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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

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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 work[1], 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 CO_2, 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 ft^2 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 O_2, CO_2, and SO_2 are obtained simultaneously at the furnace exit and stack. CO and NOx emissions are obtained at the furnace exit. System O_2, CO, and CO_2 analyzers were manufactured by Rosemount, the SO_2 analyzers were manufactured by DuPont and Ametek, and NOx 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

work at UND[2,3,4,5,6], starting from laboratory feasibility (2016-2017), bench-scale demonstration (2018-2020), pilot-scale demonstration (2020-2024) and a front-end engineering & design (FEED) study (2023-2025). Figure 1 provides a flowsheet of our technology that is implemented in the existing UND pilot plant.

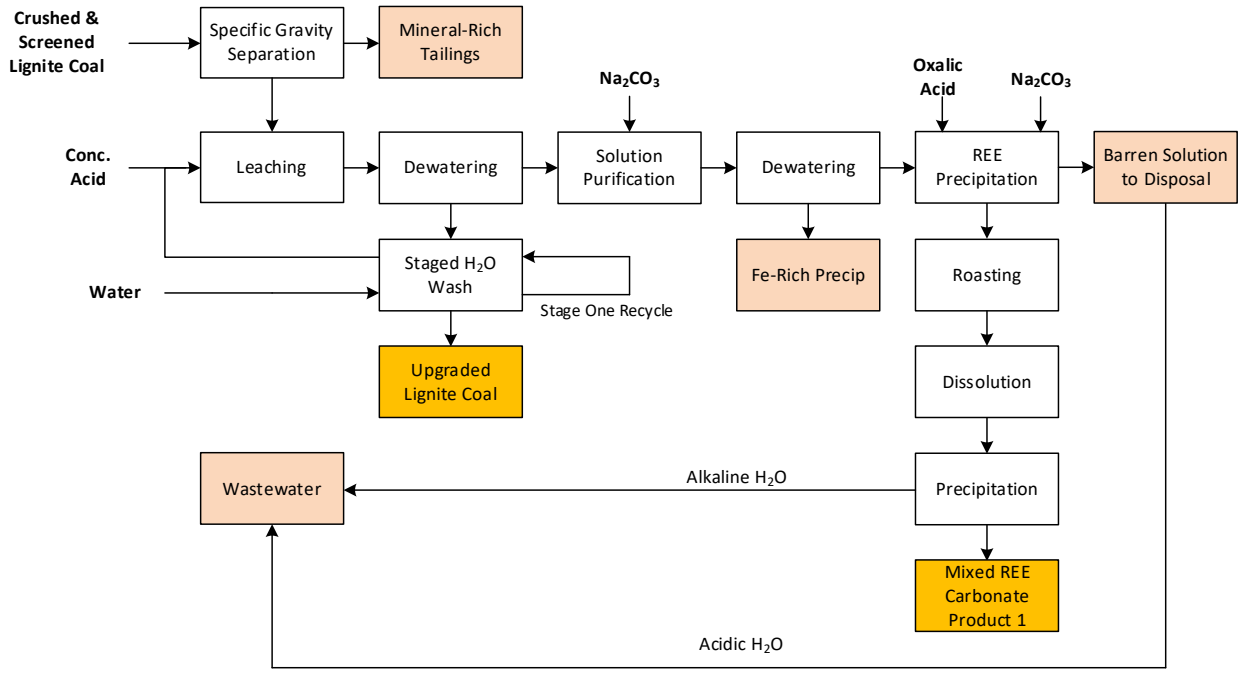

Figure 1. UND MREC process diagram.

