UNIVERSITY OF NORTH DAKOTA

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April 14th, 2023

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

Subject: "Recovery and Refining of Rare Earth Elements from Lignite Mine Wastes," Proposal to the Lignite Research, Development and Marketing Program by Dr. Daniel Laudal, Project Director and Mr. Nolan Theaker, Principal Investigator

Dear Mr. Haase:

On behalf of the University of North Dakota, I am pleased to submit Dr. Daniel Laudal's and Mr. Nolan Theaker's proposal on "Recovery and Refining of Rare Earth Elements from Lignite Mine Wastes," for consideration by the NDIC's Lignite Research, Development and Marketing Program. Dr. Laudal is the Executive Director of the UND's College of Engineering and Mines' Institute for Energy Studies and is the Project Director for this project. Mr. Nolan Theaker is a Senior Research Manager in the UND Institute for Energy Studies, and is the Principal Investigator. Dr. Laudal and Mr. Theaker are proposing a 15-month project with a total requested amount from NDIC of $2,000,000. The NDIC funding is being requested as a match to the DOE portion of the project, which is currently in the process of award negotiation for $7,999,999. The total value of the overall project would thus be $9,999,999. We anticipate a start date in approximately August 2023.

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,

Karen Katrinak

Karen Katrinak, Ph.D., Proposal Development Officer
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UNIVERSITY OF NORTH DAKOTA
COLLEGE OF ENGINEERING & MINES

RECOVERY AND REFINING OF RARE EARTH ELEMENTS FROM LIGNITE MINE WASTES

Total Project Cost: $9,999,999

NDIC Funding Request: $2,000,000

Date of Application: April 14, 2023

Project Director:
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UNIVERSITY OF NORTH DAKOTA
COLLEGE OF ENGINEERING & MINES

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ABSTRACT

Objective: The College of Engineering & Mines (CEM) at the University of North Dakota (UND), in collaboration with a comprehensive team of technical, business and host-site partners and with funding support from the U.S. Department of Energy (DOE), proposes to build on prior technology development to complete a Front-End Engineering & Design (FEED) study and develop business and financial plans for a commercial demonstration facility to recover and refine rare earth elements (REE) and critical minerals (CM) from North Dakota (ND) lignite mine wastes. The overall objective of this Phase 1 project is to produce an investment quality project and a committed team that is ready to execute the construction and operation of the REE Demonstration Facility in Phase 2 (~$250 Million).

Expected Results: The previous pre-FEED study and prior development completed by the project team identified key technical gaps. The proposed project will enable closing of those gaps to de-risk the commercialization pathway. The primary impact of the proposed project will be the advancement of a unique set of technologies that can enable cost-competitive North Dakota-based ore-to-metal rare earth elements and critical minerals production with significantly reduced environmental impact.

Duration: The total project duration is 21 months, with a 15-month technical period. The DOE will have a 6-month administrative period for the down-selection for Phase 2.

Total Project Cost: $9,999,999 ($7,999,999 from DOE and a request of $2,000,000 from NDIC)

Participants: Major participants and their project role are listed below.

Organization	Role/Competency
UND (Applicant)	Lignite mine waste REE/CM concentrate technology provider and overall lead
Barr Engineering Co. / McCarl's	Engineering, Procurement, and Construction team
WSP Golder	Wastewater treatment/disposal engineering and environmental
Rare Earth Salts Separation & Refining LLC	REE/CM separation and metallization technology provider; host site provider for separations and metallization facility; preliminary owner/operator of the separations and metallization facility
Microbeam Technologies, Inc.	Technology provider for lignite mine waste feedstock analysis/sorting and germanium and gallium separations
North American Coal Corp.	Host site provider (Falkirk Mine)
Rainbow Energy Center	Host site provider (Coal Creek Station)
BNI Coal, Ltd.	Host site provider (Center Mine)
Minnkota Power Cooperative	Host site provider (Milton R. Young Station)

Note about Nomenclature

Throughout this proposal, we use the phrase lignite mine wastes to describe the lignite-based feedstock that we use as the rare earth elements and critical minerals (REE/CM) resource. We do this to be consistent with the DOE funding opportunity (DE-FOA-0002618) requirements, which had certain limitations around the types of feedstocks that were eligible. Our feedstock represents the lignite materials that are located near the margins of the coal seams (i.e. top/bottom 6-12 inches). These materials are typically higher in ash yield and not suitable as thermal coal for the power plants. In many cases, these materials, particularly the top of the coal seams, are considered the 'cleanings' in today's lignite mining practices, which are scraped off separately and then returned into the mine pits with the overburden materials. Alternatively, we also target thin lignite seams that are not currently economic for thermal coal mining. These are typically 'mined through' and are discarded with the overburden. Because these materials are, in most cases, not provided to the power plants today, they meet DOE's feedstock eligibility criteria. We do not intend to convey any negative connotation or inaccuracy in our use of the phrase lignite mine wastes within the context of this project.

PROJECT SUMMARY

Project Objectives

The College of Engineering & Mines (CEM) at the University of North Dakota (UND), in collaboration with a comprehensive team of technical, business and host-site partners and with funding support from the U.S. Department of Energy (DOE), proposes a Phase 1 project that builds on prior technology development to complete a Front-End Engineering & Design (FEED) study to recover and refine rare earth elements (REE) and critical minerals (CM) from North Dakota (ND) lignite mine wastes. ***The end of project goal is to have an investment quality project and a committed team that is ready to execute the construction and operation of a commercial REE Demonstration Facility in Phase 2.***

Our team was recently selected for a Phase 1 award under DE-FOA-0002618 (BIL – Rare Earth Element Demonstration Facility) as ***one of only two awardees*** (West Virginia University) ***that will compete for a much larger Phase 2 opportunity (expected ~$250 Million)***. This proposal to NDIC is to provide cost share to the Phase 1 DOE award, which is currently in negotiation and is expected to begin in August 2023.

To achieve the end of project goal stated above, the Phase 1 objectives are as follows: **1)** Quantify the proposed project's job benefits and evaluate how to attract, train, and retain a qualified workforce. **2)** Identify specific DEIA goals, targeted outcomes, and implementation strategies. **3)** Ensure that the project will provide meaningful benefits to disadvantaged communities and will not result in an increased burden to the disadvantaged community. **4)** Identify and implement methods for project stakeholder engagement. **5)** Develop information for all required permit applications and other regulatory approvals, including the Environmental Assessment information for NEPA review, by the end of Phase 1. **6)** Develop an AACE Class 3 FEED study for the REE Demonstration Facility to advance the project to investment quality. **7)** Perform limited R&D to de-risk certain technology subsystems. **8)** Develop the Phase 2 business and financing plans to formalize the overall commercial structure and secure construction financing.

Project Structure

The project's preliminary organization is summarized in **Figure 1**. Additional details are provided below.

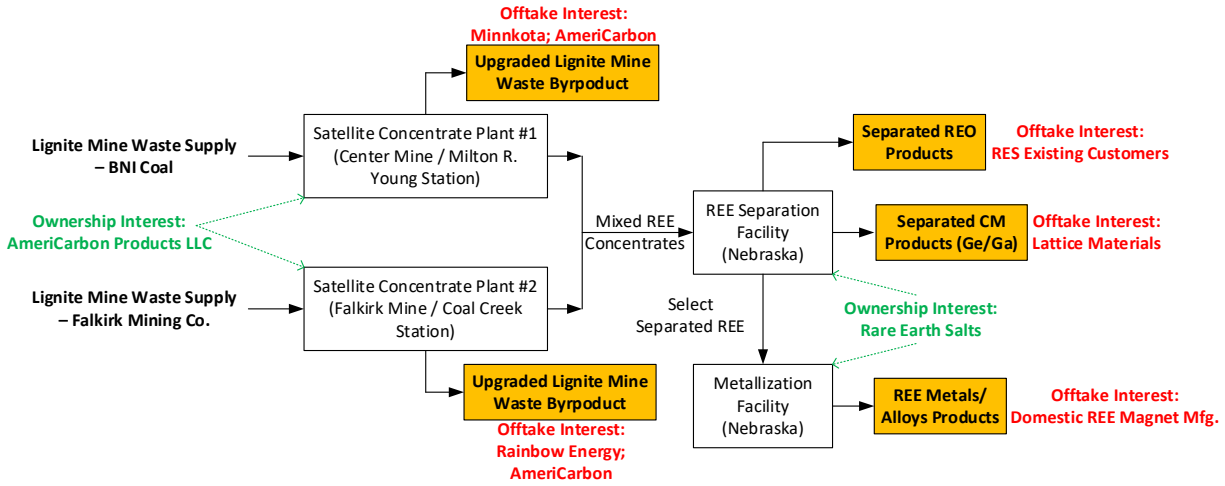


Figure 1. Preliminary structure of the REE Demonstration Facility

Mixed Rare Earth Concentrate (MREC) Plants

This project will evaluate two ND host sites producing two or more products: 1) MREC with a purity of at least 75wt% REE on an oxide or salt basis and 2) a unique lignite carbon ore that could be used as a blending fuel for the power plants or as a feedstock for high-value carbon products. We will evaluate host sites near the Center Mine / Milton R. Young Station (MRYS) and near the Falkirk Mine / Coal Creek Station. As indicated in **Figure 1**, we have received interest from project partner AmeriCarbon LLC in being part of the ownership venture should the project be selected for Phase 2. We have also received letters of interest from the lignite mines and from the power plant owners to provide feedstock (lignite mine waste) to the MREC plants and to purchase the lignite carbon ore product. The MREC plants will be designed to produce at least 1 metric ton per day (mtpd) of total MREC. The MREC is planned to be trucked to the existing REE separation facility of project partner Rare Earth Salts Separation & Refining LLC (RES) located in Nebraska.

A ***preliminary mass balance for the two ND host sites*** is presented in the following section. ***Approximately 1.1 mtpd of MREC will be produced*** (assuming a typical plant on-line / capacity factor).

Preliminary Center Mine MREC Site Mass Balance**:** The site will produce approximately 37% of the total REE. Processing 1.26 million mt/yr of lignite mine waste results in an estimated 134 mt/yr of 75% purity MREC. Assumptions are: 50% REE recovery, average ore grade containing 114 ppm REE on a dry, whole-coal-waste basis, and collecting 90% of the coal waste exposed during existing mining operations, assuming some lost recovery during mining.

Preliminary Falkirk Mine MREC Site Mass Balance**:** The site will produce approximately 63% of the total REE. Processing 1.89 million mt/yr lignite mine waste results in an estimated 233 mt/yr of 75% purity MREC with an average REE ore grade of 132 ppm (same assumptions as above).

The REE-extracted lignite co-product would represent ***<20% of the total coal fired*** by the adjacent power stations, resulting in an ***ideal quantity of high-quality blending fuel to manage ash fouling/slagging challenges***. In addition, the above REE production rates do not account for the

significant and economically important production quantities of CM, specifically, an ***estimated total production of high purity Ge and Ga at 45 mt/yr*** (combined).

REE Separation and Metallization Plants

RES plans to expand its existing commercial REE separation facility's footprint and capacity and already has land acquired or available to enable this expansion. We plan to co-locate a metallization facility that will use selected individually separated rare earth oxides (REO) from the RES facility to manufacture metals or metal alloys that would be direct feeds to commercial products, such as rare earth magnets. RES has a metallization technology in development that will be the focus of this proposed effort.

Figure 1 indicates that the germanium and gallium (Ge/Ga) concentrate products would be produced at the RES facility. However, this could also be completed at one or both of the ND host sites. The proposed project will examine the most cost-effective integration approach for the Ge/Ga products. **Lattice Materials**, a Montana-based manufacturer of Ge products, has expressed strong interest in purchasing the Ge/Ga products (see letter in Appendix 5).

RES is interested in owning/operating the separations and the metallization plants. RES already has domestic and international customers that purchase their REO products and we expect to be able to leverage those relationships for product offtake (favoring domestic customers).

Because the current domestic REE magnet manufacturing capacity is limited (or zero), the domestic market for the rare earth metals/alloys products is less certain. We will work with project partners to identify potential offtakers during the Phase 1 project. The establishment of North Dakota-based REE magnet manufacturing capacity would be a huge win for the state and opportunities for this will be explored in the proposed project in connection with other complimentary projects at UND (i.e., the Williston Basin CORE-CM project partly sponsored by NDIC).

Our team has had initial discussions with AmeriCarbon LLC about their interest (see letter in Appendix 5) in owning one or both of the two ND concentrate plants. AmeriCarbon is commercializing its

Eco-Pitch™ technology[1], which cost-effectively produces tailored pitches from domestic coal that can be used for numerous end-use applications. AmeriCarbon is currently pursuing business plans and fundraising for the first commercial pitch plant in North Dakota, which would use lignite coal as the feedstock. Lignite has several unique features compared to other coal types that are advantageous for the Eco-Pitch™ process. ***AmeriCarbon is very interested in using the REE-extracted lignite material as a feedstock*** in their in-development commercial Eco-Pitch™ plant based on early discussions with our team and initial analysis of the REE-extracted lignite materials that our technology produces. The company is interested in evaluating the technical and business opportunity of integrating the two processes at a single site to maximize the synergy between REE extraction and pitch production. AmeriCarbon will engage with our team during Phase 1 to provide technical and economic/business input for this evaluation and will consider being a key member of the owner/investor/operator team that would move forward to Phase 2.

Engineering, Procurement and Construction (EPC) Team

Barr Engineering will lead the engineering effort in Phase 1, maintaining continuity from previous projects including the pre-FEED. We have chosen to engage, from the start, the construction lead, McCarl's, for our project as well. McCarl's will evaluate the constructability of the Facility in Phase 1 and support the cost estimating. We believe this approach will be more effective than developing a design package in Phase 1 and bidding out construction. Barr will lead the FEED study during Phase 1 with the support of McCarl's. These roles would switch during Phase 2, with McCarl's leading the procurement and construction effort and Barr supporting the engineering effort. ***The EPC team is committed to using local contractors/labor whenever practical***.

Barr Engineering also has a comprehensive Environmental practice and will be able to lead the efforts around NEPA and drafting the permit applications on behalf of the project owner(s) and the federal agency. WSP Golder (Golder) will lead efforts associated with wastewater disposal at the two planned ND concentrate plant locations, preliminarily planned via Class I injection (Underground Injection Control

(UIC) program). Golder previously designed the existing operational Class I well at the Coal Creek Station site, one of our proposed ND host sites, and recently worked with Minnkota on designing and permitting a Class I well at the MRYS site, the second of the proposed ND host sites. The team has everything needed to design, permit, and construct the proposed facilities.

Our team has the support of the ND Building Trades Unions[2] (see letter in Appendix 5) through discussions with President, **Jason Ehlert**. McCarl's is a union shop; therefore, it was critical to engage with the local unions early in this project to ensure support and that the necessary skilled crafts and labor will be available when needed. Our project team's intent is to use union labor whenever possible, and we are happy to have the commitment of the NDBTU to support our project, including helping us develop the Community Benefits Plan and working towards executing a Project Labor Agreement in Phase 1.

Project Team Members and Roles

We have formed a comprehensive technical, environmental and commercial team to execute this project and position us for a future Phase 2 selection. The table below provides the project team members and their key roles in the Phase 1 project.

Organization	**Role/Competency**
UND (Applicant)	Technology provider, process engineering, project management/coordination
Barr/McCarl's	FEED study lead, NEPA and permitting lead
Golder	Wastewater treatment/disposal lead, including NEPA and permitting
RES	REE/CM separations and metallization lead, host site and preliminary owner/operator
Microbeam Technologies, Inc.	Technology provider for mine waste feedstock analysis/sorting and Ge/Ga separations
North American Coal	Host site provider (Falkirk Mine)
Rainbow Energy	Host site provider (Coal Creek Station)
BNI Coal	Host site provider (Center Mine)
Minnkota	Host site provider (Milton R. Young Station)
AmeriCarbon	Preliminary owner of the ND REE concentrate plants & offtake for REE-extracted lignite mine waste byproduct
Envergex LLC	Greenhouse gas lifecycle analysis and process modeling
Dennis James Consulting	Technical consultant - mining
MLJ Consulting	Commercial consultant
Odney	Community Benefits Plan development and implementation consultant
U.S. DOE	Project sponsor

PROJECT DESCRIPTION

Background

Lignite Mine Waste as the Feedstock

Our prior work in developing the lignite mine waste resource and our proposed MREC technology has identified the numerous performance and environmental benefits made possible by the unique properties of our proposed feedstock.[3,4,5 & 6] These are summarized as follows:

1) The organic binding of the REE/CM enables extremely rapid and highly selective REE/CM extraction with mild acids via a cation exchange process. ***Within only a few minutes of contact time, high leaching efficiencies are achieved*** while also significantly limiting the impurities (i.e., Fe, Al, Th, U) that are extracted with the REE/CM.

2) The actinides (Th, U) also appear to have an organic association in the lignite mine wastes, but one that is stronger than the REE and target CM (Ge/Ga). Therefore, ***our tuned leaching process is able to leave behind the large majority of the actinides in the lignite material where it does not represent a concern, thereby avoiding actinide up-cycling concerns within our process.***

3) High total REE concentrations have been identified at numerous sites, including the existing mines. The key unique feature of our lignite mine wastes, however, is the enrichment in the more valuable heavy REE (i.e. Dy, Tb) as compared to traditional mineral ores and other unconventional resources (i.e., higher rank coal-based materials). We are ***uniquely able to target the extremely high value applications for high-temperature REE magnets (high Dy, Tb content).***

4) We have the ability to cost-effectively co-produce very large quantities of the critical semiconductor metals Ge and Ga. We are not aware of any significant domestic production capability of these CM. The previous AACE Class 4 study indicated that ***a single MREC plant (Falkirk Mine site) would produce more than 30% of the annual domestic Ge demand***. No other coal-based resource that we are aware of is

afforded this opportunity. Our previous studies have indicated that Ge/Ga represent a major portion of our total projected revenues, offering the ability to insulate against REE market pricing fluctuations.

5) Our technology is also unique because we are able to not only recover valuable REE/CM from the lignite mine waste, but we are also able to upgrade it into a unique carbon-based ore for use as a low ash (~zero-sodium (Na)) blending fuel for thermal coal or for carbon-based products manufacturing. This provides a very large new revenue stream while also ***improving overall lignite mine resource recovery/utilization and ultimately reducing the environmental impact of mining.***

MREC Facility and Associated Technologies

The MREC facility uses technologies developed by Microbeam Technologies, Inc (MTI) and UND, and the margins of lignite seams and thin, currently uneconomic seams, as the feedstock (lignite mine wastes). These materials are typically high ash yield and not suitable for thermal coal. The first step in the process is selectively mining these materials, which is currently performed today as the 'cleanings' step the lignite mines use to generate a clean seam top. These 'cleanings' are temporarily stockpiled while the thermal coal is excavated and then later discarded to the mine pits. Our proposed plant will use those materials as the REE feedstock instead of discarding them. Because the lignite feedstock represents a major portion of the project's O&M costs, ***it will be key to the economics of the project that we minimally disrupt the existing mining operations and mine plans of our lignite mine partners.*** Selecting only the cleanings fraction, which is already separated today in current practice, will allow us to achieve this requirement.

We will use MTI's analysis and sorting technology to separate high REE from low REE materials and enable blending to achieve a stable feedstock grade once the lignite mine wastes are recovered. MTI's analysis algorithm has been tested on a range of REE concentrations and shows sensitivity to the 10s of parts per million (ppm) (**Figure 2**). The feed can be further concentrated using density-based separations (spiraling) to recover the REE-rich organic materials and reject the REE-depleted (and impurity-enriched) mineral matter before or after blending. This REE-rich organic material, similar in bulk chemical

composition to the mined thermal coal (ash content), is then sent for mild acid leaching.

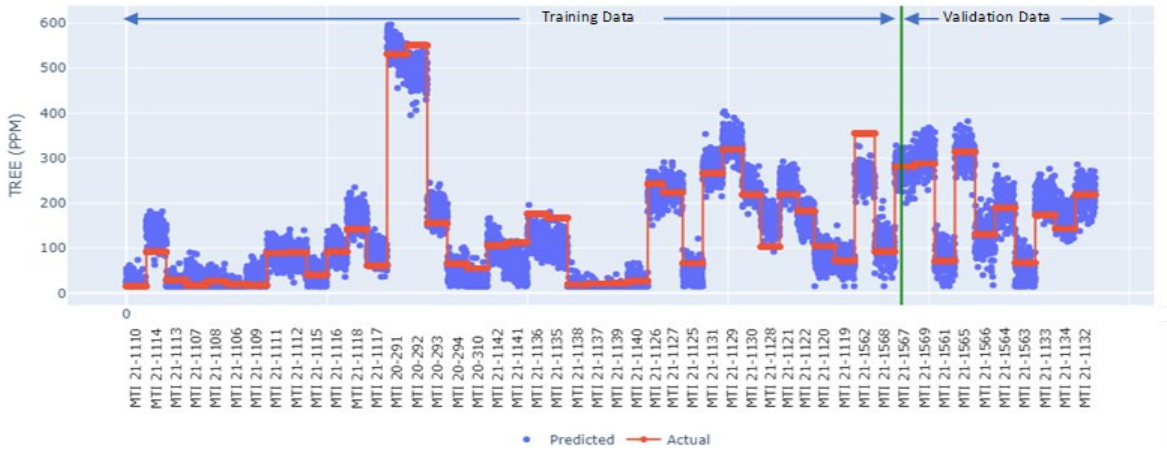


Figure 2. Ore analysis algorithm training/validation from MTI's previous development using PGNAA-DGA

The leaching leverages the organic bonding of the REE/CM in the lignite waste materials[4], extracting the REE/CM and other inorganic materials into a pregnant leach solution (PLS). The lignite material structure is essentially unchanged, except for a near complete removal of the organically bound inorganic elements. The solution is a dilute mineral acid and we maximize slurry density to reduce possible PLS dilution effects and minimize wastewater volume. **Figure 3** shows leaching efficiency (including Th/U).

The REE-extracted lignite is washed in multiple stages to recover the acid and REE/CM contained in the pore volume, then dewatered (filter press). This REE-extracted lignite material is a unique carbon-based material that is a high-value blending fuel (low ash and, importantly, near-zero sodium). This material is also an ideal feedstock for carbon-based products manufacturing, with an organic ash content between 0.25-0.5%, down from ~6% in the raw ore. **Figure 4** is a schematic of the above process steps.

The process then uses a mixture of hydrometallurgy and pyrometallurgy to recover the REE/CM product streams from the filtered PLS. A base is added to the PLS to increase the pH and precipitate iron-rich impurities. Oxalic acid is then added, along with a base to maintain the desired pH, to selectively precipitate two REE-oxalate mixtures: one with high REE purity and one enriched in scandium (Sc) and HREE (**Figures 5 & 6**). Direct precipitation purities of the first concentrate in excess of 75% have been produced using suitable process controls.

The oxalates are roasted to produce rare earth oxides (REO), which are re-dissolved in mineral acid (Ce is mostly rejected, beneficially, at this stage due to insoluble +4 oxidation state) and passed through a selective ion-exchange column to increase REE concentration to >75wt% (**Figure 7**) (reject primarily Ca & Al). The purified REE solution is then mixed with a precipitant to recover the high-purity MREC products. The Ge and Ga are volatilized during roasting and are then selectively condensed to form Ge and Ga concentrates as oxides via MTI's technology and subsequently processed to high-purity via conventional processes.[7,8] The products are at least 1 mtpd of the MREC products and the >99.99% separated Ge and Ga products. Additionally, the produced wastes, Fe-rich precipitates and wastewater, are RCRA-compliant, non-hazardous wastes, reducing potential environmental burdens associated with the process. **Figure 8** is a schematic of the PLS processing and product recovery steps.

The data presented in the preceding sections and figures below and on the next page regarding UND's MREC technology are based on bench-scale testing. We note that the bench-scale testing, while successful, also identified several opportunities/approaches for process improvement, including higher efficiency leaching and reduced chemicals consumption. These improvement opportunities are a focus in our ongoing pilot project and will be further refined in the proposed Phase 1 project.

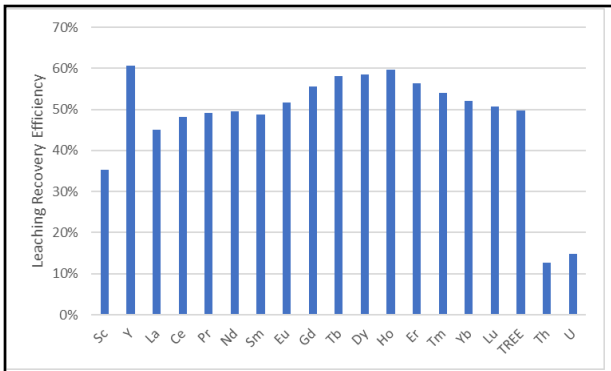


Figure 3. Leaching recovery efficiency for REEs and actinides. Improvement is expected at scale due to improved dewatering efficiency.

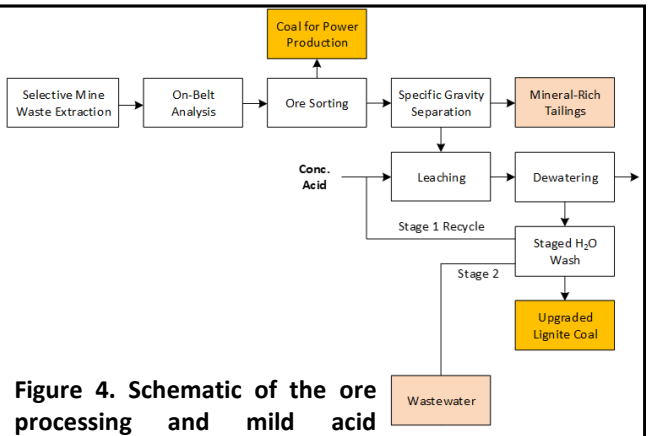


Figure 4. Schematic of the ore processing and mild acid leaching steps.

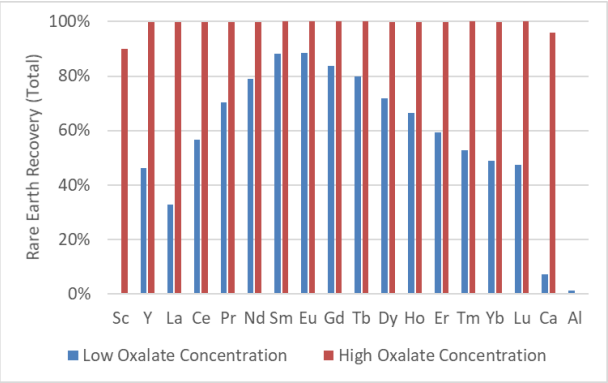


Figure 5. Oxalate precipitation recovery via UND's 2-step process. Two stages enables a high REE purity 1st product and high Sc concentration 2nd product.

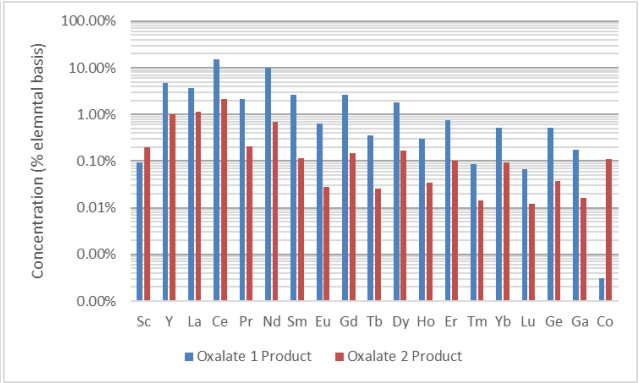


Figure 6. Oxalate precipitation purity for each of two products. Note the significant enrichment of Sc into the second product, relative to the lanthanides.

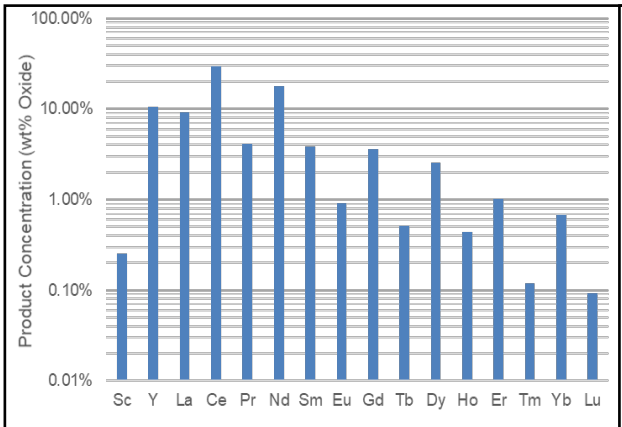


Figure 7. Product purity after calcination and ion exchange treatment. Total REE > 85%.

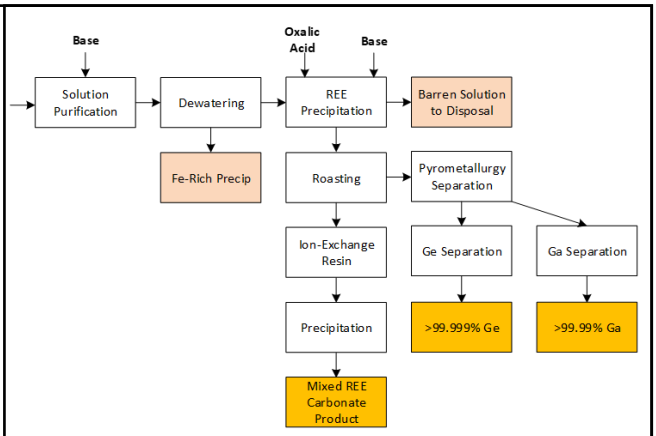


Figure 8. PLS processing and MREC and Ge/Ga product recovery steps.

Methodology

The project objectives identified previously will be achieved through the implementation of five primary efforts during the 15-month technical period: **1)** Development and execution of a Community Benefits Plan; **2)** Development of the technical and environmental information for NEPA reviews and drafting of all relevant permit applications; **3)** AACE Class 3 FEED study for the proposed REE Demonstration Facility; **4)** Limited de-risking R&D, including: a) testing MTI's feedstock analysis and sorting technology to increase to technology readiness level (TRL) 6 and optimize for this application, b) confirming the suitability of Class I injection for MREC plant wastewater disposal, c) testing RES' metallization technology with next

generation cell design to de-risk scale-up for the proposed application, and d) pilot testing in UND's existing pilot facility for host-site-specific lignite mine waste feedstocks; and **5)** Development of the business and financing plans for Phase 2 construction and operation for the REE Demonstration Facility. This work is divided into 7 tasks, described below.

Task 1 – Project Management and Planning: This task will involve all project management activities necessary to meet all technical, schedule, budget objectives, and requirements, including updating the project management plan (PMP) and the technology maturation plan (TMP). UND will lead this task with support from all project team members.

