite Energy Council manages a regional public relations program for lignite-based electricity and an education program that trains teachers from across the region about the lignite industry. Because of the important impact that governmental policies have on the competitive position of lignite and the ability to develop new lignite projects, the Lignite Energy Council is also involved in various governmental relations activities such as legislative, Congressional, and public official forums and briefings.

The Lignite Energy Council has effectively managed similar contracts with the NDIC dating back to May 1999. Based on this experience and the above-described capabilities, the Lignite Energy Council is capable of administering the Enhance, Preserve and Protect Program.

B. Key Personnel

- **EPP Project Manager**

Angie Hegre has more than 16 years of experience in the energy industry. Before she joined the Lignite Energy Council in 2019, she worked for Great River Energy as the Generation Support Coordinator. Ms. Hegre worked with Senior leadership in Minnesota and the North Dakota executive team including the Director of ND Generation. She worked with environmental reporting requirements, and compliance record retention for regulatory and safety. She worked in-line with engineering and operations managing year-end and outage reporting. Ms. Hegre was hired by the LEC in August 2019 and is the Research and Development Program Manager. She has been supporting the Lignite Research Council grant rounds to include working with the NDIC, principal investigators, technical reviewers, and technical advisor. She has taken on the requirement of the bi-annual summaries and EPP reports to the NDIC. Ms. Hegre works with the Director and Deputy Director of the ND Transmission Authority, providing reports, presentations, and research assistance. Angie attended Central New Mexico College and lived in New Mexico for over 20 years before moving back home to North Dakota in 2009.

- **EPP Principal Investigator / Technical Advisor**

Mike Holmes has nearly 40 years of experience with the development of technologies leading to the clean and efficient use of coal. Prior to coming to the Lignite Energy Council, Mr. Holmes spent 15 years each in technology

development at Babcock and Wilcox in Alliance, Ohio and The Energy and Environmental Research Center (EERC) at the University of North Dakota. At the EERC, he served as director of Energy Systems Development, where he oversaw fossil energy research areas. His principal areas of interest and expertise include CO₂ capture; fuel processing; gasification systems for coproduction of hydrogen, fuels, and chemicals with electricity; process development and economics for advanced energy systems; and emission control technologies. In January of 2017 he was hired to serve as the Senior Vice President of Research and Development for the Lignite Energy Counsel, and the NDIC appointed Mr. Holmes to serve as the Technical Advisor to the NDIC for the North Dakota Lignite Research, Development and Marketing Program. Mr. Holmes received B.S. degrees in Chemistry and Mathematics at Mayville State University and his M.S. degree in Chemical Engineering at the University of North Dakota.

- **Environmental Management and Power Markets Lead**

Jonathan Fortner is President & CEO of the Lignite Energy Council, where he directs the organization's strategic vision, government affairs, and public advocacy on behalf of North Dakota's lignite industry. Since joining the Council in 2018, he has taken a direct role in regulatory and legal strategy, working on key EPA rules (including MATS, greenhouse gas, regional haze, and coal combustion residuals) as well as the BLM Resource Management Plan. Fortner also represents the industry in regional transmission organizations as Chair of the Affiliate Sector for the MISO Advisory Committee. He holds both an MBA and MPA from the University of North Dakota, is a Policy Fellow at the University of Minnesota's Humphrey School, and a graduate of the Leadership North Dakota Program at the University of Mary.

- **Robert Paine, AECOM** – An expert in environmental and air quality modeling, Robert Paine contributed technical analyses and assessments of the proposed rules' environmental impacts, including data on air quality and emission control feasibility.
- **Isaac Orr, Always On Energy Research** – Leveraging his expertise in energy markets and policy, Isaac Orr conducted analyses on mining practices and regulatory impacts, providing detailed technical and economic data to support public comments and advocacy efforts.
- **Mack McGuffey, Troutman Pepper** – A seasoned attorney specializing in air law, Mack McGuffey provided legal analysis of federal environmental regulations, crafting legal arguments and contributing to the preparation of public comments.
- **Mike Nasi, Jackson Walker** – With extensive experience in environmental and energy law, Mike Nasi offered critical insights on regulatory compliance and

litigation strategies, helping ensure alignment between industry objectives and legal frameworks.

- **Wade Mann, Crowley Fleck** - An attorney with Crowley Fleck PLLP, brings extensive experience in lignite mining issues including regulatory analysis, environmental law, and energy policy. His expertise in interpreting federal rules, assessing industry impacts, engaging with stakeholders, and formulating strategic documentation ensures effective responses to regulatory challenges facing the lignite industry.

(Resumes of EPP Consultants are available upon request)

VALUE TO NORTH DAKOTA

With an existing lignite fleet representing more than \$18 billion of capital investment in North Dakota, it is imperative that regulatory and statutory initiatives at the federal level or initiatives by states in the region be cost-effective and based on sound science. Additionally, the EPP supports the development and monitoring of critical R&D projects and strategic studies necessary to sustain and grow the ND lignite industry. The primary objective of the EPP project is to protect and preserve industry investment. The State stands to lose approximately 3,228 direct jobs and a significant portion of the over 12,000 indirect and induced positions related to providing services to the industry if as partners, the State and the lignite industry cannot find technology solutions and proactively address the development of reasonable regulations based on sound science. Also, directly at risk if the existing lignite industry is not protected is state and local revenues of over \$107 million and gross business volume for the industry estimated at \$5.4 billion annually. The value to North Dakota of the EPP Project grant is the ability to enhance, preserve and protect an industry that has provided low-cost and reliable electricity to the region for many generations.

BUDGET - EPP PROJECT COST SUMMARY BY TASK

No additional facilities are needed to implement this budget. See Appendix 1 for more detailed budget description.

MANAGEMENT

See description of project management under “Project Description, C. EPP Project Task Summaries.” Also see Organizational Chart in Appendix 3.

The LEC will continue to maintain the proven project management system that has supported the effective execution of the EPP Program. The project team will ensure deliverables are met while keeping a clear focus on maximizing value throughout the project. This will be achieved through consistent communication with industry and state stakeholders to identify needs related to technology development, strategic studies, environmental and legal support, and power markets and transmission strategies.

Project Management Roles

- Project Manager: Angie Hegre will serve as project manager, responsible for compiling and documenting results with input from the Principal Investigator, task leads, and subcontractors.
- Technical Oversight: Mike Holmes will provide technical review and oversight for the project management task and will lead technology oversight within the R&D, environmental, and legal support efforts.
- Program Oversight: Jonathan Fortner will oversee activities related to environmental and legal support, as well as power markets and transmission strategies.

Collaborative Approach

These efforts will be guided by input from both industry and state stakeholders, with the LEC team leading collaboratively and leveraging the expertise of outside subcontractors. Examples include technical support from the EERC on strategic studies, subcontractors engaged in environmental and legal efforts such as Crowley Fleck, Jackson Walker, Troutman Pepper, and partners assisting with RTO engagement and state-level power market and transmission strategy development.

Additional details are in the Task 1 description above.

TIMETABLE

The Enhance, Preserve and Protect project will begin under this contract on January 1, 2026, and end on December 31, 2028. Semiannual project reports will be submitted to the NDIC as mentioned in the “Project Description” section.

MATCHING FUNDS

The EPP project will use non-matching funds from the lignite research fund consistent with the intent of the North Dakota Lignite Research, Development and Marketing Program as described in the “Background, A. State Policy” section. Previous grants for the EPP Project were approved to use non-matching funds from the Lignite research fund. The total nonmatching funds requested are \$3,316,695

TAX LIABILITY

I, Jonathan Fortner, certify that the Lignite Energy Council is not delinquent on any tax liability owed to the State of North Dakota.

Jonathan Fortner, President
Lignite Energy Council

CONFIDENTIAL INFORMATION

This grant application contains no confidential information.

Budget by Task

1.0	Project Management	36 months	\$518,915
2.0	Research and Development Strategies / Activities	36 months	\$1,188,729
3.0	Environmental & Legal Support Strategies / Activities	36 months	\$821,645
4.0	Power Markets and Transmission Strategies / Activities	36 months	\$787,406
	Totals	36 months	\$3,316,695

STANDARDS OF SUCCESS

The project proposal has included work task objectives (See Project Description, above). The EPP Project team will submit periodic reports addressing progress under each of the tasks. The reports shall demonstrate a portfolio of lignite research program projects that align with state and industry goals. In addition, identification of strategic studies and documentation of final results will provide measurable standards of success for the EPP project. Documented accomplishments and progress in each of the task areas will provide a standard of success.

Appendix 1

Enhance, Preserve and Protect Program Budget Estimate

January 1, 2026 – December 31, 2028 (36 months)

Project Management	\$ 518,915
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Management fees for the EPP project include the LEC providing offices, travel, rent, printing, postage, and equipment. The LEC also provides direction, administration, and technical support for the EPP Project. The project team will write the necessary reports and facilitate communication among the critical partners including the NDIC, Lignite Research Council, Lignite industry, ND Legislative Assembly, Congressional Delegation, national, regional, and state associations, federal and state agencies, and the public.

Research & Development Activities	\$1,188,729
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The budget includes funds to focus on four critical areas; emission reductions, new generation options, value-added products from lignite, and global lignite research and development activities, which will allow continued use of lignite for the benefit of North Dakota in the future.

Environmental & Legal Support	\$ 821,645
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The budget includes funding to address existing and future environmental issues which may force the early retirement of the existing lignite-based generation in North Dakota and challenge the future development of new lignite-based projects. These efforts may include developing strategies to address future federal, regional, state and local statutory, regulatory, and policy determinations.

In addition, legal consultants may be needed to assist in developing environmental and transmission strategies and in assisting with potential legal challenges at the state and federal levels. The budget includes the consultant fees and expenses and the cost of education materials.

Power Markets & Transmission Strategies	\$ 787,406
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Utility generation and transmission planning rely on demand forecast And strategies from MISO and SPP. The budget includes consultant fees and expenses to make this information available to the NDTA and industry. Funding covers the expenses associated with Authority staff participating in the numerous activities outlined in Task 4.0. The budget also includes funds for potential transmission studies.

Total:	\$3,316,695
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Appendix 2

Enhance Preserve and Protect Project Project Schedule with Milestones and Deliverables

TASK	2026												2027												2028													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
Task 1.0 Project Management																																						
1.1 Reports																																						
1.2 Advanced Energy Technology Projects																																						
1.3 Adminstration and Support																																						
Task 2.0 Research and Development																																						
2.1 Enhance, Preserve, Protect R&D																																						
- Plant of the Future																																						
- Plant Improvements																																						
Task 3.0 Environmental & Legal Support																																						
3.1 Technical Services Coordination																																						
Task 4.0 Power Markets & Transmission Strategies																																						
4.1 Technical Services Coordination																																						

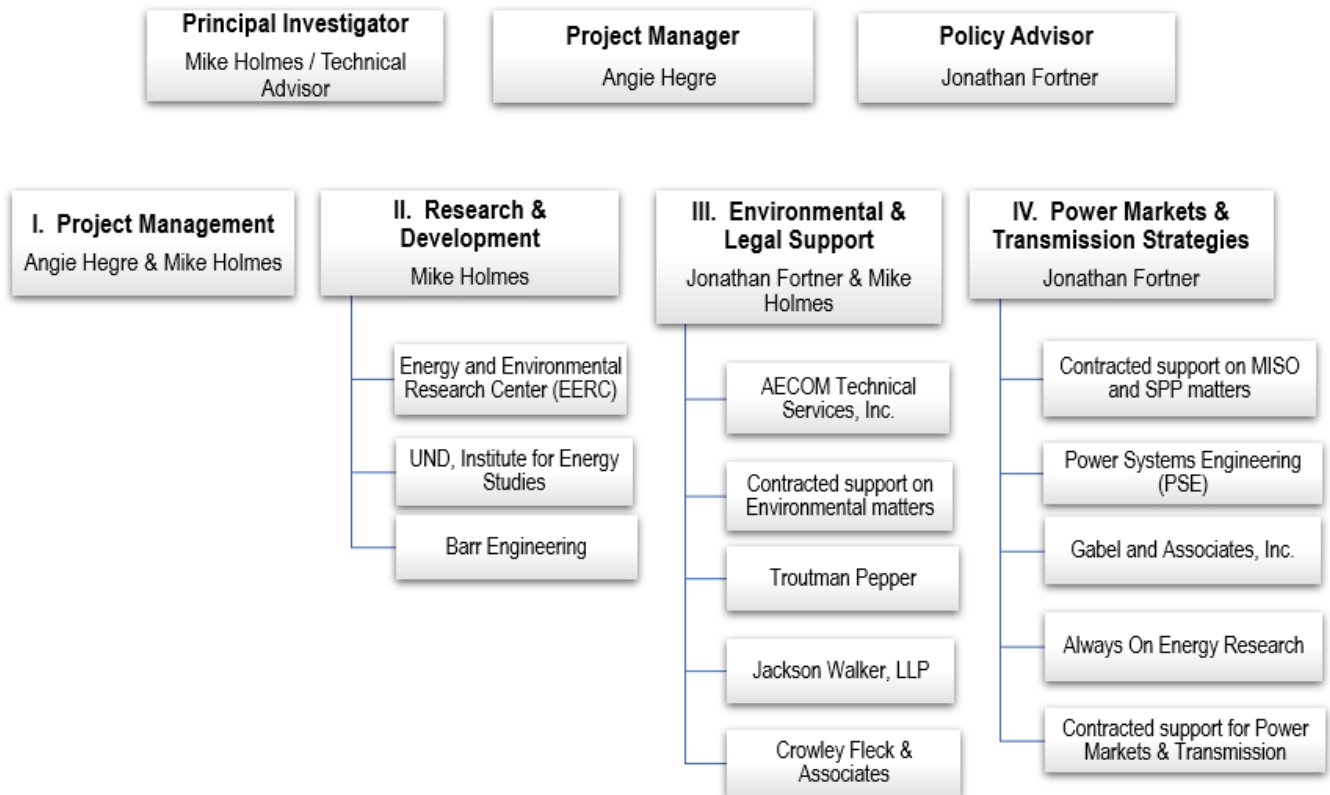
Summary of Milestones and Deliverables:

Contract Award / Project Start: January 1, 2026	
Semi Annual Report due dates	
Completion of Task 2 Reports	
Completion / Project End Date: December 31, 2028	

Appendix 3

Organizational Chart

Enhance, Preserve and Protect Organizational Chart 2026



LONG APPLICATION RATING FORM

Reviewer's Identification Number: **108B-02**

Date: **October 2025**

Proposal Number: **LRC (108B)**

Grant Application Title: **"Enhance, Preserve, and Protect the North Dakota Lignite Industry"**

Section A. Summary of Ratings:

Please **complete the questions below**, then return to this table to fill in the **yellow section** of this summary.

	Question	Rating (Enter # Circled)		Set Factor		Sub-rating
1	Objectives	4	x	9	=	36
2	Achievability	4	x	9	=	36
3	Methodology	5	x	7	=	35
4	Contribution	4	x	7	=	28
5	Awareness	5	x	5	=	25
6	Background	5	x	5	=	25
7	Project Management	4	x	2	=	8
8	Equipment Purchase	5	x	2	=	10
9	Facilities	4	x	2	=	8
10	Budget	5	x	2	=	10

50

221

**Total
Possible
Points**

250

Note: While points are necessary to establish an overall rating, comments on the various criteria are critical to truly understanding the value of a proposed project. Please elaborate in the comment sections to the maximum extent possible.

Overall Recommendation

x

FUND

FUNDING MAY BE CONSIDERED

DO NOT FUND

(Select one)

Section B. Ratings and Comments:

Please circle your response to each statement and transfer the number circled to the column entitled "Circled Number" on the first page of this form. Also, please comment on each criterion.

1. The objectives or goals of the proposed project with respect to clarity and consistency with North Dakota Industrial Commission/Lignite Research Council goals are:

Circle Answer: 1 – very unclear; 2 – unclear; 3 – clear; 4 – very clear; or 5 – exceptionally clear

Please comment: The goals are very consistent as stated in the policy section to promote wise use of our lignite resources and support research, development, and marketing strategies.

2. With the approach suggested and time and budget available, the objectives are:

Circle Answer: 1 – not achievable; 2 – possibly achievable; 3 – likely achievable; 4 – most likely achievable; or 5 – certainly achievable.

Please comment: The approach and timeline seem reasonable. Though there may be some concern with estimating need over 3 years. This may change over time, especially with the legal and policy challenges that are unknown in the future.

3. The quality of the methodology displayed in the proposal is: *Circle Answer: 1 – well below average; 2 – below average; 3 – average; 4 – above average; or 5 – well above average.*

Please comment:

4. The scientific and/or technical contribution of the proposed work to specifically address North Dakota Industrial Commission/Lignite Research Council goals will likely be:

Circle Answer: 1 – extremely small; 2 – small; 3 – significant; 4 – very significant; or 5 – extremely significant.

Please comment: Research in new opportunities for lignite use, along with marketing to help alter the "anti-coal" campaign, both specifically assist in the goals of NDIC/LRC.

5. The principal investigator's awareness of current research activity and published literature, as evidenced by literature referenced and its interpretation and by the reference to unpublished research related to the proposal is: *Circle Answer: 1 – very limited; 2 – limited; 3 – adequate; 4 – better than average; or 5 – exceptional.*

Please comment: The principal investigator has a high level of awareness and experience with over 40 years in the field, many of which focused on coal technology directly.

6. The background of the investigator(s) as related to the proposed work is:

Circle Answer: 1 – very limited; 2 – limited; 3 – adequate; 4 – better than average; or 5 – exceptional.

Please comment: Significant experience in this type of work as stated above.

7. The project management plan, including a well-defined milestone chart, schedule, financial plan, and plan for communications among the investigators and subcontractors, if any, is:

Circle Answer: 1 – very inadequate; 2 – inadequate; 3 – adequate; 4 – very good; or 5 – exceptionally good.

Please comment: The Plan appears to be achievable with routine reporting being the consistent milestones across the schedule.

8. The proposed purchase of equipment is: *Circle Answer: 1 – extremely poorly justified; 2 – poorly justified; 3 – justified; 4 – well justified; or 5 – extremely well justified. (Circle 5 if no equipment is to be purchased)*

Please comment: N/A

9. The facilities and equipment available and to be purchased for the proposed research are: *Circle Answer: 1 – very inadequate; 2 – inadequate; 3 – adequate; 4 – notably good; or 5 – exceptionally good.*

Please comment: N/A

10. The proposed budget “value”¹ relative to the outlined work and the financial commitment from other sources is of: *Circle Answer: 1 – very low value; 2 – low value; 3 – average value; 4 – high value; or 5 – very high value. (See below)*

Please comment: Considering the ROI of this industry in ND, the proposed cost over the three years is reasonable given the impact of this industry to the ND economy.

Section C. Overall Comments and Recommendations:

Please comment in a general way about the merits and flaws of the proposed project and make a recommendation whether or not to fund.

General comments: I recommend to fund this proposal as the work of the EPP directly and positively impacts the lignite industry across ND. The ND lignite industry fuels not only the local residents but also neighboring states across the Midwest. In a time when coal is targeted on regulatory and policy grounds, continued support for efficient, clean operations, along with research into new opportunities, will help sustain the responsible use of ND lignite resources.

One area for clarification in the EPP cost plan is the flexibility of the various cost allocations. Task 3.0, environmental strategies, legal support, and activities are listed as a set dollar amount throughout the 3-year plan. This area in particular may require flexibility as future legal challenges are unknown. Will this proposal allow flexibility in sharing costs across the 4 tasks if adjustment is needed?

¹ “Value” – The value of the projected work and technical outcome for the budgeted amount of the project, based on your estimate of what the work might cost in research settings with which you are familiar.

LONG APPLICATION RATING FORM

Reviewer's Identification Number: **108B-01**

Date: **November 2025**

Proposal Number: **LRC (108B)**

Grant Application Title: **"Enhance, Preserve, and Protect the North Dakota Lignite Industry"**

Section A. Summary of Ratings:

Please **complete the questions below**, then return to this table to fill in the **yellow section** of this summary.

	Question	Rating (Enter # Circled)		Set Factor		Sub-rating
1	Objectives	4	x	9	=	36
2	Achievability	3	x	9	=	27
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5	Awareness	5	x	5	=	25
6	Background	4	x	5	=	20
7	Project Management	4	x	2	=	8
8	Equipment Purchase	5	x	2	=	10
9	Facilities	5	x	2	=	10
10	Budget	4	x	2	=	8

50

200

**Total
Possible
Points**

250

Note: While points are necessary to establish an overall rating, comments on the various criteria are critical to truly understanding the value of a proposed project. Please elaborate in the comment sections to the maximum extent possible.

Overall Recommendation

X

FUND

FUNDING MAY BE CONSIDERED

DO NOT FUND

(Select one)

Section B. Ratings and Comments:

Please circle your response to each statement and transfer the number circled to the column entitled "Circled Number" on the first page of this form. Also, please comment on each criterion.

1. The objectives or goals of the proposed project with respect to clarity and consistency with North Dakota Industrial Commission/Lignite Research Council goals are:

Circle Answer: 1 – very unclear; 2 – unclear; 3 – clear; 4 – very clear; or 5 – exceptionally clear

Please comment: The main objectives outlined in the application meet the criteria required by providing assistance to the lignite industry that will help overcome existing challenges and ensure long-term feasibility of ND's lignite resources.

2. With the approach suggested and time and budget available, the objectives are:

Circle Answer: 1 – not achievable; 2 – possibly achievable; 3 – likely achievable; 4 – most likely achievable; or 5 – certainly achievable.

Please comment: The four tasks to be completed over the three-year period will provide valuable information that can be used by the lignite industry to improve existing operations, create additional economic opportunities, and prepare for the future by through studies related to forecasting long-term power demand.

3. The quality of the methodology displayed in the proposal is: *Circle Answer: 1 – well below average; 2 – below average; 3 – average; 4 – above average; or 5 – well above average.*

Please comment: The methodology in the application is clear and concise with targeted milestones and deliverables to help ensure successful outcome.

4. The scientific and/or technical contribution of the proposed work to specifically address North Dakota Industrial Commission/Lignite Research Council goals will likely be:

Circle Answer: 1 – extremely small; 2 – small; 3 – significant; 4 – very significant; or 5 – extremely significant.

Please comment: The application directly aligns with the lignite research council to preserve existing jobs and production and has potential to create new jobs and additional economic growth potential.

5. The principal investigator's awareness of current research activity and published literature as evidenced by literature referenced and its interpretation and by the reference to unpublished research related to the proposal is: *Circle Answer: 1 – very limited; 2 – limited; 3 – adequate; 4 – better than average; or 5 – exceptional.*

Please comment: The principal investigator has great expertise with a proven track record working to support and advance the lignite industry.

6. The background of the investigator(s) as related to the proposed work is:

Circle Answer: 1 – very limited; 2 – limited; 3 – adequate; 4 – better than average; or 5 – exceptional.

Please comment: Each of the key personnel identified in the application have experience working with the North Dakota lignite industry ranging from technical to legal expertise.

7. The project management plan, including a well-defined milestone chart, schedule, financial plan, and plan for communications among the investigators and subcontractors, if any, is: *Circle Answer: 1 – very inadequate; 2 – inadequate; 3 – adequate; 4 – very good; or 5 – exceptionally good.*

Please comment: Each of the above items are addressed in the application with clearly defined milestones and deliverables throughout the duration of the three year period.