The recently completed FEED study and associated technical de-risking were completed under DE-FE0032295. This work noted a number of potential improvements to REE processing economics and preliminary combustion data from blended fuel testing; however, these updates were not expanded at the pilot-scale due to the project's scope and schedule restrictions, and currently represent a risk to further

[2] Investigation of Rare Earth Element Extraction from North Dakota Coal-Related Feedstocks (DE-FE0027006). Project of the U.S. Department of Energy, National Energy Technology Laboratory (2016-2019).
[3] Rare Earth Extraction and Concentration at Pilot-Scale from North Dakota Coal-Related Feedstocks (DE-FE0031835). Project of the U.S. Department of Energy, National Energy Technology Laboratory (2019-2024).
[4] Conceptual Design of a One Tonne per Day Rare Earth Extraction and Concentration Plant from Low-Rank Coal Resources (89243320CFE000057). Contract from the U.S. Department of Energy, National Energy Technology Laboratory (2020-2022).
[5] Recovery and Refining of Rare Earth Elements from Lignite Mine Waste (DE-FE0032295). Project of U.S. Department of Energy, National Energy Technology Laboratory (2023-2025).
[6] Laudal, D. Evaluation of Rare Earth Element Extraction from North Dakota Coal-Related Feedstocks. Dissertation submitted to the University of North Dakota, 2017.

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 that 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, CO_2 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, CO_2 capture, techno-economic modeling, extraction of critical materials, environmental control systems, supercritical CO_2 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.

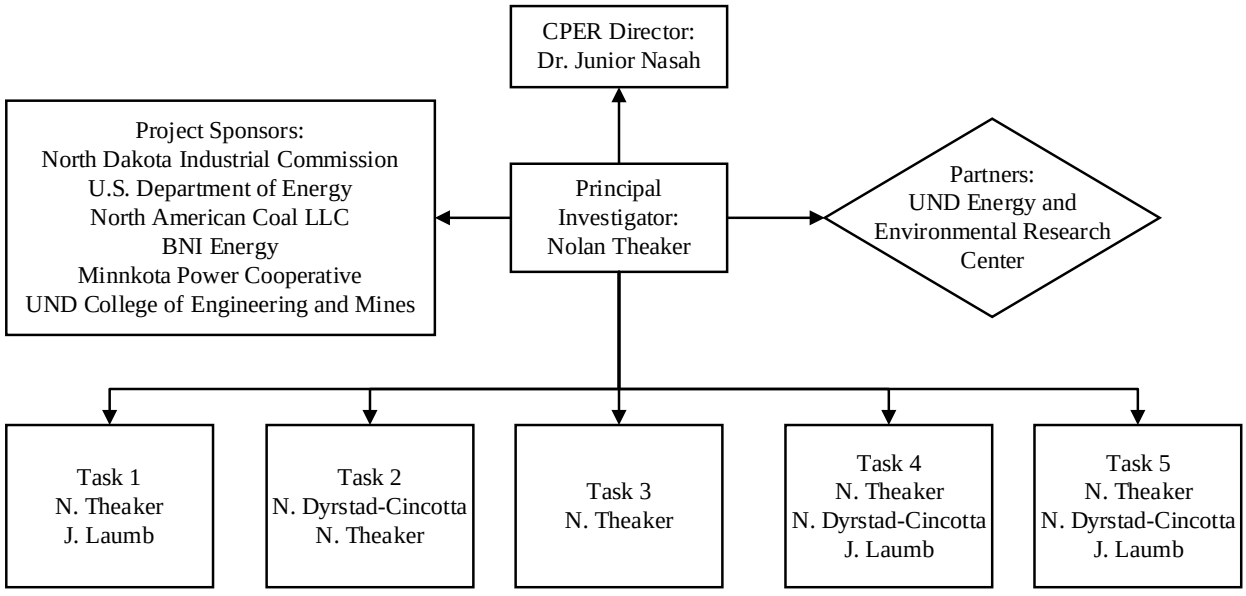

Figure 2. Project organization chart.