Task 2 – Community Benefits Plan: This task involves developing, updating, and the continuous review and implementation of four plans: **1)** Quality Jobs Plan, **2)** Diversity, Equity, Inclusion and Accessibility (DEIA) Plan, **3)** Justice40 Initiative (J40) Plan, **4)** Community, Labor, and Stakeholder Engagement Plan. UND will lead this task with support from Odney and our host site partners.

Task 3 – National Environmental Policy Act (NEPA): This task involves updating the Environmental Volume submitted previously with the DOE application and developing an Environmental Assessment that will provide the federal agency with the information to determine a Finding of No Significant Impact. We assume an Environmental Impact Statement will not be required since all host sites are on existing industrialized land. Barr will lead this task with support from Golder, UND and host site partners.

Task 4 – Permits for Construction and Operation: We have identified the applicable permits listed in the table below for the two ND host sites (MREC plants) based on a preliminary assessment. We have initially assumed that the existing permits for the existing RES facility (to be expanded in Phase 2) will need to be reviewed and modified. This task will develop all information necessary to draft ready-to-submit permit applications by the end of Phase 1. Barr will lead this task with support from Golder, UND and our host site partners.

Agency	Permit/Authorization
U.S. Army Corps of Engineers	Section 404 Authorization (Nationwide Permit)
ND DEQ	Section 401 Water Quality Certification (issued for Nationwide Permit)
ND DEQ	Air Quality Permit to Construct
ND DEQ	Construction Stormwater General NDPES Permit (NDR11-0000)
ND DEQ	Industrial Stormwater General Permit (NDR05-0000)
ND Department of Water Resources	Water Appropriation Permit
ND DEQ	Class I (Underground Injection Control Program) Injection
U.S. EPA	Aquifer Exemption Request & Approval for Class I injection

* ND DEQ: North Dakota Department of Environmental Quality

Task 5 – AACE Class 3 FEED Study: The FEED study will follow the requirements outlined in Appendix B in the FOA and will encompass the two ND MREC sites and the REO separation and metallization facility in NE. These requirements will be completed by specified leads in the following disciplines: Process Engineering, Mechanical Engineering, Electrical Engineering, Structural Engineering, Civil Engineering, Environmental Engineering, and Cost Estimation Engineering. This effort will be led by Barr Engineering and will be highly coordinated with the technology developers (UND, RES, MTI) and our construction partner (McCarl's). The division of responsibility for this task is provided in **Table 3** (found within the Management section of this proposal).

Task 6 – Circuit De-Risking Research: This task is dedicated to limited R&D on certain subsystems of the overall technology package that present the highest risk for the successful construction and operation of the REE Demonstration Facility in Phase 2. Four subtasks are included.

6.1) Ore Concentration De-Risking: MTI will lead this subtask to perform performance verification testing of their lignite mine waste online (on-belt) analysis and sorting technology. The goal will be to advance to TRL 6 by testing host-site-specific feedstock on commercial-scale analysis equipment to verify the performance of MTI's proprietary analysis algorithms and determine the most cost-effective sorting/blending configuration to include in the FEED. MTI will work with commercial equipment vendor, Energy Technologies, Inc., on this subtask.

6.2) MREC Plant Wastewater Disposal De-Risking: The previous pre-FEED study identified that

wastewater disposal was a significant component of the total plant O&M costs. Our team has since identified Class I deep well injection as a suitable and significantly lower-cost option. Golder will perform a feasibility assessment based on pre-FEED data and existing geologic characterization data available from our host site partners' CO_2 geologic storage project developments to confirm the technical and economic feasibility. This subtask will determine whether Class I injection is chosen for the FEED or another disposal option is needed.

6.3) Metallization De-Risking for Scale-Up: This subtask will leverage and expand upon existing metallization research conducted by RES to produce XRD-verified rare earth metals and enable the low-risk scale-up required for the proposed REE Demonstration Facility. The goal of this testing is to utilize newer, more environmentally controllable electrolysis cells that are commercial for other metals instead of the high-temperature, manual-based process currently used worldwide. The successful de-risking of this technology would involve using a standard electrolysis cell for similar, high-melting, and reduction point metals with minimal alterations at a scale of at least $1/10^{th}$ of the proposed demonstration scale. The standard molten salt electrolysis method will be chosen for the FEED if this de-risking is not successful.

6.4) Pilot Testing of Host-Site-Specific Lignite Mine Wastes: This task has two goals: **1)** piloting with site-specific feedstocks (previous/ongoing bench-scale testing and piloting involved substantially similar feedstocks but from other mines/locations) will provide for more accurate performance data for the FEED, which propagates from the MREC plants through the metallization facility, and **2)** we propose testing a modified leaching setup that will recycle a portion of the leachate, increasing the concentration of the REE/CM and limiting wastewater volume. Testing will examine the performance of this modified approach and will also determine any detrimental impacts, such as upcycling of contaminants (including Th, U), and increasing the solution's anionic strength. Approximately 75 tons from each of our ND host sites will be piloted. UND will lead this testing.

Task 7 – Financing and Business Plan Development and Implementation: An in-depth analysis of existing

business engagements, contracts, and financial options will be performed to most effectively prepare the project team and stakeholders for the successful construction and operation of the REE Demonstration Facility. This analysis would significantly reduce future project risk to all parties. We will develop detailed business and financing plans and implement them to close on all business and financial agreements/ contracts prior to Phase 2. We have identified a tentative commercial structure for Phase 2 (**Figure 1**). This task will build on the initial concepts to finalize and formalize our project for Phase 2 consideration.

Anticipated Results

Anticipated results will include the de-risking and deep examination of a first-of-a-kind (FOAK) REE/CM Demonstration Facility, advancement of technologies to prepare for commercial deployment at a measurable market capacity, and the development of a business and ownership model for deployment of the technologies into the US market. All of this will be accomplished with the goals of maximizing the positive impacts, such as jobs and opportunities, to the communities involved in the project, and minimizing environmental impacts.

FOAK De-Risking

REE/CM technologies focusing on unconventional resources, such as coal and coal byproducts, present FOAK risks associated with the technologies themselves and the feedstocks. We have also identified the key technical gaps that remain today, despite the several years of development of these technologies. As such, both the AACE Class 3 FEED study and the proposed de-risking R&D (Task 6) will be pursuing the mitigation/elimination of the most highly impactful risks to commercial deployment. These include items such as feasibility of permitting at the proposed scales, practicality of equipment size and chemical intake mechanisms with local infrastructure, as well as a detailed economic case, outlining a number of possible scenarios of facility operation to identify and quantify most probable scenarios of revenue. Ideal project results point towards a technically, economically, and environmentally feasible REE production facility, including a business and ownership strategy to carry forward the project into construction in Phase 2.

Increasing Technology Readiness Level

Each of the proposed technologies has been demonstrated at high TRL levels, with some sub-components at commercial scale (**Figure 9**). All subsystems, except for ore analysis (MTI) and REE metallization (RES), will be at TRL 6 or higher by the start of Phase 1. We note that some of these subsystems are less than TRL 6 today; however, these subsystems will achieve TRL 6 by the end of the ongoing pilot-scale testing at UND (DE-FE0031835; Summer 2023). We propose de-risking R&D in Phase 1 for the two subsystems currently lower than TRL 6, increasing them to TRL 6 and de-risking the overall integrated process circuits.

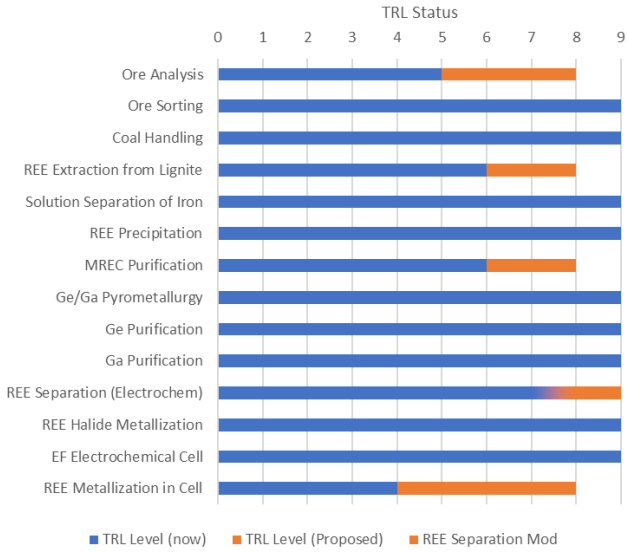


Figure 9. TRL level of each technology subsystem, current and proposed (end of Phase 2).

With the completion of the Phase 1 project, the proposed technologies would each reach a minimum of TRL 6 (having undergone prototype-scale production), and will enable the deployment to the commercial scale in the Phase 2 effort. Additionally, the evaluation of all process parameters and equipment through the lens of an AACE Class 3 FEED study will significantly improve the ability to rapidly deploy the proposed facility concept into the FOAK facility, and follow-on facilities as applicable.

Development of a Business Strategy for REE Market Deployment

The development of a robust and stable business and ownership strategy for the deployment of the proposed facility concept in a Phase 2 effort is as critical as the anticipated technical results. Task 7 is devoted entirely towards the establishment and management with new and existing contracts surrounding ownership, off-take, and other contracts to best develop a coherent, integrated business strategy, as well as the securement of financing for the deployment of the Phase 2 effort. A favorable project result for this effort would detail a strong business strategy, including identification of

owner/operators of all REE/CM-related facilities; business contracts between mines, MREC plant, coal off-taker, REE off-taker, CM off-taker, and any downstream processors; and the securement of all financing required for the construction, commissioning, and continued operation of a REE/CM production supply chain from lignite mine waste.

Facilities and Resources

UND has world-class laboratory and pilot experimental research facilities, including the pilot-scale REE/CM extraction system that is currently in operation. UND also has a commercial license for Aspen Plus, which will be used to develop mass and energy balances for the proposed FEED study. RES has 25,000 ft^2 of commercial facility and laboratory spaces and exceptional analytical capabilities. MTI has existing lab- and bench-scale facilities and world-class analytical capabilities. Host site partners, North American Coal/Rainbow Energy, BNI Coal/Minnkota, and RES have existing industrial operations that will be able to support the integration of the proposed REE Demonstration Facility. The proposed FEED study will undertake the task of identifying the most cost-effective plot space location and integration for the two proposed MREC plants and the separation and metallization facility. UND and project partners have the necessary office and computing facilities for the proposed project. We propose purchasing a limited amount of equipment in Phase 1 to modify the existing UND pilot system, which would enable us to test a modified leaching approach (de-risking R&D) and perform pilot testing for RES' metallization technology.

Techniques to Be Used, Their Availability and Capability

FEED Study

Two MREC plant sites are planned. We will evaluate each site separately, retaining the items that are common to both and updating those items that are not. For instance, the two sites will likely have different transportation, storage, feedstock blending, and waste management needs that arise from their locations and the lignite mine waste feedstock used, including high/low clay, moisture, and waste types. The separation and metallization plant will also be evaluated and incorporated.

The environmental aspects of each distinct site will affect the engineering requirements and costs for each site. An example of this is the disposal of tailings, where one site near existing permitted disposal facilities may be more easily constructed and permitted than another site requiring additional infrastructure to meet requirements for a “green field” permit.

A different Design Basis report and Process Philosophy will be developed for each site. The plans, specifications, and vendor quotes will vary between the two sites. The third site will be independent and likely similar regardless of which site is used for the final concentrate processing. The Design Basis report will include the environmental considerations as well as the technical requirements for the assumptions made with the ore body. The ore body may not be fully defined, and the Design Basis report will incorporate the robustness needed to process varying degrees of ore grade.

Our approach to these plans is to maintain a robust work breakdown structure (WBS) that maintains the separation of design documents for each site but allows for leveraging the commonalities between them. We will enhance this WBS approach by building a robust process model that addresses the requirements and differences for each site, which will translate to custom designs and documents for the two MREC sites; however, these may be more similar for the third site that processes the concentrate. The custom designs and documents for the three sites will affect all engineering disciplines.

The site-specific deliverables described in the previous section will form the basis for developing material take-offs (MTOs) and other quantities that form the basis of the AACE Class 3 opinion of installed capital cost. The resultant capital cost will be substantiated with a thorough Basis of Estimate document that indicates details such as how each of the quantities were estimated and which materials and rates were used. The Basis of Estimate will provide documentation for the cost values, including equipment and material quotes, local labor rates, references to previous projects, and industry databases. The accuracy of each line item will be estimated based on the source of the costing data, which will be aggregated to an overall estimate of cost accuracy. A similar approach will be used for the operational cost estimate.

These items will be a separate deliverable for each host site.

Circuit De-Risking Research

The research to de-risk technical areas of the project will be performed at the locations of each primary lead from Tasks 6.1 to 6.4. UND will utilize the existing pilot facility located in Grand Forks for piloting the site-specific feedstocks, capable of 1,000 lbs/hr of feed capacity. RES will utilize their existing facilities in Beatrice, NE for metallization and electrochemical research, scaling up to a prototype system of metals production, at least 10% of planned production capacity. MTI will perform on-belt analysis of lignite coal and lignite mine waste for their REE analysis and sorting mechanism at a to-be-determined mine site, and will utilize existing or new commercial sensor equipment.

Environmental and Economic Impacts while the Project is Underway

Environmental and economic impacts will be primarily limited to the project participants and project execution locations during the execution of the Phase 1 project, although the distribution of information on the potential Phase 2 project and other pertinent activities as described in the Community Benefits Plan will involve some wider distribution. Minimal environmental impacts will primarily be related to the collection, transportation, and any process wastes associated with the piloting of the REE concentrate technology, as well as limited environmental impacts associated with the other research tasks.

Economic impacts include employment opportunities for the project team members, which include several ND-entities (UND, MTI, Barr, Envergex, Odney). Several graduate and undergraduate students will also be provided valuable training opportunities, both in hands-on pilot scale demonstrations and the detailed engineering and business efforts required to develop a large-scale industrial project.

Ultimate Technological and Economic Impacts

The ultimate impacts of a successful project would be the selection of our project for Phase 2 award, which would entail a FOAK REE Demonstration Facility on the order of $250 Million. We expect that if this

first project is successful and the Demonstration Facility is able to create a sustainable operating model, then next-generation facilities will be installed at other lignite mines or low-rank coal mines. This would also provide the opportunity for downstream processing facilities and product manufacturing capacity to be 'bolted on' to expand the supply-chain footprint in a single location.

This project and its follow-on effects has the potential to provide the US a politically and environmentally stable supply chain of REE and CM, particularly of the rarer HREE and Ge/Ga, as well as developing a new major market for lignite resources. Additionally, our process generates a unique lignite carbon ore that has numerous end-use applications in carbon-based products. We describe more fully the suite of possibilities in the following paragraphs.

Market Transformation Plan

The target marketable products for the proposed plant include the magnet REEs (Nd, Pr, Tb, Dy – focusing on the Tb and Dy), Gd, Sc, Ge, Ga, and the upgraded lignite carbon ore. Other CM may be produced (i.e., Co) but are not the primary goals of this effort. Planned markets to service are the Ge and Ga semiconductor and high-purity crystal markets, the magnet markets for high-temperature applications (those that utilize significant amounts of Tb and Dy), and the blend lignite fuel and carbon-based products markets. We have secured the interest from AmeriCarbon to purchase the lignite co-product for their commercial coal tar pitch facility, which is currently in planning.

No domestic competitor exists for the production of any of the major target products (Dy/Tb, Sc, Ge, Ga); however, MP Materials[9] has a significantly larger portion of the Nd/Pr market. Little competition for high-grade pitch feedstocks exists, primarily in the form of unique, bituminous resources. Distribution channels for the carbon-based products will be co-location strategies, avoiding the costly transport of lignite; host site power plants and AmeriCarbon are potential identified customers. Distribution of REE/CM products will occur using trucking with controlled-atmosphere containers to limit REM or CM metal spoilage. Market penetration into the domestic markets is viewed as low risk, assuming a domestic

magnet industry is developed, which is the highest barrier known for domestic market involvement. RES can arrange some off-take agreements for magnet materials to non-domestic, allied nation partners, which could be a short-term option for our project until a robust domestic market appears.

Product development will be based on specific off-take agreements, primarily regarding purity and form, discussions for which are expected to be initiated early in Phase 1. Product marketing will take place through targeted marketing events and participation in conferences. The upgraded lignite co-product, with its unique properties, represents the largest potential product/value growth opportunity. Higher-value opportunities (compared to thermal fuel) for this product are expected to grow as the carbon-based product market develops.

The proposed product suite, alongside a general schematic of our process, is shown on the next page in **Figure 10**. ***We encourage reviewers of this proposal to spend some time with this figure to be able to grasp the breadth and scale of the opportunity. If this project is successful, lignite mine waste and the proposed set of technologies and partners can spawn truly exciting economic and industrial development in North Dakota and the surrounding region.***

Why the Project is Needed

This project combines elements of financial and technical de-risking that we view as essential to be able to entice private sector investment in a Phase 2 project and any follow-on projects. If we are successful in Phase 1 in developing a strong technical and business case and securing a committed team and financing, we will be eligible for a much larger Phase 2 opportunity (~$250 Million). The successful implementation of this Phase 1 project, and subsequent down-select for a Phase 2 facility, would significantly expedite the establishment of a ND-focused REE/CM industrial sector (i.e., **Figure 10**).

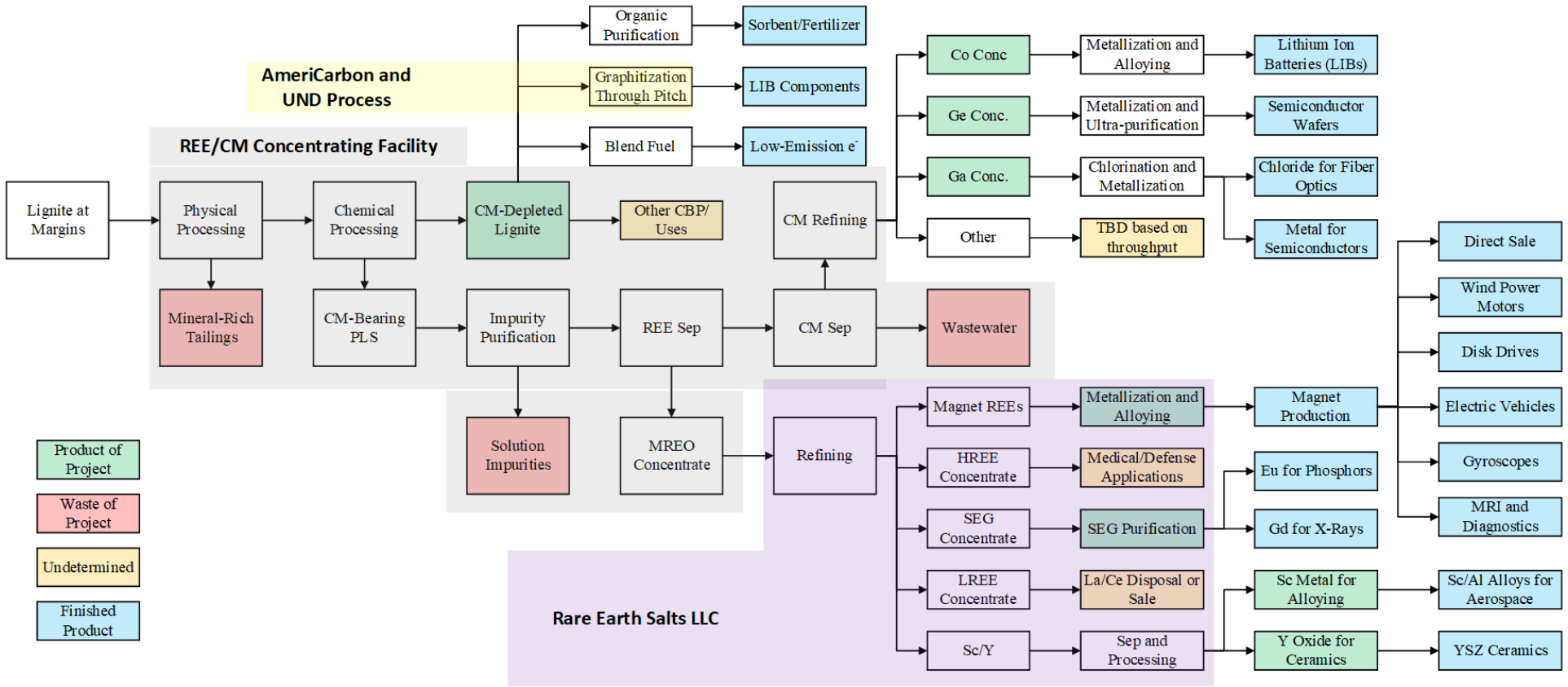


Figure 10. Overall general process schematic with project products, wastes, and planned finished products markets identified. Locations or entities involving each process have been noted. Magnet REEs are Nd, Pr, Tb, and Dy. HREE concentrate refers to the lanthanides of Ho → Lu. LREE concentrate refers to a La/Ce mixture. SEG concentrate refers to Sm, Eu, ang Gd, of which Sm is not expected to be a product of significant value.

STANDARDS OF SUCCESS

The overall standard of success is being selected by the DOE to move on to the construction and operation in Phase 2. Specific targets we will need to meet by the end of Phase 1 to achieve this standard are:

1. Successfully implement the community benefits plan that creates meaningful benefits for local communities, engages and incorporates feedback from stakeholders, and advances DEIA initiatives.
2. Complete all NEPA reviews, including the preparation of an environmental assessment (expected), and obtain a Finding of No Significant Impact by the federal agency.
3. Prepare and submit all applicable permit applications.
4. Completion of an AACE Class 3 FEED study to progress the project to investment quality
5. Increase each of the proposed technologies and technology subsystems to TRL 6.
6. Develop the business and financing plans for Phase 2; have a committed team and financing secured.

BACKGROUND

The development history of the background technologies that will be the subject of the proposed study, and ultimately the Phase 2 REE Demonstration Facility, are discussed in the following sections.

UND's Technology Development

In 2016, UND was among the first teams selected for DOE funding to evaluate REE recovery technologies for coal and coal byproducts (FOA 1202; DE-FE0027006). Our team learned/achieved the following during this initial lab-scale project (2016-2017):

- Identified numerous samples of lignite and associated materials with REE concentrations exceeding DOE's target of 300 parts per million (ppm) on a whole rock mass basis.
- Established that REE were most concentrated near the coal seam margins (roof/floor) or in thin seams in almost all cases. These materials in the existing/operational ND lignite mines are not

commonly recovered for thermal coal (power production) and are discarded with the overburden. As such, they meet DOE's definition of mine waste (an eligibility requirement for this program).

- The REE and several other high-value elements found in lignites are organically associated as complexes of carboxyl groups. This form enabled the conceptualization and initial proof-of-concept for a new technology to recover REE from the lignite mine wastes.
- Our new technology was demonstrated at the lab-scale (~60-gram batches of feedstock) and proven to be able to meet DOE's target of 2wt% REE concentration using a simple leaching process with a dilute mineral acid. The initial techno-economic assessment (TEA) indicated promising economic potential.

Our team was selected in 2017 by the DOE (competitive down-selection) to continue to a bench-scale demonstration based on the initial lab-scale project's success (DE-FE0027006). Our team learned/achieved the following during the bench-scale project (2017-2019):

- Performed additional drill core sampling/analysis to further confirm that economically relevant REE/CM concentrations exist in lignite mine waste materials in multiple locations.
- Demonstrated and optimized our lignite mine waste REE leaching process at the bench-scale (50 kg batches and 28 kg/hr semi-continuous). Also incorporated/demonstrated/optimized several additional processing steps to produce MREC products and a high-value upgraded carbon material with unique properties. We achieved a mixed REE purity of 85% during the bench-scale program and identified opportunities to improve efficiency further and reduce chemical consumption during future development phases.
- The semiconductors Gallium (Ga) and Germanium (Ge), both CM, were identified as particularly economically important co-products. Ge/Ga are also organically associated in lignite and are recovered alongside the REE during the leaching step.
- The TEA further confirmed the economic potential based on the bench-scale tests.

- The following UND-owned intellectual properties (IP) were developed and protected via patent filings, in addition to a significant amount of art, based on DE-FE0027006.
    - "Rare Earth Element Extraction From Coal," U.S. Patent No. 10,669,610
    - "Rare Earth Element Extraction From Coal," International Patent Application No. PCT/US2018/022398
    - "Generation of Rare Earth Elements From Organically-Associated Leach Solutions," U.S. Patent Application No. 17/519,346
    - "Method for Leaching Rare Earth Elements and Critical Minerals From Organically Associated Materials," U.S. Patent Application No. 17/519,341

Our team was selected by the DOE in 2019 to scale-up to pilot scale (FOA 2003; DE-FE0031835) based on the success of the lab- and bench-scale developments. The testing phase of this project is scheduled to end in 2023, with key achievements to date as follows:

- Significant additional drill core collection and analysis to further confirm economically relevant concentrations of REE/CM in lignite mine waste materials
- Design and construction of a fully integrated/continuous pilot facility (500 kg/hr lignite mine waste feed rate)
- The commissioning and initial operation of the pilot system is currently ongoing, with full operation scheduled to begin in May 2023. ***Our team is confident that high-quality pilot-scale testing/performance data will be available before the start of the proposed Phase 1 FEED study – currently slated for August 1st.***

Rare Earth Salts' Technology Development

RES was founded in 2012 with the objective of developing a cost-effective, environmentally friendly domestic supply of rare earth compounds. The company filed its first patent in 2013 (WO2014066668A1 - Method for rare earth and actinide element recovery, extraction, and separations from natural and

recycled resources) and received its first patent in 2019 (US 10,494,694 – Method for extraction and separation of rare earth elements). RES also recently filed a third patent application for the efficient separation of light rare earth elements.

In 2017, RES was a subcontractor on the DOE-funded project DE-FE0031529 awarded to Battelle Memorial Institute for extracting, concentrating, and separating rare earth elements from coal combustion by-products. Issues with the extraction and concentration of the rare earth elements only allowed time for the separation and purification of cerium and lanthanum oxides from the rare earth concentrates at 99+% purity, samples of which were provided to the DOE.

In 2019, RES was awarded a contract through the DOD DLA (DLA Strategic Materials Contract SP8000-19-P-0010) to investigate the separation of a SEG+ material. Key outcomes were:

- Separation of europium as europium oxide (purity 99.9%; third party verified)
- Separation of yttrium as yttrium oxide (purity 99.8%)
- Separation of samarium as samarium oxide (purity ~60%)
- Thorium concentrated with heavy rare earth fractions in the separations process
- RES' cell design at the time allowed aluminum to penetrate into the rare earth half-cell, causing a problematic solution gelling. This predicament had not occurred in the laboratory cells or the light rare earth concentrates they had been working with previously.

RES received funding in 2019 (amended 2020) through the DLA SBIP RIF program (SP4701-19-C-0010) to assist in commercializing their patented separations process. Key outcomes include:

- Expanding the RES facility from 10,000 ft^2 to 25,000 ft^2
- Obtaining several critical pieces of equipment to expand to full commercial scale
- Improving the electrowinning cell design to avoid aluminum transfer
- Developing a proprietary technology to separate cerium and lanthanum from rare earth mixtures at high purity and significantly reduced cost, both capital and O&M

- Developing a new approach to extract and separate rare earths from recycled fluorescent light bulb materials

UND engaged with RES on our current pilot project (FOA 2003; DE-FE0031835) based on the success of RES' separations technique with Battelle. Key achievements related to RES' work to date are as follows:

- Scaling equipment to effectively work with the amount of MREC provided by UND
- Initial studies at laboratory scale on samples provided by UND to determine problematic impurities and develop strategies to avoid issues at scale

RES is currently in the process of commissioning two separate rare earth separation and purification lines in their Nebraska facility in addition to the funded projects. The first line will separate cerium (>97% purity), lanthanum (>99% purity), and didymium (> 99.5% purity, a mixture of neodymium and praseodymium) from a light rare earth concentrate. The second line will process recycled fluorescent light bulb phosphor to obtain cerium, lanthanum, europium (>99% purity), yttrium (~99.9% purity), and terbium (~99.5% purity). These lines are both expected to be operational in Q2 2023. RES has also had one commercial sale of 17.5 MT of separated lanthanum with 99.95 - 99.99% purity.

Microbeam's Technology Development

Efforts to develop low-cost REE/CM feedstock analysis and sorting methods were initiated in 2018 through support from the NDIC and ND industry (NDIC contract FY18-LXXXIII-213). The initial REE/CM fingerprinting algorithm was developed for use in x-ray fluorescence systems and was able to predict REE concentrations. The potential for prompt gamma neutron activation elemental analysis and dual gamma attenuation (PGNAA-DGA) to distinguish between low and high-level REE samples was promising. The algorithms were trained on over 50 coals for use in a full cross-belt analysis system based on PGNAA-DGA through an SBIR award (DE-SC0021837) in 2021. Analysis using the factory equipment had very low errors for total, light, and heavy REE on challenge samples, with an overall average mean absolute error (MAE) of 0.05. The PGNAA-DGA combined the REE/CM fingerprinting algorithm integrated with ore tracking and

sorting systems and can be used to sort and blend feedstocks based on REE/CM content. The IP developed and protected for the REE predictive algorithm and the integrated sorting technology includes the following patent applications:

- "System and Method for Predicting the Presence of Rare Earth Elements," U.S. Patent Application No. 63/367,859, July 2022
- "System and Method for Predicting Abundance of Rare Earth Elements with Handheld X-Ray Fluorescence," U.S. Patent Application No. 63/148,292, February 2022
- "System and Method for Predicting the Presence of Rare Earth Elements," U.S. Application No. 17/650,773, February 2021
- "Energy System Performance Manager," U.S. Patent Application No. 63/159762, March 2022.

The Ge/Ga separation technology originated from earlier work at MTI from 2004-2007 under a National Science Foundation project (Award No. 0422050) to recover Ge from gasifier ash materials. MTI applied this technology based on the earlier work to recover Ge/Ga from mixed rare earth concentrates in project DE-FE00032124 (FOA 2404). The technology involves vaporization and selective condensation that is projected to produce an 81% Ga_2O_3 concentrate and 89% GeO concentrate from the UND-mixed REE concentrate. The Ge/Ga concentrates are further refined to 99.9999 to 99.99999% purity using known commercial methods. The IP developed and protected includes the following patent application:

- "System and Method for Producing Critical Minerals - Germanium and Gallium," U.S. Patent Application No. 17/812,484, February 2021

Joint Efforts (UND, RES & MTI)

The core technology team, consisting of UND, RES, & MTI, has collaborated for several years. This team recently partnered to complete an AACE Class 4 (pre-FEED) study using the above-discussed technologies as the basis for DOE contract 89243320RFE000032. Barr Engineering led the engineering work for the pre-FEED. A summary of the effort and key findings are as follows:

- A single REE concentrate plant, near the Falkirk Mine near Underwood, ND, was evaluated that processed 3,900 metric tons per day (mtpd) of lignite mine waste to produce 1 mtpd of a MREC at 75% purity.
- The MREC product was then separated into individual rare earth oxides (REO) at the RES processing facility in Beatrice, NE. Select REO were metallized using commercially available fused salt electrolysis at a co-located facility.
- The economic analysis results are presented in **Table 1**.