8. The proposed purchase of equipment is: *Circle Answer: 1 – extremely poorly justified; 2 – poorly justified; 3 – justified; 4 – well justified; or 5 – extremely well justified. (Circle 5 if no equipment is to be purchased)*

Please comment: No equipment is specified for purchase.

9. The facilities and equipment available and to be purchased for the proposed research are: *Circle Answer: 1 – very inadequate; 2 – inadequate; 3 – adequate; 4 – notably good; or 5 – exceptionally good.*

Please comment: No additional facilities are needed. *Similar to above, selecting 5 as a result.*

10. The proposed budget “value”¹ relative to the outlined work and the financial commitment from other sources is of: *Circle Answer: 1 – very low value; 2 – low value; 3 – average value; 4 – high value; or 5 – very high value. (See below)*

Please comment: The key personnel have direct experience with North Dakota and the lignite industry, and, as a result, the proposed budget appears very reasonable given the potential significant value of the deliverables.

Section C. Overall Comments and Recommendations:

Please comment in a general way about the merits and flaws of the proposed project and make a recommendation whether or not to fund.

General comments: The application is well written, it aligns with the lignite research, development, and marketing goals, and the project would be executed by personnel with a successful record in this area. The Research & Development Studies and Activities, Environmental Strategies and Legal Support and Activities, and Power Markets and Transmission Strategies tasks will each play a unique role in helping to protect and preserve the lignite industry.

¹ “Value” – The value of the projected work and technical outcome for the budgeted amount of the project, based on your estimate of what the work might cost in research settings with which you are familiar.



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**Research & Economic
Development**

Tech Accelerator, Suite 2050
4201 James Ray Drive Stop 8367
Grand Forks, ND 58202-8367
Website: UND.edu/research

September 30, 2025

Karen Tyler, Executive Director
North Dakota Industrial Commission
State Capitol – 14th floor
600 East Boulevard Avenue, Dept. 405
Bismarck, ND 58505-0840

Subject: "Pilot Expansion and Testing for Improving Lignite Fuels and REE Processing,"
Proposal to the Lignite Research Program, October 1, 2025 deadline

Dear Ms. Tyler:

On behalf of the University of North Dakota, I am pleased to submit our proposal on "Pilot Expansion and Testing for Improving Lignite Fuels and REE Processing," for consideration by the NDIC's Lignite Research Program. Mr. Nolan Theaker is a Senior Research Manager in the CEM Research Institute and is the Principal Investigator for this project. We are proposing a 24-month-long work plan with a total requested amount from NDIC of \$1,100,000. The NDIC funding will be matched 1:1 by \$1,100,000 cost share from industry and other sources. The total value of the project will thus be \$2,200,000. We are requesting a start date of January 1, 2026.

Please contact Mr. Theaker with any technical questions about the project at (859) 319-4635 or nolan.theaker@und.edu. If the NDIC selects this proposal for an award, please send any award documents and related communications to Sherry Zeman at sherry.zeman@und.edu for processing on behalf of UND. The \$100 application fee is being handled as an electronic payment by UND and should reach your office in a timely manner. Thank you very much for your consideration of this proposal.

Sincerely yours,

DocuSigned by:
Karen Katrinak
DD9BE15BC81D4AA...

Karen Katrinak, Ph.D., Proposal Lead
Karen.katrinak@und.edu 701-777-2505

APPLICATION CHECKLIST

Use this checklist as a tool to ensure that you have all of the components of the application package. Please note, this checklist is for your use only and does not need to be included in the package.

☐	Application
☐	Transmittal Letter
☐	Tax Liability Statement
☐	Letters of Support (If Applicable)
☐	Confidentiality Request (If Applicable)
☐	Other Appendices (If Applicable)

When the package is completed, send an electronic version to ndicgrants@nd.gov

Questions can be addressed to the Industrial Commission at 701-328-3722.

Lignite Research, Development, and
Marketing Program

North Dakota Industrial Commission

Application

**Project Title: Pilot Expansion and Testing for
Improving Lignite Fuels and REE Processing**

Applicant: University of North Dakota

Date of Application: 10/01/2025

Amount of Request: \$1,100,000

Total Amount of Proposed Project: \$2,200,000

Duration of Project: 24 Months

Point of Contact (POC): Nolan Theaker

POC Telephone: (859)-319-4635

POC Email: nolan.theaker@und.edu

POC Address:

**2844 Campus Road, STOP 8153
Collaborative Energy Complex, Room 236
Grand Forks, ND 58202-8153**

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ABSTRACT

Objective:

The proposed work has four overarching objectives: i) pilot-scale demonstration and economic evaluation of a dedicated coal cleaning approach to generating a premium fuel with reduced boiler fouling potential, ii) testing, validating and scaling approaches to improving UND's process for extracting and concentrating rare earth elements and critical minerals from lignite, iii) expanding the scope and improving the capabilities of UND's existing rare earths pilot plant to enable scaled testing of process/product improvements, and iv) preparing UND and partners for near-term commercialization using U.S. Dept. of Energy funding that is expected to be released in late 2025 (under contract in late 2026 / early 2027).

Expected Results:

The key outcomes will include performance data on fuel and combustion properties of physically and chemically beneficiated lignite and economic improvements to existing state-of-the-art REE/CM processing techniques. This will directly position UND and partners to pursue commercial opportunities.

Duration:

The proposed effort will be executed over 24 months (01/01/2026 – 12/31/2027 proposed).

Total Project Cost:

The overall project cost is \$2,200,000, with a request of \$1,100,000 from the Lignite Research Program. The Department of Energy, North American Coal Corporation, and BNI Energy are providing cost share.

Participants:

The University of North Dakota's (UND) Center for Process Engineering Research (CPER) and Energy and Environmental Research Center (EERC) will be responsible for all technical tasks. Project supporters include the North American Coal Corporation and BNI Energy. Minnkota Power Cooperative has shown an interest in the project, and their scope and cost share will be added to the project in the event of their commitment arriving prior to award finalization.

PROJECT DESCRIPTION

Objectives:

The proposed 24-month project involves four overarching objectives:

1. Premium Lignite Demonstration: Leveraging UND's existing facility, we will complete a pilot-scale demonstration of a lignite coal cleaning approach to generate a low-to-zero alkali (e.g., sodium) premium fuel from "coal cleanings", which are those higher ash materials at the top margins of the coal seams that are currently discarded in current mining practices. This work will build from engineering design and economic assessments completed in previous efforts that will be updated based upon results from this project, leading to fast commercial implementation if proven technically and economically feasible.

2. Rare Earths Process Improvements: During our decade of developing our lignite-based rare earths extraction technology, we have identified multiple opportunities for process improvements that have not yet been fully tested/optimized. We will perform laboratory-scale R&D around multiple process pathways, aimed at: 1) reducing chemical consumption, 2) improving the yield of high value elements (Sc, Ge, Ga), and 3) improving product purity/quality. These findings will then be implemented in the pilot testing proposed in the project.

3. Rare Earths Pilot Expansion and Testing: Improving and expanding the capabilities of UND's existing 12 ton/day (lignite feed) rare earth elements and critical minerals (REE/CM) pilot plant, with the goals of demonstrating process improvements and installing and commissioning new equipment that will provide for higher-quality upgraded lignite for use in carbon products manufacturing. The original pilot plant was designed in 2019 and since that time, we have learned a great deal about the overall process, including certain methods to reduce processing costs or increase product qualities. However, these methods have only been investigated at smaller scales or in limited efforts at the pilot scale and their full testing is limited or prohibited by the current capabilities of the plant. Further, the plant's coal cleaning (spirals) system is installed, but it was never able to be commissioned, and the upgraded lignite water washing system as

designed/installed was discovered to be inefficient in generating the high-quality lignite that we will need at commercial scale. This proposed project will provide the opportunity to implement these improvements.

4. Preparing for Commercial Demonstration: Finally, UND is planning to pursue a commercial project through upcoming U.S. Dept. of Energy (DOE) funding that is anticipated to be released in late 2025 (DE-FOA-0003582). The project proposed here is essential in fully preparing our design basis for ready implementation in the commercial project (anticipated to start in early/mid 2027) and for making the pilot plant ready to generate products in sufficient quantity/quality to support offtake agreements with customers.

Methodology:

The proposed effort will be divided into five tasks over the performance period of 24 months.

Task 1. Project Management and Planning

UND will maintain ongoing project, budget, and schedule tracking and will hold bi-annual (every six months), at a minimum, meetings with project sponsors to update them on current project progress. Existing reporting guidelines, including quarterly financial and technical reports, and final reporting requirements will be maintained. Additional updates will be provided each year at the relevant Energy Progress and Innovation Conference (EPIC) when possible, given conference scheduling and planning.

Task 2. Pilot Expansion and Commissioning

This task will focus on physical pilot equipment procurement, installation, and commissioning, adding to the existing scope and capabilities of UND's pilot REE facility. The task will involve a preliminary design and evaluation phase of one month to design and begin procurement actions for major equipment, followed by installation and commissioning efforts once the equipment is on-site. This task will also include effort to commission existing physical separation equipment (coal spirals – photo above right) and to evaluate options for the premium lignite fuel demonstration (to be completed in Task 4).



Task 3. Rare Earth Process Improvement Testing

This task will include laboratory-scale testing of multiple pathways aimed at validating process improvements that have potential for chemical use reduction, increasing high-value REE and CM (Sc, Ge, Ga) recovery, and improving produced mixed rare earth concentrate (MREC) and upgraded coal product purities/qualities. We will utilize the existing Techno-Economic Assessments (TEAs) developed in prior projects as guidance to evaluate potential processing changes and determine whether there are resulting economic improvement in the overall process. A brief discussion of each of the three main research interests and planned testing follows.

Reducing Chemical Usage

Two main research directives will be considered to reduce chemical usage: i) increasing the relative concentration of the REEs in the leachate solution and ii) developing solid and liquid recycle streams to internally recycle chemicals wherever feasible. We have identified multiple approaches to achieve the former target that will be tested and optimized against the TEA, including recirculating a portion of the leachate solution, which was tested in a limited fashion at pilot scale in prior work (DE-FE0032295), but never fully optimized or validated. Similarly, the chemical recycling approaches have been tested in a limited fashion in prior work (DE-FE0032295) but require further effort to validate their techno-economics. If proven viable by TEA, these learnings and approaches will be incorporated into pilot testing in Task 5, where possible.

Increasing High-Value Element Recovery

Key economic drivers of the overall process are recovery of Sc, Ge, and Ga, typically accounting for at least 50-80% of the total contained REE/CM value. While Y and the lanthanides are primarily organically associated, Sc, Ge, and Ga appear to have a more diverse chemical association in the lignites that include various mineral forms. Therefore, we typically achieve a lower yield of these elements with our standard process. We have identified a process by which we can achieve the conversion of a mineral form into an

organic form, resulting in the ability to achieve a higher yield of those elements originally bound in mineral forms. This new approach is at a relatively early Technology Readiness Level. Therefore, we do not anticipate being able to incorporate it into the pilot testing in Task 5. However, if proven viable via TEA in this project, it could be readily incorporated as a bolt-on in future pilot or commercial projects. This approach also has applicability to REE-enriched clays that are being discovered by the North Dakota Geologic Survey (NDGS) in their work¹, and if successful, could ultimately dramatically simplify the mining process for thinner or laterally inconsistent beds of REE-enriched coals.

Improving Product Purity

We will test paths associated with improving the purity and potential value of our three main products, the two MREC products and the upgraded lignite. Lignite purification will be evaluated primarily as the methods for physical separation before and after leaching to remove existing or generated mineral matter. Our REE/CM process is very effective in removing any organically associated ash, but mineral matter is not targeted by our chemical process. Full demineralization is not likely to be economically feasible (would require much more aggressive chemical processing); however, identifying the potential coal purity achievable through physical means in tandem with our REE/CM process is critical for reaching ultra-pure carbon markets (e.g. synthetic graphite for lithium batteries).

Our process produces two MREC products – the first being high-purity REE, and the second being enriched specifically in Sc. To target improving the purity/value of the first MREC product, we have identified an approach based on the growth of REE-enriched crystals, reducing the precipitation rate of other elements in solution. This process will be tested in laboratory and pilot settings using synthetic seed crystal injection and examining solution impacts, such as temperature and liquid shear rate. To target improving the purity/value of the second MREC product, we will test selective ligands (in both solvent and sorbent

¹ https://www.dmr.nd.gov/dmr/sites/www/files/documents/Survey/Publications/Report_of_Investigation/RI-137.pdf

formats) to increase the concentration of Sc and therefore dramatically reduce the presence of chemicals-consuming competitor ions (primarily Ca). The findings from these efforts could be readily incorporated into Task 5, depending on the final form of the approach and whether they're proven viable by TEA.

Task 4. Physical Separation and Sodium Removal for High-Quality Fuels

Task 4 will focus on the dedicated cleanings processing circuits aimed at producing high-quality, low-Na blending fuels for electric power combustion. This task is not connected with our REE/CM focus, but does leverage the REE/CM pilot plant. This work will focus on pilot-testing of cleanings samples from project partners (North American Coal and BNI Coal) to include physical separations, the removal of mineral and clay matter from the coals, and a leaching circuit aimed at Na removal. The physical processing will be completed using UND's installed/commissioned mineral spirals and other physical processing equipment, with the Na removal evaluated between two main processing routes: one using weak acids such as CO₂, potentially available near the power station sites, and another utilizing a low-cost method for generating dilute acids, such as biologic or inorganic pyrite oxidation methods. A third option is available if neither route is viable, using purchased mineral acids (in a much more dilute / higher pH than what we use for REE/CM processing). A pilot campaign producing at least 5 tonnes of each of the cleanings-based blend fuels will be produced once both paths are established.

Combustion testing at the EERC will then be completed utilizing blends of the cleanings-based coal and run-of-mine coals, with a full coal composition and emissions workup. Two days of combustor testing, involving up to four separate fuel types, are budgeted.

Based on the work in this task, we will update the engineering and economic analysis for a dedicated coal cleaning plant and provide the findings to our industry partners for their consideration towards commercial implementation.

Task 5. Rare Earth Extraction Pilot Operational Testing

Task 5 focuses on operating and improving the pilot testing of REE-enriched coals for REE processing purposes. This task will utilize the findings from Tasks 3 and 4 to improve the value of the overall process and various products, and will use 5-10 tonnes of material in each specific test condition to ensure steady-state conditions of various recycle streams throughout the process. Testing will require over 100 tonnes of lignite-based feedstocks, allowing for the completion of multiple process improvements and baseline evaluations to ensure accurate process performance indicators.

The upgraded lignite resulting from the REE/CM process (independent of the premium fuel produced in Task 4 testing) will be subject to combustion testing at the EERC will then be completed utilizing blends of the cleanings-based coal and run-of-mine coals, with a full coal composition and emissions workup. Two days of combustor testing, involving up to four separate fuel types, are budgeted.

Anticipated Results:

Premium Low-to-Zero Alkali Fuel Demonstration: The ability to take what is, today, wasted during the normal mining sequence (coal cleanings) and generate not only saleable, but premium coal, offers multiple value propositions: i) more coal available per surface acre, reducing the net cost of mining, ii) flexibility provided by having a meaningful volume of low-to-zero sodium coal (e.g. 5-15% of total mine production) means the mine may have the ability to target seams/zones of higher-sodium coal than would otherwise be viable, further reducing mining costs, and iii) having a premium blending fuel to mitigate sodium fouling issues may increase boiler efficiency and increase plant uptime (e.g., the time between cleaning outages). The proposed project is expected to generate results that will be immediately informative towards a decision to implement this coal cleaning approach commercially.

While this aspect of the project is not geared towards our REE/CM efforts, there is important synergy to be exploited in the event the coal cleaning is developed commercially ahead of the REE/CM processing; the REE/CM processing would be a natural bolt-on progression, that would be able to utilize all or nearly all the equipment of the coal cleaning plant.

Rare Earths Technology and Preparing for Commercial Deployment: The proposed work is essential in advancing UND's technology towards commercial deployment as we are preparing to pursue up to \$50M in DOE funding for a first-of-a-kind (FOAK) project in North Dakota. The results of the pilot testing in this project will directly inform the design of the FOAK project under the DOE funding, which would initiate its design phase in mid-late 2027 (in perfect sequence with the period of performance of this project). Without the proposed project, we would not have the ability to incorporate the process improvements that we are confident will have a significant impact on the economic value of the technology and the commercial viability of the FOAK project.

Further, and importantly, the improvements to the UND pilot plant proposed in this project, will prepare that facility to generate products in sufficient quantities and qualities needed to secure commercial offtake agreements for the FOAK project and future commercial deployments.

Facilities:

Center for Processing Engineering Research (CPER) Facilities

The project will leverage UND CPER's existing pilot-scale REE/CM facility (photo to right). This facility is located within a large off-campus research facility that houses several large demonstration projects led by UND's College of Engineering & Mines. The



facility includes two high-bay floors with a total of 35,000 ft² of demonstration space and all of the required electrical and utility needs to support the proposed new equipment.

UND CPER's REE/CM pilot facility is capable of REE/CM extraction from lignite coal or lignite mine wastes. This pilot facility operates at a nameplate capacity of 12 tons/day (lignite feed), achieved through batch-wise leaching and semi-continuous downstream leachate processing. The facility has processed more

than 140 tons of various lignite feedstocks to date and can receive feedstocks from various sources in many ways, given the heavy equipment and the flexibility of crushers available to the facility. This pilot facility is also permitted and in compliance with all requirements associated with air emissions, water emissions, and fire and industrial safety.

The facility can be segmented into six major process areas, comprising: i) Coal crushing, handling, and chemical/water intake and disbursement; ii) Physical separation and filtration of non-lignite, low-REE streams; iii) Lignite leaching, filtration, and washing; iv) Impurity precipitation and solid separations; v) REE/CM precipitation, and vi) wastewater treatment and disposal.

The project will also take advantage of UND's world-class analytical and experimental laboratories that are capable of most of the proposed analytical characterizations, including ICP-OES, XRF, XRD, and SEM-EDS. External labs will be used if needed.

EERC Combustion Testing Facility (CTF)

Combustion testing will be conducted at existing pilot-scale combustors at the EERC, utilizing their existing CTF (photo to right). The research capabilities of the CTF have been enhanced over the years and expanded to provide information on a wide range of combustion-related issues. The refractory-lined furnace may be



fired at a rate sufficient to achieve a furnace exit gas temperature (FEGT) as high as 2500°F, allowing for a wide range of operating conditions. Most tests are performed with the FEGT maintained at approximately

2000°–2200°F. The CTF is fully instrumented to provide online flue gas analysis. Three flue gas-sampling ports are available. Flue gas concentrations for O₂, CO₂, and SO₂ are obtained simultaneously at the furnace exit and stack. CO and NO_x emissions are obtained at the furnace exit. System O₂, CO, and CO₂ analyzers were manufactured by Rosemount, the SO₂ analyzers were manufactured by DuPont and Ametek, and NO_x is measured with a Thermo Electron chemiluminescent analyzer. All system temperatures, pressures, and flue gas analyses are recorded continuously to chart recorders and the system's computer-controlled data. EERC also has a cyclone-fired combustion system available that could be used.

Resources:

The project team has currently budgeted for five full-time equivalents, including engineers, technicians, fabricators, and safety personnel. This group includes individuals with unique experience in chemical processing, equipment installation and commissioning, controls development, and process operations, including the team involved in the original REE piloting construction and operation. In addition, UND has various fabrication and analytical spaces and equipment associated with the proposed pilot facilities and installation available for use.

Techniques to Be Used, Their Availability and Capability:

Techniques for data generation within this project vary depending on the specific task and activities. The results from the laboratory experiments will be meticulously recorded, including all chemical additions, solution chemistry, pH, timing, and other pertinent data. Pilot tests will involve continuous data collection using attached sensors, including information on pH, flow, total suspended solids, and gas concentrations, and output devices, such as pumps and mixers. Liquid and solid samples will be properly prepared, stored, and analyzed utilizing appropriate ASTM methods. These methods have been used previously in various REE/CM projects completed by UND-CPER and the EERC, and methods for the specific analysis will be provided.

Environmental and Economic Impacts While Project is Underway:

Environmental permits for the related pilot facilities (REE and combustion) are established and will be adhered to for compliance with all relevant water and gaseous emissions from each facility. The project will involve minor gases from combustor testing and wastewater emissions from coal cleaning and REE processing, each managed with existing, installed treatment systems. Four to five full-time-equivalent research engineers, technicians, and other related staff will be employed as a result of this project.

Ultimate Technological and Economic Impacts:

The project's overall benefits include improving coal utilization and fuel quality, improving the economic viability of ND lignite REE extraction, and improving the array of potential carbon products producible from ND lignites. The project aims to increase coal recovery (per surface acre mined) in relevant, applied mines by up to 8-10%, specifically, an ultra-low-Na fuel to improve combustion performance in ND-lignite boilers. Additionally, the project aims to reduce operating costs associated with REE extraction and improve the value of various products to further increase the likelihood of successful economic CM extraction from lignites and increase the quality and availability of unique, cleaned lignite sources for carbon product feedstock testing. The proposed project will strongly position the team and industry partners to directly pursue commercial opportunities.

Why the Project is Needed

This project is critical and timely for three reasons: i) existing fuels for ND-based lignite boilers will continue to increase in both cost and contained fouling constituents, primarily Na; ii) REE/CM development must be de-risked and accelerated to ensure the continued leadership of North Dakota in coal-related and other unconventional REE/CM resource development; and iii) the products developed from these processes must be quantified and qualified better for downstream utilization in the power generation, carbon product, and REE/CM separation fields.

STANDARDS OF SUCCESS

The proposed effort aims to gather data, develop processes, and evaluate the efficacy of those processes related to fuel and REE processing from currently low-value coal resources (high ash coal cleanings). This work will focus on improving coal resource utilization and increasing the potential value and diversity of products available from North Dakota lignite.

Increasing Energy Sustainability

The project aims to increase coal recovery and improve the overall fuel quality in both dedicated-fuel and REE extraction pathways. Increases to coal recovery can be as much as 80% of the lost coal associated the coal cleanings fraction that is currently not sent to power plants or up to ~10% of total mined coal, and the sodium/alkali content of the fuel can be nearly eliminated. This effort is also expected to result in potential economic benefits to downstream coal-utilizers, such as the power industry, by identifying the costs and best practice data associated with lignite upgrading processes, with the specific aim of reducing the fouling-related outages of combustion facilities and improving the potential value of North Dakota lignite as a feedstock to carbon product producers.

Value to North Dakota

The proposed work aims to leverage North Dakota's vast lignite resources and the significant resources available through private and federal interests in the REE and CM spaces, positioning North Dakota's resources as crucial for domestic supply chains. Updating UND's existing pilot facility will showcase the equipment, placing it at the top of the nation's REE/CM piloting capabilities, and ensure the commercial design can be based on directly applicable pilot facility data, enabling North Dakota to continue to lead the REE mineral processing space and reduce risks associated with the commercial deployment of UND's REE extraction technology.