TIMETABLE

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

ID	Task Name	Start	Finish
1	**Task 1 - Project Management and Planning**	1/1/2026	12/31/2027
2	**Task 2 - Pilot Expansion and Commissioning**	1/1/2026	9/30/2026
M1	**Milestone 1 - Physical Sep. Commissioned**		4/30/2026
M2	**Milestone 2 - REE Processing Equipment Commissioned**		9/30/2026
3	**Task 3 - REE Process Improvement Testing**	1/1/2026	12/31/2026
M3	**Milestone 3 - Chemical Savings of 10% Achieved**		7/31/2026
M4	**Milestone 4 - Ge/Ga/Sc Recovery at Least 30-40%**		10/30/2026
M5	**Milestone 5 - REE Product Purity Improved**		12/31/2026
4	**Task 4 - Physical Separation and Na Removal**	7/31/2026	2/28/2027
M6	**Milestone 6 - 70% Mineral Removal Achieved**		10/31/2026
M7	**Milestone 7 - 90% Na Removal Achieved**		1/31/2027
M8	**Milestone 8 - Combustion Testing on Processed Cleanings**		2/28/2027
M9	**Milestone 9 - Economic Assessment**		2/28/2027
5	**Task 5 - REE Extraction Pilot Testing**	3/1/2027	12/31/2027
M10	**Milestone 10 - Baseline Testing of FEED Design**		4/30/2027
M11	**Milestone 11 - Task 3 Improvement Testing Complete**		9/30/2027
M12	**Milestone 12 - 20 Tons at Best Conditions Tested**		10/31/2027
M13	**Milestone 13 - Combustion Testing on Processed Lignite**		12/31/2027
M14	**Milestone 14 - TEA Update**		12/31/2027

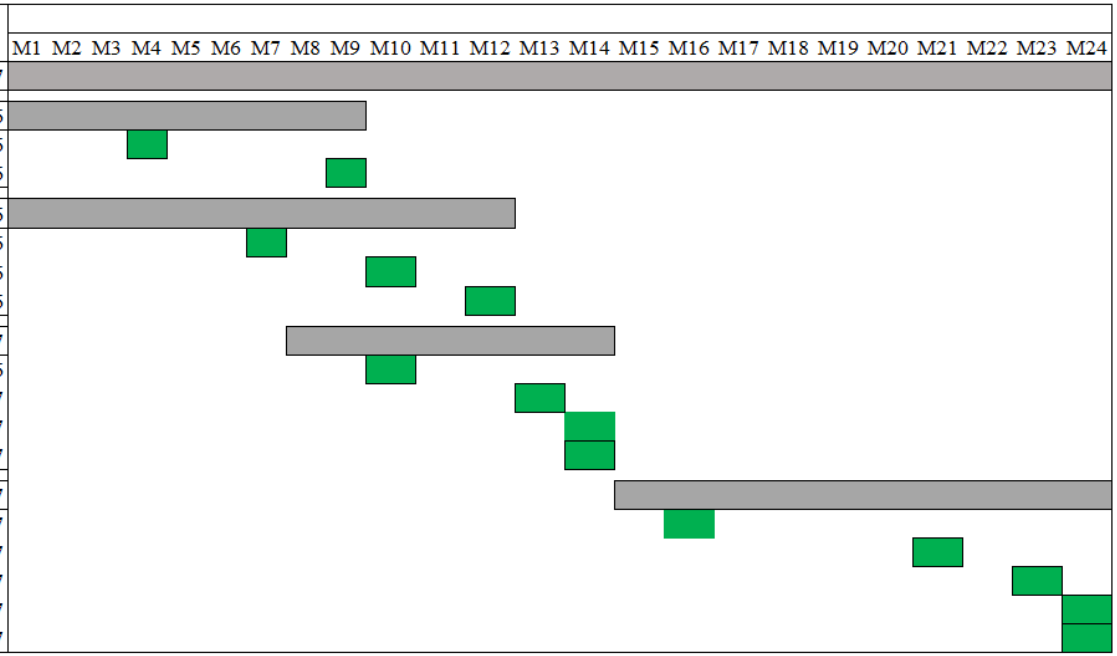

Figure 3. Project Gantt chart schedule.

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

[1]DOE 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.