Sensitivity analyses identified that sale price of the REE-extracted lignite material is the most important factor, followed by the wastewater treatment costs associated with the MREC plant. The wastewater treatment costs, in particular, represent a large potential source of improvement. The pre-FEED assumed water treatment and disposal as the method of managing the wastewater, representing 20-30% of the annual O&M; however, deep well injection (Underground Injection Control – Class I) is expected to be a significantly less expensive ($1-5/1000 gal vs. $60-250/1000 gal for treatment and disposal – based on Golder's significant experience) and more effective option. The proposed FEED study will include the evaluation and design/costing of the Class I injection option. Additionally, the expansion of purification and metallization to include more elements has the potential of significantly increasing REE/CM-based revenues (by up to 150%, based on the elements).

Table 1. AACE Class 4 pre-FEED economic metrics

Category	**Cost/Revenue ($ millions)**
Total Capital Cost	142-305
Annual O&M	184-394
Annual REE Sales Revenue	22-57
Annual REE-extracted Lignite Material Revenue	23-258
10-year NPV (best- & worst-case scenarios)	+$550 Million to -$1,270 Million

In summary, the pre-FEED indicated a negative NPV under most (but not all) scenarios; however, our team is confident that the proposed REE Demonstration Facility (Phase 2) can be profitable with DOE support (~50% of capital and project costs during the first years of operation), drastically lower cost wastewater

management (Class I injection), and the integration of product off-takers who are willing to pay a premium for the unique REE-extracted lignite material. As we described earlier, AmeriCarbon LLC, who is developing a commercial coal tar pitch production facility in ND is interested in purchasing this co-product as a feedstock to their pitch plant. Carbon-based product manufacturing (such as pitch) is a far better economic option than thermal coal. The proposed FEED study and Phase 2 business and financing plans will further refine and quantify the value of this option/opportunity.

Technical Gaps to be Addressed in the Proposed Project

The previous AACE Class 4 study identified key technical gaps that will be addressed in the proposed Phase 1 project. Specific goals related to addressing these gaps and targeting specific improvements to the baseline technologies and their economic/technical performance are:

1) The AACE Class 4 pre-FEED study was based on bench-scale testing data and incomplete information related to MREC separations using the RES and MTI technologies. The proposed FEED study will have UND pilot-scale data (more refined and commercially relevant) available, as well as the complete testing data from RES and MTI based on the MREC produced from UND's pilot testing. Combining these three new data sources will reduce contingencies and provide a commercially realistic evaluation. **Critical Success Factors**: a) availability of reliable pilot/testing data prior to the Phase 1 award and b) ability to pilot limited quantities (~75 tons) of site-specific feedstock (Center Mine and Falkirk Mine) as a part of Phase 1.

2) Significant additional resource characterization (drilling/analysis at the existing ND lignite mines) has been completed since the completion of the AACE Class 4 study, and an extensive drilling/analysis campaign will be completed ahead of and in parallel (separate efforts) to the early stages of the proposed FEED study. Locations have already been identified with a higher concentration of REE/CM (notably higher Ge/Ga) than were used as the basis for the pre-FEED. Ongoing projects, such as the Williston Basin CORE-CM effort as well as the extensive sampling plan outlined by MTI and North American Coal will further

enable more accurate long-term revenue projections. **Critical Success Factors**: a) REE/CM data available at both ND host sites sufficient to meet the DOE FOA requirement of five years of feed availability, and b) REE/CM data sufficient to develop a commercially viable mining plan and project feedstock costs.

3) The AACE Class 4 study identified wastewater treatment from the MREC production plant(s) as a major O&M component. We have identified Class I deep well injection as a far superior economic option since the completion of the earlier study. We have established that the geology at the two proposed ND host sites is favorable for injection, and our team (Golder) has extensive site-specific experience with designing and permitting Class I wells at the two proposed ND host sites. The proposed FEED study will evaluate and confirm the suitability of Class I injection and develop an AACE Class 3 design and cost estimate. **Critical Success Factors**: a) Class I injection is identified as feasible at both sites (very high likelihood); b) geologic information is available to support the design and permitting (available from host-site partners through their existing CO_2 geologic storage projects), and c) ability to permit the wells and obtain EPA aquifer exemption approval.

4) The AACE Class 4 study identified feedstock analysis/sorting as an area for significant improvement potential. Project partner MTI is developing novel analysis algorithms based on commercially existing sensor technology. Coal and associated materials are well-known for their heterogeneity. We will be able to a) increase the REE concentration in the incoming feed and/or b) blend the incoming feed to stabilize the REE concentration into a narrow range by analyzing the incoming REE-containing lignite waste materials for REE concentration and then sorting/stockpiling into ranges, such as low, med, and high. Increasing REE concentration would obviously reduce the amount of feedstock necessary to achieve desired REE production. Narrowing the REE concentration variability via blending would improve process control/reliability and reduce the equipment oversizing factor and capital costs required to guarantee production requirements, such as 1 mtpd. The proposed Phase 1 FEED study will include two key efforts: a) additional de-risking R&D associated with MTI's lignite mine waste analysis/sorting technology and b)

optimizing and integrating the feedstock analysis/sorting/blending design into the FEED based on this R&D and previous development. **Critical Success Factors**: a) prove that MTI's technology works in an on-belt/commercial configuration and b) leveraging existing performance data, generate reliable performance data and design criteria to perform the FEED and determine cost-effectiveness.

5) The AACE Class 4 study identified a need to qualify a REE metallization process to de-risk the current magnet supply chain. The technologies identified as possibilities used fluoride chemicals and were not environmentally desirable. RES has identified and conceptualized a production methodology to produce high-purity metals continuously and in a closed-loop production cycle, leading to the possibility of a fully zero discharge separation and refining facility. The proposed project will allow RES to test a standardized method of metallization at pilot scale with a modified chemical recovery/scrubber system that has been developed and tested along with the determination of final materials compatible with the final reactor design. **Critical Success Factors**: a) Successful demonstration of the proposed metallization technology at a scale of at least 1/10th the proposed REE Demonstration Facility, and b) Provide reliable performance data and design criteria to incorporate into the AACE Class 3 study.

QUALIFICATIONS

The following highlights the qualifications of the team member organizations and key personnel. The team assembled for the Phase 1 effort is uniquely qualified to successfully achieve the project objectives and ultimately execute the construction/operation of the REE Demonstration Facility in Phase 2.

University of North Dakota

UND is the technology developer and IP holder of the technology upon which this project is based. In 2016, UND was among the first teams to be awarded funds from the DOE (FOA 1202, DE-FE0027006) to develop technologies to recover 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). UND also previously led a successful project to perform a conceptual design and feasibility study (AACE Class 4) to produce 1 mtpd of REE using the proposed technology (contract 89243320RFE000032). The UND team is led by the College of Engineering & Mines (CEM), which has extensive experience in technology development, scale-up 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 in addition to the base technology and its associated DOE-funded projects noted previously: DE-FE0032060, DE-FE0032053, DE-FE0029007, DE-FE0031490, & DE-FE0032124. Our team is recognized as a leader in REE/CM related to unconventional resources. Key personnel from UND are highlighted below.

Dr. Daniel Laudal, Research Professor and Executive Director of the College of Engineering & Mines Research Institute, will be the project director (PD). He will support the project as a technical advisor and lead project management and coordination. Dr. Laudal was the technical lead for UND's original lab-scale project and the original PI for the bench-scale project (DE-FE0027006). His Ph.D. research/dissertation[4] was the foundation for the proposed technology/project. Dr. Laudal has been PI, Co-PI, or key personnel on numerous DOE, State, and Industry-funded projects, primarily focusing on technology development and scale-up, including several efforts related to REE/CM. Prior to rejoining CEM in 2021, Dr. Laudal was the Environmental Manager for Minnkota Power Cooperative (one of our host-site partners). Dr. Laudal was also the Project Tundra project development manager while at Minnkota (2019-2021). He was responsible for coordinating the efforts of a team comprised of Minnkota staff and external contractors and consultants to advance the development of the $1.5B carbon capture and geologic storage project. Key efforts that Dr. Laudal managed were: **1)** completing a FEED study for the carbon capture system, **2)** developing and submitting permit applications for air/water/waste, **3)** NEPA assessments, **4)** developing the geologic characterization information and submitting the permit applications for the CO_2 geologic storage facility, **5)** stakeholder engagement, and **6)** developing the business and financing plans. Dr. Laudal

managed a ~$50 million portfolio of federal (DOE) and State (NDIC) grants and Minnkota investment dollars to support Tundra's development. This unique experience, including commercial project development in ND, deep site-specific knowledge/experience at one of the proposed host sites (MRYS), environmental permitting and NEPA, and managing extremely large and complex projects, will greatly benefit the proposed project. Dr. Laudal holds a B.S. and Ph.D. in Chemical Engineering from UND.

Nolan Theaker, Senior Research Manager – Critical Minerals, will be the overall principal investigator (PI) and serve as UND's technical lead. Mr. Theaker has been the technical driver for UND's technology development and resource characterization efforts related to REE/CM since he joined CEM in 2018. He is widely recognized within the DOE and the 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 ongoing pilot-scale project (DE-FE0031835), and the Co-PI/technical lead on the conceptual design and feasibility study (89243320RFE000032). He is also currently involved as key personnel on two ongoing CORE-CM projects: Williston Basin and Gulf Coast. He has B.S. and M.S. degrees in Chemical Engineering from the University of Louisville, Kentucky.

Other Key Personnel: UND's team will also include business and financial development experts to lead and support Task 7. **Mr. Kevan Rusk**, CEM's Director of Business Development, is a broadly experienced manufacturing and engineering professional with an extensive background in business and relationship development, technical sales, and commercial execution. Our team will leverage Mr. Rusk's 30 years of relevant experience in leading the business planning effort in Task 7. **Mr. Anthony Maher**, Entrepreneur Lead for Startup Growth & Fundraising at UND's Center for Innovation, has spent most of his career working with innovative startup companies in the Silicon Valley. He began his career working in corporate development, conducting market analyses in Munich, Germany, for Siemens, a multinational publicly traded company. He became a founding member of Mustang Ventures based in Silicon Valley, the venture capital arm of the Siemens Communications Networks Group. He later led a global team of financial

analysts at Siemens Venture Capital, the global venture capital arm of Siemens AG. His responsibilities included evaluating and investing in innovative venture capital-backed companies by conducting business due diligence and detailed financial modeling. We will leverage Mr. Maher's extensive financial modeling/planning experience to support Task 7 activities.

Barr Engineering

Barr is a comprehensive engineering and environmental firm, providing consulting services to clients globally. Barr works with clients on large and complex engineering and environmental projects, providing services that range from initial permitting and siting assistance through process and facility design to construction management, operations support, and closure planning. Barr's services and staff have grown to meet client needs for over 50 years, with offices in seven states and Canada. Barr has collaborated with UND on technology development since its inception and was the engineering lead on the team's successful AACE Class 4 pre-FEED study. Key personnel from Barr Engineering are highlighted below.

Dr. Dan Palo, Vice President and Senior Process Engineer, will be Barr's Principal-in-Charge. He is a professional engineer with a Ph.D. in chemical engineering and has 25 years of experience in process design, plant improvement, project management, and research and development for processes that involve minerals, chemicals, fuels, and manufactured products. Dan provides engineering and management services on projects for local, national, and international clients. His technical work includes process design and modeling, plant debottlenecking, new process development, and overall project coordination.

Nick Sosalla, Mineral Processing Engineer, will be Barr's Project Manager. He has over eleven years of experience with various mineral processing and chemical engineering projects, including design, mass and energy balance calculations, process modeling, and capital and operating expense estimates. He has served clients in the mining and mineral processing industries for potash, iron ore, trona/soda ash, and

industrial sands, as well as industrial manufacturing clients. Nick has served as a process engineer and project manager for various mining and engineering projects over the past five years. Nick's work has ranged from process engineering support for studies to project management, coordinating multi-disciplinary teams, and combining field and off-site engineering work. Nick has worked closely with client engineers and project managers throughout these projects to provide efficient and effective projects and deliverables. He recently served as Project Manager for Barr's ongoing work with the UND REE pilot plant.

Ryan Rayda, Senior Structural Engineer, will be Barr's Construction Engineering Lead. He has 20 years of progressive experience in project leadership and structural design at mining facilities, power plants, material handling facilities, refineries, water treatment plants, sanitary and stormwater pumping stations, and many other heavy industrial sites. Ryan has extensive design experience related to industrial structures, structural forensics, heavy lifting operations, and building-type structures.

Ryan Siats, Vice President and Senior Chemical Engineer, will be Barr's Environmental Lead. He has 16 years of experience with environmental review, permitting and compliance, focusing on developing, constructing, and operating new/expanding facilities. He also conducts technical and economic studies for pollution-control equipment and processes and performs site evaluations and investigations. Ryan primarily works on multi-disciplinary projects in the mining and mineral processing industry in the Midwest and Intermountain West, including North Dakota.

McCarl's

McCarl's is a full-service integrated contractor and maintenance leader specializing in complex heavy industrial processes and pipe fabrication for the oil and gas, chemical, power, steel, environmental, heavy industrial, manufacturing, water treatment, and cryogenic processing industries. McCarl's will be a subcontractor to Barr and will support the FEED with constructability review and cost estimating. Their efforts will be led by **Thomas Rauch**, President – Technical Services, who specializes in high-risk project

delivery and has experience with small cap through mega-projects in North America, Africa, and Asia in mining, metals, and chemical industries.

Rare Earth Salts

RES is the technology developer and IP holder for the proposed REE separations and metallization technologies. The company has been addressing the issue of developing an environmentally friendly, cost-effective solution to the rare earth separations issue since 2012. In 2013, they developed the patented aqueous-based electrowinning foundation for their separations process. Their overall separations process has been steadily improved and built upon, including recently developed proprietary processes to decrease both the CapEx and OpEx of their overall separations stream. Many groups with DOE funding have recognized RES' technology as cutting-edge and economically feasible, including Battelle, UND, and Anactis. Key personnel from the RES team are highlighted below.

Dr. Joseph Brewer, Chief Technology Officer and President, will be the co-lead for RES on the project. Dr. Brewer has been the lead on all funded work with the DOD and DLA-related grants at Rare Earth Salts. Dr. Brewer has spent the past 16 years focused on fundamental rare earth chemistry. He conducted graduate research from 2005-2010 on functional rare earth compounds and developed high-temperature gas phase synthetic routes to produce nanowires or thin films. He obtained numerous patents during his graduate career, which led to the founding of a rare-earth-based solar thin film photovoltaic company. Dr. Brewer began research on the extraction and concentration of rare earth elements from mineral feedstocks to supply materials for the photovoltaic project during the rare earth crisis of 2010-2011. In 2012, he filed a patent on his research and co-founded RES. Dr. Brewer co-led and patented the invention of a novel separations technology from aqueous solutions. He is proficient in quantifying and identifying rare earth compounds and their fundamental chemistry due to his extensive background in rare earth chemistry. He holds a B.S. from Minot State University and an M.S. and Ph.D. from the University of Nebraska-Lincoln.

Dr. Ryan Winburn, Vice President of Research and Development, will be the co-lead for RES on the project. Dr. Winburn has been the lead or co-lead on all of the funded work with the DOE (FE0031529, FE0031835, and 89243320RFE000032). He spent fourteen years prior to joining RES as a faculty member at Minot State University (Minot, ND), where his focus was on inorganic and analytical chemistry projects. His research experience has included electrochemistry, computational chemistry, high-temperature thermal synthesis, and the development of quantitative x-ray diffraction techniques (QXRD), including studies on minimizing associated errors, developing techniques to monitor toxic elements within the environment, and working with NIST to certify standards for QXRD. Dr. Winburn is the co-developer of the patented electrowinning process used by RES. He holds a B.S. from the University of Wisconsin – Eau Claire, an M.S. from the University of North Dakota, and a Ph.D. from North Dakota State University.

Microbeam Technologies, Inc.

MTI is a commercial company with the corporate mission of providing advanced analysis tools and technologies to minimize the impacts of inorganic components in fuels on power system performance. Microbeam has completed more than 1,600 projects since 1992, providing advanced analyses of coal, biomass, petroleum coke, fly ash, slag, ceramics, metals, and other materials, and has performed consulting for researchers, the power industry, boiler manufacturers, coal companies, and the government. Microbeam's primary area of expertise lies in its understanding of fuel and related material behaviors in energy conversion systems. This extensive experience has afforded MTI an understanding of the association of REE/CM in different ranks of coal across the world. Key personnel are highlighted below.

Alex Benson, Senior Project Manager, has a B.S. degree in Mechanical Engineering. He actively leads multiple commercial projects associated with REE/CM resource evaluation, detection, measurement, and extraction in coal and associated waste materials. Mr. Benson has over three years of experience in project management and commercialization in the medical device manufacturing industry, where he led commercialization engineering activities for new product launches and capacity expansion projects. He is

one of the inventors on a US patent application held by MTI for algorithms used with handheld XRF and PGNAA-DGA for REE/CM measurements and one of the inventors of a process for Ge and Ga separation from ash materials and mixed rare earth element concentrates.

Dr. Steve Benson, President, has a Ph.D. in Fuel Science from Pennsylvania State University and over 45 years of experience in fuel analysis, fuel properties, combustion, gasification, ash transformations, and pollution control. Dr. Benson is an inventor 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 application held by MTI for algorithms used with handheld XRF and PGNAA-DGA for measuring REE-CM, and one of the inventors of a process for Ge and Ga separation from ash materials and mixed rare earth element concentrates.

WSP Golder

Golder, a member of WSP, is a consulting, design, and construction services firm specializing in the areas of earth, environment, and energy. Golder is experienced in designing, permitting, and constructing Class I injection wells for the management of process waters generated at industrial facilities. The company has unique site-specific knowledge of the two proposed ND host sites, having previously designed and permitted the existing operational Class I injection well at Coal Creek Station and designed and prepared permit applications for the planned Class I injection well at the MRYS as part of Project Tundra. The Golder team will be led by **Todd Stong**, project director, who managed the construction, operations support, and ongoing permitting of Coal Creek Station's Class I well and served as the project director for the design and permitting of a Class I well in NE and three additional Class I wells in ND.

North American Coal Corporation (NACoal)

Falkirk Mining Company, a subsidiary of NACoal, operates the Falkirk Mine near Underwood, ND. NACoal will provide technical, environmental, legal, and business input during Phase 1 to perform the FEED and to evaluate and develop the business/financial opportunity for continuing to Phase 2. **Gerard Goven**, mine

geologist at Falkirk Mine, will be the point of contact for NACoal.

Rainbow Energy Marketing Corporation (REMC)

In May 2022, REMC purchased the Coal Creek Station. REMC will provide technical, environmental, legal, and business input during Phase 1 to perform the FEED and to evaluate and develop the business/financial opportunity for continuing to Phase 2. **Stacy Tschider**, President, will be the point of contact for REMC.

BNI Coal, LTD (BNI)

BNI operates the Center Mine near Center, ND, and provides lignite coal for the adjacent Milton R. Young Station. BNI will provide technical, environmental, legal, and business input during Phase 1 to perform the FEED and to evaluate and develop the business/financial opportunity for continuing to Phase 2. **Mike Heger**, general manager of BNI Energy, will be the point of contact for BNI.

Minnkota Power Cooperative (Minnkota)

Minnkota operates the MRYS and will provide engineering, environmental, legal, and business input during Phase 1 to perform the FEED and to evaluate and develop the business/financial opportunity for continuing to Phase 2. **Craig Bleth**, VP for Project Development, will be the point of contact for Minnkota.

AmeriCarbon

AmeriCarbon is a technology development company and the owner of the proprietary and patented Eco-Pitch™ technology[10] that produces tailored pitch products from domestic coal resources, including all coal types and ranks. AmeriCarbon has demonstrated the ability to tailor its pitches for a wide variety of end-use applications. The Eco-Pitch process results in a >99% GHG emissions reduction compared to the existing coal tar pitch supply. AmeriCarbon owns and operates a pilot scale (10 tpd coal feed) research & manufacturing facility in Morgantown, WV, which is the only known pilot-scale coal liquefaction pitch production unit in the U.S. or world. As described in the attached letters of commitment, AmeriCarbon has expressed an interest in an ownership/investment role in the Phase 2 REE Demonstration Facility and

will work with our team to develop and evaluate this opportunity during Phase 1. AmeriCarbon is led by CEO **Dave Berry**, who previously served as the Associate Director of the Energy Conversion and Engineering Directorate at DOE NETL. Mr. Berry is the technical development driver for AmeriCarbon's technology platform. **Greg Henthorn**, VP for Corporate Development, leads AmeriCarbon's commercial and financial development, including their in-progress effort to install their first commercial pitch production facility in ND using lignite coal as the feedstock.

Dennis James Consulting (DJC)

Dennis James, president of DJC, is a globally recognized expert in the mining industry, with over 40 years of experience, including geology, geochemical modeling, coal and mineral exploration, and developing mine plans and budgeting for coal and mineral mining operations. Mr. James recently retired from North American Coal as Director of New Technology. Mr. James engaged with UND on our REE technology development from the start of our development in his prior capacity with NACoal. In his role at DJC, Mr. James will provide consulting to the project team related to developing and optimizing the mining plans associated with providing REE-rich feedstock at the lowest possible mining cost.

MLJ Consulting

Dr. Mike Jones, principal of MLJ Consulting, is the former VP for R&D at the Lignite Energy Council (LEC) in North Dakota and was a long-time researcher and project manager at UND's Energy & Environmental Research Center. Dr. Jones has consulted on UND's technology development for the last few years, focusing on commercialization and business planning. He has extensive knowledge and connections in the lignite industry that we will leverage to develop the Phase 2 business and financing plans.

Odney

Odney is a Bismarck, ND-based advertising and public relations consulting firm with a long history of engagement with ND's lignite and energy industries. Odney, under the leadership of CEO **Shane Goettle**,

will support the project team in developing, updating and implementing the Community Benefits Plan, with a specific focus on the Community, Labor, and Stakeholder Engagement Plan.

VALUE TO NORTH DAKOTA

The key value to North Dakota is the creation of new markets for lignite coal, with the ultimate potential of a dramatic economic and industrial development opportunity previously described in **Figure 10**. This Phase 1, and desired Phase 2 project, would enable the more rapid deployment of a REE/CM industry into both North Dakota, as well as the nation. With a FEED study completed, remaining risks for construction, commissioning, and operation would be minimized or known, and would increase the likelihood of success of the establishment of a ND-focused REE/CM industry. As noted in the previous pre-FEED study, the total jobs expected to be created from this demonstration facility are over 100, not including the significant number of mining jobs that could have more stability through the creation of new markets for lignite coal. Preliminary resource estimates suggest ND could be a sole source of Ge, and possibly Ga for the entire US, with the logical follow-on of establishing major refining and semiconductor industries in the region around this production. Additionally, the introduction of federal capital in Phase 2 both to construct, commission, and operate the REE Demonstration Facility for a number of years significantly buys down the risk both to the state, as well as private entities.

MANAGEMENT

The project organization chart is provided in **Figure 11**. Dr. Laudal (PD) will lead **Task 1** and be the administrative lead and point of contact for all project sponsors. He will be responsible for project reporting, complying with the project schedule and budget, and arranging regular meetings between the project team members. Dr. Laudal will also serve as a technical advisor to the project team. Mr. Theaker (PI) will be the task lead for **Tasks 2 and 6** and provide direction for **Tasks 3-5**. He is UND's process technology expert and will ensure continuity from the previous technology development work. Barr

Engineering will lead **Tasks 3-5** in close coordination with the UND team. **Task 6** has multiple subtasks, each led by one of the team member organizations and their task leads. Mr. Theaker will work closely with each of the **Task 6** leads to efficiently execute this effort. Mr. Kevan Rusk from UND will lead the efforts in **Task 7** in collaboration with all project team members and key personnel.

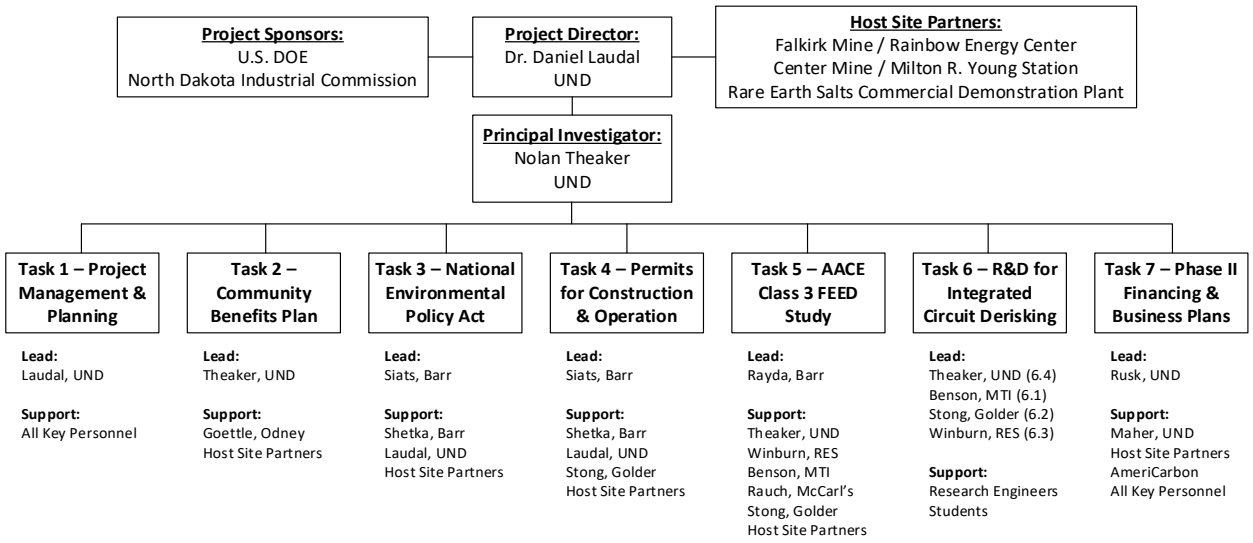


Figure 11. Project organization chart, identifying task leads and supporters.

We have identified project risks, their potential impacts and mitigation strategies, as shown in **Table 2**. This risk table will be continuously monitored and updated, as needed, during project execution.

Dr. Laudal and Mr. Theaker will work closely to ensure effective communication within the project team. The task lead structure, identified in the organization chart, provides a clear line of responsibility for each project task. The respective leads will work closely with the UND leads to execute the work and achieve the task goals. Project team meetings will be held weekly or bi-weekly to communicate progress and address any challenges or issues that arise. Individual task meetings may also be held as needed. The proposed core technical team has been collaborating on related efforts for the last several years and can comfortably execute a project of this complexity. This collaboration history provides a strong foundation for decision-making and communications.

Table 2. Project Risk Table

Perceived Risk	Risk Rating			Mitigation/Response Strategy
	Probability	Impact	Overall	
	(Low, Med, High)			
Financial Risks:				
Securing cost share	Low	Med	Low	UND has been selected for award by the DOE and expects to have a contract in place by Aug. 1 2023. The DOE award will provide 80% of the total project cost. Alternative cost-share sources, including our host-site partners and UND internal funding, can be evaluated.
A crucial activity unexpectedly requires substantial additional funds	Low	High	Low	Project and task managers will determine if any modifications can reduce costs and still meet project objectives. Additional funding will be sought if necessary.
Personnel availability	Low	High	Med	Develop a cross-functional team with strong communication capabilities and solid documentation for others to resume activities. Utilize the project team members' deep bench of engineers for support, if necessary. All key personnel are available and committed at the proposed levels.
Cost/Schedule Risks:				
Task costs are overrun	Med	Med	Low	Budgets for each participant will be developed before work begins. Costs will be monitored, and adjustments will be made to stay within the overall project budget if necessary.
Task schedules not met	Med	Med	Med	Schedules for each participant will be developed before work begins. Regular internal review meetings will be held to maintain timelines. Additional personnel resources can be allocated to tasks that are behind schedule.
Technical/Scope Risks:				
Host-site information	Low	High	Low	Host-site partners are committed to the project. See Appendix 3.
Pilot/testing data availability	Low	High	Med	UND, RES, and MTI are currently (at proposal submission) completing testing that will be needed upon Phase 1 start. Inclusion of some limited de-risking R&D.
Management, Planning, and Oversight Risks:				
Communication	Low	High	Low	Coordinate and schedule meetings and strictly follow communications plan.
Cost tracking	Low	High	Low	A resource manager will be assigned to the project to assist the PD with tracking costs.
Meeting milestones	Low	High	Low	The project schedule is organized around key milestones and the critical path. A sufficient buffer is available in the event certain tasks are delayed. Regular progress updates will be made to ensure schedule adherence.

ES&H Risks:				
Project emissions	Low	Med	Low	Testing during Task 6 will be performed at relatively small scales, and all emissions will be vented/ treated according to project team member policies.
Staff injuries	Low	High	Low	Safety training according to UND and team member policies. Operational review meeting prior to each test. A culture of safety will be implemented.
External Factor Risks:				
Unforeseen risks, e.g., natural disasters, social, legal or technical changes, project economics, or changes in political climate	Low	High	Low	Regular updates with the DOE and project partners to solve issues as they arise.

The time commitment of key personnel and total budgeted labor hours for each team member organization are listed in the tables below.

Key Personnel (organization)	**Time Commitment (FTE over 15 months)**
Nolan Theaker (UND)	0.75
Daniel Laudal (UND)	0.50
Kevan Rusk (UND)	0.30
Anthony Maher (UND)	0.35
Nick Sosalla (Barr)	0.36
Dan Palo (Barr)	0.34
Ryan Rayda (Barr)	0.17
Ryan Siats (Barr)	0.28
Thomas Rauch (McCarl's)	0.20
Steve Benson (MTI)	0.13
Alex Benson (MTI)	0.25
Ryan Winburn (RES)	1.0
Joseph Brewer (RES)	0.77

Organization	**Total Budgeted Labor Hours (15 months)**
UND	26,856
Barr/McCarl's	21,875 / 6,390
Golder	4,630
RES	9,800
MTI	7,280
NACoal	1,200 *
Rainbow Energy	500 *
BNI Coal	380 *
Minnkota	880 *
AmeriCarbon	526 *
Envergex	1,034
Dennis James Consulting	300
MLJ Consulting	285
Odney	1,090

*** Budgeted – any additional effort as in-kind cost share.**

Task 5, the AACE Class 3 FEED Study, will require substantial coordination between the team members. We have created a division of responsibility for the various activities in that Task, as provided in **Table 3**.