With the passing of HB 1459 during the 2025 ND legislative session, the legal and regulatory framework for the new REE/CM industry in North Dakota is established. This project is crucial in allowing UND and

our partners to take advantage of the immediate opportunity we have in front of us for commercialization.

The proposal will add value by leveraging and supporting ongoing work in REE, CM, and carbon product development for North Dakota-based resources. This work includes ongoing efforts related to Ge/Ga production (led by MTI, LRC-105A) due to it providing considerably larger amounts of Ge/Ga-rich mixed REE concentrates than are available solely in the scope of the limited DOE effort: proposed work for the carbon product development proposals (submitted through DE-FOA-002956) for high-value graphite, graphene, fertilizer, and building materials. The additions to the existing pilot facility will also enable UND to provide high-quality, low-ash processed coal samples for various other carbon products producers, enabling a low-cost source of high-quality, processed lignite at the tonnage scale for qualifying piloting tests. This includes North Dakota interests such as AmeriCarbon Products, who is working towards establishing a commercial lignite to coal tar pitch facility in North Dakota. UND and AmeriCarbon have discussed options for generating an ultra-low ash lignite that would allow them the opportunity to access high-purity / higher-value markets.

Potential Commercialization of the Project's Results

Two commercialization pathways for the technologies evaluated in this project will be considered: i) a direct REE extraction and coal processing pathway, and ii) the introduction of an intermediary step for coal cleaning and Na removal. Commercialization of the REE processing and carbon product development is anticipated to occur with assistance from DOE funding, including the active Notice of Intent DE-FOA-003582 for a first-of-a-kind facility, supporting up to \$50M in development of large pilots or small commercial demonstrations. The project proposed here is essential in that effort, enabling North Dakota to be competitive for these federal funds, and placing the technologies and facility capabilities in the strongest possible position.

Coal cleaning and Na removal can be more rapidly deployed, and the designed REE extraction plants would be able to take advantage of all equipment built out for this purpose. This additional functionality allows

for a lower initial CAPEX, with the more immediate benefit of coal recovery and average Na content reduction in fuels, while ongoing REE/CM resource characterization and technology demonstration can be completed.

Preserving Existing and Creating New Jobs

The proposed effort aims to create new jobs in the mineral and REE processing fields and stabilize existing mining and power generation jobs in the current industry. The overall job prospects for REE processing, as defined in previous economic assessments, ranges from ~60-110 jobs per REE extraction and concentration facility, depending on size and complexity. Further jobs associated with downstream REE and CM processing are expected, although specific numbers are unknown. Fewer jobs are expected to be created in the coal cleaning and Na removal plant concept than in the overall REE processing, but will still require new employment for commercialization. To stabilize existing mine and power generation jobs, increases to the non-fuel utilization of coal for mining jobs and the improved quality and expected benefits to power generation facilities reduce uncertainties with future mining and power generation.

Satisfying the Purposes Established in the Mission of the Program.

The project focuses on three primary pillars of the Lignite Research Program: promotion of economic, efficient, and clean uses of lignite through production of non-fuel products; preserve and create jobs involved in the production and utilization of lignite (described above); and ensure economic growth and opportunity in the lignite industry through new product development.

BACKGROUND/QUALIFICATIONS

Project Background

The proposed work builds from the decade of REE/CM technology development and mineral processing

commercial deployment and scale-ups.

It has long been known that extracting organically bound sodium (and other elements) is possible by weakly acidic or pH neutral solutions of the correct ionic character, as this has been standard in coal composition analyses such as the chemical fractionation approach used for decades on ND lignites. However, piloting of a dedicated process geared towards coal cleaning is needed to optimize the process at scale and evaluate the most cost-effective approach to generate the leaching solution (e.g., weak acids on-site, pyrite oxidation, or purchased chemicals).

Additionally, while combustion testing of the upgraded lignite produced from UND's pilot plant was completed in prior efforts under DE-FE0032295, the results were complicated by the fact that UND's coal spirals system was not operational. This resulted in ash content of 30-40% in the leached lignite, far higher than what is targeted following implementation of the upgrades to the pilot plant in the proposed project (e.g. 10-15% ash). This previous combustion testing did confirm that the leached coal – with its near-zero organically associated sodium – is expected to result in reduced boiler fouling. However, the remaining combustion performance metrics were inconclusive.

Qualifications

In 2016, UND was one of the first teams to be awarded funds from the DOE (FOA 1202, DE-FE0027006) to develop technologies for recovering REE from coal and coal byproducts. Our team has successfully advanced the technology from the lab-scale to a pilot-scale system under DE-FE0031835 (500 kg/hour of mine waste feed). The UND team is led by the Center for Process Engineering Research (CPER) at the College of Engineering & Mines (CEM), which has extensive experience in technology development, scale-up and pilot demonstrations, and techno-economic assessments in the areas of advanced power generation systems, CO₂ capture, desalination/water treatment, battery technologies, carbon-based products, and critical minerals. Our team has also led or been involved in many additional REE/CM-related projects and associated DOE-funded projects noted previously: DE-FE0032060, DE-FE0032053, DE-FE0029007, DE-

FE0031490, DE-FE0032124, and DE-FE0032295. Our team is recognized as a national and global leader in REE/CM related to unconventional resources.

Nolan Theaker, Senior Research Manager – Critical Minerals at UND’s CPER. Mr. Theaker has B.S. and M.S. degrees in Chemical Engineering from the University of Louisville, Kentucky. He will be the principal investigator (PI) for the proposed project. Mr. Theaker has been the technical driver for UND’s technology development and resource characterization efforts related to REE/CM since he joined UND in 2018. He is widely recognized within the DOE and research community as a leading expert on REE/CM technologies. Mr. Theaker was the Co-PI/technical lead on UND’s bench-scale demonstration (DE-FE0027006), the PI on the completed pilot-scale project (DE-FE0031835), and the Co-PI/technical lead on the conceptual design and feasibility study (89243320RFE000032) and FEED studies (DE-FE0032295).

Nicholas Dyrstad-Cincotta, Research Operations Manager – CPER. Mr. Dyrstad-Cincotta has B.S. and M.S. degrees in Mechanical Engineering from UND. He has extensive experience in pilot-scale process development, rare earth element extraction, and advanced coal utilization technologies. He served as Mechanical and Operations Lead for the REE pilot development (DE-FE0031835), where he directed the commissioning, modification, and operation of the pilot facility. Mr. Dyrstad-Cincotta provides mechanical, electrical, and instrumentation engineering support across UND’s College of Engineering and Mines, manages CPER research facility operations and maintenance, serves as the Safety Coordinator for CPER, and is the lead programmer for process control systems, with extensive LabVIEW and NI hardware expertise applied to dozens of successful lab, bench, and pilot-scale projects.

Jason D. Laumb, Director of Advanced Energy Initiatives at the EERC, provides leadership to a multidisciplinary team of Distinguished Researchers working on diverse projects in multiple areas of the energy sector. Topic areas include renewable energy, CO₂ capture, techno-economic modeling, extraction of critical materials, environmental control systems, supercritical CO₂ power cycles, advanced gasification technologies, pipeline safety, enhanced oil recovery, and reservoir engineering. Laumb has served as Director of Advanced Energy Systems Initiatives since 2021. Laumb holds an M.S. degree in Chemical

Engineering and a B.S. degree in Chemistry, both from the University of North Dakota. Laumb's 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.

Resumes for key personnel in the project may be found in Appendix A.

MANAGEMENT

UND, led by Mr. Theaker and the CPER team, is the lead organization for this project and will oversee all tasks, budget, and management activities. UND will schedule regular project-internal and sponsor meetings to ensure project execution is maintained at the proposed schedule below. These meetings will be used to review project status, risks, challenges, deliverable timelines, and budget, with updates to sponsors occurring no less than twice annually. Continuous budgetary evaluation for the project, both from spending rates on tasks as well as monitoring and management of required cost share, will be maintained at UND. A project organization chart is provided in Figure 2.

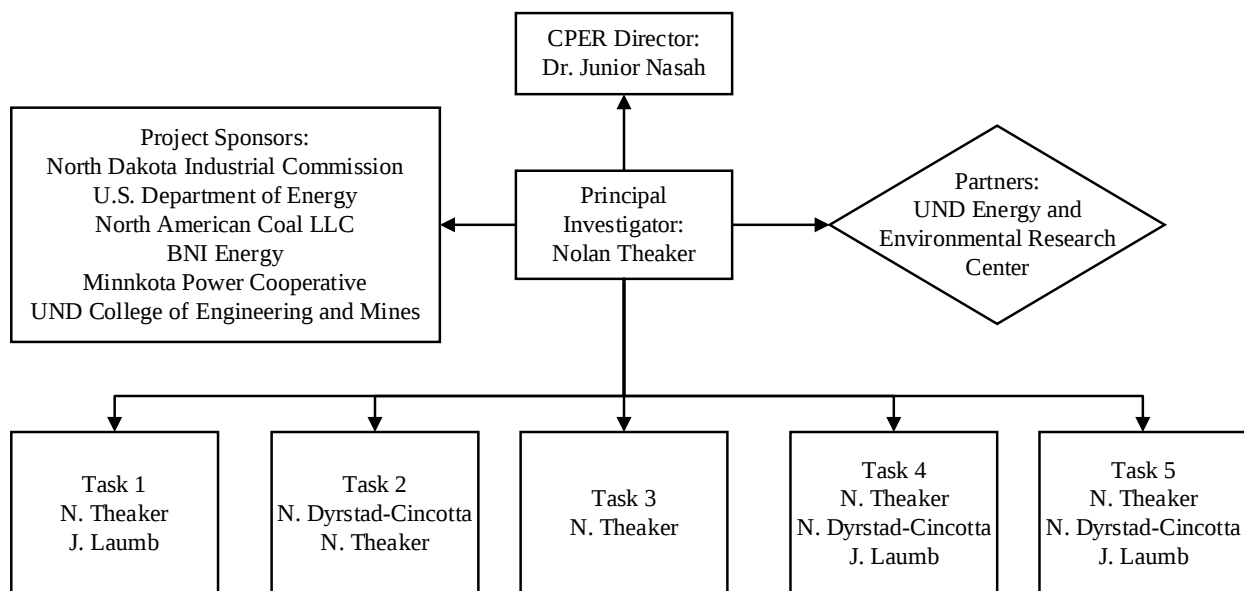


Figure 2. Project organization chart.

TIMETABLE

The proposed project is to be completed over 24 months, as shown in Figure 3.

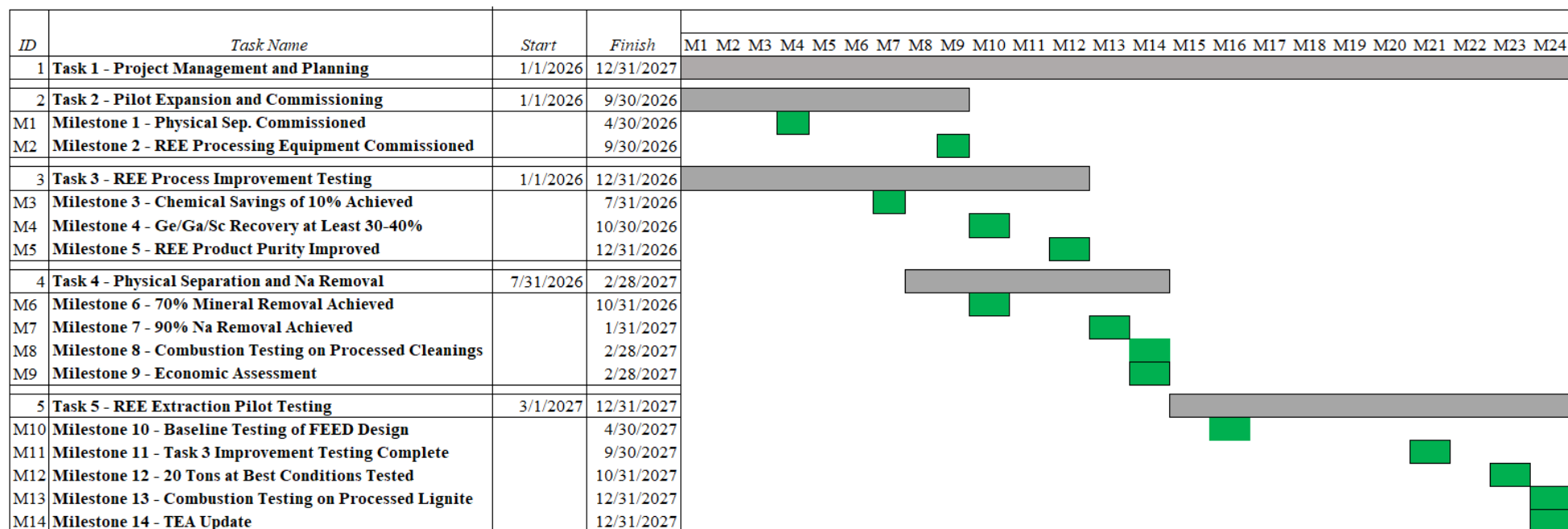


Figure 3. Project Gantt chart schedule.

Milestones

Twelve milestones are planned for the project, spanning Tasks 2-5. Each are described below.

Milestone 1. Completion of commissioning existing physical separation equipment for testing. Completion by 04/30/2026, reported in Quarterly Report 2.

Milestone 2. Completion of equipment installation and commissioning for REE processing updates to match FEED study design. Completion of 09/30/2026, reported in Quarterly Report 3.

Milestone 3. Development of processes to reduce at least one process chemical in REE extraction by at least 20% from FEED study baseline. Completion of 07/31/2026, reporting in Quarterly Report 3.

Milestone 4. Improvement in Sc, Ge, and/or Ga recovery from lignite as compared with FEED study baseline (~20-25% for each). Completion of 10/30/2026, reporting in Quarterly Report 4.

Milestone 5. Testing of systems to produce first-precipitation (without re-dissolution and processing) REE purities compared to FEED study baseline (90% first concentrate, 10% second concentrate), Completion by 12/31/2026, reporting in Quarterly Report 4.

Milestone 6. Physical separation to remove 70% of mineral-bound ash from coal cleanings achieved. Completion by 10/31/2026, reporting in Quarterly Report 3.

Milestone 7. Process for removing 90% of Na utilizing either pyritic or acid-gases available at mine/power generation facility sites. Completion by 01/31/2027, reporting in Quarterly Report 5.

Milestone 8. Combustion testing of physically processed, low-Na cleanings. Completion by 02/28/2027, reporting in Quarterly Report 5 and Combustion Testing Report.

Milestone 9. Update of previous economic assessments of coal cleaning/Na-removal processing for cleanings processing developed based on FEED and produced pilot data, completion by 02/28/2027, reporting in Quarterly Report 5.

Milestone 10. Completion of 20 tons of lignite testing using the commissioned FEED study design process at UND's pilot-scale for benchmarking against future testing. Completion by 04/30/2027. Reporting in Quarterly Report 6.

Milestone 11. Completion of promising MREC process improvement upgrades at pilot-scale. Completion by 09/30/2027, reporting in Quarterly Report 7.

Milestone 12. Completion of at least 20 tons of lignite processed for REE extraction at the best identified conditions developed in this project. Completion by 11/30/2027, reporting in the Final Technical Report.

Milestone 13. Combustion testing of REE-processed lignites. Completion by 12/31/2027, reporting in Final Technical Report and Combustion Testing Report.

Milestone 14. Update of previous economic assessments of REE/CM extraction processing for lignite developed based on FEED and produced pilot data, completion by 12/31/2027, reporting in Final Technical Report.

Deliverables

Project deliverables and planned due dates.

Deliverable Name	Task	Date Due
Quarterly Report 1	1, 2, 3	04/30/2026
Quarterly Report 2	1, 2, 3	07/30/2026
Quarterly Report 3	1, 2, 3	10/30/2026
Quarterly Report 4	1, 3, 4	01/30/2027
Quarterly Report 5	1, 4	04/30/2027
Quarterly Report 6	1, 5	07/30/2027
Quarterly Report 7	1, 5	10/30/2027
Final Technical Report	1, 2, 3, 4, 5	12/31/2027
Combustion Testing Report	4, 5	10/30/2027

BUDGET AND MATCHING FUNDS

The overall project budget is \$2,200,000, with \$1,100,000 from the NDIC and \$1,100,000 from cost share sources, outlined below in Table 1 with the complete budget outlined in Table 2.

Table 1. Sources of funds for the proposed effort.

Funding Source	Cash	In-Kind
North Dakota Industrial Commission	\$1,100,000	\$0
U.S. Department of Energy ¹	\$475,000	\$0
North American Coal	\$400,000	\$100,000
BNI Energy	\$100,000	\$25,000
Total	\$2,075,000	\$125,000

¹DOE cost share is described in detail in the section below.

Letters of commitment from North American and BNI Energy are included as an appendix to this document.

We would also like to note that we have had positive discussions with Minnkota Power Cooperative about their potential support of and participation in this project. Minnkota did express strong interest, but unfortunately was unable to process a signed letter of commitment in time for this application. If Minnkota can provide their commitment between now and when the Lignite Research Council reviews/votes on this project, we would like consideration towards including Minnkota's support at that time. This would decrease the cost share amount from DOE.

DOE Cost Share

Due to ongoing delays at the DOE in releasing new project awards and in reviewing previously submitted proposals, the project team is proposing \$475,000 of contingent DOE cost share. This DOE cost share consists of scope, budget and period of performance that is in alignment with the proposed project. However, this DOE funding is not yet under contract and is made up of several proposals that are in varying stages of DOE consideration: 1) selected for award, but caught in the award negotiations freeze with the new federal administration, 2) proposal submitted, but no selections yet made by DOE, or 3) proposal in

preparation (DE-FOA-0003582) that we expect to be awarded in late 2026. Of the portion of these DOE projects that are in alignment (e.g., would be eligible as cost share towards NDIC), a total of \$1.8M would be available if all of the projects were ultimately contracted (DOE projects valued at more than \$10M in total). We are only proposing \$475K of that amount. Our team is very confident that enough of the DOE funding will ultimately make it to contract to be able to meet the NDIC cost share requirement.

In the unlikely event that insufficient DOE funding becomes available, UND would consider two approaches to ensuring NDIC cost share requirements are met: 1) negotiate a reduction in scope and budget and/or 2) secure alternative cost share.

Given the strong commitments provided by our industry partners for this application (\$500K cash + \$125K in-kind) and the ongoing delays at DOE, we hope the LRC and NDIC will view our approach to cost share for this project as reasonable and acceptable.

Table 2. Overall Budget

Project Associated Expense	NDIC Grant	NDIC Loan	Applicant's Share (Cash)	Other Project Sponsors' Share	Total
Salaries	307,956			272,961	580,917
Fringe Benefits	158,349			140,354	298,703
Travel	3,238			2,870	6,108
Supplies	27,260			24,165	51,425
Shipping	100			88	188
Pilot Facility Rent	95,783			84,899	180,682
Pilot Facility Utilities	21,753			19,281	41,034
Pilot Facility Maintenance	5,140			4,555	9,695
Equipment Maintenance	15,908			14,100	30,008
Lab Fees and Professional Services	80,863			71,675	152,538
Equipment	169,639			150,361	320,000
Indirect Costs	214,011			189,691	403,702
Industry In-Kind	-			125,000	125,000
Total	1,100,000			1,100,000	2,200,000

Salaries

Salaries are based on current institutional base salaries, escalated 4% per year on 7/1 for non-EERC personnel and 5% for EERC personnel. Estimated hours and hourly rates are detailed in the table below, totaling \$580,917.

Any hourly salary rates based on a 40-hour work week shown in this proposal are for evaluation purposes only. UND uses payroll confirmation for effort and does not account for or report on an hourly rate.

Title	Hours	Avg. Rate	Salary Total
Principal Investigator	635	63.30	40,197
CPER Director	80	75.25	6,020
Research Associate Professor	80	68.93	5,514
Research Operations Manager	2,705	54.57	147,613
Research Engineer	2,705	43.70	118,200
Research Engineer	300	41.79	12,536
Research Engineer	300	39.57	11,872
Engineering Technician	1,560	36.21	56,494
EERC Personnel	3,059	59.65	182,471
Total			\$580,917

Fringe Benefits

Amounts shown for fringe benefits for CEM personnel are estimates determined by historical data and are provided for proposal evaluation purposes only. Actual fringe benefit costs will be charged to the grant according to each employee's actual benefits. UND's Energy & Environmental Research Center (EERC) has approved fringe benefit rates shown in the Indirect Cost Rate Agreement. Fringe rates are detailed in the table below, totaling \$292,415 for the project.

Title	Rate	Fringe Total
Principal Investigator	38.5%	15,652
CPER Director	36.1%	2,173
Research Associate Professor	37.5%	2,068

Research Operations Manager	41.9%	61,850
Research Engineer	46.6%	55,081
Research Engineer	47.8%	5,992
Research Engineer	49.3%	5,853
Engineering Technician	52.4%	29,603
EERC Personnel	66.0%	120,431
Total		\$298,703

Travel

Travel to the Energy Progress & innovation Conference is included for five people to disseminate project results. Travel rates include \$400 for registration per person, \$110 for lodging per night, \$68 for per diem per day, and \$0.70 mileage reimbursement. These costs are based on currently available pricing, GSA rates, and previous experience. Total travel is \$6,108.

Supplies

\$51,425 is estimated for project materials and supplies, itemized below. Each of the supply categories are generalized categories that contain multiple individual supply types. These values have been estimated based on prior experience and available vendor pricing information. The quantity has been shown as 1 in some categories for simplicity.

Materials & Supplies	Quantity	Unit Cost	Total Cost
Laboratory Chemicals	1	2,500	2,500
Laboratory PPE	1	250	250
Glassware Replacement	1	750	750
Pilot Chemicals	1	35,000	35,000
Pilot PPE and Safety Equipment	1	10,000	10,000
Sample Containers	500	0.25	125
EERC Supplies	1	2,800	2,800
Total			\$51,425

Shipping

\$188 is included for the shipment of samples to external ICP labs based on previous experience.

Pilot Facility Cost

Costs are included for the rent (\$180,682), utility (\$41,034), and facility (\$9,695) costs associated with the use of a minimum of 12,120 square feet in UND's off-campus pilot research facility for two years. These costs are based on the current rental agreement and estimated utilities rates and building maintenance needs.

Equipment Maintenance

\$30,008 is included for Pilot System maintenance and repairs, based on previous experience.

Lab Fees and Professional Services

\$152,538 is requested for lab fees and professional services, itemized below.

Service	Total Cost
Sample Prep	9,000
ICP-OES Analysis	19,200
SEM/EDX Analysis	1,600
XRF Analysis	1,075
ICP-MS (ext) Analysis	30,000
Natural Materials Analytical Research Lab	11,063
Combustion Test Service	23,285
Process Chemistry & Development Lab	3,108
Fuel Preparation Services	2,570
Document Production Service	1,128
EERC Shop & Operations	48,083
Engineering Services Fee	2,429
Total	\$152,538

Equipment

\$320,000 is estimated for equipment, detailed below for the proposed UND pilot expansion to execute Tasks 2, 4, and 5.

Equipment Item	Qty	Unit Cost	Total Cost
Heated, Jacketed Stainless Tank	1	55,000	55,000
Fluids Heat Exchanger	1	35,000	35,000
Stainless Steel Leaching Tank Expansion	1	15,000	15,000
Filter Press Plate Changes	1	35,000	35,000

Slurry Pumps for Pressure	4	7,500	30,000
Spirals Tanks Upgrades	3	20,000	60,000
Piping, Valving, and Fittings	1	40,000	40,000
Controls	1	35,000	35,000
Fabrication Supplies	1	15,000	15,000
Total			\$320,000

Indirect Costs

The indirect cost rates included in this proposal are the federally approved rates for the University of North Dakota. Indirect costs are calculated based on the Modified Total Direct Costs (MTDC), defined as the Total Direct Costs of the project less individual items of equipment \$5,000 or greater, tuition, rent, and subcontracts in excess of the first \$25,000 for each award. The UND CEM costs use the off-campus rate of 26%, and the UND EERC costs use the EERC rate of 51%, totaling \$403,702.

Total Costs

The total project costs are \$2,200,000, of which 50% or \$1,100,000 is requested from NDIC.

CONFIDENTIAL INFORMATION

None in this application.

PATENTS/RIGHTS TO TECHNICAL DATA

None declared with this application.

STATE PROGRAMS AND INCENTIVES

As a state-controlled institution of higher education, UND has participated in many state programs, including prior and ongoing research awards through the NDIC.

Industrial Commission

Tax Liability Statement

Applicant: University of North Dakota

Application Title: Pilot Expansion and Testing for Improving Lignite Fuels and REE Processing

Program:

- ☒ Lignite Research, Development and Marketing Program
☐ Renewable Energy Program
☐ Oil & Gas Research Program
☐ Clean Sustainable Energy Authority

Certification:

I hereby certify that the applicant listed above does not have any outstanding tax liability owed to the State of North Dakota or any of its political subdivisions.

DocuSigned by:

Karen Katrinak

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Signature

Karen Katrinak, Proposal Lead

Title

9/30/2025

Date

Nolan L. Theaker

Senior Research Manager – Critical Minerals, Center for Process Engineering Research
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 Senior Research Manager, College of Engineering and Mines Research Institute.

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, \$10M Front End Engineering Design Study, 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 CO₂ 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 CO₂. 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 CO₂ capture unit in multiple reaction conditions, including enzymatic and amine-based systems. Evaluation and comparison of catalyst performance in a holistic view for CO₂ 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-Step Cascade Electrochemical Reduction of CO₂ 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.



JASON D. LAUMB

Director of Advanced Energy 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

Education and Training

M.S., Chemical Engineering, UND, 2000.

B.S., Chemistry, UND, 1998.

Research and Professional Experience

May 2024–Present: Director of Advanced Energy Initiatives, EERC, UND.

Laumb provides leadership to a multidisciplinary team of Distinguished Researchers working on diverse projects in multiple areas of the energy sector. Topic areas include renewable energy, CO₂ capture, techno-economic modeling, extraction of critical materials, environmental control systems, supercritical CO₂ power cycles, advanced gasification technologies, pipeline safety, enhanced oil recovery, and reservoir engineering.

May 2021–May 2024: Director of Advanced Energy Systems Initiatives, EERC, UND.

Laumb provided leadership on projects related to advanced energy systems and led a multidisciplinary team of scientists and engineers working on advanced energy technologies from pollution control to new energy platforms. Principal areas of interest and expertise included renewable energy, CO₂ capture, techno-economic modeling, extraction of critical materials, environmental control systems, supercritical CO₂ power cycles, and advanced gasification technologies. Experience included 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.

September 2019–April 2021: Assistant Director of Advanced Energy Systems, EERC, UND.

Laumb assisted the EERC executive team by providing leadership on projects related to advanced energy systems. 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 CO₂ capture, techno-economic modeling, environmental control systems, supercritical CO₂ 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. 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 selective catalytic reduction technologies for NO_x control, mercury control technologies, hydrogen production from coal, CO₂ 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.

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. Laumb 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.

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. Laumb was also involved in the analysis of combustion control technologies' ability to remove mercury and the suitability of biomass as boiler fuel.

1998–2000: Scanning Electron Microscopy Applications Specialist, Microbeam Technologies, Inc., Grand Forks, North Dakota.

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 scanning electron microscopy/energy-dispersive spectroscopy; and modifying and writing FORTRAN, C+, and Excel computer programs.

Professional Activities

Member, American Chemical Society

Publications

Has coauthored numerous professional publications.

Nicholas Dyrstad-Cincotta

Education

University of North Dakota (UND), Grand Forks, ND	
Bachelor of Science Degree in Mechanical Engineering	Spring 2018
Master of Science Degree in Mechanical Engineering	Fall 2018
Master of Business Administration	Spring 2022

Research and Professional Experience

2023 Research Operations Manager, UND Center for Process Engineering Research (CPER)

- ✦ Mechanical & Operations Lead — UND Rare-Earth Extraction Pilot Plant: Directed cross-functional engineering and vendor teams through detailed equipment design, procurement, mechanical installation, instrumentation, and control-system programming for pilot-scale REE extraction commissioning.
- ✦ Provides mechanical and electrical/instrumentation engineering design expertise to researchers in CEM and campus-wide research; lead design, fabrication, and installation of experimental systems; coordinate facility operations and deliver hands-on support for research teams.
- ✦ Oversee maintenance and reliability of CEM research facilities, equipment, and infrastructure to ensure safe, uninterrupted operations.
- ✦ Safety Coordinator for CPER: Develop and deliver training programs for faculty, staff, and students; enforce safety compliance and foster a culture of safe research practices.
- ✦ Lead project programmer for CEM: Expert in NI hardware, low-voltage instrumentation, sensor wiring, and LabVIEW development; delivered dozens of successful lab, bench, and pilot-scale automation projects department-wide.

2018-2022 Research Engineer, UND Institute for Energy Studies.

- ✦ Mechanical lead on two high-temperature research projects: Modular Biomass Gasification for CoProduction of Hydrogen and Power (CH2P) project and the Flexible Carbon Capture and Storage (FLECCS).
- ✦ Several years of experience serving as Principal Investigator (PI) on two externally funded state grant projects investigating lubrication filtration technology in the power generation industry.
- ✦ Ample experience with grant proposal development, in both lead and support roles.
- ✦ Experience also includes executing the proposed research through proper budgeting, designing, procurement, fabrication, operation, programming, and report writing for the awarded projects.
- ✦ Prior experience leading, designing, commissioning, and operating several high-pressure projects, including the bench-scale Solar Desalination water treatment project called: Supercritical Water Extraction – Enhanced Targeted Recovery (SWEETR™). Additionally, served as the lead experimentalist of the previous lab-scale Phase I Supercritical Treatment Technology for Water Purification project.
- ✦ Experience with Auto CAD Inventor 3D design software developing models to meet the need of project objectives. Developed models for external fabrication, along with creation of novel prototypes, notably for the Electrostatic Lubrication Filtration (ELF) technology.

2016-2018 Junior Engineer, UND Institute for Energy Studies.

- ✦ Key developer and operator for the Phase II continuation of the High-Capacity Sorbent and Process for CO₂ project - Enhanced Capture of CO₂ with Hybrid Sorption: E-CACHYS™ bench scale project.
- ✦ Additional responsibilities include basic process and mechanical design, fabrication, instrumentation, programming, and operation of several bench scale research projects in the Chemical Looping Combustion focus area.

2015 Quality Engineering Co-op, United Technology Corporations Aerospace Systems (UTAS)

- ✦ Lead an Environmental Health and Safety team to address laceration hazards and implemented solutions to decrease opportunity for accidents plant wide.
- ✦ Gained extensive knowledge in quality engineering, lean manufacturing, and product/process design. Specific background in Achieving Competitive Excellence, UTAS' version of six sigma.
- ✦ Delivered quality controls and enhancements to proactively address problems and improve product quality, manufacturing flow, customer satisfaction and bottom-line results.
- ✦ Improved the efficiency of production operations, prepared engineering drawings in NX Siemens, a CAD modeling software, and managed the engineering change process.
- ✦ Responsibilities included verifying the quality and performance of the products in addition to troubleshooting the rectification of any existing errors or defects through product failure mode effects analysis (PFMEA).
- ✦ Additional minor responsibilities included conducting 5S and ISO 9001 audits to ensure standardization, efficiency, and safety in the workplace.

2014-2016 Research Assistant, UND Institute for Energy Studies.

- ✦ Researched and developed several sorbent-type technologies. Sorbents for the capture of postcombustion CO₂ from coal-fired power plants.
- ✦ Key personnel for implementing Capture from Existing Coal-Fired Plants by Hybrid Sorption Using Solid Sorbents Capture CACHYS™ technology - a High-Capacity Sorbent and Process for CO₂ Capture. Operated and maintained the CACHYS bench scale project.

2011-2013 Utility/Maintenance Supervisor - University of North Dakota

- ✦ Monitored and maintained the appearance, functionality, and cleanliness of the entire facility
- ✦ Ensured maintenance and repair work was completed correctly and in a timely manner
- ✦ Supervised, trained, and oversaw actions of over 20 student workers
- ✦ Facilitated large catering deliveries and returns of large dining equipment
- ✦ Locking up and securing the facility

Relevant Skills & Competencies

- ✦ LabVIEW real-time programming
- ✦ 3D Modeling – AutoCAD, Solid Works, NX Siemens
- ✦ MIG, TIG welding, manufacturing processes, machine shop tools
- ✦ Proficient in Microsoft Office 365 suite of programs
- ✦ Excellent management, leadership, project execution, oral/written communication, and analysis skills

Selected Publications/Presentations

Tomomewo, O. S., **Dyrstad-Cincotta, N.**, Mann, D., Ellafi, A., Alamooti, M., Srinivasachar, S., & Nelson, T. (2020, September 18). Proposed Potential Mitigation of Wastewater Disposal Through Treated Produced Water in Bakken Formation. American Rock Mechanics Association.

Dyrstad-Cincotta, N. “Supercritical Treatment Technology for Water Purification.” North Dakota Energy Conference & Expo (NDECE), Grand Forks, ND. November 2019.

D., Mann, M., Srinivasachar, S., **Dyrstad-Cincotta, N.** “Supercritical Treatment Technology for Water Purification.” U.S. Department of Energy (DOE) Solar Energy Technologies Office (SETO) Concentrating Solar-Thermal Power (CSP) Program Summit 2019, Oakland, CA. March 2019.

Nasah, J., Jensen, B., **Dyrstad-Cincotta, N.**, Gerber, J., Laudal, D., Mann, M., Srinivasachar, S. “Segregation of Unreacted Char from Oxygen Carriers During Chemical Looping Combustion.” 5th International Conference on Chemical Looping, 24-27 September 2018, Park City, Utah, USA.

Nasah, J., Gerber, J., Laudal, D., Mann, M., Srinivasachar, S., **Dyrstad-Cincotta, N.**, Jensen, B. “Method for Separation of Coal Conversion Products from Oxygen Carriers.” Journal, International Journal of Greenhouse Gas Control. 2019.

Das, Pail & Umerov, E. & **Dyrstad-Cincotta, Nicholas** & Rimon, Md & Mazurkivich, Matthew & Rengifo, Sara & Scott, William & Wang, Yachao & Roy, Sougata. (2025). Exploring the erosion resistance of Al6061 metal matrix composite fabricated via additive manufacturing for future lunar exploration. Progress in Additive Manufacturing. 10. 6211-6227. 10.1007/s40964-025-00966-0.

Work Bio

Mr. Dyrstad-Cincotta served as the Mechanical and Operations Lead for the U.S. Department of Energy–funded project *Rare Earth Element Extraction and Concentration at Pilot-Scale from North Dakota Coal-Related Feedstocks* (Project No. DE-0031835). In this role, he led the commissioning, modification, and operation of a first-of-its-kind pilot facility, managing equipment design, procurement, installation, instrumentation, and process programming. His leadership enabled successful demonstration of rare earth element extraction and concentration from domestic coal-related feedstocks, advancing DOE’s goal of securing critical mineral supply chains.

Beyond this project, Mr. Dyrstad-Cincotta’s expertise spans emissions control for advanced and traditional coal power generation, supercritical water treatment, and fluid-bed technology development. He has supported all fluidized-bed systems within the CLC research group, with extensive experience in emissions monitoring and combustion testing at bench, pilot, and field scales to support technology development and verification.

Additional areas of contribution include coal-based pollution measurement and control (sulfur oxides, nitrogen oxides, aerosol formation), underground coal gasification, coal beneficiation, and natural gas processing. He has several years’ experience in planning, executing, and reporting laboratory, bench, and pilot-scale research programs. Mr. Dyrstad-Cincotta also serves as Lead Programmer for process control systems at the College of Engineering & Mines Research Institute (CEMRI), where he develops automation and control solutions across diverse research projects and supports PCS integration throughout the UND College of Engineering & Mines.

North American COAL

September 22nd, 2025

Mr. Nolan Theaker
Senior Research Manager, Center for Process Engineering Research
University of North Dakota
Collaborative Energy Center, Room 246
2844 Campus Road, Stop 8153
Grand Forks, ND 58202-8153

Re: Support of the proposal entitled "Pilot Expansion and Testing for Improving Lignite Fuels and REE Processing" submitted in response to North Dakota Industrial Commission's Lignite Research Program Grant Round 108.

Dear Mr. Theaker:

On behalf of North American Coal, LLC (NAC), I am pleased to confirm our strong support for the University of North Dakota's proposal submitted to the North Dakota Industrial Commission's Lignite Research Program.

UND's proposed project represents a critical next step in advancing rare earth element (REE) extraction technology. Expanding the scope and capabilities of the current pilot plant located in Grand Forks will allow UND to produce higher-quality upgraded lignite feedstocks, test and optimize process designs developed in previous efforts, and generate improved data on the technical and economic feasibility of commercial-scale deployment. The project's focus on producing a high-quality, low-sodium fuel from mine cleanings, while refining the REE extraction process, is directly aligned with NAC's interest in creating value from lignite resources through both critical mineral recovery and advanced carbon product development.

To support this effort, NAC is committed to contributing up to **\$400,000 in cash over the two-year project period**, in addition to supplying REE-enriched and mine-cleaning coal samples for testing, valued at approximately **\$100,000**. We recognize that this investment will be instrumental in accelerating this promising technology toward commercial readiness and positioning North Dakota as a leader in REE and carbon product innovation.

We strongly encourage the Lignite Research Program to fund this important project and look forward to collaborating with the UND and EERC team to ensure its success. Please do not hesitate to contact me at the address above if you have any questions or require additional information.

Sincerely,

NORTH AMERICAN COAL, LLC



Carroll L. Dewing
Senior Vice President and Chief Operating Officer

September 19th, 2025

Mr. Nolan Theaker
Senior Research Manager, Center for Process Engineering Research
University of North Dakota
Collaborative Energy Center, Room 246
2844 Campus Road, Stop 8153
Grand Forks, ND 58202-8153

Re: Support of the proposal entitled "Pilot Expansion and Testing for Improving Lignite Fuels and REE Processing" submitted in response to North Dakota Industrial Commission's Lignite Research Program Grant Round 108.

Dear Mr. Theaker:

On behalf of BNI Coal (BNI), I am pleased to confirm our strong support for the University of North Dakota's proposal submitted to the North Dakota Industrial Commission's Lignite Research Program.

The proposed project involves expanding the scope and capabilities of the current rare earths extraction pilot plant located in Grand Forks, which will allow UND to produce higher-quality upgraded lignite feedstocks, test and optimize process designs developed in previous efforts, and generate improved data on the technical and economic feasibility of commercial-scale deployment. The project will also focus on pilot demonstration of a physical and chemical approach to producing a high-quality, low-sodium fuel from otherwise wasted or low-quality lignite (mine cleanings).

BNI is highly interested in the opportunities provided by a lower cost coal recovery and sodium removal system, improving the overall coal recovery rate and reducing acreage requirements for mining. BNI also understands the potential expansion of a commercial facility for cleaning remediation into a full REE-extraction facility would be possible in the future.

In support of your project, we commit to providing UND up to **\$100,000 in cash over the two-year period**, as well as in-kind support in coal and coal cleanings supply valued at **\$25,000**. We understand this support will be key in driving this proposed concept forward beyond and ahead of federal funding requests for commercial deployment.

We encourage the Lignite Research Program to fund this important project and look forward to the collaboration with the UND and EERC team on this effort. If you have questions or require additional information, please do not hesitate to contact me at the letterhead address.

Sincerely,



Mike Heger
President



September 18, 2025

Mr. Nolan Theaker
Senior Research Manager
College of Engineering & Mines Research Institute
University of North Dakota
2844 Campus Road, Stop 8153
Grand Forks, ND 58202

Dear Nolan:

Subject: EERC Proposal No. 2026-0026 Entitled "REE Pilot Support"

Introduction

In response to your recent request, the Energy & Environmental Research Center (EERC) is proposing to provide operations support to aid in producing rare earth element (REE) concentrate at the College of Engineering & Mines Research Institute (CEMRI) extraction facility. In addition, the EERC also proposes to perform combustion evaluations of material as indicated by CEMRI. The scope of work details can be found in the following sections.

Work Scope

Operation Support. The EERC will provide two operators and one chemist to help operate the REE extraction facility. Up to 15 weeks of operation will be supported. In addition, EERC operations staff will be available to process wastewater created during the operations of the extraction plant. The wastewater support will provide one operator for 3 weeks of time.

Combustion Evaluation. The EERC will perform up to 4 days of pilot operation using the EERC combustion test facility (CTF) to collect emissions data on coal samples provided by CEMRI. Each day will include up to 10 hours of operation. During the testing, the EERC will provide the following data:

- Performance data on combusted coal samples
 - All operational data of the pilot operation including, fuel feed rate, flue gas composition (NO_x , SO_x , CO , CO_2 , and O_2), temperatures throughout the pilot system, and X-ray fluorescence (XRF) analysis of one ash sample per fuel
 - Proximate/ultimate, heating value, and XRF ash analysis of the combusted fuels
 - Mercury emissions monitored at the stack by a continuous monitor

The pilot testing will be conducted in accordance with an agreed-upon test plan to collect the required data. After testing, data will be compiled and analyzed to assess the emissions and ash chemistry. Data will be presented in a final report.

The fuels to be tested in the CTF will be determined in collaboration with CEMRI. Fuels will be prepared for combustion at the EERC, and fuel samples must arrive at EERC facilities at least 2 weeks prior to the scheduled test.

Mr. Theaker/2
September 18, 2025

Cost

The estimated cost is \$589,718 as shown in the table below and the attached budget. These costs include system setup/operations, fuel preparation, sample analysis, data analysis, and reporting. The detailed labor budget, supplies, laboratory and other fees, facilities, and administrative costs are shown in the budget. The work will be conducted in accordance with the University of North Dakota collaboration form.

Project Associated Expense	Total Project
Labor	\$297,826
Supplies	\$2,800
Laboratory Fees & Services	
Natural Materials Analytical Research Lab	\$10,852
Combustion Test Service	\$22,841
Process Chemistry & Development Lab	\$3,049
Fuel Preparation Service	\$2,521
Document Production Service	\$1,106
Shop & Operations	\$47,168
Engineering Services Fee	\$2,379
Total Direct Costs	\$390,542
Facilities & Administration	\$199,176
Total Project Costs	\$589,718

If you have any questions regarding the proposed work scope or schedule, please contact me by phone at (701) 777-5114 or by email at jlaumb@undeerc.org.

Sincerely,

DocuSigned by:
Joshua Stanislawski for
8365CA182B464C3...

Jason D. Laumb
Director of Advanced Energy Initiatives

Approved by:

DocuSigned by:
Charles D. Gorecki
29A98751E2B84D7

Charles D. Gorecki, CEO
Energy & Environmental Research Center

JDL/rlo

Attachments



APPENDIX A

DESCRIPTION OF EQUIPMENT

COMBUSTION EQUIPMENT

The Energy & Environmental Research Center (EERC) has been performing controlled combustion tests using bench- and pilot-scale test combustors for many years. These include drop-tube furnace systems (atmospheric and pressurized) that burn grams of fuel per minute and pilot-scale units that burn 50–250 pounds of fuel per hour. The unit of interest for this project is the combustion test facility (CTF).

Combustion Test Facility

Research programs have been under way at the EERC for more than 30 years to study ash fouling of boiler heat-transfer surfaces in coal-fired utility boilers. A 550,000-Btu/hr pulverized coal (pc) pilot plant test furnace was constructed in 1967 to evaluate the influence of variables, including ash composition, excess air, gas temperature, and tube wall temperatures on ash fouling. Results from this work have shown a strong correlation among ash characteristics, boiler operating parameters, and degree of fouling.

The research capabilities of the CTF have been enhanced over the years and expanded to provide information on a wide range of combustion-related issues. To achieve a wide range of operating conditions, the refractory-lined furnace may be fired at a rate sufficient to achieve a furnace exit gas temperature (FEGT) as high as 2500°F. Most tests are performed with the FEGT maintained at approximately 2000°–2200°F. Research applications of this pilot-scale combustion equipment have included the following:

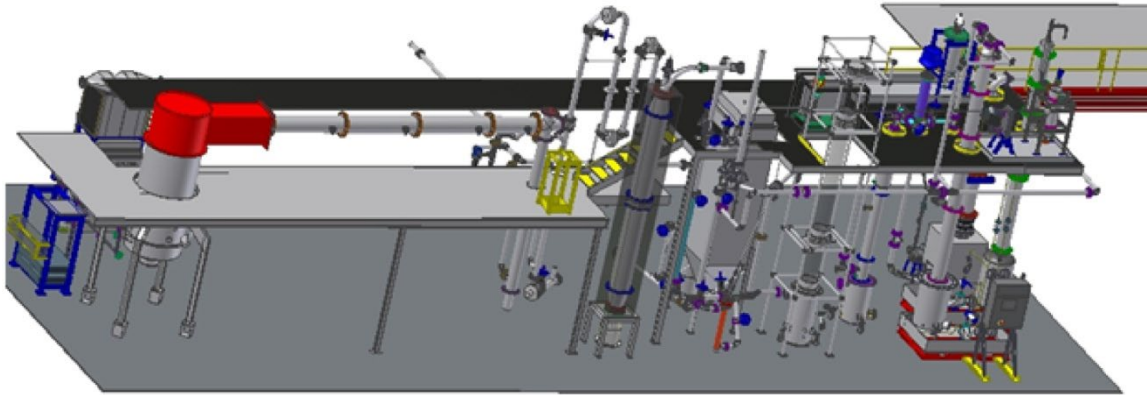
- Determine ash-fouling rates and the strength, composition, and structure of fouling deposits for coals of all ranks.
- Determine the effectiveness of ash-fouling additives.
- Apply sophisticated analytical methods to characterize input coal, ash, and deposits.
- Correlate coal and ash properties with deposit growth rates and strength development.
- Evaluate the combustion characteristics of coal–water fuels, biomass fuels, municipal solid waste, and petroleum coke.
- Determine fly ash collection properties of various fuels by electrostatic precipitation or fabric filtration using a pulse-jet baghouse, including high-temperature applications.
- Evaluate the slagging potential and slag corrosion in a simulated wet-bottom firing mode.
- Perform flame stability tests for comparing a particular fuel at full load and under turndown conditions.
- Evaluate fouling, slagging, and electrostatic precipitator (ESP) performance for blends of bituminous and subbituminous coals.
- Evaluate the combustion properties of petroleum coke alone and in blends with subbituminous and lignite coals.