Table 3. Division of responsibility for the AACE Class 3 FEED study

TPT = Technology Provider Team consisting of UND, RES & MTI

Deliverable / Description	Responsible	Support
PROCESS ENGINEERING		
Project Scope Description - DEFINED	UND	
Facility Production / Capacity - DEFINED	UND	
Circuit/Facility Location(s) - SPECIFIC	UND	
Complete Block Flow Diagrams	UND	
Draft Plant Flowsheets	McCarl's	Barr
Process Design Criteria	TPT	Barr
Draft Utility Flow Diagrams	Barr	
Plant Mass and Energy Balances	TPT / McC	McCarl's
Plant Water Balance	Barr	McCarl's
Piping & Instrumentation Diagrams - Assuming 25-30	McCarl's	Barr
Line Lists & Valve Lists	McCarl's	Barr
Process & Utility Equipment List	Barr	McCarl's
Equipment Specifications / Vendor Info	Barr	McCarl's
Control Philosophy	Barr	
Complete Steady State Emissions Data	Barr	
MECHANICAL ENGINEERING		
2D Sheets for Tanks & Equipment, General Plant Arrangements	McCarl's	Barr
(3) Filter Press, (2) Belt Filters, (5) Scrubber Systems, Crusher Layout, (2) Resin Column Systems, (2) Elec Cells, REE Salt System (?), Metallization System(?)	McCarl's	Barr
Tank Modeling/Layouts (35), Pump modeling (25)	McCarl's	Barr
Building 3D Layout	McCarl's	Barr
Preliminary Pipe Routings	McCarl's	Barr
ELECTRICAL ENGINEERING		
E&I Engineering Design Criteria	Barr	
Single Line Diagrams	Barr	
Electrical Equipment List	Barr	
Motor List, Load List	Barr	
Motor Wiring Diagrams	Barr	
Instrument List	Barr	
Instrument Data Sheets	Barr	
MCC's Conceptual Arrangements & Drawings	Barr	McCarl's
Layouts - 3D Modeling	Barr	McCarl's
Input / Output Count	Barr	
CIVIL/STRUCTURAL		
Concrete Drawings (Details, Specifications)	Barr	
Preliminary/Top of Concrete in 3D Model	McCarl's	Barr
Structural Drawings - Details, Specifications (platforms, building, etc.)	Barr	
Preliminary Structure (beams/columns, grating/platforms, etc.) in 3D Model	McCarl's	Barr
PROJECT MANAGEMENT & PROJECT CONTROLS		
Document Control - Drawing List and Transmittal	McCarl's	Barr
Defined Integrated Project Plan / PEP	McCarl's	Barr
Defined Project Master Schedule	McCarl's	Barr
Defined Escalation Strategy	McCarl's	Barr

Defined Work Breakdown Structure	McCarl's	Barr
Defined Project Code of Accounts	McCarl's	Barr
Preliminary Contracting Strategy	McCarl's	Barr
Constructability Workshop	McCarl's	Barr
CAPITAL & OPERATING COST ESTIMATE		
Earthworks	McCarl's	Barr
Civil / Structural	McCarl's	Barr
Equipment & Tankage Quotes	Barr / UND	McCarl's
Piping	McCarl's	Barr
Electrical	McCarl's	Barr
Controls & Programming (Equipment and Controls, Inc. quote)	Barr	McCarl's
Indirects	McCarl's	Barr
EPC / EPCM	Barr	McCarl's
Owner's Costs (in conjunction with Client)	McCarl's	Barr
Construction Manpower Estimate	McCarl's	Barr
Capital Cost Reviews	McCarl's	Barr
Operating Cost Estimate	McCarl's	Barr
Cashflow Analysis	Barr/UND	
REPORTING		
Design Basis Report	Barr/TPT	
Performance Results Report	Barr/TPT	
Technology Gap Analysis	Barr/TPT	
Cost Results Report	McCarl's	Barr/UND
Project Execution Plan Presentation	McCarl's	Barr/UND
GHG/LCA Report	Envergex	Barr/UND
Final Report	Barr/UND	

TIMETABLE

The project schedule is provided in **Figure 12**. The milestone log is provided in **Table 4**. Note: the schedule and milestone log shown are the same as provided with the DOE application that assumed a 6/7/2023 start date. The schedule and start date will be updated accordingly once the project officially begins. We have also developed two SMART milestones, presented below.

Year 1. **Specific:** Overall technology and integrated circuits successfully de-risked. **Measurable**: Increase the TRL level of all technology subsystems/circuits to TRL 6 and provide performance data and design criteria for incorporation in the FEED. **Achievable**: The proposed Task 6 lays out our plan to achieve this milestone. **Relevant**: This milestone is necessary to achieve the project objectives. **Timely**: The project

schedule enables engineering activities to commence while Task 6 is being executed. Upon Task 6 completion, results can be input into engineering work.

Year 2. **Specific**: Secure Phase 2 financing. **Measurable**: Firm commitments for the non-federal cost share requirements (at least 50% of total Phase 2 costs). **Achievable**: The FEED study will need to provide a solid business case and the technology must be sufficiently de-risked. **Relevant**: Our ultimate goal is a Phase 2 project. **Timely**: Must be completed by the end of Phase 1.

Table 4. Milestone Log

Task	Milestone Title & Description	Completion	Verification Method
1.0	Project Award	06/07/2023	Cooperative agreement
1.0	Update Project Management Plan	07/07/2023	PMP file
1.2	Update Technology Maturation Plan	09/05/2023	TMP file
2.0	J40 Plan Proposal	09/05/2023	Plan proposal file
2.0	J40 Full Plan	12/04/2023	Full Plan file
2.0	Engagement Plan Development Proposal	09/05/2023	Plan proposal file
2.0	Engagement Plan Development Full Plan	12/04/2023	Full Plan file
2.0	DEIA Plan Update	09/05/2023	DEIA plan file
2.0	Quality Jobs Plan	09/05/2023	Quality Jobs Plan file
2.0	Community Benefits Plan Update	12/04/2023	CBP file
3.0	Environmental Volume Update (pre-NEPA review)	07/07/2023	EV file
3.0	NEPA Review (Environmental Assessment)	09/04/2024	EA documentation
4.0	Finalize all ND permit applications	07/09/2024	Application documents
4.0	Finalize all NE permit applications	01/18/2023	Application documents
5.0	30% FEED completion	10/30/2023	Quarterly reporting
5.0	60% FEED completion	02/01/2024	Quarterly reporting
5.0	90% FEED completion	04/11/2024	Quarterly reporting
5.0	FEED cost estimate	09/04/2024	Quarterly reporting
6.1	Feedstock analysis/sorting performance optimized	09/01/2023	Quarterly reporting
6.2	Confirmation of Class I suitability for wastewater disposal	09/01/2023	Quarterly reporting
6.3	Metallization de-risking FEED data	11/29/2023	Quarterly reporting
6.3	Modification and testing of metallization prototype	05/23/2024	Quarterly reporting
6.4	Site-specific feedstock pilot performance for FEED data	09/01/2023	Quarterly reporting
6.4	Product purity and waste stream compositions determined	11/29/2023	Quarterly reporting
7.1	Secure Phase 2 financing	09/04/2024	Phase 2 application
7.2	Phase 2 business plan	09/04/2024	Phase 2 application
7.2	Securement of off-take agreements	09/04/2024	Phase 2 Application
1.0	Phase 2 Application	09/04/2024	Phase 2 application
1.0	Go/No-Go for Phase 2	03/07/2025	DOE decision

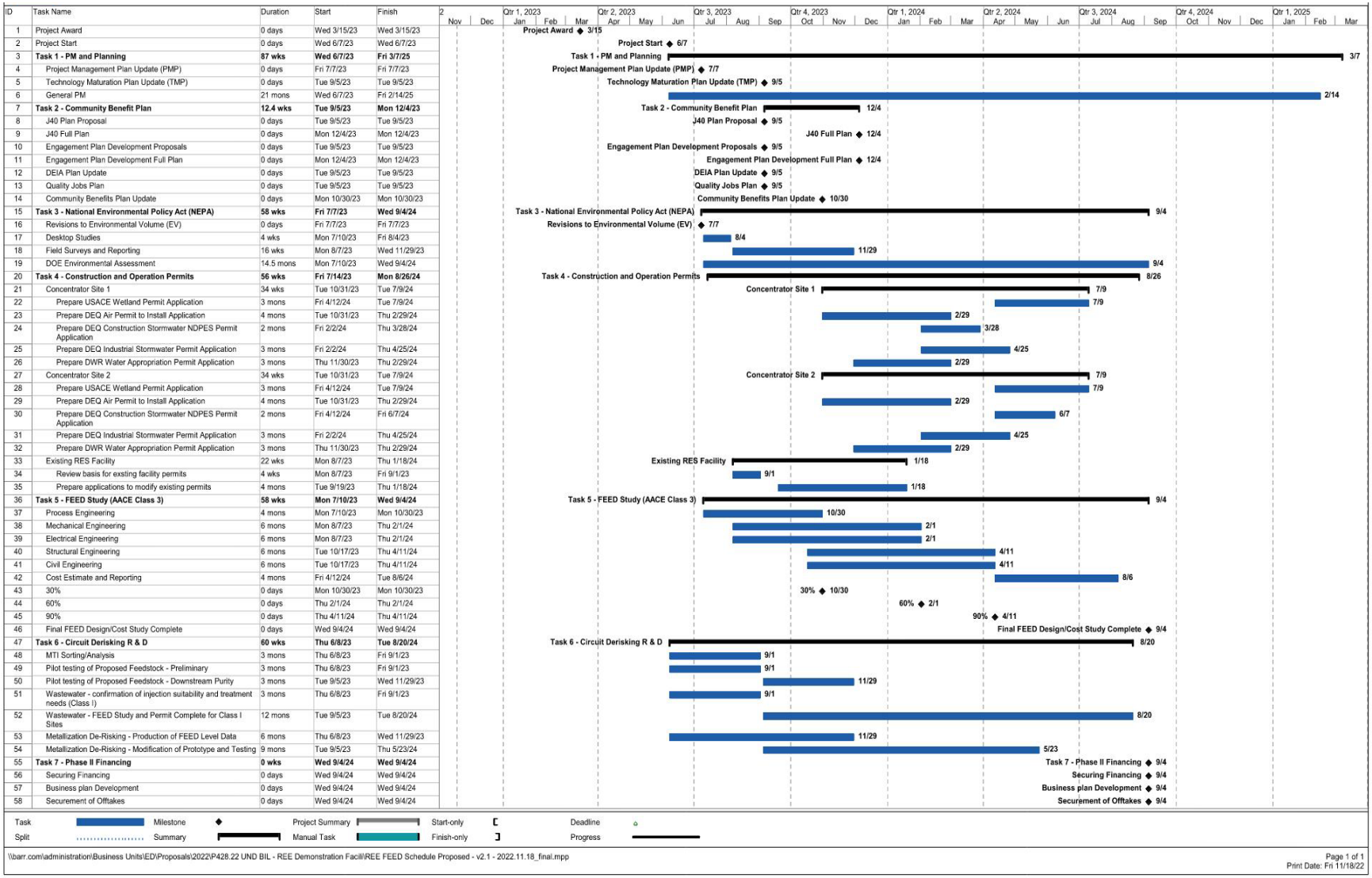


Figure 12. Project schedule

BUDGET

The budget breakdown is provided in **Table 5**. We are requesting $2,000,000 from NDIC, representing 20% of the total budgeted cost. Budget notes are provided in Appendix 1. Letters of commitment for each our subcontractors are provided in Appendix 2.

Table 5. Budget breakdown

Cost Category	DOE Share	NDIC Share	Total Project
Personnel	-	1,061,385	1,061,385
Fringe Benefits	-	336,918	336,918
Travel	10,440	31,710	42,150
Equipment	110,000	-	110,000
Supplies	118,639	4,161	122,800
Barr Engineering	*3,999,660*	-	*3,999,660*
Microbeam Technologies	*748,873*	-	*748,873*
WSP Golder	*736,644*	-	*736,644*
Rare Earth Salts	*645,200*	-	*645,200*
Envergex LLC	*249,900*	-	*249,900*
Odney	*130,800*	-	*130,800*
North American Coal	*95,000*	-	*95,000*
Rainbow Energy Center	*95,000*	-	*95,000*
BNI Coal	*95,000*	-	*95,000*
Minnkota Power Cooperative	*95,000*	-	*95,000*
AmeriCarbon LLC	*50,000*	-	*50,000*
MLJ Consulting	*49,875*	-	*49,875*
Dennis James Consulting	*66,000*	-	*66,000*
Total Contracts	7,056,952	-	7,056,952
Other Direct Costs	428,286	25,000	453,286
Total Direct Costs	9,183,491	-	9,183,491
Indirect Costs	275,682	540,826	816,508
Total Project	**7,999,999**	**2,000,000**	**9,999,999**

MATCHING FUNDS

The Department of Energy will provide $7,999,999 in cash cost share, representing about 80% of the budgeted project cost. The DOE contract is currently being negotiated with DOE and is expected to be in place under award number DE-FE0032295 by August 1, 2023. The DOE award selection notification letter is included as Appendix 4.

As noted in **Table 5** above, our team includes multiple private sector partners in the lignite industry and AmeriCarbon. The proposed budget includes a nominal budget for Minnkota, Rainbow Energy, BNI Coal and North American Coal in the amount of $95,000 and a nominal budget in the amount of $50,000 for AmeriCarbon. However, as noted in each of their respective letters of commitment, any **costs incurred beyond this initial nominal budget will be provided as in-kind cost share.** As we have discussed in this proposal, the key outcome of Phase 1 will be the business and technical information required to move on to Phase 2 construction and operation. As such, ***Phase 1 will be our opportunity to put together the commercial team and financing to pursue the Phase 2 opportunity as a new business***. Each of our lignite industry partners and AmeriCarbon have expressed their interest in evaluating this opportunity. While the in-kind cost share noted above is not contractually obligated, it is our expectation that if a business case exists, one or more of these partners will be interested in being a part of the commercial venture that pursues Phase 2. This would very likely require substantial effort beyond the initial nominal budgets.

TAX LIABILITY

A copy of UND's Tax Liability Statement is provided in Appendix 6.

CONFIDENTIAL INFORMATION

No confidential information is provided in this application.

APPENDICES

Appendix 1 – UND Budget Notes

Appendix 2 – Subcontractor Letters of Commitment

Appendix 3 – Host Site Commitment Letters

Appendix 4 – DOE Award Selection Letter

Appendix 5 – Letters of Interest (feedstock supply, product offtake, project ownership)

Appendix 6 – UND Tax Liability Statement

Appendix 7 – Resumes of Key Personnel

REFERENCES

[1] www.americarbon.com
[2] https://ndbtu.org/
[3] Lepke, James P., "Upgrade of rare earth element concentrate by selective dissolution and ion exchange" (2021). *Theses and Dissertations*. 4085. https://commons.und.edu/theses/4085/
[4] Laudal, Daniel A., et al. "Leaching behavior of rare earth elements in Fort Union lignite coals of North America." International Journal of Coal Geology. 191:112-124. 2018. https://doi.org/10.1016/j.coal.2018.03.010
[5] Laudal, Daniel A., "Evaluation of rare earth element extraction from North Dakota coal-related feed stocks" (2017). *Theses and Dissertations*. 2123. https://commons.und.edu/theses/2123.
[6] https://www.osti.gov/biblio/1785352
[7] Curtolo, D.C., et al. "High purity germanium, a review on principle theories and technical production methodologies." Journal of Crystallization Process and Technology. 7:65-87. 2017.
[8] Bautista, Renato G. "Processing to obtain high-purity gallium." JOM March 2003.
[9] https://mpmaterials.com/what-we-do/
[10] http://www.americarbon.com/blank/

APPENDIX 1 – UND BUDGET NOTES

Explanation of Splitting of Budgetary Items

For the ease of contracting, cost-tracking, and overall project management, cost categories and line items, where possible, have been completely covered under a solitary funding source. For ease of contracting, all subrecipients and subcontractors have been placed directly underneath the DOE award, as well as all equipment purchases (as DOE requires disposition of equipment at the completion of all DOE contracts). As such, only UND-based expenses will be covered underneath the scope of the proposed NDIC effort.

Additionally, all pilot supplies and analysis related expenses have been covered underneath the DOE effort, as well as DOE-mandated travel, leaving the expenses left to be covered to include personnel, fringe benefits, the ASPEN license associated with UND's workscope on the FEED study, and approximately 40% of the total outreach materials costs, with this budget to be used exclusively for ND-based outreach activities. Detailed accounting of these costs is found below, covering the entire 21-month proposed effort.

Personnel

Personnel	Hours Budgeted	Hourly Rate ($)	Total Cost ($)
Project Director	1300	103	$133,900
Principal Investigator	1950	45	$87,750
Director, Business Development	780	103	$80,340
Business & Finance Planner	910	37	$33,670
Research Engineers (5)	13000	38	$494,000
Resource Manager	856	32	$27,405
Graduate Students (3)	5460	28.85	$157,521
Undergraduate Students (4)	2600	18	$46,800

*Hourly rates determined from escalated, actual salary rates for names personnel, and on positional UND salaries for the Research Engineer, Graduate Student, and Undergraduate Student rates.

Explanation of Work

Project Director and Principal Investigator

The PD and PI for this effort will be integrally involved in all tasks, with the PD having a larger role in Task 1 and 7 (Project Management and Planning, and Business and Financing Plan Development), and the PI having a larger role in the technically-focused tasks (Tasks 2-6), although involvement in all tasks by both parties is planned.

Director, Business Development

This role will be most primarily used during the Business and Financing Plan Development Task (Task 7), although will also be utilized during the execution of Task 2 (Community Benefits Plan), in assisting access and involvement throughout the state.

Business and Finance Planner

This role will be solely focused on supporting the project's Task 7, primarily focused on the efforts associated with UND's potential licensure and technical support to interested/involved parties.

Research Engineer

These five positions will be occupied by full-time staff, and will be essential in the completion of Task 5 and 6: FEED-related work (such as mass/energy/water balances, equipment sizing, and other related engineering activities); and the De-risking research associated with the operation of UND's pilot facility. Those employed by this project are planned to be full-time during the scope of UND's work on the represented tasks.

Resource Manager

The resource manager will assist the PD and PI in management and cost-tracking of the project, and as such is only involved in Task 1, Project Management and Planning.

Graduate Students

Three graduate students are planned for full-time work on this project, including for assistance in FEED-related work and modeling, as well as with pilot operations for Tasks 5 and 6.

Undergraduate Students

Four undergraduate students are budgeted for this project, solely focused on pilot-scale research and operations, and are intended to be employed as coop engineers during the period of pilot operation (Fall semester, 2023).

Fringe Benefits

Fringe benefits are estimated based on historic rates within UND, although only the true cost of each dedicated employee on the project will charge their specific rates during project execution. The table below estimates the fringe benefits for each employee category.

Personnel	**Fringe Rate**	**Total Fringe Benefits**
Project Director	35.0%	$46,865
UND Staff Positions*	40.0%	$289,266
Graduate Students	0.50%	$788
Undergraduate Students	0.00%	$0

*This includes the PI, Director of Business Development, Business and Finance Planner, Resource Manager, and Research Engineer positions

Travel

Travel costs for the project, as mentioned above, include all travel costs not associated with mandated DOE-related travel. This includes three trips to various locations in ND for outreach and project meetings, travel to Beatrice, NE for related project meetings and outreach at this site location, and two conference attendances, currently budgeted as Clearwater Clean Energy Conference visits for project dissemination. Current state or federal, where appropriate, GSA rates have been used for these activities. For legibility reasons, the tables below represent the same trips, just separated into two tables to convey all requisite information.

Purpose of Travel	Depart From	Destination	No. of Days	No. of Travelers
Domestic Travel		**Budget Period 1**		
ND host site visit	Grand Forks, ND	Bismarck, ND	3	3
ND host site visit	Grand Forks, ND	Center, ND	3	3
ND host site visit	Grand Forks, ND	Underwood, ND	3	3
NE host site visit	Grand Forks, ND	Beatrice, NE	3	3
NE host site visit	Grand Forks, ND	Beatrice, NE	3	3
Technical Conference (i.e. Clearwater Clean Energy Conf.)	Grand Forks, ND	Clearwater, FL	5	3
Technical Conference (i.e. Clearwater Clean Energy Conf.)	Grand Forks, ND	Clearwater, FL	5	3

Purpose of Travel	Lodging per Traveler	Flight per Traveler	Vehicle per Traveler	Per Diem Per Traveler	Cost per Trip	Basis for Estimating Costs
Domestic Travel	**Budget Period 1**					
ND host site visit	$294	$0	$65	$177	$1,608	Current GSA rates
ND host site visit	$294	$0	$65	$177	$1,608	Current GSA rates
ND host site visit	$294	$0	$65	$177	$1,608	Current GSA rates
NE host site visit	$294	$800	$0	$177	$3,813	Current GSA rates
NE host site visit	$294	$800	$0	$177	$3,813	Current GSA rates
Technical Conference (i.e. Clearwater Clean Energy Conf.)	$865	$1,200	$0	$345	$9,630	Current GSA rates. Includes conference registration
Technical Conference (i.e. Clearwater Clean Energy Conf.)	$865	$1,200	$0	$345	$9,630	Current GSA rates. Includes conference registration

Supplies

A total of $4,161 of supplies is requested for the development, printing, mailing, and dissemination of outreach-related materials for the project.

Other Direct Costs

$25,000 is requested as an other direct cost to cover the UND commercial ASPEN license required for the project. Due to the non-academic research nature of the project, the commercial license is required, and costs $20,000 per year for UND (an additional $5,000 to cover the total 15-month technical period).

Indirect Costs

UND has two indirect rates, one for on-campus work, and another for off-campus work. All tasks, save the Pilot activity in Task 6 utilize the on-campus rate of 41%, which is applied to all budgeted items (exemptions from UND's indirect rate include tuition waivers, equipment expenditures, and subcontracts expenditures after the first $25,000). The off-campus rate maintains the same exemptions, although is only a rate of 26%. As such, personnel and fringe expenses expected for the project throughout the execution of Task 6 for off-campus related activities use the lower 26% indirect rate.

Location of Work	Indirect Rate	Direct Expenses	Indirect Expenses
On-Campus	41%	$1,076,270	$441,271
Off-Campus	26%	$382,904	$99,555
Total	37%*	$1,459,174	$540,826

*Rate based on a weighted average, and not the planned project charge rate. Indirects associated with actual expenses will be charged at either the 41% or 26% rates, expecting a 37% average rate.

APPENDIX 2 – SUBCONTRACTOR LETTERS OF COMMITMENT

resourceful. naturally.
engineering and environmental consultants

BARR

November 21, 2022

Dan Laudal, Ph.D.
Director, Institute for Energy Studies
College of Engineering and Mines
University of North Dakota
Sent via email: daniel.laudal@und.edu

Re: Letter of Commitment for Phase 1

Dear Dr. Laudal:

This letter confirms Barr Engineering Co.'s commitment to your proposal to the U.S. Department of Energy (DE-FOA-0002618) entitled "FEED Study: Recovery and refining of rare earth elements from lignite mine wastes."

Having partnered with UND on previous phases of development for this technology, Barr has intimate knowledge of the process, equipment, and challenges of this project. We have enjoyed working with your team, and we value the complementary combination of skill sets our teams bring to projects like this.

As you pursue an award for FEED development under the current FOA, we look forward to supporting you with engineering and environmental services, including:

- NEPA compliance reporting
- Construction and operation permit preparation
- Multi-discipline design for the concentrator
- Capital and operating cost estimation
- FEED Study report preparation

Barr has extensive experience associated with mineral processing and environmental compliance and permitting both in North Dakota and Nebraska relevant to this study, as well as nationally and internationally. The leaders of our engineering and environmental teams are mostly based in Minnesota and North Dakota, and this local presence is a great advantage for the project team.

Our proposed budget for the above scope of work is $3,999,662, as detailed in our budget justification, and as described in our written subcontract proposal.

We are very excited to partner with the UND team on this project and we look forward to hearing of a successful proposal outcome.

Sincerely,

Daniel R. Palo, PhD, P.Eng., PE
Vice President
801.333.8421

RARE EARTH SALTS

5331 Element Avenue
Beatrice, NE 68310
(402) 806-4400

November 14, 2022

Dan Laudal, Ph.D.
Director | Institute for Energy Studies
College of Engineering & Mines
University of North Dakota
Sent via email: daniel.laudal@und.edu

Subject: Letter of commitment for Phase 1

Dear Dr. Laudal,

This letter confirms Rare Earth Salt's commitment to your proposal to the U.S. Department of Energy (DE-FOA-0002618) entitled "FEED Study: Recovery and refining of rare earth elements from lignite mine wastes."

Rare Earth Salts (RES), a Nebraska limited liability company, is a producer of rare earth oxides that has developed a novel, patented approach proven to separate and refine all 16 rare earth elements (REEs) to purities between 99 and 99.99%. The process is environmentally friendly and has an expected to have a lower cost per kilogram separated than a traditional Chinese solvent extraction (SX) facility (~2-4$/kg vs $4-6/kg) and up to an 50% reduction in Capex as compared to a similarly sized SX facility. This significantly reduces the cost of the development, acquisition, sustainment, and total ownership of domestically sourced REEs.

RES will apply our novel green separations and refining technologies to concentrates provided from the lignite mine waste to generate cost competitive refined rare earth oxide products. RES has also developed unique chemistries and processes for the metallization or rare earth elements for use in magnet production in a closed-loop environmentally friendly manner.

Our proposed budget for the above scope of work is $650,000, as detailed in our budget justification.

We are very excited to partner with the UND team on this project and we look forward to hearing of a successful proposal outcome.

Sincerely,

Joseph R Brewer, PhD

CTO and President

joseph.brewer@rareearthsalts.com 402-806-4400

MICROBEAM TECHNOLOGIES, INC.

www.microbeam.com

Dan Laudal, PhD
Director | Institute for Energy Studies
College of Engineering & Mines
University of North Dakota
Sent via email: daniel.laudal@und.edu

November 15, 2022

Subject: Letter of Commitment for Phase 1

Dear Dr. Laudal:

This letter confirms Microbeam Technologies Incorporated's commitment to your proposal to the U.S. Department of Energy (DE-FOA-0002618) entitled "FEED Study: Recovery and refining of rare earth elements from lignite mine wastes."

Microbeam provides advanced analysis of carbon-ores and associated waste materials to determine abundance of form of major, minor and trace elements that includes REE-CM. Since 1992, Microbeam has performed more than 1640 projects providing advanced analysis and interpretation that are used to predict and manage fuel properties that impact plant performance. Microbeam's primary area of expertise lies in its understanding of the behavior of carbon-ore related impurities in energy conversion systems.

Microbeam's scope of work is summarized as follows:

Task 1.0 Project Management and Reporting – Under this task, MTI will assist UND to coordinate activities to effectively accomplish the work. MTI will work with UND and project team members to ensure that project plans, results, and decisions are appropriately documented, and project reporting and briefing requirements are satisfied.

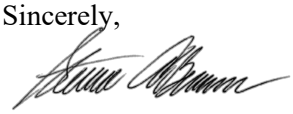
Task 5.0 FEED – In the FEED portion of this project, Microbeam will provide designs for the lignite mine waste sorting system and the germanium and gallium extraction process. For the lignite mine waste sorting system, Microbeam will provide an optimized design for the full stream elemental analyzer (FSEA), the high-speed sort gate, and the sorting system that can be integrated into the overall demonstration facility design. For the Ge and Ga extraction process, Microbeam will provide the design of equipment and process flow diagrams that will be integrated into the UND process to extract, separate and purify Ge and Ga products.

Task 6.0 De-risking R&D – In support of the De-risking R&D portion of the project, Microbeam will conduct validation activities for the lignite mine waste sorting system. This effort will consist of installing the sorting algorithm on a FSEA at an operating plant, conducting stop belt sampling, sample analysis, and validation of the sorting system results with the laboratory analysis.

Task 7.0 Business and Finance Plans – For the Business and Finance Plans, Microbeam will provide equipment and operating estimates for the lignite mine waste sorting system and the germanium and gallium extraction process. Microbeam will work with UND to determine impacts of these technologies on the overall techno-economic evaluation of the demonstration facility.

Our proposed budget for the above scope of work is $748,873, as detailed in our budget justification.
MTI is very excited to partner with the UND team on this project and we look forward to a successful proposal outcome. If you have any questions, please do not hesitate to contact me at 701-213-7070 or at sbenson@microbeam.com.

Sincerely,



Steven A. Benson, PhD
President

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info@microbeam.com

BNI energy

AN ALLETE COMPANY

November 14, 2022

Dan Laudal, Ph.D.
Director | Institute for Energy Studies
College of Engineering & Mines
University of North Dakota

Sent via email: daniel.laudal@und.edu

Subject: Letter of commitment for Phase 1

Dear Dr. Laudal,

This letter confirms BNI Energy's (BNI) commitment to your proposal to the U.S. Department of Energy (DE-FOA-0002618) entitled "FEED Study: Recovery and refining of rare earth elements from lignite mine wastes."

BNI owns and operates the Center Mine, near Center, ND. Center Mine has an annual lignite coal production of about 4 million tons and provides lignite to the adjacent Milton R. Young Station. We understand that your proposed technology and facility would use lignite mine waste materials, the REE-enriched materials located at the margins of our coal seams and in thin seams that are today not used for power production.

Our commitment to this project involves the following scope of work: **1)** provide technical, environmental and economic information necessary to complete your proposed FEED study, **2)** based on the results of the FEED study, evaluate whether this is a commercial opportunity we would like to pursue, and **3)** if yes, work with your team to develop the Phase 2 financing and business plan. Our budget for the proposed 15-month project is $95,000. This includes labor hours for engineering, environmental, financial and legal staff for a total of about 380 hours at an average labor rate of $250/hr. Any effort beyond this budgeted amount will be provided as in-kind cost share towards your project.

BNI has been a long-time supporter of your technology development and we recognize the value that your technology can bring to our company, the lignite industry as a whole, the state of ND and the country. We hope the DOE gives your proposal serious consideration and we look forward to hearing of a successful proposal outcome and beginning work on this exciting project.