- Evaluate sorbent injection for SO_x control, and assess integrated particulate and SO_x–NO_x control.
- Evaluate several CO₂ capture technologies.

The CTF is fully instrumented to provide online analysis of the flue gas. Three flue gas-sampling ports are available. Flue gas concentrations of O₂, CO₂, and SO₂ are obtained simultaneously at the furnace exit and stack. Emissions of CO and NO_x are obtained at the furnace exit. System O₂, CO, and CO₂ analyzers are manufactured by Rosemount; the SO₂ analyzers are manufactured by DuPont and Ametek; and NO_x is measured with a Thermo Electron chemiluminescent analyzer. All system temperatures, pressures, and flue gas analyses are recorded continuously to chart recorders and the system's computer-controlled data acquisition system.

Coal is pulverized remotely in a hammer-mill pulverizer to a size of 70% less than 200 mesh (75 µm). The coal is then charged to a microprocessor-controlled weight loss feeder from a transport hopper. Combustion air is preheated by an electric air heater. The pc is screw-fed by the gravimetric feeder into the throat of a venturi section in the primary air line to the burner. Heated secondary air is introduced through an annular section surrounding the burner. Heated tertiary air is added through two tangential ports in the furnace wall about 1 ft above the burner cone. The percentages of the total air used as primary, secondary, and tertiary air are usually 10%, 30%, and 60%, respectively. An adjustable-swirl burner, which uses only primary and secondary air with a distribution of approximately 15% and 85%, respectively, is used during flame stability testing. Flue gas passes out of the furnace into a 10-in.-square duct that is also refractory-lined. Located in the duct is a vertical probe bank designed to simulate superheater surfaces in a commercial boiler. The fouling probes are constructed of 1.66-in.-outside-diameter Type 304 stainless steel pipe cooled to a surface metal temperature of 1000°F (or other specified temperature) with steam. Deposit strength can be assessed by laboratory determinations using a drop impactor technique and by scanning electron microscopy (SEM). The drop impactor technique provides a calculated measurement of deposit strength, taking into account the conditions under which the test was performed. SEM point count provides a point-by-point analysis of the deposit. These data can be used to calculate the viscosity of each data point that can be related to deposit strength.

After leaving the probe bank duct, the flue gas passes through a series of water-cooled heat exchangers before discharging through either an ESP or pulse-jet baghouse. Wet flue gas desulfurization (WFGD), spray dryer, and selective catalytic reduction systems are available and can also be installed as back-end controls on the unit. The test furnace has numerous ports that permit observation of the probes and the furnace burner zone during the test run. These ports can also be used for installation of additional test probes, auxiliary measurements, or photography or injection of additives. Figure A-1 shows a schematic of the unit. Figure A-2 is a photograph to give an idea of scale.



EERC BP37508.CDR

Figure A-1. CTF and auxiliary systems.



EERC BP34573.CDR

Figure A-2. Picture of the CTF.

Wet Flue Gas Desulfurization System

The pilot-scale WFGD system is shown schematically in Figure A-3. The column is 7 in. in diameter, with a height of approximately 20 ft. The scrubber is equipped with packing to ensure that the scrubber solutions do not simply run down the walls of the scrubber. The column is made of plastic material, while the spray nozzles are stainless steel.

Fuel Analyses

Proximate and ultimate determinations and heating value analyses are performed on the fuel using ASTM International (ASTM) Methods D3172, D5142, and D3176. The fuels may also be chemically analyzed by wavelength-dispersive X-ray fluorescence (WDXRF), as described in ASTM Method D4326. Predictive models for slag and ash behavior under reducing environments can be employed as a screening tool for potentially challenging fuels.

The EERC fuels laboratory can test fuels using standard proximate, ultimate, Btu, and particle-size analyses. Selected slag and fly ash samples may be analyzed using WDXRF using a Rigaku ZSX PRIMUS II analyzer. Samples may also be analyzed using X-ray diffraction and SEM techniques. Extensive mineral classification libraries are available for mineral-phase identification. Gasification process carbon conversion is typically evaluated based on the carbon present in the ash. Loss-on-ignition tests on the ash determine carbon conversion.

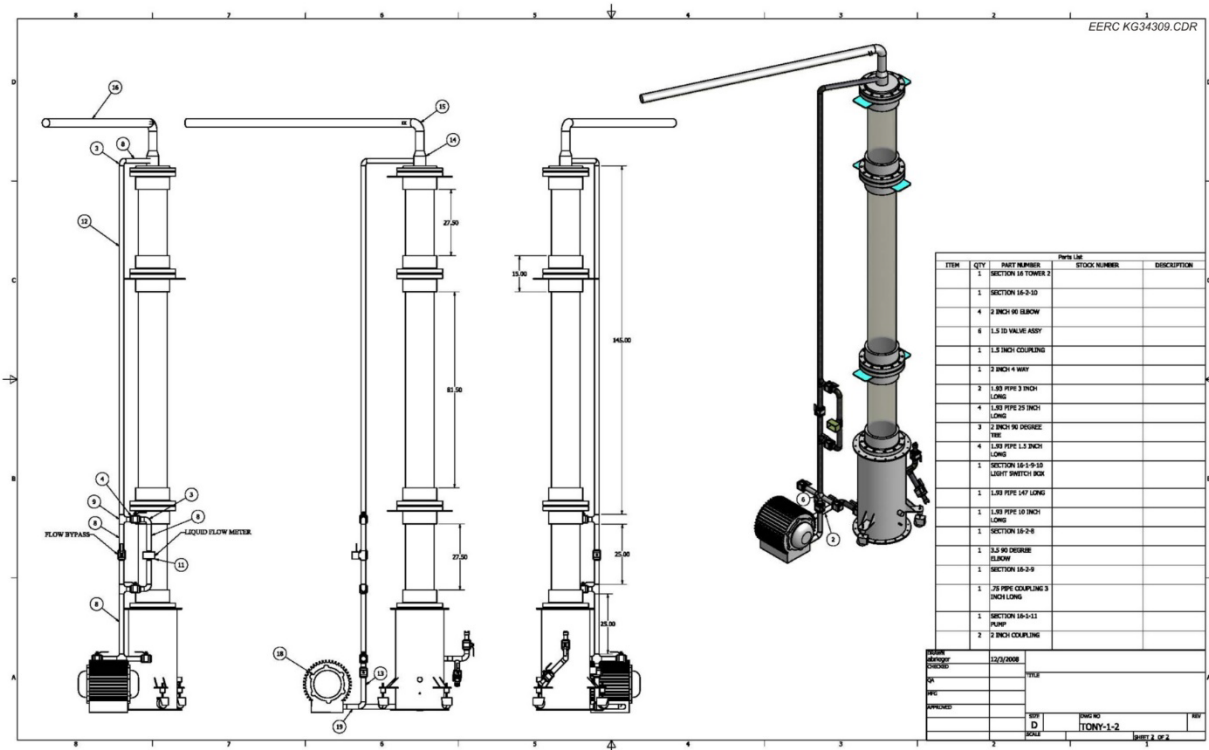


Figure A-3. Schematic of the pilot-scale WFGD system.

TECHNICAL REVIEWER RATING SUMMARY

LRC (108B): “Pilot Expansion and Testing for Improving Lignite Fuels and REE Processing”

Submitted by: University of North Dakota

Principal Investigator: Nolan Theaker

Project Duration: 24 months

Request for: \$1,100,000

Total Project Costs: \$2,200,000

Rating Category	Weighting Factor	Technical Reviewer Rating			Average Weighted Score
		39-01	39-02	39-03	
Objective	9	5	4	5	
Achievability	9	4	4	4	
Methodology	7	5	4	5	
Contribution	7	5	5	5	
Awareness	5	5	4	5	
Background	5	5	5	5	
Project Management	2	5	4	5	
Equipment Purchase	2	4	4	4	
Facilities	2	5	5	5	
Budget	2	4	4	4	
Average Weighted Score:		237	214	237	229.3

Maximum Weighted Score:

250

OVERALL RECOMMENDATION:

FUND

FUNDING MAY BE CONSIDERED

DO NOT FUND

	X	X	X	

TECHNICAL REVIEWERS' COMMENTS

1. **OBJECTIVES**

The objectives or goals of the proposed project with respect to clarity and consistency with North Dakota Industrial Commission/Lignite Research Council goals are: 1 – very unclear; 2 – unclear; 3 – clear; 4 – very clear; or 5 – exceptionally clear.

Reviewer 39-01 (Rating: 5) The proposed project will lead to enhancements to the existing technology for REE/CM extraction from ND lignite that has been developed at UND. This work will address all three goals of the NDIC/LRC program, namely the development of new jobs, protection of existing lignite jobs and higher value-added options for the ND lignite resource.

Reviewer 39-02 (Rating: 4) This project directly relates to NDIC/LRC goals for continued and efficient use of lignite resources.

Reviewer 39-03 (Rating: 5) Removal of sodium from discarded coal and further development and maturation of a Rare Earth Element technology both meets all North Dakota lignite industry goals and answers a National Security goal as well.

2. **ACHIEVABILITY**

With the approach suggested and time and budget available, the objectives are: 1 – not achievable; 2 – possibly achievable; 3 – likely achievable; 4 – most likely achievable; or 5 – certainly achievable.

Reviewer 39-01 (Rating: 4) The information given presents a well thought out approach to achieving the stated goals. Based on the experience of the team, I believe the time and budget estimated will result in achieving the stated goals.

Reviewer 39-02 (Rating: 4) The two-year time frame seems sufficient with the various phases listed in project plan. One concern that is brought up in proposal is the DOE cost share of \$475k which is still unknown. However, the plan does have contingency plans if this portion of the cost is not available, through scope changes or additional investment from other sources. For reference, the report does state, "our team is very confident that enough of the DOE funding will ultimately make it to the contract".

Reviewer 39-03 (Rating: 4) A 24-month project estimated to cost \$2.2 million is detailed in the report. The DOE has promised a 50% cost share. An experienced team has submitted detailed budget table and timeline; there is no good reason to doubt their estimates.

3. **METHODOLOGY**

The quality of the methodology displayed in the proposal is: 1 – well below average; 2 – below average; 3 – average; 4 – above average; or 5 – well above average.

Reviewer 39-01 (Rating: 5) The methodology noted that includes both laboratory and pilot scale work is well thought out and should lead to a positive outcome for significant enhancements to this critically important technology.

Reviewer 39-02 (Rating: 4) No comment

Reviewer 39-03 (Rating: 5) The methods planned were detailed as well as objectives, tasks, responsible party, and milestones based on prior experience with existing equipment. Tables, lists and charts were also given with the detailed descriptions.

4. **CONTRIBUTION**

The scientific and/or technical contribution of the proposed work to specifically address North Dakota Industrial Commission/Lignite Research Council goals will likely be: 1 – extremely small; 2 – small; 3 – significant; 4 – very significant; or 5 – extremely significant.

Reviewer 39-01 (Rating: 5) The proposed work has the potential to significantly enhance the current and future opportunities for the ND Lignite Resource. In addition, the potential strategic value to the US is very significant, leading to a domestic REE/CM supply chain.

Reviewer 39-02 (Rating: 5) No comment

Reviewer 39-03 (Rating: 5) Successful removal of sodium from discarded coal will increase the mined per ton value and the REE technology development will also create added value, develop a new industry, create additional technical jobs and answer an important national security need.

5. **AWARENESS**

The principal investigator's awareness of other current research activity and published literature as evidenced by literature referenced and its interpretation and by the reference to unpublished research related to the proposal is: 1 – very limited; 2 – limited; 3 – adequate; 4 – better than average; or 5 – exceptional.

Reviewer 39-01 (Rating: 5) The team assembled is very well published in this area.

Reviewer 39-02 (Rating: 4) The team at UND along with EERC references nearly 10 years of research directly related to the REE/CM field and has a very qualified team continuing in various research activities sponsored by private industry, state programs, and US DOE.

Reviewer 39-03 (Rating: 5) Dr. Theaker has a great deal of experience with coal cleaning and REE extraction as well the specific issues associated with that technology. The DOE refer to him as the most highly respected REE development expert.

6. **BACKGROUND**

The background of the investigator(s) as related to the proposed work is: 1 – very limited; 2 – limited; 3 – adequate; 4 – better than average; or 5 – exceptional.

Reviewer 39-01 (Rating: 5) The Team assembled is world recognized as leaders in developing a US based supply chain for REE/CM resources!

Reviewer 39-02 (Rating: 5) The lead researchers are highly qualified and reference multiple previous studies in this field.

Reviewer 39-03 (Rating: 5) Director Laumb has worked at EERC for 25 years on many lignite projects. He is very familiar with lignite mining and coal analytical methods. He has managed many projects and has written many professional publications. Mr. Dyrstad-Cincotta has operated the existing coal cleaning equipment and aware of it's current capabilities & areas to improve.

7. **PROJECT MANAGEMENT**

The project management plan, including a well-defined milestone chart, schedule, financial plan, and plan for communications among the parties involved in the project, is: 1 – very inadequate; 2 – inadequate; 3 – adequate; 4 – very good; or 5 – exceptionally good.

Reviewer 39-01 (Rating: 5) The proposal includes a well-defined set of milestones that will allow the project sponsors to monitor progress toward the stated goals.

Reviewer 39-02 (Rating: 4) Overall time table is well laid out with quarterly reporting standards planned along with detailed deliverables as per the task completed.

Reviewer 39-03 (Rating: 5) This proposal does include all the afore mentioned elements. Of particular note also was a milestones list containing a detailed description of the expected result.

8. **EQUIPMENT PURCHASE**

The proposed purchase of equipment is: 1 – extremely poorly justified; 2 – poorly justified; 3 – justified; 4 – well justified; or 5 – extremely well justified. (Circle 5 if no equipment is to be purchased.)

Reviewer 39-01 (Rating: 4) The equipment to be purchased includes items that have been identified and justified as critical to successful completion of the proposed work.

Reviewer 39-02 (Rating: 4) Much of the costs listed are for upgrades, maintenance, and enhancements of the existing pilot system. The new equipment list is clearly laid out with specific equipment items listed.

Reviewer 39-03 (Rating: 4) On page 26 of the proposal equipment totaling \$320,000 was listed. Based on prior experience with the existing equipment, this list addresses what's needed to improve the coal cleaning and segregation improvements.

9. **FACILITIES**

The facilities and equipment available and to be purchased for the proposed research are: 1 – very inadequate; 2 – inadequate; 3 – adequate; 4 – notably good; or 5 – exceptionally good.

Reviewer 39-01 (Rating: 5) The equipment identified as available, and the proposed additions noted in the proposal are exceptional.

Reviewer 39-02 (Rating: 5) Facility costs are listed definitively with a breakdown for rent, utilities, and maintenance costs for the pilot research facility.

Reviewer 39-03 (Rating: 5) UND and EERC are poised to take this technology to the next level. Their experience and recommendation for that next level also have the DOE's endorsement.

10. **BUDGET**

The proposed budget value relative to the outlined work and the financial commitment from other sources is of: 1 – very low value; 2 – low value; 3 – average value; 4 – high value; or 5 – very high value.

Reviewer 39-01 (Rating: 5) The proposed work has the potential to move the work on recovering REE/CM from ND Lignite from the pilot scale activity that shows significant

promise to technology that identifies a financially viable pathway to accomplish the goal of a domestic supply chain. The proposal not only discusses the enhancements that are anticipated but also identifies funding mechanisms that can be used to fund a commercial-scale demonstration of this technology soon. The large contributions by private companies currently operating lignite-based facilities are also a big plus helping to ensure commercial entities have a significant interest in seeing this work move to a commercial project. The work also focuses on near term technology that could significantly enhance the economics of current uses of ND lignite, namely the operation of lignite-fired boilers. The value to the state of North Dakota of this work is very high

Reviewer 39-02 (Rating: 4) Value is high relative to the potential impact of the results. The project is teamed up with both operating coal mining companies in ND, along with utilities that operate coal plants in ND.

Reviewer 39-03 (Rating: 4) Improving the value of severed lignite by removing sodium in a discarded portion and commercial development of the REE extraction technology will benefit ND and potentially provide very high value: NAC, BNI, and the DOE recognize that importance and will provide a 50% cost share.

OVERALL COMMENTS AND RECOMMENDATIONS:

Please comment in a general way about the merits and flaws of the proposed project and make a recommendation whether or not to fund.

Reviewer 39-01 (Rating: FUND) The project as outlined is one this reviewer strongly supports. The work clearly meets the objectives of the NDIC/Lignite Research Council. Not only does the project develop enhancements to technology already being developed for application to ND Lignite it identifies funding sources that could be used to complete the decisive step that would be required to move this technology from a development activity to a commercial project. It also includes a time line to accomplish that goal. As with any development activity there are significant risks with this activity, but this work will take the first steps with a plan that mitigates the risk in moving forward. The milestone chart has identified a number of key milestones that can be used to monitor progress to the goal and therefore allow for corrections to the plan if warranted.

I strongly recommend funding for this activity provided UND is successful at obtaining the funding noted from the US Department of Energy. If that does not occur and the proposers are able to identify additional sponsors to fully fund the proposed work, I would be supportive of that as well. If less than full funding from sponsors is obtained and the NDIC technical representative is comfortable with a reduced scope that still moves this technology forward I would support that option as well.

Reviewer 39-02 (Rating: FUND) I recommend funding the pilot expansion for REE processing. This project continues valuable research in the lignite field for REE/CM's. However, this project also adds additional value for fuel quality and mining efficiency. Task 4 discusses the possibility of sodium removal to allow for higher mining production, meaning more tons/acre with less waste in the segregated stream. The project team has the experience and expertise to continue the next phase to enable commercialization. I also want to highlight the proposal references the correlation with HB 1459 in the past legislative session. This bill enables the regulatory framework for REE/CM extraction and commercialization. The pilot expansion project is a crucial step to using lignite for such production.

Reviewer 39-03 (Rating: FUND) Building on previous REE and sodium cleaning work with ND lignite, UND and EERC plans to increase the value of the severed tons and make ND a leader in domestic REE production (an issue that also has strong National Security implications). This represents a good plan/proposal and experienced approach that also leverages DOE dollars. Therefore, I recommend Funding the project!

Lignite Research, Development and
Marketing Program

North Dakota Industrial Commission

Application

Project Title: Efficient Refining of Germanium
Metal from Fly Ash-Derived Concentrates

Applicant: Microbeam Technologies
Incorporated

Date of Application: October 1, 2025

Amount of Request: \$400,000

Total Amount of Proposed Project: \$1,200,000

Duration of Project: 24 months

Point of Contact (POC): Alex Benson

POC Telephone: 701-330-0308

POC Email: abenson@microbeam.com

POC Address:

4200 James Ray Drive, Ste 193
Grand Forks ND 58202-6090

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ABSTRACT

Objective:

The objective of this project is to demonstrate the ability to efficiently refine germanium-rich concentrates derived from lignite fly ash materials. This project builds on Microbeam's demonstrated ability to produce >60% Ge concentrates from lignite-derived fly ash. To achieve the project objective, Ge concentrate will be exposed to a direct reduction process to produce Ge metal (>90% purity). The Ge metal will be further refined to 99.999% pure Ge metal (5N Ge) using zone refining. This process significantly decreases the cost of the production of 5N Ge and reduces the environmental impact by bypassing extensive hydrometallurgical steps.

Expected Results:

The testing results will provide information on the ability to produce 5N Ge from lignite-derived Ge concentrates at a lower cost and environmental impact. The project will involve the production of concentrates using Microbeam's pyrometallurgical process for use in the direct reduction process. Efforts will focus on the following: 1) production of concentrates while acquiring and setting up the direct reduction equipment, 2) assessment/management of the impacts of the impurities on the properties of the direct reduction Ge metal, 3) identification of all impurities in process streams and evaluation of any environmental issues associated with disposal, and 4) technical and economic evaluation of the integration production of 5N Ge. The project will determine the feasibility of the direct reduction process for scale-up.

Duration:

The duration of the project will be 24 months.

Total Project Cost:

\$1,200,000 including \$400,000 from NDIC and \$800,000 from AmeriCOM.

Participants:

Funding support will come from AmeriCOM who provides support to the optics industry that supplies optical components for commercial and government entities through AmeriCOM's Defense Precision Optics Consortium (DPOC). AmeriCOM released a Request for Proposal # ACOM-25-01 for laboratory-scale projects to recover and refine germanium. This proposed effort is submitted in response to the RFP and builds on past projects with the Army to develop a domestic source of high purity germanium.

Subrecipient includes: IR Power Systems, LLC.

Stakeholders include: North American Coal and Great River Energy.

PROJECT DESCRIPTION

Objectives:

The overall objective of this project is to demonstrate the ability to efficiently refine germanium-rich concentrates derived from lignite fly ash materials. To achieve the project objective, Ge concentrates will be exposed to a direct reduction process to produce Ge metal (>90% purity). The Ge metal will be further refined to 99.999% pure Ge metal (5N Ge) using zone refining. This process significantly decreases the cost of the production of 5N Ge and reduces the environmental impact by bypassing extensive hydrometallurgical steps.

This project builds on Microbeam's demonstrated ability to produce >60% Ge concentrates from lignite fly ash. The specific project objectives include: 1) production of gram quantities of >60% purity concentrates from lignite-derived fly ash; 2) determination of impurity profiles in the concentrate and adjust concentrate production operation to minimize the incorporation of unwanted impurities, 3) design, procure, and assemble equipment required to perform direct reduction of the Ge concentrates; 4) conduct direct reduction testing of Ge concentrates to produce >90% pure Ge metal compatible for zone-refining, characterize all process streams and determine types and abundance of impurities; and 5) perform technical and economic assessment of the overall integrated process.

Figure 1 illustrates the overall process to produce Ge metal as well as other products using Microbeam's pyrometallurgical process. The process produces two product streams shown as A and B. Stream A is the dominant stream used to produce Ge products. However, lesser amounts have lower concentrations and can be processed by the conventional process shown in Stream B. The process is designed to enhance the recovery of materials in Stream A.

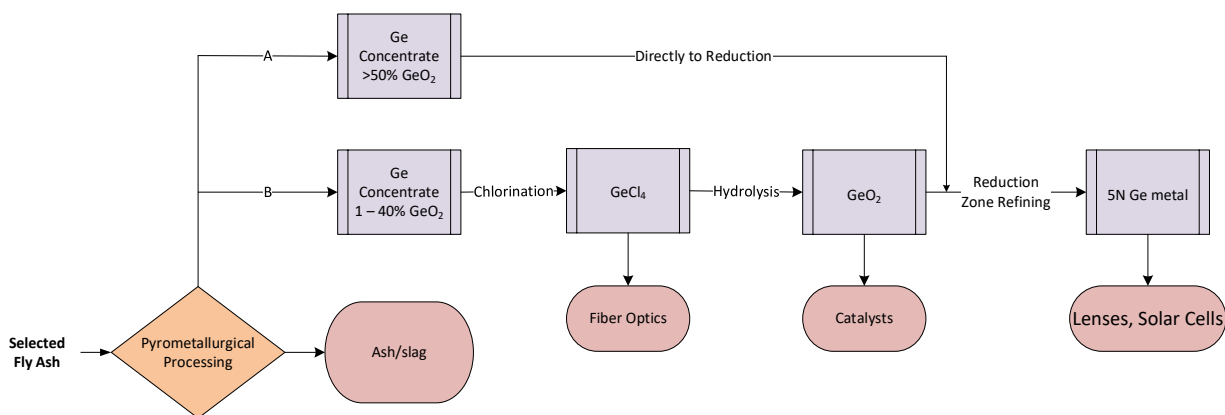


Figure 1. Overall Simplified Flow Diagram of the Germanium Purification Process and Products.