Sincerely,

Mike Heger
General Manager – BNI Energy

Minnkota Power COOPERATIVE
A Touchstone Energy® Cooperative

5301 32nd Avenue South
Grand Forks, ND 58201

Phone 701.795.4000
www.minnkota.com

November 10, 2022

Dan Laudal, Ph.D.
Director | Institute for Energy Studies
College of Engineering & Mines
University of North Dakota
Sent via email: daniel.laudal@und.edu

Subject: Letter of commitment for Phase 1

Dear Dr. Laudal,

This letter confirms Minnkota Power Cooperative's (MPC) commitment to your proposal to the U.S. Department of Energy (DE-FOA-0002618) entitled "FEED Study: Recovery and refining of rare earth elements from lignite mine wastes."

MPC is the operator of the Milton R. Young Station (MRYS), a 2-unit 705 MW lignite-fired power plant near Center, ND. MRYS purchases over 4 million tons/year of lignite coal from the adjacent Center Mine, operated by BNI Coal, Ltd. We understand that your proposed REE Demonstration facility would use lignite mine wastes from the Center Mine, and after the REE processing could yield a unique and high-quality lignite coal that may be an ideal blending fuel for the MRYS. Specifically, we understand that your technology would create a low-sodium (essentially zero) fuel that could contribute to decreased boiler fouling and operational/efficiency challenges at the MRYS.

Our commitment to this project involves the following scope of work: **1)** provide technical, environmental and economic information necessary to complete your proposed FEED study, **2)** based on the results of the FEED study, evaluate whether this is a commercial opportunity we would like to pursue, and **3)** if yes, work with your team to develop the Phase 2 financing and business plan. Our budget for the proposed 15-month project is $95,000. This includes labor hours for engineering, environmental, financial and legal staff for a total of about 880 hours at an average labor rate of $108/hr. Any effort beyond this budgeted amount will be provided as in-kind cost share towards your project.

MPC has been a long-time supporter of your technology development and we recognize the value that your technology can bring to our company, the lignite industry as a whole, the state of ND and the country. We hope the DOE gives your proposal serious consideration and we look forward to hearing of a successful proposal outcome and beginning work on this exciting project.

Sincerely,

Craig J. Bleth

Craig J. Bleth, P.E.
Vice President of Power Supply
Minnkota Power Cooperative
cbleth@minnkota.com

North American COAL

November 17, 2022

Dan Laudal, Ph.D.
Director | Institute for Energy Studies
College of Engineering & Mines
University of North Dakota

Sent via email: daniel.laudal@und.edu

Subject: Letter of commitment for Phase 1

Dear Dr. Laudal,

This letter confirms North American Coal's (NACoal) commitment to your proposal to the U.S. Department of Energy (DE-FOA-0002618) entitled "FEED Study: Recovery and refining of rare earth elements from lignite mine wastes."

Falkirk Mining Company, a subsidiary of NACoal, owns and operates the Falkirk Mine near Underwood, ND. Falkirk Mine has an annual lignite coal production of about 8 million tons and provides lignite to the adjacent Coal Creek Station, the largest power plant in ND. We understand that your proposed technology and facility would use lignite mine waste materials, the REE-enriched materials located at the margins of our coal seams and in thin seams that are today not used for power production.

Our commitment to this project involves the following scope of work: **1)** provide technical, environmental and economic information necessary to complete your proposed FEED study, **2)** based on the results of the FEED study, evaluate whether this is a commercial opportunity we would like to pursue, and **3)** if yes, work with your team to develop the Phase 2 financing and business plan. Our budget for the proposed 15-month project is $95,000. This includes labor hours for engineering, environmental, financial and legal staff for a total of about 1,200 hours at an average labor rate of $75.00/hr. Any effort beyond this budgeted amount will be provided as in-kind cost share towards your project.

NACoal has been a long-time supporter of your technology development and we recognize the value that your technology can bring to our company, the lignite industry as a whole, the state of ND and the country. We hope the DOE gives your proposal serious consideration and we look forward to hearing of a successful proposal outcome and beginning work on this exciting project.

Sincerely,
THE NORTH AMERICAN COAL CORPORATION

Carroll L. Dewing
Vice President – Operations

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

RAINBOW
ENERGY CENTER

November 16, 2022

Dan Laudal, Ph.D.
Director | Institute for Energy Studies
College of Engineering & Mines
University of North Dakota

Sent via email: daniel.laudal@und.edu

Subject: Letter of commitment for Phase 1

Dear Dr. Laudal,

This letter confirms Rainbow Energy Center's commitment to your proposal to the U.S. Department of Energy (DE-FOA-0002618) entitled "FEED Study: Recovery and refining of rare earth elements from lignite mine wastes."

Earlier this year, Rainbow Energy Center LLC (Rainbow), an affiliate of Rainbow Energy Marketing Corporation, purchased the Coal Creek Station, a 1,151 MW lignite-fired power plant near Underwood, ND. Coal Creek Station is North Dakota's largest power plant, and purchases about 8 million tons/year of lignite from the adjacent Falkirk Mine. We understand that your proposed REE Demonstration facility would use lignite mine wastes from the Falkirk Mine, and after the REE processing would yield a unique and high-quality lignite coal that may be an ideal blending fuel for the Coal Creek Station. Specifically, we understand that your technology would create a low-sodium (essentially zero) fuel that could significantly decrease boiler fouling and operational/efficiency challenges at Coal Creek Station.

Our commitment to this project involves the following scope of work: **1)** provide technical, environmental and economic information necessary to complete your proposed FEED study, **2)** based on the results of the FEED study, evaluate whether this is a commercial opportunity we would like to pursue, and **3)** if yes, work with your team to develop the Phase 2 financing and business plan. Our budget for the proposed 15-month project is $95,000. This includes labor hours for engineering, environmental, financial and legal staff for a total of about 500 hours at an average labor rate of $200/hr. Any effort beyond this budgeted amount would be provided as in-kind cost share towards your project.

Rainbow is interested in supporting your project development, as we recognize the value that your technology can bring to our company, the lignite industry as a whole, the state of ND and the country. We hope the DOE gives your proposal serious consideration and we look forward to hearing of a successful proposal outcome and engaging with your team on this exciting project.

Sincerely,

Stacy L. Tschider
President

919 S 7th St., Ste. 405 | PO Box 837 | Bismarck, ND 58502 | Phone: 701.222.2290 | Fax: 701.255.7952 | rainbowenergycenter.com

AmeriCarbon

November 1, 2022

Dan Laudal, Ph.D.
Director | Institute for Energy Studies
College of Engineering & Mines
University of North Dakota
Sent via email: daniel.laudal@und.edu

Subject: Letter of commitment for Phase 1

Dear Dr. Laudal:

This letter confirms AmeriCarbon Products. LLC's (AmeriCarbon) commitment to your proposal to the U.S. Department of Energy (DE-FOA-0002618) entitled "FEED Study: Recovery and refining of rare earth elements from lignite mine wastes."

AmeriCarbon owns the proprietary and patented Eco-Pitch™ process, which produces tailored pitch products from domestic coal with >99% GHG reduction relative to current coal tar pitch supply. Our pitch can be used for a wide range of applications, including graphite and carbon electrodes, structural panels, carbon fibers, lithium-ion batteries, and conductive/insulating foams. Our team has been evaluating opportunities in North Dakota to locate a commercial pitch production facility that would use lignite coal as the feedstock. Lignite's unique properties provide key advantages for pitch production. Based on our collaboration with your team relating to carbon-based products development, we are extremely excited about the potential to use the REE-extracted lignite material that you will produce at your proposed REE Demonstration Facility. Specifically, this material could be an extremely valuable feedstock for our pitch plant. As such, we are interested in exploring ownership/investment possibilities in the proposed REE facility to leverage this synergy. We intend to work with your team during Phase 1 to develop the necessary information to enable our evaluation of this exciting opportunity.

Our commitment to this project involves the following scope of work: **1)** provide technical, environmental and economic information necessary to complete your proposed FEED study, **2)** based on the results of the FEED study, evaluate whether this is a commercial opportunity we would like to pursue, and **3)** if yes, work with your team to develop the Phase 2 financing and business plan. Our budget for the proposed 15-month project is $50,000. This includes labor hours for engineering, environmental, financial and legal staff for a total of about 526 hours at an average blended labor rate of $95/hr. Any effort beyond this budgeted amount will be provided as in-kind cost share towards your project.

We hope the DOE gives your proposal serious consideration and we look forward to hearing of a successful proposal outcome and beginning work on this exciting project.

Sincerely,

David A. Berry
Chief Executive Officer
AmeriCarbon Products, LLC
david.berry@americarbon.com
(740) 644-1303

November 14, 2022 Proposal No. 202226716

Dan Laudal, PhD
Director | Institute for Energy Studies
College of Engineering & Mines, University of North Dakota
Sent via email: daniel.laudal@und.edu

LETTER OF COMMITMENT FOR PHASE 1

Dear Dr. Laudal:

This letter confirms Golder Associates USA Inc.'s (Golder's) commitment to your proposal to the US Department of Energy (DE-FOA-0002618) entitled "FEED Study: Recovery and refining of rare earth elements from lignite mine wastes."

Golder is an independent consulting, design, and construction services firm specializing in the areas of earth, environment, and energy. Golder is experienced in designing, permitting, and constructing Class I injection wells for the management of process waters generated at industrial facilities, including unique site-specific knowledge and experience with existing operational and proposed Class I injection wells near the two proposed host sites.

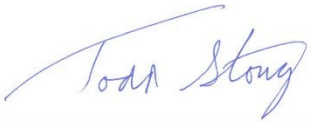
Golder is committed to your proposed project and will support it by performing the following tasks associated with Class I injection wells for each of the two host sites: 1) conceptual design, 2) injection well design and permit application preparation, 3) aquifer exemption request preparation, 4) surface facilities design, 5) engineer's construction and operations and maintenance cost estimates, and 6) project management and site visits.

Our proposed budget for the above scope of work is $736,644, as detailed in our attached proposal. Golder submits this proposal, expressly contingent upon the scope and pricing therein and on the assumption that contract terms and conditions can be agreed upon between Golder and UND.

We are very excited to partner with UND on this project and we look forward to a successful proposal outcome.

Sincerely,

Golder Associates USA Inc.



Todd Stong, PE
Director

AMS/TJS/af

Enclosures: Proposal for Class I (Non-hazardous) Injection Well System Design, Falkirk Mine and Center Mine

https://golderassociates.sharepoint.com/sites/168692/project files/1 proposal and project management/technical_work/_rev 0/formatted/202226716-pro-0-und_class_i_injection_well-golder_commitment_letter_14nov22.docx

Envergex LLC
10 Podunk Road
Sturbridge, MA 01566

November 16, 2022

Dr. Daniel Laudal
Director | Institute for Energy Studies
College of Engineering & Mines, University of North Dakota
2844 Campus Rd. Stop 8153, Grand Forks, ND 58202

RE: Letter of commitment to University of North Dakota's proposal to the U.S. Department of Energy (DE-FOA-0002618) entitled "FEED Study: Recovery and refining of rare earth elements from lignite mine wastes."

Dear Dr. Laudal,

Envergex, LLC. (Envergex) is pleased to provide this letter of commitment to participate in the FEED study for the recovery and refining of rare earth elements (REE) from mine wastes. UND's proposed FEED study represents a continuation of the development of unique technology for rare earth elements production that has demonstrated economic potential through multiple scale-ups and increasing technology definition. Envergex will provide services for development and modeling related to life cycle analysis of the overall technology for REE recovery and processing. The anticipated project duration is from about June 1, 2023 to August 31, 2024.

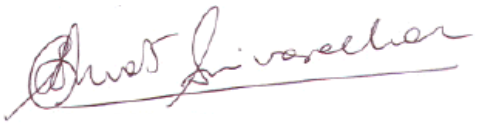
Envergex LLC (www.envergex.com) is a green energy company, in business since 2006, which focuses on bridging opportunities in the energy industry to business solutions with innovative ideas and partnerships. Envergex has products and services in four main areas: CO_2 capture; chemical looping technology, value-added product manufacturing; and control of air pollutants.

Specific work scope for Envergex is listed below. Envergex will support UND is developing a Greenhouse Gas (GHG) Life Cycle Analysis (LCA) report describing GHG emissions resulting from each material, energy and operation required to extract, transport, refine, and produce the final marketed rare earth salt and rare earth metal (REM) and/or critical mineral metal (CMM) product, inclusive of any additional co-products produced in each circuit of the demonstration facility. All REE/CMM processing circuits will be modelled to reflect the REE demonstration facility as a complete system. The proposed process will occur across four separate facilities; waste coal recovery, mixed concentrate production, rare earth refining, and metallization, including two REE extraction/concentration facilities in North Dakota and one REE separation and refining facility in Nebraska.

The LCA will be performed using the SimaPro 7.2 software. Inventory data from the GREET model will be prioritized. The global warming potential shall be reported in both the 100-year and 20-year time horizons as required in the FOA and will include a contribution analysis, sensitivity analysis of key parameters, discussion of data limitations, and recommendations for improving lifecycle GHG performance. THE LCA report deliverable will include the LCA model for UND and DOE review.

The budget for the proposed work is $249,900. Details are provided in the attachment along with the budget justification. We are excited about continuing our collaborations with the University of North Dakota, and look forward to a successful project. If there are any questions, please do not hesitate to contact me.

Sincerely,



Srivats Srinivasachar
President, Envergex LLC
(508) 347-2933
Email: srivats.srinivasachar@envergex.com

November 16, 2022

Dan Laudal, Ph.D.
Director | Institute for Energy Studies
College of Engineering & Mines
University of North Dakota
Sent via email: daniel.laudal@und.edu

Subject: Letter of commitment for Phase 1

Dear Dr. Laudal,

This letter confirms Odney, Inc.'s commitment to your proposal to the U.S. Department of Energy (DE-FOA-0002618) entitled "FEED Study: Recovery and refining of rare earth elements from lignite mine wastes."

Odney is a full-service communications company with extensive experience in community and stakeholder outreach. Our experience is also specific with respect to the communities impacted by this project.

Our proposed scope of work for this project includes research, preliminary interviews, stakeholder identification and analysis, and development and execution of the Community, Labor, and Stakeholder Engagement Plan.

Our proposed budget for the above scope of work is $130,800, consisting of an estimated 1,090 of staff labor hours at an average rate of $120/hour.

We are very excited to partner with the UND team on this project and we look forward to hearing of a successful proposal outcome.

Sincerely,

Shane Goettle
CEO
117 West Front Avenue
P.O. Box 2035
Bismarck, ND 58502-2035
Office: 701.557.7592
Cell: 701.426.0576
www.odney.com

Dennis James Consulting LLC

Office: (972) 908-2730
Mobile: (214) 914-5778

1806 Longwood Court
Allen, TX 75013

Email: djamesconsulting@att.net

November 14, 2022

Dan Laudal, Ph.D.
Director, Institute for Energy Studies
College of Engineering & Mines
University of North Dakota
Sent via email: daniel.laudal@und.edu

Re: Letter of commitment for Phase 1

Dear Dr. Laudal,

This letter confirms Dennis James Consulting LLC's commitment to your proposal to the U.S. Department of Energy (DE-FOA-0002618) entitled "FEED Study: Recovery and refining of rare earth elements from lignite mine wastes."

I have been involved in the geology and geochemistry of North Dakota lignites for over 40 years. I have also been involved with the University of North Dakota's rare earth elements (REE) extraction projects since their inception. As such, I have a keen interest in continued involvement in the development of an industry to commercially extract REE from lignite.

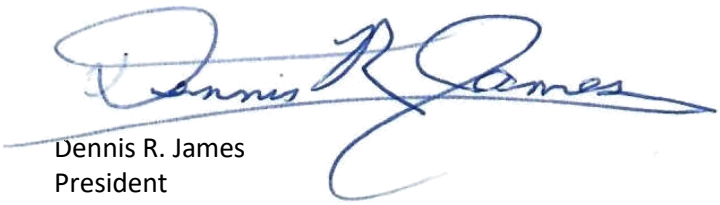
Dennis James Consulting LLC's scope of work for the project will be primarily two parts. I will assist the project in developing and planning processes to handle and crush the lignite. I will also work with others on business development plans and coordinating mine activities with the REE plant.

Our proposed budget for the above scope of work is $66,000.00, as detailed in our budget justification.

We are very excited to partner with the UND team on this project and we look forward to hearing of a successful proposal outcome.

Sincerely,

Dennis James Consulting LLC



Dennis R. James
President

MLJ Consulting
841 Orchard Circle
Grand Forks, ND 58201

November 5, 2022

Dan Laudal, Ph.D.
Director | Institute for Energy Studies
College of Engineering & Mines
University of North Dakota
Sent via email: daniel.laudal@und.edu

Subject: Letter of commitment for Phase 1

Dear Dr. Laudal,

This letter confirms MLJ Consulting's commitment to your proposal to the U.S. Department of Energy (DE-FOA-0002618) entitled "FEED Study: Recovery and refining of rare earth elements from lignite mine wastes."

MLJ Consulting was founded in 2017 and is focused on exploiting the properties of low-rank coals to develop additional revenue streams that will allow for environmentally sound use of these resources. Michael L Jones, PhD is the principal of MLJ Consulting and has over 40 years experience working with low-rank coal resources. Recent work has explored ND lignite resources as a significant domestic source of rare earth elements.

MLJ Consulting will work with the assembled team on the development of the business plan for the activity as well as developing the financing plan for the proposed demonstration facility. We believe we will be successful in developing a financial plan that includes significant support from the private sector, the State of North Dakota, and the federal government.

The proposed budget for MLJ Consulting for the above scope of work is $49,875 based on 285 hours of effort over 15 months.

I am very excited to partner with the UND team on this project and we look forward to being notified of a successful proposal outcome.

Sincerely,

Michael Jones

Michael L Jones, PhD
President, MLJ Consulting
701-739-1419
Jones_ml2003@yahoo.com

APPENDIX 3 – HOST-SITE COMMITMENT LETTERS

BNI energy

AN ALLETE COMPANY

November 14, 2022

Dan Laudal, Ph.D.
Director | Institute for Energy Studies
College of Engineering & Mines
University of North Dakota

Sent via email: daniel.laudal@und.edu

Subject: Phase 1 host-site commitment letter and expression of interest in Phase 2

Dear Dr. Laudal,

This letter expresses BNI Energy's (BNI) interest in being a host-site for the REE Demonstration Facility that is outlined in your proposal to the U.S. Department of Energy (DE-FOA-0002618) entitled "FEED Study: Recovery and refining of rare earth elements from lignite mine wastes."

BNI owns and operates the Center Mine near Center, ND. Center Mine has an annual lignite coal production of about 4 million tons and provides lignite to the adjacent Milton R. Young Station.

This letter confirms our willingness to serve as a host-site for Phase 1 and to engage with your team during the Phase 1 project to provide technical, economic, environmental and business/commercial information related to the FEED study and economic assessment of the REE Demonstration Facility. We also confirm our interest in evaluating the results of the FEED study to determine whether this is a commercial opportunity that we would like to pursue if your team is successful in moving on to Phase 2, the construction and operation phase. This letter is only a commitment for the Phase 1 evaluation and an expression of interest in Phase 2. If Phase 2 proves to be an opportunity we would like to pursue, contracts and other legal/commercial agreements would need to be drafted and executed at a later date.

BNI has been a long-time supporter of your technology development and we recognize the value that your technology can bring to our company, the lignite industry as a whole, the state of ND and the country. We hope the DOE gives your proposal serious consideration and we look forward to hearing of a successful proposal outcome and beginning work on this exciting project.

Sincerely,

Mike Heger
General Manager – BNI Energy

Minnkota Power COOPERATIVE
A Touchstone Energy® Cooperative

5301 32nd Avenue South
Grand Forks, ND 58201

Phone 701.795.4000
www.minnkota.com

November 10, 2022

Dan Laudal, Ph.D.
Director | Institute for Energy Studies
College of Engineering & Mines
University of North Dakota
Sent via email: daniel.laudal@und.edu

Subject: Phase 1 host-site commitment letter and expression of interest in Phase 2

Dear Dr. Laudal,

This letter expresses Minnkota Power Cooperative's (MPC) interest in being a host-site for the REE Demonstration Facility that is outlined in your proposal to the U.S. Department of Energy (DE-FOA-0002618) entitled "FEED Study: Recovery and refining of rare earth elements from lignite mine wastes."

MPC operates the Milton R. Young Station, a 2-unit 705 MW power plant near Center, ND. MPC owns Unit 1, and our affiliate company Square Butte Electric Cooperative owns Unit 2. MPC operates both of the Units. MRYS purchases over 4 million tons/year of lignite coal from the adjacent Center Mine, operated by BNI Coal, Ltd.

This letter confirms our willingness to serve as a host-site for Phase 1 and to engage with your team during the Phase 1 project to provide technical, economic, environmental and business/commercial information related to the FEED study and economic assessment of the REE Demonstration Facility. We also confirm our interest in evaluating the results of the FEED study to determine whether this is a commercial opportunity that we would like to pursue if your team is successful in moving on to Phase 2, the construction and operation phase. This letter is only a commitment for the Phase 1 evaluation and an expression of interest in Phase 2. If Phase 2 proves to be an opportunity we would like to pursue, contracts and other legal/commercial agreements would need to be drafted and executed at a later date.

MPC has been a long-time supporter of your technology development and we recognize the value that your technology can bring to our company, the lignite industry as a whole, the state of ND and the country. We hope the DOE gives your proposal serious consideration and we look forward to hearing of a successful proposal outcome and beginning work on this exciting project.

Sincerely,

Craig J. Bleth

Craig J. Bleth, P.E.
Vice President of Project Development
Minnkota Power Cooperative
cbleth@minnkota.com

North American COAL

November 17, 2022

Dan Laudal, Ph.D.
Director | Institute for Energy Studies
College of Engineering & Mines
University of North Dakota

Sent via email: daniel.laudal@und.edu

Subject: Phase 1 host-site commitment letter and expression of interest in Phase 2

Dear Dr. Laudal,

This letter expresses North American Coal's (NACoal) interest in being a host-site for the REE Demonstration Facility that is outlined in your proposal to the U.S. Department of Energy (DE-FOA-0002618) entitled "FEED Study: Recovery and refining of rare earth elements from lignite mine wastes."

Falkirk Mining Company, a subsidiary of NACoal, owns and operates the Falkirk Mine near Underwood, ND. Falkirk Mine has an annual lignite coal production of about 8 million tons and provides lignite to the adjacent Coal Creek Station, the largest power plant in ND.

This letter confirms our willingness to serve as a host-site for Phase 1 and to engage with your team during the Phase 1 project to provide technical, economic, environmental and business/commercial information related to the FEED study and economic assessment of the REE Demonstration Facility. We also confirm our interest in evaluating the results of the FEED study to determine whether this is a commercial opportunity that we would like to pursue if your team is successful in moving on to Phase 2, the construction and operation phase. This letter is only a commitment for the Phase 1 evaluation and an expression of interest in Phase 2. If Phase 2 proves to be an opportunity we would like to pursue, contracts and other legal/commercial agreements would need to be drafted and executed at a later date.

North American Coal has been a long-time supporter of your technology development and we recognize the value that your technology can bring to our company, the lignite industry as a whole, the state of ND and the country. We hope the DOE gives your proposal serious consideration and we look forward to hearing of a successful proposal outcome and beginning work on this exciting project.

Sincerely,
THE NORTH AMERICAN COAL CORPORATION

Carroll L. Dewing
Vice President – Operations

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

RAINBOW
ENERGY CENTER

November 16, 2022

Dan Laudal, Ph.D.
Director | Institute for Energy Studies
College of Engineering & Mines
University of North Dakota

Sent via email: daniel.laudal@und.edu

Subject: Phase 1 host-site commitment letter and expression of interest in Phase 2

Dear Dr. Laudal,

This letter expresses Rainbow Energy Center's interest in being a host-site for the REE Demonstration Facility that is outlined in your proposal to the U.S. Department of Energy (DE-FOA-0002618) entitled "FEED Study: Recovery and refining of rare earth elements from lignite mine wastes."

Earlier this year, Rainbow Energy Center LLC (Rainbow), an affiliate of Rainbow Energy Marketing Corporation, purchased the Coal Creek Station, a 1,151 MW lignite-fired power plant near Underwood, ND. Coal Creek Station is North Dakota's largest power plant, and purchases about 8 million tons/year of lignite from the adjacent Falkirk Mine.

This letter confirms our willingness to serve as a host-site for Phase 1 and to engage with your team during the Phase 1 project to provide technical, economic, environmental and business/commercial information related to the FEED study and economic assessment of the REE Demonstration Facility. We also confirm our interest in evaluating the results of the FEED study to determine whether this is a commercial opportunity that we would like to pursue if your team is successful in moving on to Phase 2, the construction and operation phase. This letter is only a commitment for the Phase 1 evaluation and an expression of interest in Phase 2. If Phase 2 proves to be an opportunity we would like to pursue, contracts and other legal/commercial agreements would need to be drafted and executed at a later date.

Rainbow is interested in supporting your project development, as we recognize the value that your technology can bring to our company, the lignite industry as a whole, the state of ND and the country. We hope the DOE gives your proposal serious consideration and we look forward to hearing of a successful proposal outcome and engaging with your team on this exciting project.

Sincerely,

Stacy L. Tschider
President

919 S 7th St., Ste. 405 | PO Box 837 | Bismarck, ND 58502 | Phone: 701.222.2290 | Fax: 701.255.7952 | rainbowenergycenter.com

RARE EARTH SALTS

5331 Element Avenue
Beatrice, NE 68310
(402) 806-4400

November 14, 2022

Dan Laudal, Ph.D.
Director | Institute for Energy Studies
College of Engineering & Mines
University of North Dakota
Sent via email: daniel.laudal@und.edu

Subject: Host Site Commitment Letter

Dear Dr. Laudal,

This letter confirms Rare Earth Salt's commitment to your proposed project to the U.S. Department of Energy (DE-FOA-0002618) entitled "FEED Study: Recovery and refining of rare earth elements from lignite mine wastes."

Rare Earth Salts (RES), a Nebraska limited liability company, is a producer of rare earth oxides that has developed a novel, patented approach proven to separate and refine all 16 rare earth elements (REEs) to purities between 99 and 99.99%. The process is environmentally friendly and has an expected to have a lower cost per kilogram separated than a traditional Chinese solvent extraction (SX) facility (~2-4$/kg vs $4-6/kg) and up to an 50% reduction in Capex as compared to a similarly sized SX facility. This significantly reduces the cost of the development, acquisition, sustainment, and total ownership of domestically sourced REEs.

RES will apply our novel green separations and refining technologies to concentrates provided from the lignite mine waste to generate cost competitive refined rare earth oxide products. RES has also developed unique chemistries and processes for the metallization or rare earth elements for use in magnet production in a closed-loop environmentally friendly manner.

We are very excited to partner with the UND team on this project and we look forward to hearing of a successful proposal outcome.

Sincerely,

Joseph R Brewer, PhD

CTO and President

joseph.brewer@rareearthsalts.com 402-806-4400

APPENDIX 4 – DOE AWARD NOTIFICATION LETTER

April 3, 2023

SENT VIA ELECTRONIC MAIL

University of North Dakota
Attn: Daniel Laudal
Tech Accelerator Room 2050
4201 James Ray Drive, Stop 8367
Grand Forks, ND 58202-8367
daniel.laudal@und.edu

SUBJECT: Selection of Application for Negotiation Under Funding Opportunity Announcement Number DE-FOA-0002618, titled "BIL - Rare Earth Element Demonstration Facility"

Dear Daniel Laudal:

We are pleased to provide this update on your application. The Department of Energy's DOE), Office of Fossil Energy and Carbon Management (FECM) in collaboration with the Office of Manufacturing and Energy Supply Chains (MESC) has completed its evaluation of your application submitted in response to the subject Funding Opportunity Announcement (FOA). The application below has been recommended by FECM for negotiation of a financial award (Note: This notification does not guarantee Federal Government funding, as funding will only be obligated upon completion of successful negotiations):

Application: Recovery and refining of rare earth elements from lignite mine wastes, Daniel Laudal, GRANT13758729

Receipt of this letter does not authorize you to commence with performance of the project. DOE makes no commitment to issue an award and assumes no financial obligation with the issuance of this letter. Applicants do not receive an award until award negotiations are complete and the Contracting Officer executes the funding agreement. Only an award document signed by the Contracting Officer obligates DOE to support a project.

DOE intends to make a public announcement of the selections and requests that your organization and subrecipients do not make any announcement of your selection prior to the DOE announcement. At the time of the announcement, we will provide you with a link to the announcement and inform you that the embargo has officially been lifted via subsequent email. You will then be free (and encouraged) to announce your selection publicly.

The award negotiation process may take up to 90 days. You must be responsive during award negotiations (i.e., provide requested documentation) and meet the stated negotiation deadlines. Failure to submit the requested information and forms by the stated due date, or any failure to conduct award negotiations in a timely and responsive manner, may cause DOE to cancel award negotiations and rescind this selection. DOE reserves the right to terminate award negotiations at any time for any reason.

Please complete the following items and submit to DOE no later than 04/10/2023:

- Pre-Award Information Sheet (available at https://www.netl.doe.gov/business/business-forms/financial-assistance)
- Copies of updated rate agreement(s), if applicable

If your organization, including any subrecipient or contractor, anticipates involving foreign nationals (FNs) in the performance of the award, your organization is required to provide a list of all FNs planned to participate on the award along with basic information about each. You must download and complete the "Foreign National Participation Document" located at https://www.netl.doe.gov/business/business-forms/financial-assistance under Post Selection Forms/Information and submit the completed document to basicinfo@netl.doe.gov with a courtesy copy to the assigned Project Manager (PM) and the DOE Award Administrator.

Upon receipt of the completed "Foreign National Participation Document," we will create a secured file sharing drop box folder(s) for **FNs in Principal Investigator (PI)/Co-PI roles, for FNs from countries of risk (i.e., China, Iran, North Korea and Russia), and for FNs from countries identified on the U.S. Department of State's list of State Sponsors of Terrorism located at https://www.state.gov/state-sponsors-of-terrorism/ for submission of additional information**. The additional information will NOT be required for any of the other FNs planned to participate on the award, and therefore, a folder(s) will not be created.

As part of the requirement to submit additional information for PIs/Co-PIs, for FNs from countries at risk, and for FNs from countries identified as State Sponsors of Terrorism, your organization must ensure completion of the "Foreign National Participation **Data** Document" also located at https://www.netl.doe.gov/business/business-forms/financial-assistance. The document and all required attachments must be uploaded to the secured file sharing drop box folder(s) provided by DOE's FN Request Coordinator. The assigned PM will contact the appropriate FN Data Entry POC in the event there are issues with the submission.

Please note that all FNs in PI/Co-PI roles, FNs from countries of risk, and FNs from countries identified on the U.S. Department of State's list of State Sponsors of Terrorism are **NOT** permitted to participate on the award until written authorization is received from the Contracting Officer.