In the past, germanium was produced commercially in the US as a by-product of zinc and lead ore processing¹. Today most of the Ge metal is produced outside of the US via hydrometallurgical processes using zinc ore and coal-derived feedstocks. These hydrometallurgical methods require managing waste

¹ Piedmont, J.R. and Riordan, R.J., The supply of Germanium for Future United States Demands, SPEI, Vol. 131, Practical Infrared Optics (1978), p 113.

streams that are challenging and costly due to the presence of toxic impurities such as those found in zinc and lead ores. Figure 2 shows the conventional processes used to recover and refine Ge from zinc ore overlain with Microbeam's pyrometallurgical processes (shown in the blue outlined boxes) to produce Ge concentrate combined with a direct reduction process.

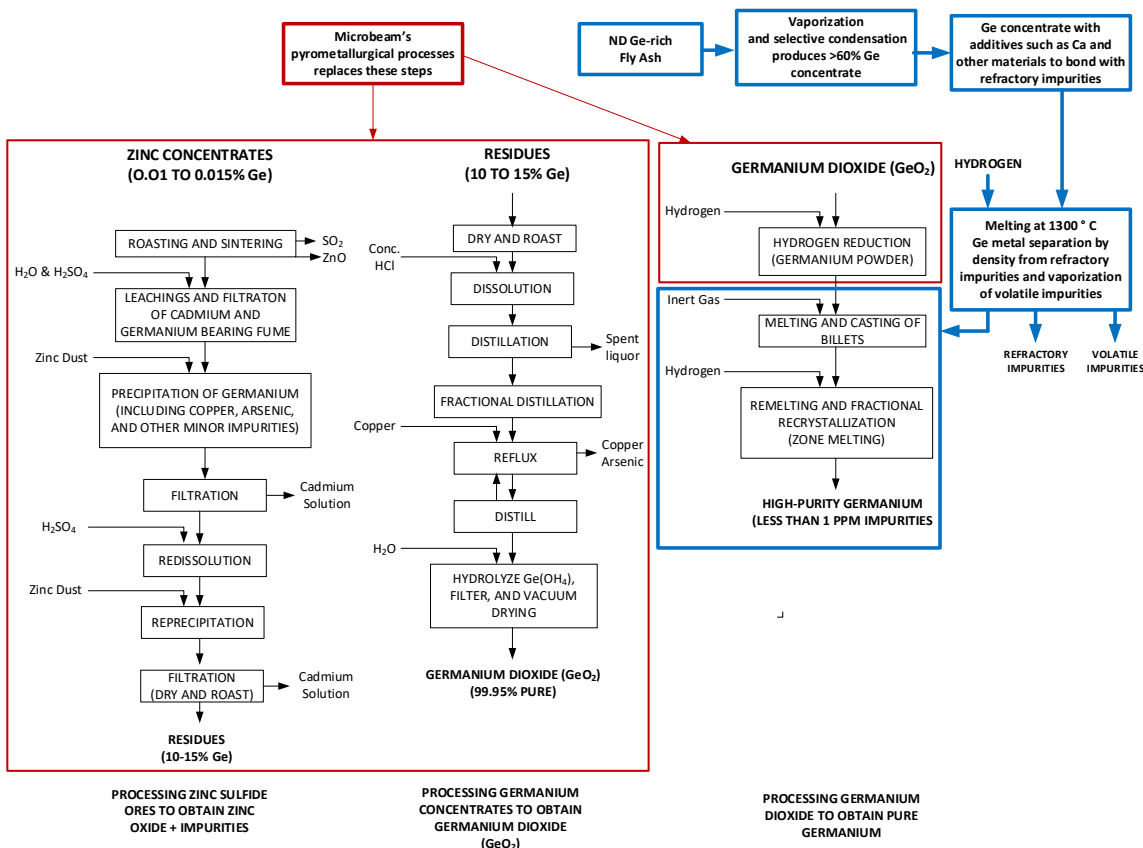


Figure 2. Comparison of an example of Ge metal production using mainly hydrometallurgical processes with Microbeam's pyrometallurgical processes combined with concentrate direct reduction.

Methodology:

The scope of work is designed to meet the project objectives.

Scope of Work

Task 1. Management and Reporting

The project will be managed and directed by the PI to meet all technical, schedule and budget objectives. Regular internal project status meetings will be held to coordinate activities to accomplish the work. In addition, the PI will ensure that project plans, results, and decisions are documented, and project reporting requirements are met.

Task 2. Production of Ge Concentrates for Testing

Subtask 2.1 Fly Ash Selection and Concentrate Production

Lignite samples of high Ge content (>250 ppm (ash basis)) will be combusted to produce fly ash for Ge concentrate production. The fly ash will be processed to produce an enriched fraction that can contain Ge levels as high as 3,500 ppm. Microbeam will work with the project partners to obtain coal and fly ash samples. The goal is to use Microbeam's pyrometallurgical process to produce gram quantities of >60% purity concentrates from lignite-derived fly ash under conditions that optimize Ge content and minimize incorporation of impurities. This will be accomplished by increasing the temperature and ash throughput of Microbeam's online metalloid recovery (OMR). The OMR is a prototype Ge recovery system from coal ash designed and constructed as part of a National Science Foundation Phase II SBIR². The OMR operates in a batch mode and has performed over 300 tests to produce condensed metal concentrates. The OMR system will be upgraded with a higher temperature vaporization system with continuous feed, processed ash discharge system, and a higher capacity product recovery system. In addition, the process control system, data acquisition, and gas analysis will also be improved.

The OMR will be used to process up to 50 g/min of enriched fly ash that will produce up to 300 mg/min of 60% Ge concentrate. Past efforts have shown that the efficiency of releasing the Ge from the fly ash ranged from 77 to 86%. A conservative estimate to produce 10 grams of pure Ge metal would require the OMR to process about 7 kg of enriched ash. This would produce about 20 grams of 60% concentrate. The target quantity of concentrate to be produced for this project is 300 grams. This would require about 100 kg of enriched fly ash. In a worst-case scenario, it would require about a month and a half to produce the 300 grams of concentrate.

Subtask 2.2 Concentrate Characterization

The operating condition of the OMR will be varied to optimize the conditions to selectively condense and capture primarily Ge phases. The abundance of impurities in the concentrate will be determined and adjustments to OMR operation will be made to minimize the incorporation of unwanted impurities. Once conditions are optimized, Ge concentrate production runs will be performed to produce enough concentrate for direct reduction and zone refining. The Ge concentration and abundance, type, and form of the impurities in the concentrate will be determined in samples collected from the OMR. The samples will be analyzed using x-ray fluorescence (XRF) and a scanning electron microscope equipped with an energy dispersive system for x-ray microanalysis (SEM-EDS). In addition, inductively coupled plasma-mass spectrometry (ICP-MS) will be used to determine the abundance of trace elements. Efforts will also track the behavior and fate of specific elements that can be co-produced including antimony, gallium, zinc, and tin. The team will also measure components such as arsenic and lead that can cause environmental impacts.

² Microbeam Technologies Inc, NSF SBIR Phase II: Feasibility of On-line Metalloid Recovery in Gasification Systems, NSF Award Number: 0422050, Final Report, July 31, 2007

Task 3. Direct Reduction

Subtask 3.1 Reduction Reactor System

A reduction furnace system will be designed to expose 10 to 50-gram batches of Ge concentrate along with selected additives to a reducing environment at temperatures ranging from 1000 to 1300°C. Additives will be used to bond with selected impurities allowing for their separation from the Ge melt phase. The system requires an oxygen free environment during heating and cooling. The system is illustrated in Figure 3. Equipment components and supplies will be purchased, and the system will be set up in Microbeam's laboratory. The components include a high temperature furnace, graphite crucibles, stirring paddles, viscometer, and a temperature control system.

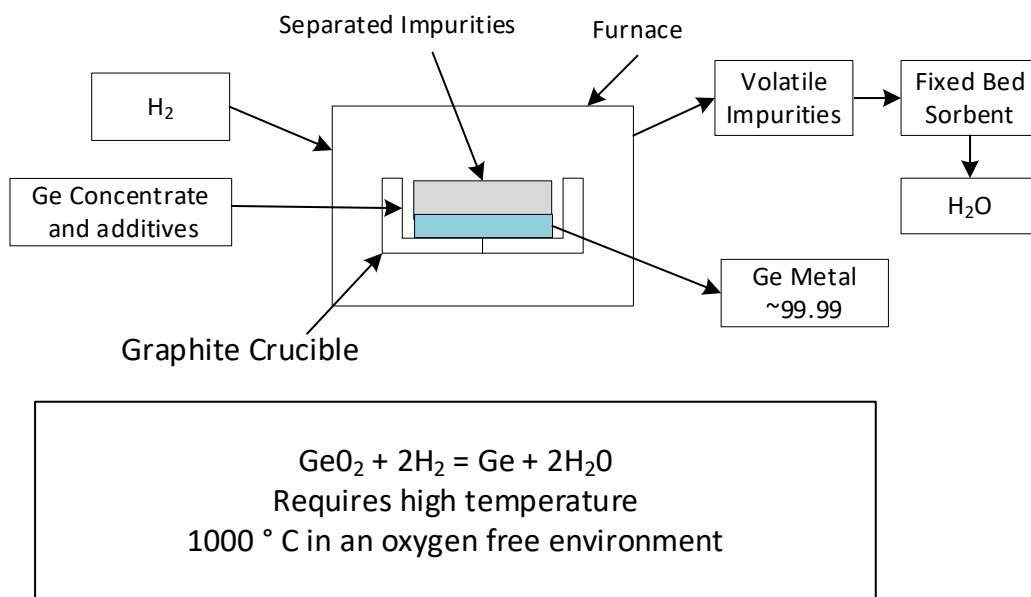


Figure 3. Simplified batch direct reduction system.

Subtask 3.2 Direct Reduction Testing of Ge-Concentrate

Selected Ge-concentrates will be tested to determine the ability to separate the Ge metal from the impurities in the concentrate. The operating conditions and the additives will be selected in order to bond with impurities and separate from the Ge melt. Certain additives will be combined with refractory elements to allow for separation. The operating conditions will be optimized to vaporize the volatile impurities and will be captured using a fixed bed filter containing active sorbent materials. The cooled Ge metal and slag portion will be physically separated.

Subtask 3.3 Analysis of Ge Metal and Impurities

The concentrate samples will be analyzed using XRF, SEM-EDS, ICP-MS, SEM phase mapping (SEM-PM), and x-ray diffraction (XRD) to evaluate the products and impurities produced. Bulk compositions (major, minor, and trace elements) will be measured using the XRF and ICP-MS. Phase analysis to determine crystalline components will be quantified using XRD and amorphous/crystalline phase microstructural

composition/phase distributions will be determined using the SEM-PM procedure. These analyses will provide information on the purity of the Ge metal as well as the ability to separate and capture impurities associated with the Ge concentrate.

Task 4. Micro-scale Zone Refining

Subtask 4.1 Procurement of Micro - Zone Refining Equipment

Microbeam will procure and construct micro-scale zone refining equipment similar to the equipment used in the micro-electronics industry. The system is illustrated in Figure 4 and will have the capability to process milligram to gram size samples. The system consists of a quartz tube enclosure for inert atmosphere, a micro induction coil/power supply capable of heating to 1100 °C, motorized translation stage for controlled movement of the coil, and a thermal camera for real time monitoring.

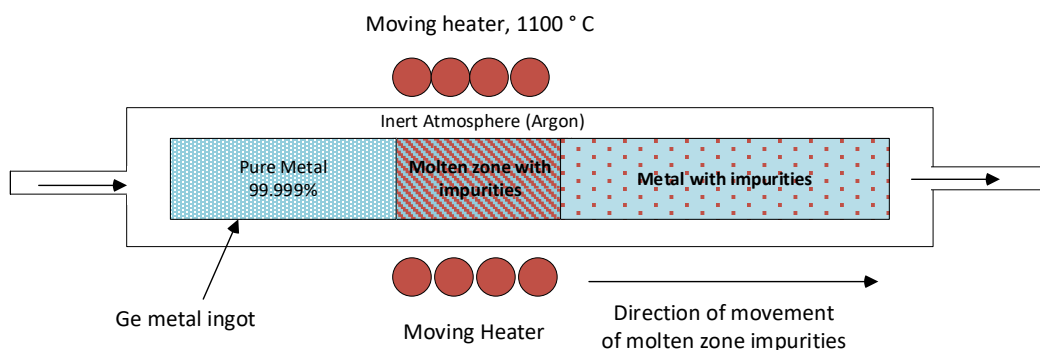


Figure 4. Simplified diagram of the zone refining system.

Subtask 4.2 Testing of Zone-refining of produced metals

The ability to remove the impurities using zone refining of the Ge metal produced as part of the direct reduction and phase separation process will be determined. The goal of the processing is to achieve 99.999% purity Ge metal. The methods of analysis will include ICP-MS to determine the abundance of any impurities present. In addition, the microstructure properties (phase distribution and homogeneity) of the product materials will be determined using SEM-EDS analysis.

Task 5. Technical and Economic Assessment

MTI will update the technical and economic feasibility assessment (TEA) from the Phase I Army project based on the optimized processing and the concentrate processing results. The capital and operational expense estimates will be equivalent to a Class 5 cost analysis by the American Association for Costing Engineers (AACE) and is expected to have a +100%/-50% accuracy.

Anticipated Results:

The primary result is the demonstration of a more environmentally benign and efficient process to refine Ge concentrates derived from ND lignite coal to produce high purity Ge for the optics industry. In addition, the team expects to show that the process is an improvement over conventional extraction from zinc ore.

The TEA work will look to provide information on the economic advantages of the technology and the viability of the overall technology to provide a domestic supply on the order of 15,000 kg/yr.

Facilities and Resources:

Microbeam has two locations, one in Grand Forks, ND, and one in Minnetonka, MN. The Grand Forks location focuses on computer modeling and data processing. The Minnetonka location has about 7,000 square feet of office, shop, and laboratory/testing space. The facility houses high temperature furnaces, two advanced computer-controlled scanning electron microscopes equipped with x-ray microanalysis (CCSEM), chemical fractionation equipment, an x-ray fluorescence spectrometer, a laser-based particle sizer, an ash fusion/slag surface tension system, and associated sample preparation equipment. In addition, the shop/laboratory testing area has a shop area for fabrication, assembly, construction and modification of testing equipment as well as an area for a fluidized bed reactor, metals recovery system, sample preparation and field test staging area. The metals recovery system was designed to be used to study the vaporization, condensation, and capture of critical minerals such as germanium, gallium, and antimony.

Techniques to Be Used, Their Availability and Capability:

Techniques available at Microbeam:

- Metalloid/metal concentrating facilities – Metals recovery facilities (OMR) will be used to produce up to 300 grams of concentrate from Ge-rich fly ash.
- High temperature furnace systems – The furnace systems will be used to perform controlled temperature and atmosphere melting and phase separation testing.
- Advanced analysis methods - Automated scanning electron microscopes with x-ray microanalysis capabilities are available to characterize the microstructure of direct reduction products using phase mapping procedures. Phase mapping allows for visualization of separated phases such as the pure Ge component and the separated crystallized calcium iron phases from the melt.
- Bulk chemical analysis - X-ray fluorescence will be used to track the abundance of germanium and impurities in the fly ash, concentrate, reduction products, and zone refined materials.
- Phase distribution predictions -Thermochemical equilibrium modeling of the distribution of gas, liquid and solid species associated with Ge and impurities will be performed using FactSAGE.

Techniques procured and assembled as part of the project:

- A direct reduction system will be designed and constructed to reduce and purify Ge concentrate.
- A micro-zone refining system will be constructed to produce high purity Ge metal from the direct reduction system.

Techniques available as a service:

- Purity of Ge intermediate and product materials will be determined using ICP-MS analysis. Analysis of the Ge-concentrate, direct reduction Ge product, and zone-refined metal (99.999% Ge metal product) will be performed.
- X-ray diffraction analysis will be performed to determine the crystalline phases present in the Ge metal intermediate and final products.

Environmental and Economic Impacts while Project is Underway:

The project will be performed on a laboratory-scale and will not have an environmental impact. The project will not impact power plant or mining operations. Requests will be made to obtain coal and fly ash samples from coal mines and power plants.

Ultimate Technological and Economic Impacts:

Currently, Ge is not available in sufficient quantities to support defense and commercial needs. The production of Ge from the abundant North Dakota lignite resources has the potential to meet the US Department of Defense (DoD) needs as well as commercial uses for Ge. Ge is an essential component in production of infrared optics, fiber optics, solar cells and other electronics critical to the Army and other Defense applications. In addition, as part of the modernization efforts ongoing at DoD, the availability of Ge is critical to programs such as C5ISR (Command, Control, Communications, Computers, Combat Systems, Intelligence, Surveillance, and Reconnaissance). The C5ISR Center is part of the US Army Combat Capabilities Development Command (DEVCOM).³ The technology the project team aims to demonstrate has the potential to provide a stable source of Ge that can play a role in the mission of the C5ISR Center. All these platforms and systems are dependent upon Ge-based components that provide reliable high performance, as well as allow for miniaturization. These Ge components also play a key role in high-frequency RF and electronic warfare systems (SiGe alloys for use in devices to detect, jam, spoof, and intercept enemy signals), infrared optics (forward looking IR, search and tracking sensors, and missile guidance systems), space-based ISR and communications (high efficiency solar cells and sensors), and signal processing and spectrum sensing (high electron mobility (high speed)) (allows for real time spectrum monitoring, adaptive jamming, and electronic warfare). Ge is critical for both offensive and defensive spectrum operations requiring a secure and stable supply.

This request for cost share is to support the submission of this project for funding in response to the AmeriCOM RFP ACOM-25-01. The aim of the AmeriCOM RFP is to fund projects to develop sources of Ge for the optics industry that supports DoD needs quickly. Microbeam believes that this technology has the ability to scale to a pilot facility with relatively quick success. The benefits of this technology and the feedstock do not require a large facility to produce significant Ge materials. In the Phase I Army funded SBIR project, the project team determined that a pilot-scale facility could be constructed for approximately \$11-12 million with an annual operating cost of \$5 million to produce 1,000 kg to 8,000 kg per year. However, current Ge concentrations in the ash at the project partner's facilities is enough to

³ [Home - Combat Capabilities Development Command C5ISR Center](#)

support the production of at least 1,000 kg/yr. Given the current high Ge costs (~\$4,000/kg), this facility would be close to supporting itself within the first year of operation (approximately \$4M in revenue compared to \$5M operating costs). As operations continue and the supporting processes mature, the Ge concentrations in the feedstock will increase and the process will operate more efficiently, increasing revenue while decreasing operating costs. The optimal production rate for this pilot facility is 5,000 kg/yr but will have the capacity to produce 8,000 kg/yr. This could result in revenues ranging from \$6.5 million to \$24 million depending on the cost of Ge and the production output of the pilot facility - \$1,300/kg to \$3,000/kg and 5,000 kg/yr to 8,000 kg/yr.

A commercial scale facility that could produce 15,000 kg/yr is estimated to cost approximately \$15 million in capital and \$7 million in annual operating costs with additional costs related to engineering, business/marketing, and permitting costs associated with this effort. The technology is intended to be collocated with an ash producing facility (power plant or coal-based ash producing facility) to reduce the operational, waste management, and emissions costs.

Why the Project is Needed:

The Ge supply chain is dominated by foreign countries. In addition, China banned shipments to the US as well as trans-shipment through other countries⁴. The lack of readily available Ge is limiting the ability to produce infrared optics, thermal imaging systems, satellite solar panels, and emerging quantum and photonics platforms. The Army is estimating it will require levels as high as 10,000 kg/yr for at least a 5-year duration to upgrade Ge windows and lenses in tanks. This does not include the needs of the Air Force, Space Force and other DoD applications. Based on a USGS commodities report, the US imported 38,000 kg of Ge in 2023, up 20% from 2022. The US has been over 50% reliant on imports. Worldwide demand was 130,000 kg/yr with a compound annual growth rate (CAGR) of 3.3% since 2001.

STANDARDS OF SUCCESS

The standards of success include the ability to produce high purity Ge for DoD and commercial applications with reduced environmental impacts and lower costs. The uses for the Ge products improve the efficiency of electrical components as described in the earlier section of this proposal. The lignite resource contains Ge and during the utilization of the lignite the Ge is concentrated in selected fractions of the fly ash. The plant that will produce Ge is anticipated to be collocated at a mine and power plant in North Dakota and will provide new high paying jobs to operate the plant to produce the Ge concentrates and refine the concentrate.

BACKGROUND/QUALIFICATIONS

Technical Background

Microbeam is a small business that conducts a combination of research, development, and service projects for industry and government clients related to the form, fate, and behavior of inorganic

⁴ Asia Financial. (2025, July 21). China stops most antimony exports but rare earth sales to US soar. Asia Financial. <https://www.asiafinancial.com/china-stops-most-antimony-exports-but-rare-earth-sales-to-us-soar>.

components in coal and other feedstocks in energy conversion and critical mineral recovery systems. Microbeam has conducted over 1700 projects for clients worldwide associated with diagnosing problematic fuel property impacts and developing solutions to improve energy conversion plant performance. This experience has provided Microbeam with a deep understanding of the behavior of fuel associated inorganic components that have provided key insights into novel methods to recover and concentrate critical minerals derived from coal.

Microbeam began working on projects associated with germanium fate and behavior in high temperature processes in service analysis work for commercial coal gasification technology developers. Accumulations of Ge deposits on heat exchangers and gas filters created operational problems in 260 MWe integrated gasification combined cycle (IGCC)⁵. Analysis of the deposits found Ge levels in layered syngas cooler deposits that cause plugging were as high as 54%. The forms of Ge in the deposit included GeS, Ge, and GeO₂. The level of Ge in the feed coal fired at this facility was less than 10 ppm (dry coal-basis) on average. Microbeam received an SBIR research project from the US Department of Energy (DOE) to identify measures to minimize the accumulations⁶ through managing process conditions and the use of Ge sorbents.

Based on an understanding of the Ge accumulation processes, MTI was awarded National Science Foundation (NSF) Phase I and II SBIR projects⁷ to recover Ge on-line from a coal gasification process through selective condensation of Ge to produce a Ge concentrate. The NSF Phase II SBIR project involved the design and construction of a laboratory-scale prototype system called the Online Metalloid Recovery Unit (OMR) to recover Ge-rich materials from coal-fired gasifiers and gasification ash materials. The prototype system demonstrated the ability to revaporize Ge from ash materials and selectively condense vaporized Ge. The conditions for selective condensation of Ge are dependent upon gas temperature, probe surface temperature, gas composition, and pressure.

In a project funded by DOE, NDIC, and the ND lignite industry, led by University of North Dakota (UND), it was discovered that Ge and Ga were co-extracted with rare earth elements from ND lignite and were present in mixed REE concentrate. However, in the calcining of the MREC the Ge and Ga would vaporize and be lost. In order to recover the Ge and Ga, Microbeam teamed with UND and proposed that the pyrometallurgical technology developed as part of the NSF funded projects to recover Ge from ash could replace the calcining step and recover both Ge and Ga from the UND's MREC. The project was awarded by DOE to first develop the concept and now in the second phase of the project a bench-scale process is being tested to recover Ge and Ga from MREC.

In 2024 Microbeam was awarded a DoD Army SBIR Phase I project to assess the technical and economic feasibility of producing > 60% Ge concentrates from lignite coal-derived fly ash. Coal fly ash samples

⁵ Benson, S.A., Katrinak, K.A., Characterization of a Germanium-rich Gasifier Deposits, MTI Report 344, 1997.

⁶ Benson, S.A., Katrinak, K.A., and Laumb, J., Abatement of Filter Corrosion and Plugging in IGCC Systems, Phase I Final Report, SBIR, DE-GE03-99ER82829, June 2000.

⁷ Microbeam Technologies Inc, NSF SBIR Phase II: Feasibility of On-line Metalloid Recovery in Gasification Systems, NSF Award Number: 0422050, Final Report, July 31, 2007.

received from project partners were tested along with ash produced in the laboratory using the OMR. The Ge level in Ge-concentrates produced was as high as 69% GeO₂. The OMR tests conducted with syngas performed significantly better with respect to the % of total Ge released from the ash was 77 to 86%.

The following is a short discussion of work conducted by others related to the ability to vaporize and condense Ge and Ga. Pyrometallurgical processes have been utilized to vaporize and condense Ge from ash-related materials and Ga-related materials from nuclear waste materials. Zhang and Xu⁸ examined the feasibility of recovering germanium from coal fly ash using a vacuum reduction pyrometallurgical process. They used a pilot scale reactor to produce a reducing environment at high temperatures combined with vacuum to vaporize and condense Ge. The recovery of germanium through the pilot scale testing was 94.64%. The thermal vaporization and deposition of gallium oxide in hydrogen was studied by Butt and others⁹. The work was associated with removing gallium from PuO_{2-x} associated with dismantling and declassifying nuclear weapons. They developed a thermal method that involved heating the Ge₂O₃ in an Ar-H₂ at temperatures in excess of 1000 °C to vaporize the gallium oxide as Ga₂O (g) and separate it from PuO_{2-x}. During the gas cooling in the furnace, the Ga₂O (g) condenses out as Ga(l) and Ga₂O₃ (s). They were able to condense the materials out on copper and SiO₂ substrates and demonstrated the deposited materials consisted of Ga₂O₃ and metallic Ga. They utilized equilibrium thermodynamics to determine the vaporization and condensation process temperatures and atmospheres.

The state of the art for the extraction and recovery of Ge from zinc production¹⁰ is a solvent extraction using an acid such as sulfuric acid to produce a leach solution that is reprecipitated to form a 1-15 percent Ge concentrate. The Ge concentrate is extracted with HCl followed by distillation to produce GeCl₄ followed by hydrolysis to produce GeO₂, metallization through reduction reactions to produce Ge metal, and zone refining to remove impurities.

This project builds on Microbeam's demonstrated ability to produce >60% Ge concentrates from lignite fly ash. The >60% Ge concentrate allows for direct reduction/purification and zone refining skipping the environmentally challenging chlorination processes.

Key Personnel

Alex Benson, Mr. Benson will be Principal Investigator for this project. Mr. Benson is currently the Chief Operating Officer at Microbeam. He has a B.S. degree in Mechanical Engineering from the University of St. Thomas. Mr. Benson has over 6 years of experience conducting projects associated with critical minerals. Currently he leads multiple commercial projects associated with REE/CM resource evaluation, detection, measurement, and extraction from carbon-ore and associated waste materials. He was the project PI (DE-SC0021837) and is one of the inventors on a US patent held by Microbeam for algorithms

⁸ Zhang, L. and Xu, Z., An environmentally-friendly vacuum reduction metallurgical process to recover germanium from coal fly ash, *Journal of Hazardous Materials* 312 (2016) 28–36

⁹ Butt, D.P., Park Y., and Taylor, T.N., Thermal vaporization and deposition of gallium oxide in hydrogen, *Journal of Nuclear Materials*, 264, January (1999) 71-77.

¹⁰ Curtolo, D.C., Friedrich, S. and Friedrich, B. (2017) High Purity Germanium, a Review on Principle Theories and Technical Production Methodologies. *Journal of Crystallization Process and Technology*, 7, 65-84.

used with handheld XRF and PGNAA-DGA for REE/CM measurements and of a US patent for Ge and Ga separation from ash materials and mixed rare earth element concentrates. He is currently the lead Project Manager on the DOE and Industry funded project (DE-FE0032522) to produce germanium and gallium from REE concentrates. Mr. Benson has over seven years of manufacturing engineering, project management and commercialization in the medical device manufacturing industry. He led engineering activities for new product launches and capacity expansion projects.

Dr. Ari Campanaro, Dr. Campanaro, Research Scientist, has PhD and MS degrees in Chemistry from the University of Minnesota and BA in Chemistry and Mathematics from Gustavus Adolphus College. Dr. Campanaro conducts research on the fate and behavior of rare earth elements, germanium, and gallium in pyro and hydrometallurgical processes. This includes developing methods for determining the abundance of Ge and Ga in feedstocks and products, producing Ge concentrates using laboratory-scale equipment, and performing thermochemical equilibrium predictions of the partitioning of germanium and gallium in pyrometallurgical processes. She also participates in performance of technical and economic assessments of Ge and Ga production technologies. Dr. Campanaro was the technical lead for the recent DoD Army SBIR project entitled “Production of Germanium Concentrates from Coal Ash” coordinating all analysis, testing, data interpretation, and reporting.

Eric Kolb, Mr. Kolb, Research Engineer and Shop Manager, has a B.S. degree from UND in Mechanical Engineering. Mr. Kolb worked with UND on the design, construction, and operation of UND’s pilot-scale REE and CM processing plant (DE-FE0031835). His experience associated with the UND system will provide important information that will facilitate integrating the Ge and Ga recovery process into the UND MREC production process. Mr. Kolb has experience in performing analysis using electron microscopes as well as performing tests using the metals recovery unit and other high temperature equipment at Microbeam. Mr. Kolb will coordinate equipment assembly and shakedown efforts associated with the Ge concentrate production, direct reduction, and zone refining.

Dr. Steve Benson, Dr. Benson, Microbeam President, has a BS in Chemistry from Minnesota State University and a Ph.D. in Fuel Science from Pennsylvania State University. Dr. Benson’s role in this project will be to assist and advise the Principal Investigator and Technical Lead. Prior to joining Microbeam full time in 2017 he held faculty and research positions at the UND. He was PI on the DOE and industry funded project (FOA 1202, DE-FE0027006) to develop technologies to recover REE from coal and coal byproducts as well as the current DOE and industry funded project (DE-FE0032522) to produce germanium and gallium from REE concentrates. He has 45 years of experience in fuel analysis, fuel properties, combustion, gasification, ash transformations, pollution control, and critical mineral recovery. In addition, Dr. Benson has developed and managed numerous complex multidisciplinary research, development and commercialization projects associated with the utilization of coal funded by US DOE and industry. Dr. Benson is one of the inventors on a US patent held by UND for the extraction of REE/CM from lignite and associated materials, one of the inventors on a US patent held by MTI for algorithms used with handheld XRF and PGNAA-DGA for measuring REE-CM, and one of the inventors of a patent for the process of producing separated Ge and Ga concentrates from ash materials and mixed rare earth element concentrates.

Michael Hulen, Mr. Hulen, IR Power Systems' Chief Executive Officer, has extensive experience in materials science related to production of infrared crystals such as Czochralski (CZ) growth of germanium crystals for night vision optics. He has experience in sourcing feedstock materials from coal ash, as well as knowledge of the process steps to upgrade and refine germanium into its useable forms. The forms include germanium tetrachloride GeCl_4 (primarily for fiber optics), germanium dioxide GeO_2 (for PET plastics), germanium 5N+ zone refined metal ingots (feedstock for crystal growth), and CZ optical crystals (for thermal imaging). Mr. Hulen will use this experience to assist in the design and operation of the refinement processes outlined in this proposal.

MANAGEMENT

Microbeam will lead this project and will be responsible for communication with project team members (IR Power Systems) and all project stakeholders (NDIC, NACoal, and GRE). Microbeam shall manage and direct the project in accordance with the proposal task structure and project contract to meet all technical, schedule, and budget objectives and requirements. Microbeam will ensure that project plans, results, and decisions are appropriately documented, and project reporting and briefing requirements are satisfied. Alex Benson, the project PI, will lead the project management efforts for Microbeam.

The project organizational structure illustrated in Figure 5 is designed to provide support for the PI, Alex Benson, in conducting the project on time and within budget.

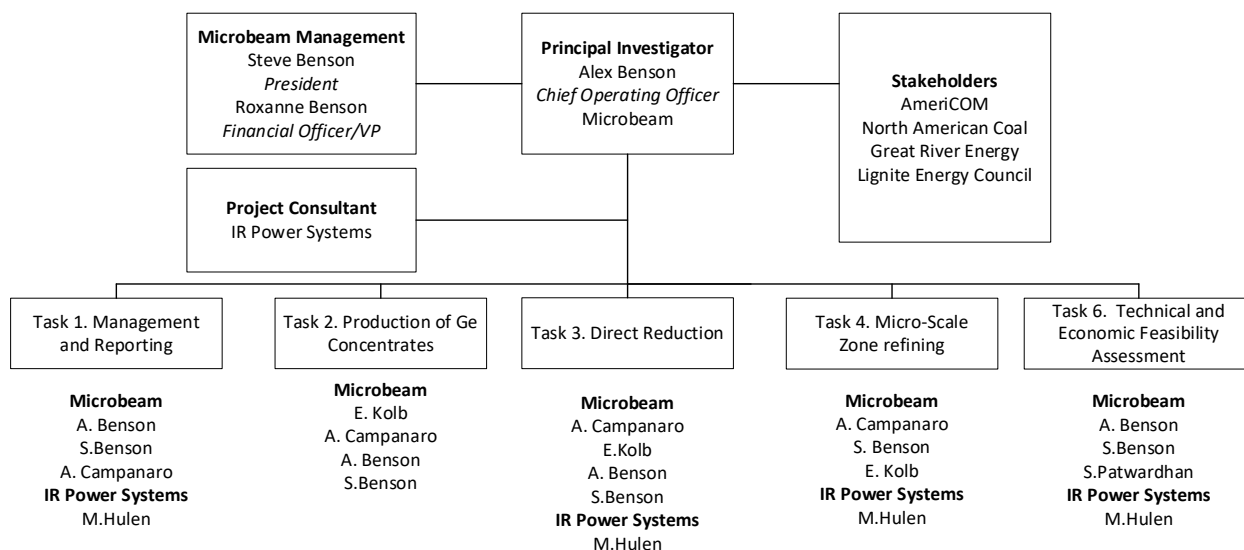


Figure 5. Project organizational management chart.

A project timeline, further discussed in the next section, has been put together and highlights milestones throughout the project. These milestones are evaluation points throughout the project to ensure the project is on track to meet the goals and objectives laid out in this proposal. A summary of those milestones is shown in Table 1.

Table 1. Project milestones.

Task/ Subtask	Milestone Title/Description	Planned Completion Date	Verification Method
1	Final Report	11/26/2027	Final Report
2.1	Ge Concentrate Available For Direct Reduction	10/5/2026	Analytical Characterization of Ge Concentrate; Sufficient Quantity Produced for Direct Reduction Shakedown Testing; Quarterly Report
3.1	Reduction Reactor System Operational	11/30/2026	Shakedown testing complete; Quarterly Report
3.3	Evaluation of Direct Reduction Process	9/6/2027	Analytical Characterization of Direct Reduction Product; Quarterly Report
4.1	Micro-Zone Refinement Equipment Operational	5/17/2027	Shakedown testing complete; Quarterly Report
4.2	Evaluation of Final Ge Product	11/1/2027	Analytical Characterization of Final Ge Product; Final Report
5	Technical and Economic Assessment	11/26/2027	Final Report

TIMETABLE

The proposed project has a two-year timeline with an anticipated start date of December 1st, 2025. Figure 6 shows the project timeline by task, including milestones.



Figure 6. Project timeline.

BUDGET

Table 2 details the overall project costs, separating the portion of the project supported by AmeriCOM and NDIC. The NDIC portion of the budget primarily supports the selection and procurement of coal and ash samples, the direct reduction equipment, the micro-zone refining equipment, and the characterization of samples collected and produced throughout the project.

Table 2. Project budget.

	Total Budget	AmeriCom	NDIC Cash
Budget Category	Incl. Cost Share	Share	Cash Share
Personnel	\$ 307,509.00	\$202,786.00	\$ 104,723.00
Fringe Benefits	\$ 105,937.00	\$ 69,860.00	\$ 36,077.00
Total Personnel & Fringe Benefits	\$ 413,446.00	\$272,646.00	\$ 140,800.00
Travel	\$ 5,613.00	\$ -	\$ 5,613.00
Equipment	\$ 219,002.00	\$162,810.00	\$ 56,192.00
Supplies	\$ 13,810.00	\$ -	\$ 13,810.00
Consultants	\$ 80,000.00	\$ 80,000.00	\$ -
Analysis	\$ 77,448.00	\$ 38,065.00	\$ 39,383.00
Total Direct Costs	\$ 809,319.00	\$553,521.00	\$ 255,798.00
Indirect Costs:	\$ 170,174.00	\$112,221.00	\$ 57,953.00
G&A Costs	\$ 220,507.00	\$134,258.00	\$ 86,249.00
Total Overhead & G&A Costs	\$ 390,681.00	\$246,479.00	\$ 144,202.00
Total Direct and Indirect Costs	\$ 1,200,000.00	\$800,000.00	\$ 400,000.00

The Personnel costs are associated with the selection, procurement, and characterization of samples along with the construction and operation of the micro-zone refining process.

The Travel costs are associated with traveling to ND to meet with project stakeholders, select Ge-rich coal and ash samples, and procuring those samples for use in this project as well as attendance at the 2026 or 2027 Society for Mining, Metallurgy & Exploration (SME) MineXchange conference to present on this technology.

The Supplies costs are associated with materials required for the construction and operation of the direct reduction and micro-zone refining process.

The Equipment costs are associated with equipment required for the direct reduction and micro-zone refining processes.

The Analysis costs are associated with the characterization of coal and ash feedstocks and the Ge products throughout the refinement process.

This project supports the overall Ge extraction, separation, and refinement efforts that Microbeam has been developing that the NDIC has supported. In the past 3 to 4 years, the NDIC has provided or committed \$396,000 for completed or active projects with a total of \$3.2 million in non-NDIC funds supporting these efforts.

CONFIDENTIAL INFORMATION

Information considered confidential in this project is limited to the composition (including Ge concentrations) of the coal and ash utilized as feedstock and the extraction/separation technology for creating the Ge concentrate. However, the focus of this project is the evaluation of the direct reduction process to refine the Ge concentrate to GeO₂ or Ge metal so that information doesn't impact the ability to provide updates on the progress of this project. Therefore, Microbeam will not be filing a confidentiality request.

PATENTS/RIGHTS TO TECHNICAL DATA

Microbeam reserves the rights to new methods developed as part of this project related to the extraction, separation, or refinement of Ge from coal ash and coal byproducts.

STATE PROGRAMS AND INCENTIVES

Microbeam has received funding from the NDIC on 5 projects in the past five years. Table 3 shows the summary of that funding.

Table 3. State programs Microbeam has participated in within the last five years.

Project Name	NDIC Funding	Matching Funds	Timeframe
North Dakota Rare Earth and Critical Element Resource Evaluation – Contract No. FY21-XCV-235	\$504,871.20	\$504,871.20 (Industry)	3/2021-12/2024
Development of Novel Sintered Carbon-Ore Building Materials – Contract No. FY22-XCVII-242	\$62,500	\$586,907 (DOE, Industry)	10/2021-2/2024
Production of Ge and Ga Concentrates for Industrial Processes (Phase I) – Contract No. FY22-XCVII-240	\$20,000	\$256,329.93 (DOE, Industry)	1/2022-12/2023
Lignite Resource Evaluation for Advanced Utilization Opportunities – Contract No. FY22-101-247	\$1,238,994.18	\$1,239,000 (Industry)	1/2023-12/2025 (active)
Production of Ge and Ga Concentrates for Industrial Processes (Phase II) – Contract No. FY24-105-259	\$376,000	\$2,758,978 (DOE, Industry)	11/2024-1/2028 (active)

IDENTIFYING INFORMATION:

NAME: Benson, Alexander

POSITION TITLE: Chief Operating Officer

PRIMARY ORGANIZATION AND LOCATION: Microbeam Technologies Inc., Minnetonka, Minnesota, United States

Professional Preparation:

ORGANIZATION AND LOCATION	DEGREE (if applicable)	RECEIPT DATE	FIELD OF STUDY
University of St Thomas., St. Paul, Minnesota, United States	BS	12/2011	Mechanical Engineering

Appointments and Positions

2024 - present	Chief Operating Officer, Microbeam Technologies Inc., Minnetonka, Minnesota, United States
2024 - 2024	Program Manager, Microbeam Technologies Inc., Minnetonka, Minnesota, United States
2019 - 2024	Sr. Project Manager, Microbeam Technologies Inc., Minnetonka, Minnesota, United States
2017 - 2019	Sr. Research Engineer (part-time), Microbeam Technologies Inc., Denver, Colorado, United States
2017 - 2019	Manufacturing Manager, Medtronic - Minimally Invasive Technology Group, Boulder, Colorado, United States
2016 - 2017	Sr. Product Engineer, Medtronic - Minimally Invasive Technology Group, Boulder, Colorado, United States
2015 - 2016	Sr. Manufacturing Engineer, Medtronic Energy and Component Center, Minneapolis, Minnesota, United States
2012 - 2015	Manufacturing Engineer, American Medical Systems, Minnetonka, Minnesota, United States
2007 - 2012	Lab Assistant (part-time), Microbeam Technologies Inc, Grand Forks, North Dakota, United States

Products**Products Most Closely Related to the Proposed Project**

1. Fuka M, Kolb E, Benson A, Benson S., inventors. Microbeam Technologies, Inc., assignee. System And Method For Predicting Abundance Of Rare Earth Elements. United States of America 11,733,184 B2. 2023 August 22.
2. Benson A, Benson S, Kolb E, Fuka M. Development of Low-Cost Rare Earth Element Analysis and Sorting Methods. [revised 2021 January]. [Print]. 2017 July. Other: Contract No. FY18-LXXXIII-213
3. Benson SA, Benson AS., inventors. Microbeam Technologies Incorporated, assignee. System and Method for Producing Critical Minerals. United States of America 12,031,165 B2.

2024 July 07.

Other Significant Products, Whether or Not Related to the Proposed Project

1. Benson S, Patwardhan S, Stadem D, Langfeld J, Benson A, Desell T. Application of Condition Based Monitoring and Neural Networks to Predict the Impact of Ash Deposition on Plant Performance. Accepted for presentation at 28th International Conference on the Impact of Fuel Quality on Power Production and the Environment, 2022.; 2022.

Certification:

When the individual signs the certification on behalf of themselves, they are certifying that the information is current, accurate, and complete. This includes, but is not limited to, information related to domestic and foreign appointments and positions. Misrepresentations and/or omissions may be subject to prosecution and liability pursuant to, but not limited to, 18 U.S.C. §§ 287, 1001, 1031 and 31 U.S.C. §§ 3729-3733 and 3802.

Certified by Benson, Alexander in SciENCv on 2025-09-30 14:37:31

IDENTIFYING INFORMATION:

NAME: Benson, Steven

POSITION TITLE: President, sbenson@microbeam.com, 701-213-7070

PRIMARY ORGANIZATION AND LOCATION: Microbeam Technologies Incorporated ,
Grand Forks, North Dakota, United States**Professional Preparation:**

ORGANIZATION AND LOCATION	DEGREE (if applicable)	RECEIPT DATE	FIELD OF STUDY
Pennsylvania State University, University Park, Pennsylvania, United States	PHD	05/1987	Fuel Science
Minnesota State University, Moorhead, Minnesota, United States	BS	07/1977	Chemistry

Appointments and Positions

1991 - present President, sbenson@microbeam.com, 701-213-7070, Microbeam Technologies Incorporated , Grand Forks, North Dakota, United States

2015 - 2017 Associate Vice President for Research, Energy & Environmental Research Center, University of North Dakota, Grand Forks, North Dakota, United States

2010 - 2014 Chair Petroleum Engineer Department and Director Institute for Energy Studies, University of North Dakota, Grand Forks, North Dakota, United States

2008 - 2010 Professor, Chemical Engineering, University of North Dakota, Grand Forks, North Dakota, United States

1994 - 2008 Associate Director for Research/Senior Research Manager, Energy & Environmental Research Center, University of North Dakota, Grand Forks, North Dakota, United States

1986 - 1994 Senior Research Manager, Energy & Environmental Research Center, University of North Dakota, Grand Forks, North Dakota, United States

1984 - 1987 Graduate Research Assistant, Pennsylvania State University, University Park, Pennsylvania, United States

1983 - 1984 Research Supervisor, UND Energy Research Center, Grand Forks, North Dakota, United States

1977 - 1983 Research Chemist, ERDA and US DOE, Grand Forks Energy Technology Center, Grand Forks, North Dakota, United States

Products**Products Most Closely Related to the Proposed Project**

1. Benson SA., Benson AS.. Systems and Method for Producing Critical Minerals. Patent No.: US 12,031,165 B2. 2024 July 07.

2. Fuka M, Kolb E, Benson A, Benson S. System and Method for Predicting the Presence of Rare Earth Elements. Patent No. US 11,733,184 B2. 2023 August 22.
3. Laudal D, Benson S. Rare Earth Extraction from Coal. US Patent US 10,669,610 B2. 2020 June 02.
4. Laudal DA, Benson SA, Addleman RS, Palo D. Leaching behavior of rare earth elements in Fort Union lignite coals of North America. International Journal of Coal Geology. 2018 April 15; 191:112.
5. Benson AS, Patwardhan S, Kolb E, Benson SA. Production of Germanium Concentrates from Coal Ash. SBIR Phase I - Topic Area #A244-055.. 2025 August 19.

Other Significant Products, Whether or Not Related to the Proposed Project

1. Lyu Z, Patwardhan S, Stadem D, Langfeld J, Benson S, Thaelke S, Desell T. Neuroevolution of recurrent neural networks for time series forecasting of coal-fired power plant operating parameters. The Genetic and Evolutionary Computation Conference (GECCO 2020). 2021 July 10.
2. Benson AS, Benson SA, Stadem D, Kolb E, Rew B, Morgan D. Development of Low-Cost Rare Earth Element Analysis and Sorting Methods. Final Report, ND Industrial Commission, Contract No. FY18-LXXXIII-213. 2021 January 01.
3. Laudal DA, Benson SA, Palo D, Addleman AS. Rare Earth Elements in North Dakota Lignite Coal and Lignite-Related Materials. ASME, J. Energy Resour. Technology. 2018 April 09; 140(6):062205.
4. Stadem D, Patwardhan S, Fuka M, Benson S. Condition Based Monitoring and Predicting Ash Behavior in Coal Fired Boilers - III - Coal Tracker Optimization. Pittsburgh Coal Conference. 2019 September.