The Contracting Officer will notify your organization of DOE's decision regarding the participation of FNs in PI/Co-PI roles, from countries of risk (i.e., China, Iran, North

Korea, and Russia), and from countries identified on the U.S. Department of State's list of State Sponsors of Terrorism**.** The DOE reserves the right to request additional information or deny participation of any FN at any time.

Please provide the requested documents to the attention of Carla Winaught, who is the DOE Award Administrator from the Finance and Acquisition Center handling the administrative portion of your application. Ms. Carla Winaught can be reached at 304-285-4530 or Carla.Winaught@netl.doe.gov. Mr. Michael Fasouletos is the DOE Project Manager from the Project Management Division handling the technical portion of your application and can be reached at 304-285-5335 or Michael.Fasouletos@netl.doe.gov.

Sincerely,

Ashley Reichl

Ashley E. Reichl
Contracting Officer
Finance and Acquisition Center

cc: FOA File
Basicinfo@netl.doe.gov
Sherry Zeman, sherry.zeman@und.edu
Michael Fasouletos, NETL Project Manager, michael.fasouletos@netl.doe.gov
Carla Winaught, Contract Specialist, Carla.Winaught@netl.doe.gov

APPENDIX 5 – LETTERS OF INTEREST

AmeriCarbon

November 1, 2022

Dan Laudal, Ph.D.
Director | Institute for Energy Studies
College of Engineering & Mines
University of North Dakota
Sent via email: daniel.laudal@und.edu

Subject: Expression of ownership interest

Dear Dr. Laudal:

This letter confirms AmeriCarbon Enterprises, LLC's (AmeriCarbon) interest in evaluating an ownership role in the REE Demonstration Facility outlined in your proposal to the U.S. Department of Energy (DE-FOA-0002618) entitled "FEED Study: Recovery and refining of rare earth elements from lignite mine wastes."

AmeriCarbon owns the proprietary and patented Eco-Pitch™ process, which produces tailored pitch products from domestic coal with >99% GHG reduction relative to current coal tar pitch supply. Our team has been evaluating opportunities in North Dakota to locate a commercial pitch production facility that would use lignite coal as the feedstock. Lignite's unique properties provide key advantages for pitch production. Based on our collaboration with your team relating to carbon-based products development, we are extremely excited about the potential to use the REE-extracted lignite material that you will produce at your proposed REE Demonstration Facility. Specifically, this material could be an extremely valuable feedstock for our pitch plant. As such, we are interested in exploring ownership/investment possibilities in the proposed REE facility to leverage this synergy.

We envision forming a special purpose entity (SPE), in the form of a joint venture with other stakeholders, to commercialize the REE technology. The SPE would build, own, and operate the REE Demonstration Facility. AmeriCarbon would establish the entity with its capital partners and seek co-investment the North American Coal Corporation and other key stakeholders. Prior to Phase 2 of the proposed project, the SPE would seek an exclusive license from the University of North Dakota (UND).

AmeriCarbon and its engineering contractors will also work with UND and its commercial partners to develop plans for linkage and integration of the REE Demonstration Facility product stream as a feedstock for AmeriCarbon's commercial pitch production facility. The parties would develop protocols for ensuring arm's length agreements among the coal suppliers, the SPE, AmeriCarbon, and all purchasers of offtake products from the REE Demonstration Facility.

AmeriCarbon has initiated engineering design for its commercial facility and has secured funding commitments for the initial phases of facility development. We have ongoing discussions with companies seeking to purchase pitch from our facility and our anticipated timelines for construction of the pitch production facility are in advance of the REE Demonstration Facility (and are not dependent thereon). We hope the DOE gives your proposal serious consideration and we look forward to hearing of a successful proposal outcome and beginning work on this exciting project.

Sincerely,

David A. Berry
Chief Executive Officer
AmeriCarbon Enterprises, LLC
david.berry@americarbon.com
(740) 644-1303

RAINBOW
ENERGY CENTER

November 16, 2022

Dan Laudal, Ph.D.
Director | Institute for Energy Studies
College of Engineering & Mines
University of North Dakota

Sent via email: daniel.laudal@und.edu

Subject: Letter of interest in purchase of REE-extracted lignite from the proposed REE Demonstration Facility

Dear Dr. Laudal,

This letter expresses Rainbow Energy Center's interest in purchasing the upgraded lignite material that would be produced at the proposed REE Demonstration Facility that is outlined in your proposal to the U.S. Department of Energy (DE-FOA-0002618) entitled "FEED Study: Recovery and refining of rare earth elements from lignite mine wastes."

Earlier this year, Rainbow Energy Center LLC (Rainbow), an affiliate of Rainbow Energy Marketing Corporation, purchased the Coal Creek Station, a 1,151 MW lignite-fired power plant near Underwood, ND. Coal Creek Station is North Dakota's largest power plant, and purchases about 8 million tons/year of lignite from the adjacent Falkirk Mine. We understand that your proposed REE Demonstration facility would use lignite mine wastes from the Falkirk Mine, and after the REE processing would yield a unique and high-quality lignite coal that may be an ideal blending fuel for the Coal Creek Station. Specifically, we understand that your technology would create a low-sodium (essentially zero) fuel that could significantly decrease boiler fouling and operational/efficiency challenges at Coal Creek Station.

This letter confirms our willingness to engage with your team during the Phase 1 project to provide technical information related to our coal feed requirements and to evaluate the potential value of your unique lignite coal byproduct. This letter is only an expression of interest. If Phase 2 proves to be an opportunity we would like to pursue, contracts and other legal/commercial agreements would need to be drafted and executed at a later date.

Rainbow is interested in supporting your project development, as we recognize the value that your technology can bring to our company, the lignite industry as a whole, the state of ND and the country. We hope the DOE gives your proposal serious consideration and we look forward to hearing of a successful proposal outcome and engaging with your team on this exciting project.

Sincerely,

Stacy L. Tschider
President

919 S 7th St., Ste. 405 | PO Box 837 | Bismarck, ND 58502 | Phone: 701.222.2290 | Fax: 701.255.7952 | rainbowenergycenter.com

Minnkota Power COOPERATIVE
A Touchstone Energy® Cooperative

5301 32nd Avenue South
Grand Forks, ND 58201

Phone 701.795.4000
www.minnkota.com

November 10, 2022

Dan Laudal, Ph.D.
Director | Institute for Energy Studies
College of Engineering & Mines
University of North Dakota
Sent via email: daniel.laudal@und.edu

Subject: Letter of interest in purchase of REE-extracted lignite from the proposed REE Demonstration Facility

Dear Dr. Laudal,

This letter expresses Minnkota Power Cooperative's (MPC) interest in purchasing the upgraded lignite material that would be produced at the proposed REE Demonstration Facility that is outlined in your proposal to the U.S. Department of Energy (DE-FOA-0002618) entitled "FEED Study: Recovery and refining of rare earth elements from lignite mine wastes."

MPC is the operator of the Milton R. Young Station (MRYS), a 2-unit 705 MW lignite-fired power plant near Center, ND. MRYS purchases about 4 million tons/year of lignite coal from the adjacent Center Mine, operated by BNI Coal, Ltd. We understand that your proposed REE Demonstration facility would use lignite mine wastes from the Center Mine, and after the REE processing could yield a unique and high-quality lignite coal that may be an ideal blending fuel for the MRYS. Specifically, we understand that your technology would create a low-sodium (essentially zero) fuel that could contribute to decreased boiler fouling and operational/efficiency challenges at the MRYS.

This letter confirms our willingness to engage with your team during the Phase 1 project to provide technical information related to our coal feed requirements and to evaluate the potential value of your unique lignite coal byproduct. This letter is only an expression of interest. If Phase 2 proves to be an opportunity we would like to pursue, contracts and other legal/commercial agreements would need to be drafted and executed at a later date.

MPC has been a long-time supporter of your technology development and we recognize the value that your technology can bring to our company, the lignite industry as a whole, the state of ND and the country. We hope the DOE gives your proposal serious consideration and we look forward to hearing of a successful proposal outcome and engaging with your team on this exciting project.

Sincerely,

Craig J. Bleth

Craig J. Bleth, P.E.
Vice President of Project Development
Minnkota Power Cooperative
cbleth@minnkota.com

November 7, 2022

Dan Laudal, Ph.D.
Director | Institute for Energy Studies
College of Engineering & Mines
University of North Dakota

Sent via email: daniel.laudal@und.edu

Subject: Letter of interest in purchasing Ge/Ga products

Dear Dr. Laudal,

Lattice Materials is encouraged by the results of bench- and pilot-scale testing to recover Rare Earth Elements and Critical Minerals such as germanium and gallium conducted by the UND Team that includes: Microbeam Technologies Inc, Barr Engineering, Rare Earth Salts and several others. We understand that the project Team is submitting a proposal entitled "FEED Study: Recovery and refining of rare earth elements from lignite mine wastes" to the U.S. Department of Energy (DE-FOA-0002618). This letter expresses Lattice Material's interest in purchasing germanium products that would be produced at the proposed REE Demonstration Facility.

Lattice Materials is the world's leading manufacturer of silicon and germanium parts. With over 30,000 sq ft of space and capabilities ranging from crystal growth to polishing and even thin film coating of parts, we're the go-to source for top defense contractors, national labs, semiconductor fabs and many others. As one of the only sources for domestically grown silicon and germanium, Lattice Materials is trusted for the most difficult, high risk and sensitive projects. In-house experts from the customer service department through every step of production are ready to help with your project. Lattice Materials is an American company, founded in 1989 and based in Bozeman, Montana. Our mission has always been to provide our customers with world-class service, competitive pricing, flawless quality, and rapid delivery. In short, we aim for total customer satisfaction and our continued growth proves that we are meeting that goal.

This letter confirms our willingness to engage with your team during the Phase 1 project to provide technical information related to our required purchasing specifications and to work with your team to evaluate the quality and value of your Ge products. This letter is only an expression of interest. If Phase 2 proves to be an opportunity we would like to pursue, contracts and other legal/commercial agreements would need to be drafted and executed at a later date.

We understand that your technology is a particularly promising source of domestic Ge/Ga production. We are excited at the prospects of a new domestic resource of raw materials for our business and wish you success in your proposal to DOE.

If you have questions and require additional information, please contact me at 406-556-5743 or jessicah@latticematerials.com.

Sincerely,

Jessica Higgins
President
Lattice Materials LLC

AmeriCarbon

November 1, 2022

Dan Laudal, Ph.D.
Director | Institute for Energy Studies
College of Engineering & Mines
University of North Dakota
Sent via email: daniel.laudal@und.edu

Subject: Letter of interest in purchase of REE-extracted lignite from the proposed REE Demonstration Facility

Dear Dr. Laudal:

This letter confirms AmeriCarbon Enterprises, LLC's (AmeriCarbon) interest in purchasing the upgraded lignite material that would be produced at the proposed REE Demonstration Facility that is outlined in your proposal to the U.S. Department of Energy (DE-FOA-0002618) entitled "FEED Study: Recovery and refining of rare earth elements from lignite mine wastes."

AmeriCarbon owns the proprietary and patented Eco-Pitch™ process, which produces tailored pitch products from domestic coal with >99% GHG reduction relative to current coal tar pitch supply. Our pitch can be used for a wide range of applications, including graphite and carbon electrodes, structural panels, carbon fibers, lithium ion batteries, and conductive/insulating foams. Our team has been evaluating opportunities in North Dakota to locate a commercial pitch production facility that would use lignite coal as the feedstock. Lignite's unique properties provide key advantages for pitch production. Based on our collaboration with your team relating to carbon-based products development, we are extremely excited about the potential to use the REE-extracted lignite material that you will produce at your proposed REE Demonstration Facility. Specifically, this material could be an extremely valuable feedstock for our pitch plant.

This letter confirms our willingness to engage with your team during the Phase 1 project to provide technical information related to our coal feed requirements and to evaluate the potential value of your unique lignite coal byproduct. This letter is only an expression of interest. If Phase 2 proves to be an opportunity we would like to pursue, contracts and other legal/commercial agreements would need to be drafted and executed at a later date.

We hope the DOE gives your proposal serious consideration and we look forward to hearing of a successful proposal outcome and beginning work on this exciting project.

Sincerely,

David A. Berry
Chief Executive Officer
AmeriCarbon Enterprises, LLC
david.berry@americarbon.com
(740) 644-1303

North American COAL

November 17, 2022

Dan Laudal, Ph.D.
Director | Institute for Energy Studies
College of Engineering & Mines
University of North Dakota

Sent via email: daniel.laudal@und.edu

Subject: Letter of interest in feedstock supply to the proposed REE Demonstration Facility

Dear Dr. Laudal,

This letter expresses North American Coal's (NACoal) interest in being a feedstock supplier to the proposed REE Demonstration Facility that is outlined in your proposal to the U.S. Department of Energy (DE-FOA-0002618) entitled "FEED Study: Recovery and refining of rare earth elements from lignite mine wastes."

Falkirk Mining Company, a subsidiary of NACoal, owns and operates the Falkirk Mine near Underwood, ND. Falkirk Mine has an annual lignite coal production of about 8 million tons and provides lignite to the adjacent Coal Creek Station, the largest power plant in ND. We understand that your proposed technology and facility would use lignite mine waste materials, the REE-enriched materials located at the margins of our coal seams and in thin seams that are today not used for power production.

This letter confirms our willingness to engage with your team during the Phase 1 project to provide feedstock-specific information related to the FEED study and economic assessment of the REE Demonstration Facility. We also confirm our interest in evaluating the results of the FEED study to determine whether this is a commercial opportunity that we would like to pursue if your team is successful in moving on to Phase 2, the construction and operation phase. This letter is only an expression of interest. If Phase 2 proves to be an opportunity we would like to pursue, contracts and other legal/commercial agreements would need to be drafted and executed at a later date.

North American Coal has been a long-time supporter of your technology development and we recognize the value that your technology can bring to our company, the lignite industry as a whole, the state of ND and the country. We hope the DOE gives your proposal serious consideration and we look forward to hearing of a successful proposal outcome and beginning work on this exciting project.

Sincerely,
THE NORTH AMERICAN COAL CORPORATION

Carroll L Dewing

Carroll L. Dewing
Vice President – Operations

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

BNI energy

AN ALLETE COMPANY

November 14, 2022

Dan Laudal, Ph.D.
Director | Institute for Energy Studies
College of Engineering & Mines
University of North Dakota

Sent via email: daniel.laudal@und.edu

Subject: Letter of interest in feedstock supply to the proposed REE Demonstration Facility

Dear Dr. Laudal,

This letter expresses BNI Coal Ltd.'s (BNI) interest in being a feedstock supplier to the proposed REE Demonstration Facility that is outlined in your proposal to the U.S. Department of Energy (DE-FOA-0002618) entitled "FEED Study: Recovery and refining of rare earth elements from lignite mine wastes."

BNI owns and operates the Center Mine, near Center, ND. Center Mine has an annual lignite coal production of about 4 million tons and provides lignite to the adjacent Milton R. Young Station. We understand that your proposed technology and facility would use lignite mine waste materials, the REE-enriched materials located at the margins of our coal seams and in thin seams that are today not used for power production.

This letter confirms our willingness to engage with your team during the Phase 1 project to provide feedstock-specific information related to the FEED study and economic assessment of the REE Demonstration Facility. We also confirm our interest in evaluating the results of the FEED study to determine whether this is a commercial opportunity that we would like to pursue if your team is successful in moving on to Phase 2, the construction and operation phase. This letter is only an expression of interest. If Phase 2 proves to be an opportunity we would like to pursue, contracts and other legal/commercial agreements would need to be drafted and executed at a later date.

BNI has been a long-time supporter of your technology development and we recognize the value that your technology can bring to our company, the lignite industry as a whole, the state of ND and the country. We hope the DOE gives your proposal serious consideration and we look forward to hearing of a successful proposal outcome and beginning work on this exciting project.

Sincerely,

Mike Heger
General Manager – BNI Energy

NORTH DAKOTA STATE BUILDING AND CONSTRUCTION TRADES COUNCIL

2901 Twin City Dr. Suite 201
Mandan, North Dakota 58554
(701) 663-8821

November 16, 2022

Dan Laudal, Ph.D.
Director | Institute for Energy Studies
College of Engineering & Mines
University of North Dakota

Subject: Letter of Support for the Phase I Front End Engineering & Design Study

Dear Dr. Laudal,

This Letter of Support represents a shared understanding and commitment between the North Dakota State Building and Construction Trades Council (North Dakota's Building Trades Unions), the University of North Dakota, and your project team to implement a Project Labor Agreement (PLA) for the proposed Rare Earth Elements Demonstration Facility that is outlined in your proposal to the U.S. Department of Energy (DE-FOA-0002618) entitled "FEED Study: Recovery and Refining of Rare Earth Elements from Lignite Mine Wastes."

North Dakota's Building Trades Unions is very excited about this opportunity, and we look forward to engaging with your team during Phase I of the project to prepare for the ultimate goal of Phase II, "Construction and Operation". During this engagement in Phase I, it is agreed by all parties to work in concert to develop the PLA for the Community Benefits Plan that will address the following: 1) the Quality Jobs Plan, 2) Diversity, Equity, Inclusion, and Accessibility Plan, 3) Justice40 Initiative Plan, and 4) Community, Labor, and Stakeholder Engagement Plan.

Sincerely,

Jason Ehlert
President
701.541.2989
Jason@ndbtu.org

North Dakota's Building Trades Unions is comprised of fifteen Labor Organizations with thousands of local union members in the state. Our members work in all aspects of construction, civil, commercial, heavy and industrial and have been servicing the energy generation industry for decades. From foundation to finish, we have been leading the way to promote careers in construction through family supporting wages and benefits, Registered Apprenticeship Programs, and a high emphasis on safety that have led to several generations of craftsperson's in local communities across North Dakota.

APPENDIX 6 – UND TAX LIABILITY STATEMENT

Industrial Commission

Tax Liability Statement

Applicant:
University of North Dakota

Application Title:
Recovery and Refining of Rare Earth Elements from Lignite Mine Wastes

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.

Karen Katrinak

Signature

Karen Katrinak
Proposal Development Officer

Title

April 13, 2023

Date

APPENDIX 7 – RESUMES OF KEY PERSONNEL

Dr. Daniel A. Laudal
daniel.laudal@und.edu
701-777-5745

Education and Training

University of North Dakota	Chemical Engineering	B.S. 2006
University of North Dakota	Chemical Engineering	Ph.D. 2017

Research and Professional Experience

2022-Present Research (full) Professor, Department of Chemical Engineering
2021-Present Director, UND Institute for Energy Studies (IES)
Leading the research and academic programs in Energy at the College of Engineering & Mines. Help realize the IES goal of developing UND into a premier "Energy University" that "inspires the creation of new knowledge to enable the development of revolutionary energy technologies, train the next generation of energy experts, and establish advanced industries required to make affordable emissions free energy technologies a reality". Responsibilities include identifying key technical and economic barriers to the development of secure, affordable, and reliable energy production technologies; identifying proposal opportunities and develop new relationships with potential partners; and drawing from resources across campus building teams to deliver the research, education, and outreach required to meet the needs of public and private partners.

2019-2021 Environmental Manager / Project Tundra Project Manager, Minnkota Power Coop.
Led the environmental regulatory compliance and environmental planning efforts for a generation & transmission cooperative serving eastern ND and northwestern MN. As Project Tundra Project Manager, led Minnkota's development of a $1.5B world-scale carbon capture and storage project for the Milton R. Young Station, a lignite coal fired power plant in ND. Responsibilities included leading development of the design, permitting and financing of the carbon capture plant and geologic storage facility.

2016-2018 Manager: Major Projects, UND Institute for Energy Studies.
Primary roles included developing and writing funding proposals, managing research projects, coordinating IES research staff and students, and process design/development of innovative solutions to challenges in the energy industry. Principal Investigator or Project Manager or several DOE, State and industry funded projects. Research focused on the following major areas: carbon management for the power industry, production of co-products from coal and associated materials, value-added opportunities/technology development for North Dakota's energy industries.

2012-2015 Research Engineer, UND Institute for Energy Studies.
Lead researcher or principal investigator on several federal, state and industry funded projects. Work involved early-stage R&D of novel processes and technologies, primarily focusing on laboratory- and bench-scale demonstrations. Areas of focus included chemical looping combustion and post combustion carbon dioxide capture.

2008-2012 Research Engineer, UND Energy & Environmental Research Center.
Research involved design and operation of various lab and pilot-scale gasification, combustion and advanced power systems. Gained invaluable experience with high pressure and high temperature systems and fluidized beds.

2006-2008 Field Engineer, Schlumberger Oilfield Services.
Design, execution and evaluation of well cementing operations in the Williston Basin.

Selected Publications/Patents

Laudal, D., Benson, S. "Rare earth element extraction from coal." U.S. Patent No. 10,669,610. March 2017

Theaker, N., **Laudal, D.,** Lucky, C. "Generation of rare earth elements from organically associated leach solutions." U.S. Patent Application No. 17/519,346. Filed May 2022.

Theaker, N., **Laudal, D.** "Method for leaching rare earth elements and critical minerals from organically associated materials." U.S. Patent Application No. 17/519,341. Filed May 2022.

Laudal, D., Benson, S., Addleman, S., Palo, D. "Leaching behavior of rare earth elements in Fort Union lignite coals of North America." International Journal of Coal Geology 191 (2018) 112-124.

Laudal, D., Benson, S., Addleman, S., Palo, D. "Rare earth elements in North Dakota lignite coal and lignite-related materials." ASME Journal of Energy Resources and Technology 140 (2018).

Park, D., Middleton, A., Smith, R., Deblonde, G., **Laudal, D.,** Theaker, N., Hsu-Kim, H., Jia, Y. "A biosorption-based approach for selective extraction of rare earth elements from coal byproducts." Separation and Purification Technology. Volume 241:116726. June 2020.

Van der Watt, J.G., **Laudal, D**., Krishnamoorthy, G., Feilen, H., Mann, M., Shallbetter, R., Nelson, T., Srinivasachar, S. "Development of a spouted bed reactor for chemical looping combustion." Journal of Energy Resources and Technology. 140(11), 112002 (8 pages), November 2018.

Nelson, T., van der Watt, J.G., **Laudal, D**., Feilen, H., Mann, H., Srinivasachar, S. "Reactive jet and cyclonic attrition analysis of ilmenite in chemical looping combustion systems." International Journal of Greenhouse Gas Control. Volume 91, December 2019, 102837.

Nasah, J., Jensen, B., Dyrstad-Cincotta, N., Gerber, J., **Laudal, D**., Mann, M., Srinivasachar, S. "Method for separation of coal conversion products from oxygen carriers." International Journal of Greenhouse Gas Control. Volume 88, September 2019, pages 361-370.

Emerson, S., Zhu, T., Davis, T. Peles, A., She, Y., Willigan, R., Vanderspurt, T., Swanson, M., **Laudal**, **D**. "Liquid Phase Reforming of Woody Biomass to Hydrogen". International Journal of Hydrogen Energy, August 2013.

Nolan L. Theaker

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

Education and Training

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

Research and Professional Experience

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

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

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

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

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

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

Publications/Presentations

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

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

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

Patents/Applications:

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

Synergistic Activities

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

Kevan M. Rusk
kevan.rusk@und.edu
701-330-0887

Education and Training

University of North Dakota Mechanical Engineering B.S. 1992

Research and Professional Experience

University of North Dakota – Grand Forks, ND
Director of Business Development, College of Engineering and Mines – 2022 - Present

- Lead efforts to build working relationships with industry, government, and research entities in support of CEM's research mission.
- Responsible for finding opportunities for CEM to grow its externally funded research, especially within CEM's recently established research initiatives for advanced materials and manufacturing, sustainable infrastructure, and artificial intelligence.
- Develop and leverage a network of contacts at companies, government agencies, and research entities in order to identify relevant opportunities.
- Assist in managing select funded projects, serving as a liaison between the sponsor and researcher.

Composites One – Schaumburg, IL
Manager, Marketing Technology and Technical Support - 2020-2022

- Leading North American team of 10 Technical Support Managers, driving sales results through world-class Customer support (on-site training, troubleshooting and product / process guidance) – leading to $1.3 Billion in sales in 2021 (~20% growth) for #1 composites material distributor in North America
- Developed and implemented product and opportunity evaluation process, evaluating over 50 potential suppliers in first year. Chairing the Corporate Steering Committee, implemented 17 high-quality suppliers and opportunities resulting from these evaluations.
- Led internal evaluation of Kitting operations for Aerovac (newly acquired subsidiary of Composites One) resulting in several Operational Excellence changes, fundamentally improving several "Voice of Customer" identified opportunities.
- Responsible for developing and managing the demonstrations in the CAMX Demo Zone at the biggest Composites trade show in North America ($~250k annual investment for demo zone space at CAMX). The Composites One Demo Zone is consistently the most anticipated attraction at the trade show.

Dixie Chemical - Pasadena, TX
Director, Thermoset Sales and Business Development - 2016-2019

- Supported Dixie's global commercial activity for anhydride curing agents in the pultrusion, filament winding and syntactic foam casting markets.
- Drove global sales through a combination of relationship-building, supporting Customer's objectives and providing superior hands-on product and technical support.
- Translated "Voice of the Customer" to Dixie's product development team to accurately prioritize / target Dixie product development results.
- Represented Dixie Chemical in ACMA's Rebar and Pultrusion councils.

University of North Dakota – Grand Forks, ND
Director, UND Tech Accelerator - 2013-2016

- Recruited 6 new tenants to the Tech Accelerator in 2.5 years, including a Life Sciences company, an Energy Services company and an Unmanned Aerial Systems (UAS) company. Secured a $450k Research ND grant for this startup (EdgeData). Responsible for Operation and Management of $17 Million technology facility, including BSL 2 and BSL 3 BioTech labs.
- Responsibility for leading ongoing University of North Dakota business development in the UAS sector, identifying and leveraging UND research capability to growing industry presence in Grand Forks.
- Appointed to a number of internal University boards and advisory groups (UAS Advisory Board, NexusND leadership team, Division of Economic Development UAS sector lead)
- Identified, justified and secured hiring of UND Biosafety Officer, enabling "next-level" Biosafety research at UND.

LM Wind Power - 2006-2013
Director of Global Operational Quality – Grand Forks, ND
Director, Global Core Engineering - Kolding, Denmark
Senior Global Project Manager – Grand Forks, ND
Engineering and CI Manager – Grand Forks, ND

- Operational Quality - Responsible for leading Operations Quality, Global Process Engineering, Technology Transfer, and Non-destructive Testing and Measurements. Converted Customer requirements to actionable and achievable process and product specifications.
- Core Engineering - Led all technical resources in Blade Design, Materials and Processes, Structural Engineering, Aerodynamics Engineering, and Reliability Engineering departments (125 Engineers across 6 global locations) to support new product programs and develop foundation technologies. Spearheaded concept of cross-functional material system design (involving reinforcement, sizing and resin system providers in a "team" approach to material system design).
- Developed and executed, as member of the LM Grand Forks Management team, a 25% improvement in top line revenue, and greater than 50% EBITDA improvement from 2008 vs. previous year.

Advanced Closed Molding – Grand Forks, ND
Director of Operations - 2005-2006

- Directed all operations, customer support, engineering, sourcing and quality for open and closed mold programs for all activities in $5 million start-up custom composites molding company.

Anthony C. Maher
Entrepreneur Lead for Startup Growth & Fundraising, UND Center of Innovation,
University of North Dakota (UND) anthony.maher@und.edu (408) 887-9336

Education and Training

University of Illinois Chicago	BA Psychology and Philosophy	1998
Santa Clara University	MBA/Finance concentration	2019

Professional Experience

2021-Present Entrepreneur Lead for Startup Growth & Fundraising, UND Center for Innovation

Supporting the mission of the UND Center for Innovation (CFI) to identify and advance the development of innovative ventures, as well as to help bring new products and technologies to market. Responsibilities include designing and managing entrepreneurial programming focused on developing new ventures. Responsibilities also include fostering funding opportunities by identifying and managing capitalization opportunities at the state and national level, including institutional venture capital firms and corporations. This position also includes grant research and proposal preparation, including stewardship of granted EDA and federally funded awards to support regional economic and entrepreneurial development.

2012-2020 Lead Consultant, Independent Consulting Services

Liaise with diverse clients in the technology sector by leveraging experience in early-stage investing and with emerging companies to provide business development consulting services and strategic planning. Evaluate client needs to provide in-depth market research, business evaluations, and strategic and financial analysis. Representative examples include guiding an energy company in the electrical vehicle space with analysis of the M&A landscape and strategic options based on research of industry trends, current participants, and input from expert resources; providing full-scale business and financial modeling for an international insurance company with the goal of entering emerging markets and improving profitability; and supporting a digital financial services company with in-depth business planning to provide products with increased security.

2009-2012 Co-Founder, LED-SLS, Inc.

Conceptualized and launched start-up venture focused on next-generation LED lighting solutions connected via wireless networks, providing energy-efficient natural lighting for commercial customers. Developed business plan, corporate presentation, and financial forecast. Managed prototype development and oversaw pilot projects across markets and geographies. Leveraged network to collaborate with industry experts, investment professionals, potential customers, and market research organizations to establish business model and financial plans. Led engineering contract manufacturers in the design of prototypes, thermodynamic systems, and wireless capabilities, and managed costing activities to ensure alignment with business plans.

2004-2007 Senior Associate/Associate, Siemens Venture Capital (SVC)

Leader within the global corporate venture arm of Siemens AG with $1B assets under management. Focused on making equity investments in innovative technologies to enhance

Siemens' core business scope across communications, energy, industrial infrastructure, and healthcare. Managed a team of seven financial analysts while pursuing investments in communications networks, devices, and applications. Collaborated with senior executives through all stages of the investment process, including sourcing, due diligence, and preparation of detailed business, market, forecast modeling and company valuations. Accomplishments include national and international minority equity investments, as well as quarterly preparation of business, financial and valuation reporting for up to eight portfolio companies.

2000-2004 Analyst/Senior Analyst Senior, Siemens Venture Capital (SVC)

Supported investment partners in the sourcing and analysis of investment opportunities with emerging technology companies in the areas of communications networks, applications, and devices. Distinguished as the only Analyst responsible for making and managing investments, including sourcing and due diligence for semiconductor company CSR (publicly traded on the London stock exchange, then acquired by Qualcomm) and enterprise security company Oblix (acquired by Oracle). Significantly improved quarterly EBIT forecasting by developing and implementing a financial review process for the global investment portfolio.

1998-2000 Analyst, Mustang Ventures, Siemens Information & Communications Networks

Founding member of $150 million corporate venture capital fund of the Siemens Information & Communication Networks division. Responsible for developing internal processes towards identifying, conducting due diligence, and implementing equity investments.

1998-1998 Product Planner: Broadband Access, Siemens Communications Division

Collected historical, current, and projected market share data for company broadband access products. Developed strategic recommendations that outlined the rate of adoption of emerging technologies and products.