Certification:

I certify that the information provided is current, accurate, and complete. This includes but is not limited to information related to domestic and foreign appointments and positions.

I also certify that, at the time of submission, I am not a party to a malign foreign talent recruitment program.

Misrepresentations and/or omissions may be subject to prosecution and liability pursuant to, but not limited to, 18 U.S.C. §§ 287, 1001, 1031 and 31 U.S.C. §§ 3729-3733 and 3802.

Certified by Benson, Steven in SciENCv on 2025-09-29 20:45:36

IDENTIFYING INFORMATION:

NAME: Kolb, Eric

POSITION TITLE: Research Engineer/Shop Manager

PRIMARY ORGANIZATION AND LOCATION: Microbeam Technologies Inc., Minnetonka, Minnesota, United States

Professional Preparation:

ORGANIZATION AND LOCATION	DEGREE (if applicable)	RECEIPT DATE	FIELD OF STUDY
University of North Dakota , Grand Forks , North Dakota, United States	BS	12/2020	Mechanical Engineering

Appointments and Positions

2025 - present Research Engineer/Shop Manager , Microbeam Technologies Inc., Minnetonka, Minnesota, United States

2021 - 2025 Research Engineer , Microbeam Technologies Inc., Minnetonka , Minnesota, United States

2020 - 2021 Associate Research Engineer , Microbeam Technologies Inc., Grand Forks , North Dakota, United States

2019 - 2020 Intern, Microbeam Technologies Inc , Grand Forks , North Dakota, United States

Products**Products Most Closely Related to the Proposed Project**

1. Benson A, Benson S, Fuka M, Kolb E. Development of Low-Cost Rare Earth Element Analysis and Sorting Methods. [revised 2021 January]. [Print]. 2017 July. Other: Contract No. FY18-LXXXIII-213
2. Benson A, Benson S, Fuka M, Kolb E., inventors. Microbeam Technologies Inc., assignee. System And Method For Predicting Abundance Of Rare Earth Elements With Handheld X-Ray Fluorescence. United States of America 11,733,184. 2021 February 11.

Other Significant Products, Whether or Not Related to the Proposed Project**Certification:**

I certify that the information provided is current, accurate, and complete. This includes but is not limited to information related to domestic and foreign appointments and positions.

I also certify that, at the time of submission, I am not a party to a malign foreign talent recruitment program.

Misrepresentations and/or omissions may be subject to prosecution and liability pursuant to, but not limited to, 18 U.S.C. §§ 287, 1001, 1031 and 31 U.S.C. §§ 3729-3733 and 3802.

Certified by Kolb, Eric in SciENcv on 2025-09-30 10:19:36

IDENTIFYING INFORMATION:

NAME: Campanaro, Ariana

ORCID iD: <https://orcid.org/0000-0001-7932-8735>

POSITION TITLE: Research Scientist

PRIMARY ORGANIZATION AND LOCATION: Microbeam Technologies, Inc, Minnetonka, Minnesota, United States**Professional Preparation:**

ORGANIZATION AND LOCATION	DEGREE (if applicable)	RECEIPT DATE	FIELD OF STUDY
University of Minnesota Twin Cities, Minneapolis, Minnesota, United States	PHD	07/2024	Chemistry
University of Minnesota Twin Cities, Minneapolis, Minnesota, United States	MS	01/2021	Chemistry
Gustavus Adolphus College, St. Peter, Minnesota, United States	BA	06/2019	Chemistry and Mathematics

Appointments and Positions

2024 - present Research Scientist, Microbeam Technologies, Inc, Minnetonka, Minnesota, United States

2019 - 2024 Research Assistant, University of Minnesota Twin Cities, Minneapolis, Minnesota, United States

2019 - 2021 Teaching Assistant, University of Minnesota Twin Cities, Minneapolis, Minnesota, United States

2018 - 2019 Chemical Manufacturing and QA/QC Intern, Innovative Surface Technologies, St. Paul, Minnesota, United States

2017 - 2018 Undergraduate Researcher, Gustavus Adolphus College, St. Peter, Minnesota, United States

Products**Products Most Closely Related to the Proposed Project**

1. Benson A, Patwardhan S, Campanaro A, Kolb E, Benson S. Production of Germanium Concentrates from Coal Ash. Final Scientific and Technical Report. SBIR Phase I - TOPIC AREA #A244-055. 2025 August 19.
2. Benson A, Patwardhan S, Kolb E, Campanaro A, Benson S. Production of Germanium and Gallium Concentrates for Industrial Processes. Annual Update Meeting. DE-FE0032124. 2025 July.
3. Theaker E, Fuka M, Campanaro A, Anderson L, Stadem D, Patwardhan S, Benson A, Benson S. FEED Study: Recovery and Refining of Rare Earth Elements from Lignite Mine Waste. Leached Coal Evaluation Report. 2025 March.

4. Campanaro A, Theaker E, Stadem D, Fuka M, Patwardhan S, Benson A, Benson S. Assessment of Fuel Properties and Boiler Fireside Performance. Final Report for DE-FE0031995. 2024 December.

Other Significant Products, Whether or Not Related to the Proposed Project

1. Campanaro AL, Struve MN, James V, Lee Penn R. Sorption of polycyclic aromatic hydrocarbons by microplastic films: Characterizing kinetics, isotherms, and impacts of sludge exposure. Chemosphere. 2025 Oct;387:144664. PubMed PMID: [40886594](#).
2. Badzinski TD, Campanaro AL, Brown MH, List C, Penn RL, Maurer-Jones MA. Effects of Enzyme Hydrolysis in Biofilm Formation and Biotic Degradation on Weathered Bioplastics. ACS Omega. 2025 May 6;10(17):17394-17403. PubMed Central PMCID: [PMC12059950](#).
3. Campanaro AL, Simcik MF, Maurer-Jones MA, Penn RL. Sewage sludge induces changes in the surface chemistry and crystallinity of polylactic acid and polyethylene films. Sci Total Environ. 2023 Sep 10;890:164313. PubMed PMID: [37211112](#).

Certification:

I certify that the information provided is current, accurate, and complete. This includes but is not limited to information related to domestic and foreign appointments and positions.

I also certify that, at the time of submission, I am not a party to a malign foreign talent recruitment program.

Misrepresentations and/or omissions may be subject to prosecution and liability pursuant to, but not limited to, 18 U.S.C. §§ 287, 1001, 1031 and 31 U.S.C. §§ 3729-3733 and 3802.

Certified by Campanaro, Ariana in SciENcv on 2025-09-30 12:58:32

North American *COAL*

September 30, 2025

Alexander Benson
Chief Operating Officer
Microbeam Technologies Inc.
4200 James Ray Drive, Ste 193
Grand Forks, ND 58202

Re: Support of the proposal entitled "Efficient Refining of Germanium Metal from Fly Ash-Derived Concentrates" submitted in response to AmeriCOM solicitation number ACOM-25-01: "Laboratory-Scale Germanium Recovery using Hydrometallurgical Processing".

Dear Mr. Benson:

North American Coal, LLC (NAC) is pleased to support Microbeam Technologies Incorporated's efforts in demonstrating the ability to efficiently refine germanium-rich concentrates from lignite fly ash materials to salable products. The successful demonstration of this technology could reduce the time and costs associated with refining germanium concentrates to GeO_2 and Ge metal. In support of the project, NAC will provide Ge-rich coal to be used in the combustion and liquefaction processes that produce the ash feedstock for Microbeam's process.

AmeriCOM is leading a public-private partnership "Defense Precision Optics Consortium (DPOC)" whose mission is to improve the nation's capacity to produce and deliver precision optics to meet defense acquisition and operational needs. The AmeriCOM DPOC receives funding support from the US Department of Defense (DoD) office of Industrial Base Analysis and Sustainment (IBAS) and is authorized to subcontract portions of the research program.

This technology is of specific interest to NAC since high levels of these elements (up to 160 ppm Ge (dry coal basis)) have been found in some of the coal currently mined. North Dakota operations, where testing of this technology would be conducted, include Falkirk, Coteau, and Coyote Creek with a total annual production of over 25 million tons annually in North Dakota. NAC has supported the Microbeam in Department of Energy and Department of Defense funded projects related to the extraction of Ge from lignite derived rare earth concentrates and fly ash. This project will continue in the development of this technology as a whole.

In addition to providing coal, NAC will participate in meetings throughout the project to provide input on the technical and economic feasibility of the technology. If you have questions and require additional information, please contact me by phone or email.

Sincerely,

NORTH AMERICAN COAL, LLC



Carroll L. Dewing
Senior Vice President and Chief Operating Officer

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

 A NACCO COMPANY



12300 Elm Creek Boulevard
Maple Grove, Minnesota 55369-4718
763-445-5000
greatriverenergy.com

September 30, 2025

Alexander Benson
Chief Operating Officer
Microbeam Technologies Inc.
4200 James Ray Drive, Ste 193
Grand Forks, ND 58202

Re: Support of the proposal entitled "Efficient Refining of Germanium Metal from Fly Ash-Derived Concentrates" submitted in response to AmeriCOM solicitation number ACOM-25-01: "Laboratory-Scale Germanium Recovery using Hydrometallurgical Processing".

Dear Mr. Benson:

Great River Energy (GRE) is pleased to support Microbeam Technologies Incorporated's efforts in demonstrating the ability to efficiently refine germanium-rich concentrates from lignite fly ash materials to salable products. The successful demonstration of this technology could reduce the time and costs associated with refining germanium concentrates to GeO_2 and Ge metal. In support of the project, GRE will provide Ge-rich coal ash to be used as the feedstock for Microbeam's process.

AmeriCOM is leading a public-private partnership "Defense Precision Optics Consortium (DPOC)" whose mission is to improve the nation's capacity to produce and deliver precision optics to meet defense acquisition and operational needs. The AmeriCOM DPOC receives funding support from the US Department of Defense (DoD) office of Industrial Base Analysis and Sustainment (IBAS) and is authorized to subcontract portions of the research program.

This technology is of specific interest to GRE as it provides an alternative use for the fly ash produced at the Spiritwood Station. GRE has supported the Microbeam in Department of Defense funded projects related to the extraction of Ge from lignite derived fly ash. This project will continue in the development of this technology as a whole.

Great River Energy is a not-for-profit wholesale electric power cooperative serving 26 member-owner distribution cooperatives. Together, GRE systems provide reliable, cleaner electricity while maintaining affordable rates for 1.7 million people.

In addition to providing coal, GRE will participate in meetings throughout the project to provide input on the technical and economic feasibility of the technology. If you have questions and require additional information, please contact me by phone or email.

Sincerely,

GREAT RIVER ENERGY

A handwritten signature in black ink, appearing to read 'Todd Overgard'.

Todd Overgard
Director, Corporate Development

TECHNICAL REVIEWER RATING SUMMARY

LRC (108C): “Efficient Refining of Germanium Metal from Fly Ash-Derived Concentrates”

Submitted by: Microbeam Technologies, Inc.

Principal Investigator: Alex Benson

Project Duration: 24 months

Request for: \$400,000

Total Project Costs: \$1,200,000

Rating Category	Weighting Factor	Technical Reviewer Rating			Average Weighted Score
		39-04	39-05	39-06	
Objective	9	5	5	4	
Achievability	9	4	4	2	
Methodology	7	4	5	3	
Contribution	7	5	4	4	
Awareness	5	5	4	4	
Background	5	5	5	5	
Project Management	2	5	5	3	
Equipment Purchase	2	5	5	3	
Facilities	2	4	5	4	
Budget	2	5	5	4	
Average Weighted Score:		232	229	176	212.3

Maximum Weighted Score:

250

OVERALL RECOMMENDATION:

FUND

FUNDING MAY BE CONSIDERED

DO NOT FUND

	X	X		
			X	

TECHNICAL REVIEWERS' COMMENTS

1. **OBJECTIVES**

The objectives or goals of the proposed project with respect to clarity and consistency with North Dakota Industrial Commission/Lignite Research Council goals are: 1 – very unclear; 2 – unclear; 3 – clear; 4 – very clear; or 5 – exceptionally clear.

Reviewer 39-04 (Rating: 5)

Please comment: This project is focused on demonstrating a path to producing 99.999% pure Ge metal from ND Lignite fly ash. This would demonstrate a domestic supply chain for a critically needed element for a number of defense applications and other high technology applications. Currently the US imports a large portion of this metal. It is high value and could provide additional economic activity based on ND's Lignite resource. Thus, providing additional value add options from Lignite resources. This clearly meets the goals of the NDIV/LRC.

Reviewer 39-05 (Rating: 5) The project goals are clearly defined and in direct alignment with NDIC goals. The ability to produce pure germanium metal at low cost and with minimal environmental impact will directly benefit the lignite industry in the State.

Reviewer 39-06 (Rating: 4) The goal of the project is to build upon past NDIC funded work to produce 5 nine germanium from germanium rich concentrates that were produced from lignite-derived fly ash.

2. **ACHIEVABILITY**

With the approach suggested and time and budget available, the objectives are: 1 – not achievable; 2 – possibly achievable; 3 – likely achievable; 4 – most likely achievable; or 5 – certainly achievable.

Reviewer 39-04 (Rating: 4) The approach, time and budget are likely sufficient to meet the objectives identified in this proposal. The work outlined should be able to completed with the resources noted. It is a challenging question being addressed and a positive outcome, although possible it is not guaranteed.

Reviewer 39-05 (Rating: 4) This project will build on extensive work already done in the area by MTI. While it is not guaranteed that they can reach the proposed 99.999% purity level, based upon their previous record of success and the proposed approach, it is highly likely that they can achieve the proposed goals. The budget and timeframe seem reasonable for the proposed work scope.

Reviewer 39-06 (Rating: 2) The authors indicated that a reduction furnace will be designed to purify the Ge, but do not provide supporting information as to why this system is expected to work. The fact that the system is yet to be designed is concerning, suggesting the authors may not know exactly how to achieve the desired result. Additionally, the scope of work references selected additives to bond with impurities, but it implies that the proper additives to use for the separation of impurities are unknown and will be determined during the process testing. Hence between the potential for the yet to be designed process to be inadequate to achieve the results and not knowing which additives are needed, it is not clear if the work will be successful in achieving the results.

3. **METHODOLOGY**

The quality of the methodology displayed in the proposal is: 1 – well below average; 2 – below average; 3 – average; 4 – above average; or 5 – well above average.

Reviewer 39-04 (Rating: 4) The methodology laid out in the proposal is logical offers a very good chance for success.

Reviewer 39-05 (Rating: 5) This is a well thought out project that builds on extensive work already performed by MTI. The proposed tasks are logical and needed to accomplish their objectives.

Reviewer 39-06 (Rating: 3) The overall plan to get to the final objective is clear, but the specific methodology to achieve the goals of each subtask is unclear. Additional detail is needed regarding the experimental setup to help understand if the methodology is sound.

4. **CONTRIBUTION**

The scientific and/or technical contribution of the proposed work to specifically address North Dakota Industrial Commission/Lignite Research Council goals will likely be: 1 – extremely small; 2 – small; 3 – significant; 4 – very significant; or 5 – extremely significant.

Reviewer 39-04 (Rating: 5) The proposed work is focused on demonstrating a significant new value-added product based on ND Lignite. This would represent an additional revenue generating strategy that I believe a very important to the long term economic success of the Lignite industry.

Reviewer 39-05 (Rating: 4) This project has the potential to provide the pathway for the production and sale of a new value-added product from North Dakota lignite, which is in direct alignment with NDIC/LRC goals. The technical components of the proposal will demonstrate the ability of the process to meet the 99.999% purity goal, while the preliminary TEA will provide insights into the potential profitability of the process.

Reviewer 39-06 (Rating: 4) If successful, this project would meet the NDIC/LEC goals of developing processes for extraction of rare earth elements from lignite and lignite-derived fly ash.

5. **AWARENESS**

The principal investigator's awareness of other current research activity and published literature as evidenced by literature referenced and its interpretation and by the reference to unpublished research related to the proposal is: 1 – very limited; 2 – limited; 3 – adequate; 4 – better than average; or 5 – exceptional.

Reviewer 39-04 (Rating: 5) The cited literature demonstrates a exceptional awareness of current research and literature in this field

Reviewer 39-05 (Rating: 4) The proposal references key literature in the topic area, and provides a brief review of competing technologies. In addition, a look at the participants resumes indicate they have a broad and deep background in this area.

Reviewer 39-06 (Rating: 4) The principal investigator has provided several references to groundbreaking research in the field of germanium concentration and is aware of the work performed to date in the field.

6. **BACKGROUND**

The background of the investigator(s) as related to the proposed work is: 1 – very limited; 2 – limited; 3 – adequate; 4 – better than average; or 5 – exceptional.

Reviewer 39-04 (Rating: 5) The experience cited and success in earlier projects demonstrate exception background that will be critical to successful completion of the proposed work.

Reviewer 39-05 (Rating: 5) This teams brings a wealth of experience related to this work as indicated both by the strength of their resumes, and more importantly, through

the various other research projects related to this work that have already been completed.

Reviewer 39-06 (Rating: 5) The investigators have been performing research in the concentration of Ge for nearly 20 years and have significant recent experience in similar projects.

7. **PROJECT MANAGEMENT**

The project management plan, including a well-defined milestone chart, schedule, financial plan, and plan for communications among the parties involved in the project, is: 1 – very inadequate; 2 – inadequate; 3 – adequate; 4 – very good; or 5 – exceptionally good.

Reviewer 39-04 (Rating: 5) The proposal included a detailed milestone chart and a clear plan for communication with the participants in the project.

Reviewer 39-05 (Rating: 5) The project management structure including roles and responsibilities is well laid out. The tasks are logically structured including their timing and the proposed milestones.

Reviewer 39-06 (Rating: 3) The project management plan does not discuss risk mitigation and contingency plans if initial designs or additives are not adequate to produce the desired results. The timeline and milestones are reasonable for the project. The proposal indicates there will be regular communications between the investigators and subcontractor, though does not provide specific communication plans.

8. **EQUIPMENT PURCHASE**

The proposed purchase of equipment is: 1 – extremely poorly justified; 2 – poorly justified; 3 – justified; 4 – well justified; or 5 – extremely well justified. (Circle 5 if no equipment is to be purchased.)

Reviewer 39-04 (Rating: 5) All of the equipment identified is critically needed to complete the proposed work.

Reviewer 39-05 (Rating: 5) MTI will purchase the equipment required to construct the processing equipment for the reduction and micro-zone refining process. These are the key elements of the proposed effort, and therefore essential for the project. MTI will also be using equipment that is already operational in support of this effort.

Reviewer 39-06 (Rating: 3) Equipment purchases including the reduction reactor system and micro-zone refining equipment are needed to complete the project. However, no specifics are given as to the expected costs for each system, and considering the reduction reactor has not been designed, it is unknown how the costs were derived.

9. **FACILITIES**

The facilities and equipment available and to be purchased for the proposed research are: 1 – very inadequate; 2 – inadequate; 3 – adequate; 4 – notably good; or 5 – exceptionally good.

Reviewer 39-04 (Rating: 4) The facilities noted in the proposal a very good. The equipment to be purchased is required for completion of the proposed work.

Reviewer 39-05 (Rating: 5) With the addition of the equipment to be purchased under this grant, MTI will have the facilities and equipment required to complete the proposed work. From the descriptions provided in the text, it appears that MTI has been able to maintain state-of-the-art equipment while simultaneously building up the required software/AI capabilities including experienced personnel required to perform the proposed scope of work.

Reviewer 39-06 (Rating: 4) MTI has existing equipment for the concentration of germanium from fly ash as well as existing analytical equipment for the characterization of samples produced.

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10. **BUDGET**

The proposed budget value relative to the outlined work and the financial commitment from other sources is of: 1 – very low value; 2 – low value; 3 – average value; 4 – high value; or 5 – very high value.

Reviewer 39-04 (Rating: 5) The budget for the proposed activities includes a cost share of 67% and additional contributions including raw materials and consultation with key personnel at two companies currently operate concerns that could be the source of the required raw materials. Their interest and willingness to participate assures that the necessary partners to achieve the goal of a commercially viable domestic supply for Ge metal is possible.

Reviewer 39-05 (Rating: 5) MTI is proposing to leverage this project with two dollars cash contributions to each dollar from the NDIC. It also appears that additional in-kind

contributions (not shown in the budget) will be made by North American Coal in terms providing germanium rich coal to use as a part of this project, and both North American coal and Great River Energy will provide, at no cost to the project, personnel to provide input into the technical and economic feasibility of the project, and time and travel to project related meetings.

Reviewer 39-06 (Rating: 4) The project is 2/3 funded from another source. The applicant references that AmeriCOM has issued an RFP for the work but does not indicate if the funding has been secured. Cost share funding status should be verified. The budget table references consultants which is presumably for IR Power Systems who was previously described as a subrecipient. It should be verified if there are other consultants on the project.

OVERALL COMMENTS AND RECOMMENDATIONS:

Please comment in a general way about the merits and flaws of the proposed project and make a recommendation whether or not to fund.

Reviewer 39-04 (Rating: FUND) I believe the proposed project on Germanium refining from North Dakota fly ash is a very good candidate for funding under the Lignite Research Council program. The only shortcoming noted, is that the cost share funding has been applied for but not approved for funding at the time of submission. I assume that this cost share will be approved and available prior to the start date and therefore would be a condition for funding.

The work focuses on what this reviewer believes is a critical opportunity for the ND Lignite Resource which is identifying additional revenue streams based on new products that can be produced from Lignite. This work will provide the data necessary to move this technology to the next scale and result in significant investment in North Dakota. The developers believe the logical location would be adjacent to the plant generating the fly ash which would result in additional capital investment in the state. With the availability of the cost share funding, I strongly support this proposal.

Reviewer 39-05 (Rating: FUND) This is a well written proposal that demonstrates MTI will be able to advance their current technology to the point where 99.999% germanium can be produced from lignite fly ash materials. Their objective of producing a value-added product from lignite aligns with NDIC/LRC goals. Germanium has significant commercial value and is needed by industries in support of the Department of Defense and other industries needing high quality optics. AmeriCom has expressed interest in building a pilot and eventually a commercial facility in North Dakota which would add jobs and revenue to the lignite regions of the state. This project builds upon the success of previous projects funded through NSF, DoD, NDIC and others. The project is leveraged 2:1 making it a good value the NDIC, and includes letters of support from North American Coal and Great River Energy.

Reviewer 39-06 (Rating: FUNDING MAY BE CONSIDERED) The proposed project builds on prior work conducted by the PI and organization in developing Ge rich concentrates from lignite fly ash. The project is focused on further purifying the Ge to 5 nine purity. This meets the goals and objectives of the LEC as well as current national security goals. The systems to further purify the Ge have not yet been designed and the specific additives needed to separate the impurities either have not been selected or not specified in the proposal. This creates risk that the investigators may not be able to achieve the desired results. Further justification for equipment costs is also needed. Funding may be considered if the team can provide more information on the experimental setup and the rationale for why they believe it will work.