Dr. Daniel R. Palo, PhD, PE
Vice President, Senior Process Engineer, Barr Engineering Co. (Barr)
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Education and Training

University of Minnesota	Chemical Engineering	BS 1994
University of Connecticut	Chemical Engineering	PhD 1999

Registration

Professional Engineer (Chemical): 14 US States and Province of Saskatchewan

Research and Professional Experience

2011-Present Senior Process Engineer, Barr Engineering Co.
2018-Present Vice President, Barr Engineering Co.
Providing process engineering services for scoping, prefeasibility, and feasibility studies for mineral processing clients; conducting technical evaluations and pilot plant testing for new and existing processes; modeling and optimizing equipment, sub-processes, and whole plants using METSIM and/or CHEMCAD software; coordinating vendor trials for new equipment installations and upgrades; providing plant layout, equipment specification, cost estimation, and project oversight for various mineral and chemical process applications building and coordinating teams that conduct advanced research and development in mineral processing, energy, and fuels.
2005-2011 *Deputy Co-Director and Senior Research and Development Leader for the Microproducts Breakthrough Institute, Pacific Northwest* National Laboratory
Providing business development and outreach around key programs and providing project management and technical research services
1999-2011 Research Engineer, Pacific Northwest National Laboratory
Leading project tasks in energy and chemical process development; managing a large multi-year development project for the U.S. Army; working to design, fabricate, test, and evaluate new devices and processes; contributing to creation of a spin-off company to commercialize microchannel process technology.
1995-1999 Graduate Research Assistant, Chemical Engineering Department of University of Connecticut
Planning and assembling laboratory infrastructure, supervising students, designing custom test equipment, and conducting investigations into various applications of supercritical CO2, including catalysis, conductive polymers, and heavy metal chelation.

Selected Publications

RA Dagle, JA Lizarazo-Adarme, V Lebarbier Dagle, MJ Gray, JF White, DL King, DR **Palo**, Syngas conversion to gasoline-range hydrocarbons over Pd/ZnO/Al2O3 and ZSM-5 composite catalyst system, Fuel Processing Technology 2014, 123, 65-74

Yu-Wei Su, Sudhir Ramprasad, Seung-Yeol Han, Wei Wang, Si-Ok Ryu, Daniel R. **Palo**, Brian K. Paul, Chih-hung Chang, Dense CdS Thin Films On Fluorine-Doped Tin Oxide Coated Glass By High-Rate Microreactor-Assisted Solution Deposition, Thin Solid Films, 2013, 532, 16-21.

Sudhir Ramprasad, Yu-Wei Su, Chih-Hung Chang, Brian K. Paul, Daniel R. **Palo**, Continuous Microreactor-Assisted Solution Deposition for Scalable Production of CdS Films, ECS J. Solid State Sci. Technol. 2013, 2(9), P333-P337.

Vanessa M. Lebarbier, Robert A. Dagle, Libor Kovarik, Jair A. Lizarazo-Adarme, David L. King, Daniel R. **Palo**, Synthesis of Methanol and Dimethyl Ether from Syngas over Pd/Zno/Al2O3 Catalysts, Catal. Sci. Technol., 2012, 2, 2116-2127.

Zhu, Y.; Jones, S.B.; Biddy, M.J.; Dagle, R.A.; **Palo**, D.R. Single-step syngas-to-distillates (S2D) process based on biomass-derived syngas – A techno-economic analysis, Bioresource Technology, 2012, 117, 341.

Palo, D. R.; Dagle, R. A.; Holladay, J. D. Methanol Steam Reforming for Hydrogen Production, Chem. Rev., 2007, 107, 3992.

Palo, D. R.; Stenkamp, V. S.; Dagle, R. A.; Jovanovic, G. N. Industrial Applications of Microchannel Process Technology in the United States. In Applied Micro and Nano Systems, Vol. 5 (AMN5); Wiley VCH, 2006, N. Kockman, Ed.

Palo, D. R.; Holladay, J. D.; Dagle, R. A.; Chin, Y.-H. Integrated Methanol Fuel Processors for Portable Fuel Cell Systems. In Microreactor Technology and Process Intensification; ACS Symposium Series, 2005, Y. Wang and J. Holladay, Eds., vol. 914, pp. 209-223.

Selected Patents

Robert S. Wegeng, Daniel R. **Palo**, Steven D. Leith, Paul H. Humble, Shankar Krishnan, Robert A. Dagle Solar Thermochemical Reactor System for Concentrated Solar Energy Capture and Storage, U.S. Pat. 9,950,305, 2018.

Daniel R. **Palo**, Jamelyn D. Holladay, Robert A. Dagle, Robert T. Rozmiarek, Compact Integrated Combustion Reactors, Systems and Methods of Conducting Integrated Combustion Reactions, US Pat. 8,696,771, 2014.

Nicholas W. Sosalla
Senior Mineral Processing Engineer, Barr Engineering Co. (Barr)
nsosalla@barr.com 218.262.8644

Education and Training

University of Minnesota-Twin Cities	Chemical Engineering	BS 2011

Research and Professional Experience

2011-Present Senior Mineral Processing Engineer, Barr Engineering Co.
Working on a variety of mineral processing and chemical engineering projects including design, mass and energy balance calculations, process modeling, and capital and operating expense estimates. He has served clients in the mining and mineral processing industries for iron ore, trona/soda ash, and industrial sands as well as industrial manufacturing clients. Specific project experience includes reviewing P&IDs of a soda ash plant and trona mine while on site and modeling the entire facility from ore to final product within a process simulation modeling software; dynamically modeling various portions of a potash operation in Saskatchewan to minimize losses and increase production capabilities and performing economic analysis to provide capital cost, operating cost, and payback period estimates; evaluating multiple potash operations in Saskatoon to identify upgrades and practices required to meet fine-particle-sized dust-emissions regulations; sampling and modeling of concentrator production lines to provide an updated mass balance for an iron ore operation in Minnesota; sampling and process modeling of concentrator and agglomerator production to provide an iron, silica, and mercury mass balance for an iron ore operation in Minnesota; providing preliminary design for the addition of a thickening system to a Canadian iron ore operation to improve tailings basin management; providing preliminary design services, including mass balance, energy balance, capital expense, and operating expense calculations, for a proprietary chemical process for a confidential client in Ohio; assisting with development of pilot plant testing for reclaimed iron ore processing and analysis of the produced data for a confidential client in Minnesota; analyzing the existing operations of a hydroseparator system to aid in determining its effects on downstream tailings basin management; assessing and documenting the entire process flow for two frac sand processing facilities as a part of a due diligence review.
06-10/2011 Mineral Processing Intern, Minnesota mining operation
Interning in a mineral processing facility's analytical laboratory where he performed analytical experiments to ensure production output met required quality standards and performed testing to analyze the performance of laboratory equipment statistically.
06-08/2010 Chemical Engineering Intern, Minnesota mining operation
Interning in chemical engineering for a mining and mineral processing facility where he designed experiments to optimize process machinery efficiency; created mathematical models to aid in process stability and control; and helped monitor, control, and maintain the taconite pellet creation process and process machinery.

Ryan R. Rayda, PE
Senior Structural Engineer, Barr Engineering Co. (Barr)
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Education and Training

University of Wyoming	Architectural Engineering	BS 2001
University of Wyoming	Structural Engineering	MS 2003

Registration

Professional Engineer: Connecticut, Michigan, Minnesota, Montana, North Dakota, South Carolina, South Dakota, Texas, Wyoming

Research and Professional Experience

2016-Present Senior Structural Engineer, Barr Engineering Co.
Leading preliminary design and project development for a phosphate rock bio-leach facility in the western US, assisting the client with navigating the challenges associated with a unique funding mechanism, and developing a larger EPC-type team to progress the project through final design and construction. Leading a large, multidisciplinary team on a fast-track project to restore critical material handling infrastructure to a central North Dakota mining facility that was damaged during a severe weather event; coordinating a diverse team of engineers, scientists, field personnel, and forensic investigators in emergency response, assessment, strategy development, planning, design, detailing, and ultimately restoration of this facility in an aggressive timeframe; collaborating with the owner, many subcontractors, fabricators, and suppliers. Leading a structural design team for an ash handling conversion project at power plants in North Dakota and South Dakota; Designing the conversion of the plants' existing wet ash handling systems to dry conveyor systems included 3D scanning, modeling, clash detection, modifying existing structural steel for support of new equipment, designing new equipment supports and an ash storage bunker, detailed coordination with equipment suppliers, and extensive support during construction. Leading a regional team through planning and field operations for a demonstration test implementing a novel sorbent injection system designed to reduce fouling in a North Dakota power generating facility; collaborating with equipment suppliers, material suppliers, plant personnel, researchers, laboratories, and designers to lay out the demonstrations system and integrate it with the existing infrastructure at the test facility.
2006-2016 Senior Project Structural Engineer, CWSTRUCTURAL Engineers
Designing structures to accommodate addition of a material analysis equipment and new material handling equipment at a central North Dakota power plant; the design required modification of an existing conveyor gallery to house a material analyzer used to monitor the presence of nuclear elements; the new conveyor sections and analyzer were integrated into an existing conveyor system, requiring detailed analysis of the existing structure and coordination with the expanded conveyor housing. Managing and leading structural design for a horizontal-collector-well pumphouse for a municipality in central North Dakota; several innovative construction techniques were developed for this project in coordination with the contractor to facilitate sinking of the caisson into the riverbed and erection of the complex, bi-axial, elliptically rolled framing members.

Ryan D. Siats
Senior Chemical Engineer, Barr Engineering Co. (Barr)
rsiats@barr.com 218.788.6364

Education and Training

University of Minnesota-Duluth	Chemical Engineering	BS 2007
University of Phoenix	Business Administration	MBA 2009

Research and Professional Experience

2011-Present Senior Chemical Engineer, Barr Engineering Co.
Assisting clients with environmental impact assessment, permitting, and compliance, especially involving the development, construction, and operation of new and expanding facilities. He also conducts technical and economic feasibility studies for pollution-control equipment and processes and performs site evaluations and investigations. Specific project experience includes developing and managing systems for achieving and maintaining compliance with multiple regulations and requirements; managing a complex project involving mercury-reduction research and the testing of potential mercury-emission-reduction technologies for a group of Minnesota taconite-mining companies; preparing a PSD permit application for a mining client proposing to expand its production capacity by installing new process units and increasing the throughput of existing ones. Work included updating a BACT analysis to meet PSD requirements and conducting air-dispersion modeling to verify compliance with ambient-air-quality standards for Class I and Class II areas; completing applications for Title V permit renewals for power stations, taconite plants, and manufacturing facilities encompassing permit evaluation, emission-unit and regulatory review, and emission calculations; managing or providing technical assistance for air-dispersion modeling projects; helping facilities comply with air quality regulations by completing reports, notifications of compliance status, preconstruction notifications, and initial notifications of applicability; developing the curriculum for a training course and associated compliance tools pertaining to NSR applicability for a range of facilities; completing a permitting analysis for a system that recovered waste dust and recycled it back into the process at a mining facility; preparing an air permit to incorporate MACT standards into an existing Title V permit, eliminating redundant and unnecessary requirements; preparing and submitting emission inventories, compliance certifications, TRI reports, and pollution-prevention plans; developing and implementing systems for project review, including (PSD) and New Source Review (NSR) evaluations, permit applicability, and multimedia impacts; preparing permit applications and negotiating permit conditions; developing and providing environmental training for employees; coordinating stack testing and compliance monitoring; conducting inspections and environmental audits of industrial facilities; and tracking new and evolving regulations and determining their impact on the facility.

2014 *Environmental Manager, Cliffs Natural Resources*
Providing regulatory analysis and compliance program development for multiple operating taconite facilities, analyzed multimedia regulatory developments and forecasted implications across multiple facilities, assessed proposed regulations and provided feedback to state and federal agencies toward scientifically derived environmental compliance standards, developed and implemented programs for state and federal compliance demonstration, fostered relationships with federal/state/local government officials and regulatory staff, managed and

supported cross-functional teams toward business opportunities and cost-effective solutions, identified short- and long-term gaps in environmental review and permitting for mine plan development, and maintained multimillion-dollar environmental capital forecast.

2013-2014 *Environmental Manager, Cliffs Natural Resources*

Managing environmental programs for a greenfield mining project; overseeing incorporation of new and emerging regulations and guidelines into project EA and permitting work; presenting proposed project to provincial, federal, and tribal government units; leading completion of supporting documentation for part of a provincial and federal environmental assessment; identifying opportunities to implement cost-effective project engineering solutions; coordinating field-survey work among cultural, flora, and fauna consultants; maintaining multimillion-dollar environmental baseline monitoring program and interpreting results; and managing exploration camp compliance with provincial and federal regulations.

2012-2013 *Environmental Manager, Cliffs Natural Resources*

Managing and performing audits of company programs and procedures as a lead auditor and audit team member for programs and procedures encompassed ISO 14001, ISO 9001, the Clean Air and Clean Water Acts, CERCLA, EPCRA, RCRA, and TSCA.

2006-2012 Environmental Engineer, United States Steel Corporation

Managing cross-functional teams in acquiring modifications to a facility PSD air permit for construction and increased production; developing and maintaining facility programs for environmental protection, stewardship, and sustainability; forming relationships with regulatory staff while working with cross-functional teams to interpret new multimedia environmental regulations; managing procurement, installation, and maintenance of pollution-control equipment and continuous emissions-monitoring systems to comply with state and federal air quality regulations; researching and pilot-testing methods for preventing tailings-basin fugitive emissions; managing a certified Type III industrial solid-waste landfill, including securing a permit modification, coordinating with cross-functional teams, and overseeing compliance with a stipulation agreement; maintaining air quality permits and accompanying plans; submitting permit-required documents and routine reporting; managing permit modifications for business development; completing project assessments and documentation required for modified air emissions; conducting an engineering analysis of unconventional fugitive-emissions control; and reviewing emerging air-quality regulations and possible effects on the facility and company.

Ryan S. Winburn, Ph.D.
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ryan.winburn@rareearthsalts.com

Professional Preparation

1996-1999	Ph. D., Analytical Chemistry with Inorganic Emphasis; North Dakota State University, Fargo, ND
1991-1995	M. S., Physical Chemistry; University of North Dakota, Grand Forks, ND
1987-1991	B. S., Chemistry, American Chemical Society certified; University of Wisconsin-Eau Claire, Eau Claire, WI

Appointments

2013 –	Vice President for Research and Development, Rare Earth Salts Supervise and participate in a small research group focused on the conversion and separation of rare earth elements/compounds. Prepare patent applications and budgets for the group.
2000 -	Owner/CEO, Ryan Winburn Consulting
2006-2013	Chairperson, Division of Science, Minot State University
1999-2013	Assistant Professor of Chemistry, Minot State University
1998-1999	Graduate Teaching/Research Fellow, North Dakota State University
1996-1998	Teaching/Research Assistant, North Dakota State University
1995	Adjunct Professor, University of Minnesota-Crookston, Crookston, MN
1991-1995	Teaching/Research Assistant, University of North Dakota
1991	Laboratory Technician, University of Wisconsin-Eau Claire

Research Achievements

Vice President of Research and Development (2013-present)

Develop techniques for the conversion and separation of rare earth materials

- Developed novel separation technique for the rare earth elements
- Investigated existing methodologies for conversion of rare earth oxides and oxalates into other rare earth compounds for use in separations
- Investigate selective and specific reactions involving rare earth elements
- Investigate separation of transition and refractory elements, from materials with and without rare earth elements.

CEO/Owner Ryan Winburn Consulting

Certify SRMs for X-ray Analysis

- Worked with a team of scientists on the certification of SRMs 676 (Alumina powder), 676a (Alumina Powder) and 674b (Quantitative Powder Diffraction Standard).

Provide training in quantitative analysis using X-ray diffraction

Assistant Professor at Minot State University

Research involved a number of different areas of focus:

- Thermal synthesis of brownmillerite, including ‘real-time’ monitoring of the reaction via XRD.

- Investigation of error sources and minimizing their effect on quatitative XRD (QXRD) of complex mixtures, eg. coal combustion by-products
- Computational studies of 13-15 materials as potential precursors for 13-15 semiconductors.
- Development of extraction and analysis techniques for quantification of toxic elements (particularly Cd) from both biologic (plant and animal tissues) and geologic samples
- QXRD studies on geologic samples, bulk and heavy mineral separates, to determine providence of various formations in SW North Dakota and NW South Dakota.

Selected Publications/Patents/Certificates

"Rietveld Quantitative X-Ray Diffraction of NIST Fly Ash Standard Reference Materials" R.S. Winburn, D.G. Grier, G.J. McCarthy, and R.B. Peterson, *Powd. Diff*.. **2000**, 15, 163-172.

"Quantification of Ferrite Spinel and Hematite in Fly Ash Magnetically Enriched Fractions" R.S. Winburn, S.L. Lerach, G.J. McCarthy, D.G. Grier and J.D. Cathcart, *Adv. X-Ray Anal.*, **2000**, 43, 350-355.

"Factors Influencing Quantitative Results for Coal Combustion By-Products Using the Rietveld Method" R.M. Gonzalez, T.D. Lorbiecke, B.W. McIntyre, J.D. Cathcart, M. Brownfield, and R.S. Winburn, *Adv. X-Ray Anal*., **2002**, 45, 188-193.

"Addressing the Amorphous Content Issue in Quatitative Phase Analysis: The Certification of NIST Standard Reference Material 676a" J.P. Cline, R.B. Von Dreele, R. Winburn, P.W. Stephens and J.J. Filliben, Acta Cryst, **2011**, A67, 357-367.

"Method for extraction and separation of rare earth elements." US Patent No. 10,494,694. J.R. Brewer; R.S. Winburn, and J. Beaudoin. December 2019.

Standard Reference Material 676 Alumina Internal Standard for Quantitative Analysis by X-Ray Powder Diffraction, 20 September 2005, J.P. Cline, R. Winburn, R.B. Von Dreele, A. Huq, P.W. Stephens, S. B. Schiller, H-k. Liu, and J.J. Filliben,, National Institute of Standards and Technology, Gaithersburg, MD 20899.

Standard Reference Material 674b X-Ray Diffraction Intensity Set for Quantitative Analysis by X-Ray Powder Diffraction, 21 September 2005, R.S. Winburn, J.P. Cline, D. Black, M.H. Mendenhall, A. Henins, R.B. Von Dreele, J.J. Filliben, and I. Aviles, National Institute of Standards and Technology, Gaithersburg, MD 20899.

Standard Reference Material 676a Alumina Internal Standard for Quantitative Analysis by X-Ray Powder Diffraction, 28 January 2008, J.P. Cline, D. Black, D. Windover, A. Henins, R.B. Von Dreele, R. Winburn, P.W. Stephens, J.J. Filliben, and A.M. Possolo, National Institute of Standards and Technology, Gaithersburg, MD 20899.

Joseph Reese Brewer

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joseph.brewer@rareearthsalts.com

Professional Preparations

University of Alabama-Tuscaloosa	Postdoc	Electrical Engineering	2010-11
University of Nebraska-Lincoln	Ph.D.	Inorganic Chemistry	2010
University of Nebraska-Lincoln	M.S.	Chemistry	2007
Minot State University	B.S.	Chemistry	2004

Professional Appointments

2012-Present	Chief Executive/Technical Officer, Rare Earth Salts, LLC.
2010-2012	Chief Technology Officer, Rare Earth Solar, LLC.
2010-2011	Postdoctoral Researcher, University of Alabama, Tuscaloosa, AL
2010-2010	Postdoctoral Researcher, University of Nebraska-Lincoln, Lincoln, NE
2004-2005	Laboratory Technician, Johns Manville Technical Center

Research Achievements

Chief Technology Officer (2013-present, Rare Earth Salts)
Develop novel processes for the extraction and separation of rare earth elements from low grade rare earth ore bodies.

- Developed low cost green chemistry extraction process for the recovery of rare earths from low grade rare earth ore bodies.
- Developed low cost green chemistry extraction process for the recovery of rare earths from recycled compact fluorescent light bulbs and recycled magnets.
- Developed unique leach chemical regeneration techniques to decrease environmental impact of acid pit storage ponds.
- Co-developed unique cost-effective separations process for individual separation of rare earth elements utilizing a small chemical footprint and benign processing conditions.
- Developed large scale close-looped green separations process for light rare earth elements.

Chief Technology Officer (2011-present, Rare Earth Solar)
Develop deposition methods for the commercialization of rare-earth element based photovoltaics

- Developed new sputter deposition process for the in-situ synthesis of low cost highly textured rare-earth chalcogenide based *p* and *n*-type layers for photovoltaic devices.
- Determined process conditions to alter *p* and *n*-type layer electronic properties from metallic to semiconducting while maintaining crystal structure.

Graduate Research Assistant (2005-2010)
Advisor: Dr. "Barry" Chin Li Cheung, Department of Chemistry, University of Nebraska–Lincoln
Advanced the chemical synthesis of rare-earth (RE = Y, La, Ce, Pr, Nd, Sm, Gd, Tb, Dy, Ho) compounds

- Developed new general chemical vapor deposition (CVD) synthetic schemes to fabricate single-crystalline rare-earth hexaboride nanostructures with well-controlled diameters and shapes
- (nanowires, nanopencils and nanoobelisks).
- Developed a new synthetic methodology for the rapid growth of highly textured (100) rare-earth nitride thin films by CVD
- Developed a new CVD synthesis strategy for the stoichiometry controlled growth of crystalline rare-earth sulfide nanomaterials and thin films

Publications

1) Zhou, Y.; Lawrence, N. J.; Wang, L., Kong, L.; Wu, T.-S., Liu, J.; Gao, Y.; Brewer, J. R.; Lawrence, V. K.; Sabirianov, R. F.; Soo, Y.-L.; Zeng, X. C.; Dowben, P. A.; Mei, W. N.; Cheung, C. L., Resonant Photoemission Observations and DFT Study of s-d Hybridization in Catalytically Active Gold Clusters on Ceria nanorods. *Angewandte Chemie* **2013,** *52* (27), 6936-6939. DOI: 10.1002/anie.201301383

2) Marin, C. M.; Wang, L.; Brewer, J. R.; Mei, W. N.; Cheung, C. L., Crystalline alpha-Sm2S3 Nanowires: Structure and Optical Properties of an Unusual Intrinsically Degenerate Semiconductor. *Journal of Alloys and Compounds* **2013,** *563,* 293-299. DOI:10.1016/j.jallcom.2013.02.082

3) Gernhart, Z. C.; Jacobberger, R. M.; Wang, L.; Brewer, J. R.; Dar, M. A.; Diercks, D. R.; Mei, W. N.; Cheung, C. L., Existence of Erbium Hexaboride Nanowires. *Journal of the American Ceramic Society* **2012,** *28,* 3992-3996**.** DOI:10.111/j.1551-2916.2012.05427.x

4) Jacobberger, R. M.; Brewer, J. R.; Cheung, C. L., Vertical Growth of Metallic Hexaboride Nanowires and their Field Emission Properties. *World Journal of Engineering* **2011,** *18(suppl.),* 509-510.

5) Brewer, J. R.; Jacobberger, R. M.; Diercks, D. R.; Cheung, C. L., Rare Earth Hexaboride Nanowires: General Synthetic Design and Analysis Using Atom Probe Tomography. *Chemistry of Materials* **2011,** *23* (10), 2606-2610.

6) Lawrence, N. J.; Brewer, J. R.; Wang, L.; Wu, T.-S.; Wells-Kingsbury, J.; Ihrig, M. M.; Wang, G.; Soo, Y.-L.; Mei, W.-N.; Cheung, C. L., Defect Engineering in Cubic Cerium Oxide Nanostructures for Catalytic Oxidation. *Nano Letters* **2011,** *11* (7), 2666-2671.

7) Brewer, J. R.; Gernhart, Z.; Liu, H.-Y.; Cheung, C. L., Growth of [100]-Textured Gadolinium Nitride Films by CVD. *Chemical Vapor Deposition* **2010,** *16* (7-9), 216-219.

8) Wang, G.; Brewer, J. R.; Chan, J. Y.; Diercks, D. R.; Cheung, C. L., Morphological Evolution of neodymium Boride Nanostructured Growth by Chemical Vapor Deposition. *J. Phys. Chem. C* **2009**, *113*, 10446-10451.

9) Deo, N.; Brewer, J. R.; Reinhardt, C. E.; Nikolic, R. J.; Cheung, C. L., Conformal Filling of Silicon Micropillar Platform with $_{10}$Boron. *J. Vac. Sci. Technol. B* **2008,** *26* (4), 1309-1314.

10) Wang, G.; Brewer, J. R.; Namavar, F.; Sabirianov, R. F.; Haider, H.; Garvin, K. L.; Cheung, C. L., Structural Study of Titanium Oxide Films Synthesized by Ion Beam-Assisted Deposition. *Scanning* **2008,** *30* (2), 59-64.

11) Namavar, F.; Wang, G.; Cheung, C. L.; Sabirianov, R. F.; Zeng, X. C.; Mei. W.; Bai, J.; Brewer, J. R.; Haider, H.; Garvin, K. L., Thermal Stability of Nanostructurally Stabilized Zirconium Oxide. *Nanotechnology*, **2007**, *18*, 415702-

Patents

1) *Crystalline nanostructures*. US 8,247,070 B2. CL Cheung; JR Brewer; N Deo. Filed on Oct 30, 2007.

2) *Rare earth sulfide thin films.* PCT/US2011/031454. CL Cheung; JR Brewer. Filed on April 6, 2011.

3) *Cerium oxide having high catalytic performance.* PCT/US2011/031467. CL Cheung; NJ Lawrence; JR Brewer; G Wang. Filed on April 6, 2011

4) *Method for rare earth and actinide element recovery, extraction and separations from natural and recycled resources.* PCT/US2012/61717916. JR Brewer; NJ Lawrence. Filed on October 24, 2012.

5) *Method for extraction and separation of rare earth elements.* PCT/US2015/045423. Joseph R Brewer; Ryan S. Winburn. Filed on August 15, 2014.

6) *Method for separating rare earth elements from leach solutions*. Patent Pending. Filed April 5, 2022

STEVEN A. BENSON, PH.D.
President, Microbeam Technologies Incorporated, Grand Forks, ND 58202
sbenson@microbeam.com, 701-213-7070

Education and Training

Minnesota State University	Chemistry	B.S. 1977
Pennsylvania State University	Fuel Science	Ph.D. 1987

Research and Professional Experience

1991 – Present President, Microbeam Technologies Incorporated. Dr. Benson founded Microbeam Technologies Incorporated (MTI), a spin-off company from the University of North Dakota to conduct service analysis of materials using automated methods aimed at assessing efficiency and reliability problems in renewable and fossil energy conversion systems. MTI also conducts measurement and modes of occurrence of critical minerals in carbon-ore related feedstocks. MTI began operations in 1992 and has conducted over 1640 analysis projects for industry, government, and research organizations worldwide. Dr. Benson is responsible for technical direction, data interpretation and proposal preparation.

2015 – 2017 Associate Vice President for Research, Energy & Environmental Research Center, University of North Dakota -- Dr. Benson was responsible for developing and managing projects on the clean and efficient use of fossil and renewable fuels.

2010 – 2014 Chair/Director, Petroleum Engineering Department and Institute for Energy Studies – Dr. Benson coordinated energy related education and research activities that involved faculty, research staff, and students.

2008 – 2017 Professor, Chemical and Petroleum Engineering, University of North Dakota -- Dr. Benson was responsible for teaching courses on energy production and associated environmental issues. Dr. Benson conducted research, development, and demonstration projects aimed at solving environmental, efficiency, and reliability problems associated with the utilization of fuel resources in refining/combustion/gasification systems that included: petroleum coke utilization, transformations of fuel impurities; carbon dioxide separation and capture technologies, advanced analytical techniques, and computer-based models.

1999 – 2008 Senior Research Manager/Advisor, Energy & Environmental Research Center, University of North Dakota (EERC, UND) -- Dr. Benson was responsible for leading a group of about 30 highly specialized chemical, mechanical and civil engineers along with scientists whose aim was to develop and conduct projects and programs on combustion and gasification system performance, environmental control systems, the fate of pollutants, computer modeling, and health issues for clients worldwide.

1994 – 1999 Associate Director for Research, EERC, UND -- Dr. Benson was responsible for the direction and management of programs related to integrated energy and environmental systems development. Dr. Benson led a team of over 45 scientists, engineers, and technicians.

1989 – 1991 Assistant Professor of Geological Engineering, Department of Geology and Geological Engineering, UND -- Dr. Benson was responsible for teaching courses on scanning electron microscopy/x-ray microanalysis, fuel geochemistry, fuel/crude behavior in refining, combustion and gasification systems, and analytical methods of materials analysis.

1986 – 1994 Senior Research Manager, Fuels and Materials Science, EERC, UND -- Dr. Benson was responsible for management and supervision of research on the behavior of inorganic constituents in fuels in combustion and gasification.

1984 – 1986 Graduate Research Assistant, Fuel Science Program, Department of Materials Science and Engineering, The Pennsylvania State University -- Mr. Benson took course work in fuel science, chemical engineering (at UND), and ceramic science and performed independent research leading to a Ph.D. in Fuel Science.

1983 – 1984 Research Supervisor, Distribution of Inorganics and Geochemistry, Coal Science Division, UND Energy Research Center – Mr. Benson performed sampling and analysis of coal-bearing stratigraphic sequences to determine abundance of major, minor and trace elements including critical minerals. He was responsible for management and supervision of research on coal geochemistry.

1977 – 1983 Research Chemist, Energy Resources Development Administration (ERDA) and U.S. Dept of Energy Grand Forks Energy Technology Center, Grand Forks, ND -- Mr. Benson performed analysis of coal-related materials using X-ray fluorescence, x-ray diffraction, scanning electron microscopy/x-ray microanalysis, and inductively coupled plasma.

Selected Publications and Presentations

1. Benson S, Fuka M, Kolb E, Benson A. System and Method for Predicting the Presence of Rare Earth Elements. US Patent Application No.: 63/367,859. 2022 July.
2. Fuka M, Kolb E, Benson A, Benson S. System and Method for Predicting Abundance of Rare Earth Elements with Handheld X-Ray Fluorescence. US Patent Application No.: 63/148,292. 2022 February.
3. Benson S, Patwardhan S, Stadem D, Langfeld J. Energy System Performance Manager. US Patent Application 63/159762. 2021 March.
4. Benson S, Benson A. System and Method for Producing Critical Minerals - Germanium and Gallium. US Patent Application No.: 17/812,484. 2021 February.
5. Fuka M, Kolb E, Benson A, Benson S. System and Method for Predicting the Presence of Rare Earth Elements, US Application No.: 17/650,773. 2021 February.
6. Laudal, D. A., Benson, S.A., Palo, D., and Addleman, R.S., Rare Earth Elements in North Dakota Lignite Coal and Lignite-Related Materials, ASME, J. Energy Resour. Technol 140(6), 062205 (Apr 09, 2018) (9 pages).
7. Laudal, D. A., Benson, S.A., Addleman, R.S., and Palo, D., Leaching behavior of rare earth elements in Fort Union lignite coals of North America, International Journal of Coal Geology, Volume 191, 15 April 2018, Pages 112-124.
8. 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.
9. Laudal D, Benson S. Rare Earth Extraction from Coal. US Patent US 10,669,610 B2. 2017 March.
10. Lyu Z, Patwardhan S, Stadem D, Langfeld J, Benson S, Thoelke 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.

Patents – 4 patents issued

7,574,968 **-** Method and apparatus for capturing gas phase pollutants such as sulfur trioxide.
7,628,969 - Multifunctional abatement of air pollutants in flue gas.
7,981,835 - System and method for coproduction of activated carbon and steam/electricity.
8,277,542- Method for capturing mercury from flue gas
10,669,610 - Rare Earth Extraction from Coal

Synergistic Activities

- Lignite Energy Council, Distinguished Service Award, Research & Development, 1997, 2003, 2005, and 2008. College of Earth and Mineral Science Alumni Achievement Award, Pennsylvania State University, 2002; Science and Technology Award, Impacts of Fuel Impurities Conference, 2014.
- Provided testimony to the United States Senate Committee on the Environment and Public Works – Mercury emissions control at coal fired power plants - 2008 and 2005.

ALEXANDER S. BENSON
Sr Project Manager, Microbeam Technologies Incorporated, Grand Forks, ND 58202
abenson@microbeam.com 701-330-0308

Education and Training

University of St. Thomas Mechanical Engineering B.S. 2011

Professional Experience

2019 – Present Sr Project Manager, Microbeam Technologies Incorporated. Mr. Benson is responsible for the management of multiple commercial projects and subcontracts on Department of Energy Projects. He develops project plans and manages resources to meet deadlines and financial commitments. Projects he has led include development of REE predictive algorithms using computer modeling and machine learning, REE resource evaluations, and REE processing and extraction projects. He has created commercialization plans for a DOE sponsored Rare Earth Element extraction from coal project. He interprets analysis results and uses computer-based models to predict fuel performance for multiple fuel types. Mr. Benson also prepares proposals and writes reports for clients.

2017 – 2019 Sr. Research Engineer (part-time), Microbeam Technologies Incorporated. Mr. Benson analyzed datasets using statistical methods to determine potential relationships and correlations between fuel properties and plant parameters. Worked with computer scientists to develop neural networks based on observed correlations.

2017 – 2019 Manufacturing Manager, Medtronic – Minimally Invasive Technology Group. Mr. Benson managed manufacturing operations of a medical device manufacturing plant with an annual budgeted Cost of Production of $360M. He was responsible for managing a three-shift manufacturing team of 7 production supervisors and 350+ production personnel. He managed manufacturing build plans to meet financial commitments and demand requirements for 134 SKUs, including developing production capacity, growth, and expansion plans to meet customer demand. He was responsible for ensuring his production team met demand while providing products that met stringent FDA standards.

2016 – 2017 Sr. Product Engineer, Medtronic – Minimally Invasive Technology Group. Mr. Benson led commercialization activities for new product launches related to manufacturing build plans, engineering line design and validation to meet FDA quality requirements, and production personnel training. He implemented process improvements of new manufacturing lines to improve output, yield, and efficiency, using statistical analysis and six sigma tools.

2015 – 2016 Sr. Manufacturing Engineer, Medtronic Energy and Component Center. Mr. Benson was responsible for providing 24-hour engineering support of lithium ion battery manufacturing lines. He managed a cross-functional team through the commercialization of new lithium ion battery manufacturing lines, leading yield and efficiency improvements through product design and equipment improvement projects.

2012 – 2015 Manufacturing Engineer, American Medical Systems. Mr. Benson oversaw multiple medical device manufacturing lines, managing yield, efficiency, and other process improvement projects. He was a member of a team to develop and commercialize a novel antimicrobial coating process for implantable medical devices.

Selected Publications and Patent Applications

1. Benson S, Fuka M, Benson A. System and Method for Predicting the Presence of Rare Earth Elements. US Patent Application No.: 63/367,859. 2022 July.
2. Benson S, Benson A. System and Method for Producing Critical Minerals – Germanium and Gallium. US Patent Application No.: 17/812,484. 2021 February.

3. 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 63/148,292. 2021 February 11.
4. 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.
5. Stadem, D., Benson, A., & Benson, S. (2022, September 19). Phase Mapping using Images from Backscattered Electron Imaging and Energy.

DAVID STADEM
Sr. Research Scientist, Microbeam Technologies Incorporated, Grand Forks, ND 58202
dstadem@microbeam.com, (701) 757-6204

Education and Training

University of North Dakota	Energy Engineering	Ph.D. (in progress)
Augustana University	Chemistry	B.A. 2012

Research and Professional Experience

2021–present Senior Research Scientist, Microbeam Technologies, Inc.
Lead for Algorithm Development and Neural Network Projects: technical lead for developing and maintaining internal and external software tools and processes for data analysis and reporting; develops and reviews machine learning and physicochemical model workflows; Technical lead for development, installation, and maintenance of coal tracking (CT) and combustion system performance indices (CSPI) software utilizing sorting and blending to optimize performance at a full-scale power plant; Experienced in software development and deployment using Python, C#, and C/C++; Principal investigator on commercial and government-funded projects.

2018–present Ph.D. Student (part-time), Energy Engineering, University of North Dakota.
Mr. Stadem completed coursework around experimentation and advanced modeling of systems; gained experience in Minitab, Fluent, HSC, Matlab, and other analytical software systems. Research titled "Monitoring and Controlling the Impact of Fluctuating Feedstock Properties on Energy Conversion Systems"; Expected graduation date May 2023.

2014–2021 Research Scientist, Microbeam Technologies, Inc.
Mr. Stadem performed advanced SEM-EPMA analysis on field samples as well as laboratory- produced samples; specialized in forensic examination of high-temperature multiphase reactions of complex inorganic species; developed advanced techniques for data manipulation, analysis, and presentation. He assisted in management of projects to minimize the impacts of fuel impurities on the performance of combustion and gasification systems firing a wide range of solid fuels. He developed and adapted predictive models pertaining to slag viscosity, inorganic partitioning between bottom ash and fly ash, chemisorption/adsorption of aerosols, deposit buildup rate on heat transfer surfaces, sulfur capture by alkali/alkaline earth constituents, image recognition for physical association of minerals in solid fuels, etc. He utilized a variety of programming languages. Mr. Stadem is experienced in the Microsoft Office suite, Tableau, SPSS, FactSage, and Fluent.

2012–2014 R&D Scientist & Lab Technician, Novartis Animal Health, Inc., Larchwood, IA.
Mr. Stadem eveloped and improved USDA-compliant ELISA and other assays for use in the production of novel/existing animal vaccines. He modified Specific Outlines (SO's) to maintain USDA compliance. He drafted new SOPs and Quality Records (QRs) according to SO's in compliance with GMP-like standards.

2012-2012 Analytical Chemist, Gevo, Inc., Luverne, MN.
Mr. Stadem prepared and analyzed samples in complex matrices for HPLC and GC analysis, recording and communicating data to analytical team and to internal customers; maintained equipment and laboratory.

Selected Publications and Presentations

1. Stadem, D., Benson, A., & Benson, S. (2022 September). *Phase Mapping using Images from Backscattered Electron Imaging and Energy Dispersive Spectroscopy of Ash*. Pittsburgh Coal Conference, Pittsburgh, PA.
2. Patwardhan, S., Stadem, D., Benson, S., & Krishnamoorthy, G. (2022 September). *Modeling Ash Partitioning in Slagging Energy Conversion Systems*. Pittsburgh Coal Conference, Pittsburgh, PA.
3. Lyu, Z., Patwardhan, S., Stadem, D., Langfeld, J., Benson, S., Thoelke, S., & Desell, T. (2021). Neuroevolution of recurrent neural networks for time series forecasting of coal-fired power plant operating parameters. In *Proceedings of the Genetic and Evolutionary Computation Conference Companion* (pp. 1735–1743). Association for Computing Machinery.
4. Benson, S., Patwardhan, S. S., Stadem, D. J., & Langfeld, J. F. (2021 March). *Energy system performance manager* (United States Patent Application No. 63/159762).
5. Desell, T. J., ElSaid, A. A., Lyu, Z., Stadem, D., Patwardhan, S., & Benson, S. (2020). Long term predictions of coal fired power plant data using evolved recurrent neural networks. *At - Automatisierungstechnik*, *68*(2), 130–139.
6. ElSaid, A., Benson, S., Patwardhan, S., Stadem, D., & Desell, T. (2019). Evolving Recurrent Neural Networks for Time Series Data Prediction of Coal Plant Parameters. In P. Kaufmann & P. A. Castillo (Eds.), *Applications of Evolutionary Computation* (pp. 488–503). Springer International Publishing.
7. Stadem, D., Patwardhan, S., Fuka, M., Benson, S. (2019 September). Condition Based Monitoring and Predicting Ash Behavior in Coal Fired Boilers - III - Coal Tracker Optimization, Pittsburgh Coal Conference, Pittsburgh, PA., September 2019.
8. Patwardhan, S., Stadem, D., Fuka, M., & Benson, S. (2019 June). *Condition Based Monitoring and Predicting Ash Behavior in Coal Fired Boilers -II -Coal Properties Optimization*. Clearwater Clean Energy Conference, Clearwater, FL.

Synergistic Activities

- Development of REE-predictive algorithms for low-cost in-mine REE analytical methods (Lignite Research Program of the North Dakota Industrial Commission, awarded Aug. 2017).
- Various small industry SEM service and consulting projects (2014-present)
- Limestone Sorbent Optimization projects (industry, 2016-present)
- Condition Based Monitoring and Predicting Ash Behavior in Coal Fired Boilers (US Department of Energy, 2018-2021)
- Developing Tools to Manage Slag Flow Behavior in Combustion and Gasification Systems under Low-NOx Conditions (Lignite Research Program of the North Dakota Industrial Commission, 2014-2017).

ERIC KOLB
Engineer and Lead for Engineering Design/Construction/Operations Projects, Microbeam Technologies Incorporated Grand Forks, ND 58202
ekolb@microbeam.com, 701-757-6200

Education and Training

University of North Dakota	Mechanical Engineering	B.S. 2020
Society of Mining Engineers	Short Course on Fundamentals of Mineral and Metallurgical Processing	2022

Research and Professional Experience

2021-Present Engineer and Lead for Engineering Design/Construction/Operations Projects, Microbeam Technologies Incorporated.
Mr. Kolb works on a range of projects focused on environmental and energy technologies that require engineering design, construction, and operations. Recent efforts have focused on design, fabrication, and operations of a rare earth element extraction plant at a pilot scale. Mr. Kolb also develops process flow diagrams and performs heat and material balance calculations for a critical mineral processing facility to recover germanium and gallium. Other work includes developing methods for analyzing coal for REE and developing predictive algorithms. Eric has experience working with North Dakota geology conducting a resource evaluation gathering cores.

2020-2021 Associate Research Engineer, Microbeam Technologies incorporated. Mr. Kolb worked on the design of a rare earth element extraction plant at pilot scale. He also worked on other projects contributing laboratory experiments, data interpretation, and design experience.

2019-2020 Intern, Microbeam Technologies incorporated. Mr. Kolb worked on various projects with power systems and gasification technology. He conducted various laboratory experiments for projects gathering data and doing data interpretation. He also operated and maintained the laboratory and scanning electron microscope equipped with an x-ray microanalysis system.

Publications and Patent Applications

1. Kolb E.; Newcomb J.; 2022 “Use of Deposition Probe to Collect Boiler Tube Deposit” Pittsburgh Coal Conference Oral Presentation, Virtual 19-22 September.
2. Fuka M, Kolb E, Benson A, Benson S. System and Method for Predicting the Presence of Rare Earth Elements, US Application No.: 17/650,773. 2021 February.
3. Fuka M, Kolb E, Benson A, Benson S. System and Method for Predicting Abundance of Rare Earth Elements with Handheld X-Ray Fluorescence. US Patent Application No.: 63/148,292. 2022 February
4. Benson S, Fuka M, Kolb E, Benson A. System and Method for Predicting the Presence of Rare Earth Elements. US Patent Application No.: 63/367,859. 2022 July.

Synergistic Activities

1. "Rare Earth Element Extraction and Concentration at Pilot-Scale from North Dakota Coal-Related Feedstocks"(DE-FE0031835). Subcontract to the University of North Dakota.
2. “North Dakota Rare Earth and Critical Element Resource Evaluation” (FY21-XCV-235) – North Dakota Industrial Commission funded research Project.

3. “Production of Germanium and Gallium Concentrates for Industrial Process” (DE-FE0032124)
4. "Conceptual Design of a One Ton Per Day Rare Earth Oxide Extraction and Concentration Plant from Low-Rank Coal Resources" (89243320RFE000032). Subcontract to University of North Dakota.
5. "Development of Low-Cost Rare Earth Element Analysis and Sorting Method" - North Dakota Industrial Commission funded research project. Developing an REE predictive algorithm to be used with pXRF and PGNAA to assist in the exploration, identification, and sorting of REE in coal.

MATT FUKA, M.S.
Senior Research Engineer, Microbeam Technologies Incorporated, Grand Forks, ND 58202
mfuka@microbeam.com, 701-213-6147

Education and Training

University of North Dakota	Mechanical Engineering	M.S. 2018
University of North Dakota	Mechanical Engineering	B.S. 2015

Research and Professional Experience

2021 – Present Senior Research Engineer, Microbeam Technologies, Inc.

Mr. Fuka currently provides technical direction and management of commercial projects funded by US and international clients associated with the high temperature behavior of materials in combustion and gasification systems. He identifies measures to improve performance and reliability of boilers/gasifiers based on an understanding of the chemical physical processes occurring in the plant and laboratory-derived experimental data. Mr. Fuka has developed databases and predictive algorithms for sensors to allow for quantification of REE and CM contents in carbon-ore and related materials. He is also a PI on one and an active contributor in multiple DOE funded projects. The areas Mr. Fuka leads include, laboratory-scale ash deposition/sintering/corrosion process testing, physical property testing and modeling of materials (strength, density, thermal conductivity, ash fusion temperatures), and thermochemical equilibrium modeling. Mr. Fuka also drafts proposals, prepares technical reports and communicates results of work with clients.

2018 – 2021 Research Engineer, Microbeam Technologies, Inc.

The main areas of Mr. Fuka work's included scanning electron microscopy (SEM) and x-ray microanalysis, laboratory-scale ash deposition/sintering/corrosion process testing, physical property testing, and thermochemical equilibrium modeling.

2018 Research Assistant, Microbeam Technologies, Inc.

Mr. Fuka prepared and analyzed samples using SEM/x-ray microanalysis for commercial and government clients. He also conducted and analyzed data from laboratory sintering and high temperature viscosity testing.

2016 – 2018 Graduate Research/Teaching Assistant, University of North Dakota

Mr Fuka synthesized and characterized novel ternary boride and carbide powders via pressureless reaction. He conducted and analyzed mechanical performance and tribology tests on ternary boride and carbide reinforced composites, and bioplastics made from lignin and PLA. He fabricated, conducted and analyzed compressive strengths of sintered fly ash-based composites for proppant design.

2015 – 2016 Design Engineer, Odra Street Sweepers

Mr. Fuka improved design of the mechanical, electrical and hydraulic systems on the Broom Badger street sweeper.

Selected Publications/Patent Applications

- M. Fuka, "Development of Novel Sintered Carbon-Ore Building Materials", 2022 Resource Sustainability Annual Project Review Meeting.

- S. Benson, M. Fuka, E. Kolb, A. Benson, "System and Method for Predicting the Presence of Rare Earth Elements", US Patent Application No.: 63/367,859. 2022 July.
- M. Fuka, E. Kolb, A. Benson, S. Benson, "System and Method for Predicting Abundance of Rare Earth Elements with Handheld X-Ray Fluorescence", US Patent Application No.: 63/148,292. 2022 February.
- M. Fuka, E. Kolb, A. Benson, S. Benson, "System and Method for Predicting the Presence of Rare Earth Elements", US Application No.: 17/650,773. 2021 February.
- S. Gupta, K. M. Hall, M. R. Fuka, M. Dey, S. K. Ghosh "Method of Fabricating Lignin Based Polymeric Systems", (Publication Number US20190255817 A1 – Filing Date: Feb. 16, 2018).
- Q. Tran, M. Fuka, M. Dey, S. Gupta, "Synthesis and Characterization of Novel Ti_3SiC_2 Reinforced Ni-Matrix Multilayered Composites based Solid Lubricants", Lubricants: Wear and Corrosion Resistant Coatings 2019, 7(12), 110; DOI: https://doi.org/10.3390/lubricants7120110.
- D. Stadem, S. Patwardhan, M. Fuka, J. Langfeld, A. Benson, and S. Benson, "Condition Based Monitoring and Predicting Ash Behavior in Coal Fired Boilers–III–Coal Properties Optimization", Proceedings of 36th Annual International Pittsburgh Coal Conference (2019 PCC).
- M. Fuka. "Synthesis and Characterization of Novel Ternary Borides (MoAlB) and Their Composites", The University of North Dakota, ProQuest Dissertations Publishing, 2018. 10814246.
- M. Dey, M. Fuka, F. AlAnazi, and S. Gupta, "Synthesis and Characterization of Novel Ni-Ti_3SiC_2 Composites", Proceedings of 42nd Int'l Conf & Expo on Advanced Ceramics & Composites (ICACC 2018).
- M. F. Riyad, M. Fuka, R. Lofthus, Q. Li, N. M. Patel, and S. Gupta "Novel Engineered Cementitious Materials by Using Class C Fly Ash as a Cementitious Phase", Ceramics Transaction, Materials Science & Technology (MS&T) 2015.

Synergistic Activities

- REE and CM Database and Algorithm Development: Developed databases and algorithms for predicting REE and CM in lignite carbon-ores. The predicted data is applied to upstream sensors that can allow for optimized carbon-ore sorting.
- Slag and Ash Database and Algorithm Development: Developed databases and algorithms for predicting various slag and ash properties during combustion and gasification. The predicted data allows for recommendations to optimize boiler and gasifier performance.
- Commercial Technology Development: Developing commercially scalable method to produce novel sintered carbon-ore building materials.

DENNIS R. JAMES

CONTACT INFORMATION:

Home Address 1806 Longwood Court, Allen, Texas 75013 USA
Telephone +1 (214) 914-5778
Email Address djamesconsulting@att.net

EDUCATION: University of Mary (Bismarck, ND) – Masters of Business Administration – May 2002
University of Mary (Bismarck, ND) – Master of Management – May 2001
Purdue University (West Lafayette, IN) – Master of Science – Geochemistry – May 1977
Youngstown State University (Youngstown, OH) – Bachelor of Science – Geology – August 1975

SUMMARY OF QUALIFICATIONS:

Mr. James has over 40 years of coal industry experience in geology and geochemistry, with involvement in exploration, development, operations, and reclamation of coal mines. Utilization of coal has been a primary focus area as it relates to identifying and solving coal quality related issues at plants utilizing coal. In addition, working with design engineering groups to design and build new facilities.

PROFESSIONAL HIGHLIGHTS:

2021 – Present Dennis James Consulting LLC – Allen, Texas
President

2011 - 2020 The North American Coal Corporation – Dallas, Texas
Director - New Technology (retired)

2007 - 2011 The North American Coal Corporation – Dallas, Texas
Manager of Technology

2002 - 2007 The North American Coal Corporation – Bismarck, ND
Fuel Quality Administrator (support function)

1997 - 2007 The Falkirk Mining Company – Underwood, ND and The Coteau Properties Company – Beulah, ND (North American Coal subsidiaries)
Staff Geologist

1989 - 1997 The Falkirk Mining Company – Underwood, ND (a North American Coal subsidiary)
Senior Geologist

1987 - 1989 The North American Coal Corporation – Bismarck, ND
Senior Geologist – Special Projects

1986 - 1987 The North American Coal Corporation – Cleveland, OH
Senior Geologist – Exploration

1983 - 1986 The Coteau Properties Company – Beulah, ND (a North American Coal subsidiary)
Senior Mine Geologist

1981 - 1983 The Coteau Properties Company – Bismarck, ND (a North American Coal subsidiary)
Mine Geologist

1977 - 1981 The B & M Coal Corporation – Columbus, IN
Geologist

1975 - 1977 The National Science Foundation Energy – Related (Coal) – West Lafayette, IN
Trainee – Purdue University

1974 - 1975 The Adamas Lapidary & Gem Shop – Youngstown, OH
Salesman

1973 - 1975 Youngstown State University – Youngstown, OH
Teaching Assistant

AWARDS:

Oct. 2009 American Institute of Professional Geologists (AIPG) Presidential Award of Merit, for work on the AIPG Energy Policy (Coal Chairman)

Oct. 2005 North Dakota Lignite Energy Council Distinguished Service Award, R&D, for work developing technologies to remove mercury from lignite-fired emissions

Oct. 2002 North Dakota Lignite Energy Council Distinguished Service Award, Government Affairs, for work with EPA on Mercury MACT issues

PROFESSIONAL MEMBERSHIPS & CERTIFICATIONS:

National Coal Council, Department of Energy (2016 – Present)

American Institute of Professional Geologists
Member and Certified Professional Geological Scientist (CPGS #4970)
Vice President of the North Dakota Section (1996)
President of the North Dakota Section (1997-2004)

American Association of Petroleum Geologists
Member (#18262-6)
Energy Minerals Division Member
Certified Coal Geologist (CCG #08)

State of Indiana - Certified Professional Geologist (CPG #72)

Society for Mining, Metallurgical, and Exploration – Member (#1583100)

American Geological Institute - Member (#42419)

PATENTS:

Method of Enhancing the Quality of High-Moisture Materials Using System Heat Sources:

- United States (Serial No. 11/107,152 filed on April 15, 2005. Issued as U.S. Patent No. 7,275,644).
- Also filed: Pakistan, PCT, Europe, Canada, Australia, South Africa, China, Japan, India, Indonesia, and Russia

Dr. Michael L Jones
President, MLJ Consulting, LLC
Jones_ml2003@yahoo.com 701-7391419

Education and Training

Bemidji State College	Physics	B.S. 1967
University of North Dakota	Physics	M.S. 1973
University of North Dakota	Physics	PhD 1978

Research and Professional Experience

2017- Present President, MLJ Consulting

After retiring from the Lignite Energy Council, Dr. Jones formed MLJ Consulting to provide consulting services based on his over 40 years working on research and development of energy and environmental technologies with special emphasis on lignite coal. Recent work has focused on extracting Rare Earth Elements for ND lignite with an economically viable technology.

2009-2016; Vice President R&D, Lignite Energy Council and the Technical Director for the State of North Dakota Lignite Research Program. Dr Jones responsibilities include identification of critical issues to facilitate the enhanced use of lignite coal. Technologies of interest include combustion, gasification chemical from coal and hydrogen from coal. Provides recommendation to the Lignite Research Council and the North Dakota Industrial Commission on funding of R&D activities to ensure completion of critical project in support of enhanced use of North Dakota lignite. Develops strategies to increase working relationships with research groups around the world including US DOE, EPRI, Canadian lignite coal users and others.

2004–2009: Senior Research Advisor, Energy & Environmental Research Center (EERC), University of North Dakota (UND). Dr. Jones' responsibilities include management of and technical direction for multidisciplinary science and engineering research teams focused on a wide range of integrated energy and environmental technologies. Specific program areas of interest include clean and efficient use of low-grade fuels, matching of fuel characteristics to system design and operating parameters, development of advanced power systems based on low-grade fuels, fundamentals of low-grade fuel combustion, ash behavior in low-grade fuel conversion systems, and analysis of inorganic materials in low-grade fuels. Projects emphasize a cradle-to-grave approach from resource assessment, to optimum utilization systems, to minimization of emissions and waste management featuring by-product utilization.

2004–2016: Adjunct Professor, Physics, UND.

1994–2004: Adjunct Assistant Professor, Physics, UND

1983–2004: Associate Director, Industrial Relations and Technology Commercialization, EERC, UND. Dr. Jones' responsibilities include planning, staffing, and technical direction of combustion and gasification research, including projects in combustion chemistry or gasification chemistry, behavior during coal utilization, fluidized-bed combustion, coal–water fuels,

SO_x/NO_x removal, and particulate removal and characterization. Special emphasis was given to low-rank coal systems; activities ranged from field testing of full-scale power plants, to pilot-scale studies, to laboratory investigations that examine both fuel and system characteristics and their impacts on overall performance.

1990–1994: Adjunct Professor, Department of Chemical Engineering, The University of Utah, Salt Lake City, Utah.

1979–1983: Grand Forks Energy Technology Center, U.S. Department of Energy, Grand Forks, North Dakota. Dr. Jones' responsibilities included technical direction of research and development projects related to combustion technology for low-rank coals, with specific responsibility for fundamental research on pulverized coal combustion. Directed research on new, specialized analytical procedures for determination of inorganics and trace elements in coal and materials derived from coal combustion and conversion processes. Instrumentation included methods Auger/ESCA spectrometer, scanning electron microscope, x-ray diffraction, x-ray fluorescence, argon plasma spectrometer, and atomic absorption spectrometer.

Professional Activities

Member: National Coal Council 2012-2020

Member: Technology Advisory Board for Plains CO2 Reduction Partnership 2009-2018

Member: Executive Board for the University of North Dakota College of Engineering and Mines

Awarded Energy Champion for 2016 by Energy and Environmental Research Center, May 2016

Publications and Presentations

Dr. Jones has authored or co-authored over 100 publications and presentations

NAME: Srivats Srinivasachar

POSITION TITLE & INSTITUTION: President, Envergex LLC

A. PROFESSIONAL PREPARATION
(see PAPPG Chapter II.C.2.f.(i)(a))

INSTITUTION	LOCATION	MAJOR/AREA OF STUDY	DEGREE (if applicable)	YEAR (YYYY)
Boston University, School of Management	Boston, MA	Master of Business Administration	M.B.A.	2004
Massachusetts Institute of Technology	Cambridge, MA	Chemical Engineering	Sc.D.	1986
Indian Institute of Technology	Chennai, India	Chemical Engineering	Bachelor of Technology	1981

B. APPOINTMENTS
(see PAPPG Chapter II.C.2.f.(i)(b))

From - To	Position Title, Organization and Location
2006-Present	President, Envergex LLC, Sturbridge, MA
1999-2006	Technical Manager - Environmental Control Technology (Mar. 2003-2006); Principal Consulting Engineer - New Product Business Development (Oct. 1999- Mar. 2003), ALSTOM Power, Inc., Windsor, CT
1993-1999	Environmental Group Leader, (Oct. 1997 – Sept. 1999); Senior Consulting Engineer, (1994 – 1997), ABB Combustion Engineering, Inc., Windsor, CT
1986-1993	Manager - Environmental Remediation and Resource Utilization (1992-1993), Principal Research Scientist (1986-1992), Andover, MA

C. PRODUCTS

(see PAPPG Chapter II.C.2.f.(i)(c))

Products Most Closely Related to the Proposed Project

1. U.S. Patents 9,121,606 and 9,624,109, “Method of manufacturing carbon-rich product and co-products”
2. U.S. Patent 7,981,835, “System and method for coproduction of activated carbon and steam/electricity”
3. Benson, S.A., Crocker, C.R., Hanson, S.K., McIntyre, K.A., Just, B.J., Raymond, L.J., Pflughoeft-Hassett, D.F, Srinivasachar, S., Barry, L.T. and Doeling, C.M., “JV Task 115-Activated Carbon Production from North Dakota Lignite – Phase IIA,” Final Report, U.S. Department of Energy Cooperative Agreement No. DE-FC26-98FT40321, June 2008
4. U.S. Patent 8,840,706, “Capture of carbon dioxide by hybrid sorption”
5. Srinivasachar, Srivats. Capture of carbon dioxide by hybrid sorption. United States: N. p., 2014. Web https://www.osti.gov/biblio/1159907-capture-carbon-dioxide-hybrid-sorption
6. U.S. Patent 6,749,681, “Method of Producing Cement Clinker and Electricity”
7. Van der Waat, J., Laudal, D., Feilen, H., Krishnamoorthy, G., Mann, M., Shallbetter, R., Nelson, T. and Srinivasachar, S.(2018). Development of a spouted bed reactor for chemical looping combustion. Journal of Energy Resources Technology, 140 (11), 112002
8.Nelson, Teagan, Johannes G. van der Watt, Daniel Laudal, Harry Feilen, Michael Mann, and Srivats Srinivasachar. "Reactive jet and cyclonic attrition analysis of ilmenite in chemical looping combustion systems." International Journal of Greenhouse Gas Control 91 (2019): 102837.

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

1. U.S. Patent 8,277,542, “Method of capturing mercury from flue gas”
2. U.S. Patent 8,069,797, “Control of Mercury Emissions from Solid Fuel Combustion”
3. U.S. Patent 6,089,171, “Minimum Recirculation Flame Control Pulverized Solid Fuel Nozzle Tip”
4. U.S. Patent 6,089,023, “Steam Generator System Operation”
5. Srinivasachar, Srivats, Nelson, Teagan, Mann, Michael, Dyrstad-Cincotta, Nicholas, and Laudal, Daniel. Supercritical Treatment Technology for Water Purification - Phase I STTR Final Technical Report. United States: N. p., 2019. Web https://www.osti.gov/biblio/1543262-supercritical-treatment-technology-water-purification-phase-sttr-final-technical-reportTomomewo, O. S., Dyrstad-Cincotta, N., Mann, D., Ellafi, A., Alamooti, M., Srinivasachar, S., & Nelson,

D. SYNERGISTIC ACTIVITIES

(see PAPPG Chapter II.C.2.f.(i)(d))

Expertise in energy and environmental engineering, power plant systems, and cross-industry product development; Led product/process development groups - ALSTOM Power Inc. (now a GE company); Secured multiple patents and published over 50 technical papers. Dr. Srinivasachar is developing carbon capture technologies for fossil-fired power plants on an ARPA-E project (DE-AR0001314); has developed models for integrating energy storage with fossil power plants (DE-SC0020863); is demonstrating on a commercial scale sorbent injection for aerosol mitigation in power plants DE-FE0031756 - project originated from STTR funding; team member Coal FIRST FEED study (Coal and Gas Boiler and Turbine Concept) DE-FE0031995 . Dr. Srinivasachar is also the inventor of multiple activated carbon technologies which he scaled from pilot-scale to successful demonstration at three full-scale plants. About 250,000 lb of product have been supplied to six power plants for emission control .