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December 1, 2021

Ms. Karlene Fine
Executive Director
ATTN: Lignite Research, Development and Marketing Program
North Dakota Industrial Commission
State Capitol, 14th Floor
600 East Boulevard Avenue, Department 405
Bismarck, ND 58505-0840

Dear Ms. Fine:

Subject: EERC Proposal No. 2022-0069 Entitled "Advanced Processing of Coal and Coal Waste to Produce Graphite for Fast-Charging Lithium Ion Battery Anode"

The University of North Dakota (UND) Energy & Environmental Research Center (EERC), in collaboration with the UND Institute for Energy Studies (IES), is pleased to submit the subject proposal to validate an approach to make high-grade graphite from North Dakota lignite and lignite coal waste and to fabricate and test a fast-charging lithium ion battery anode prototype made from the produced graphite.

Enclosed please find an original and one copy of the subject proposal along with a check for $100. The EERC and IES are departments within UND, which is a state-controlled institution of higher education and is not a taxable entity; therefore, it has no tax liability.

This transmittal letter represents a binding commitment by the EERC and IES to complete the project described in this proposal. If you have any questions, please contact me by telephone at (701) 777-5051 or by e-mail at aazenkeng@undeerc.org.

Sincerely,

DocuSigned by:
048DB552AD204BF...
Alexander Azenkeng
Assistant Director for Critical Materials

Approved by:

DocuSigned by:
29499751E2B84D7...
Charles D. Gorecki, CEO
Energy & Environmental Research Center

AZ/ro

Enclosures

Lignite Research, Development and Marketing Program

North Dakota Industrial Commission

Application

Project Title: Advanced Processing of Coal and Coal Waste to Produce Graphite for Fast-Charging Lithium Ion Battery Anode

Applicant: University of North Dakota Energy & Environmental Research Center

Principal Investigator: Dr. Alexander Azenkeng

Date of Application: December 1, 2021

Amount of Request: $500,000

Total Amount of Proposed Project: $1,545,000

Duration of Project: 36 months

Point of Contact (POC): Dr. Alexander Azenkeng

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ABSTRACT

Objective: The goal of the proposed work is to develop an approach to make high-grade graphite (high crystallinity, spherical particles, and <0.2 wt% ash) from North Dakota (ND) lignite and lignite coal waste (LCW) using laboratory bench-scale systems. The graphite will be produced by two processes: 1) an EERC-developed process for coal-derived high-value carbon products and 2) coal tar pitch (CTP) obtained from a commercial vendor. The produced graphite will be further functionalized and used to fabricate a fast-charging (FC) lithium ion battery (LIB) anode prototype.

Expected Results: The anticipated results from this project include production of high-grade graphite from ND lignite or LCW and ND lignite-derived CTP, a FC LIB anode prototype with a charging rate greater than the 370 mAh/g for most commercial systems, and a report of the techno-economic feasibility of the technological process. Together, these results will demonstrate the potential for ND lignite-derived graphite to be used in energy storage applications for the large and growing electric vehicles (EVs) industry and large LIB market and the feasibility of scaling up such a technology. On a broader level, it is expected that the produced graphite represents an important value-added product from ND lignite that can be used in other markets such as aluminum production, nuclear power generation, and energy storage in EVs, LIBs, etc., which could attract some of these industries to ND.

Project Duration: 36 months, with an anticipated start date of February 1, 2022.

Total Project Cost: The total project cost is $1,500,000. The University of North Dakota (UND) Energy & Environmental Research Center (EERC), in collaboration with the UND Institute of Energy Studies (IES), is requesting $500,000 from the North Dakota Industrial Commission (NDIC) Lignite Research, Development and Marketing Program. The U.S. Department of Energy (DOE) has awarded $1,000,000 for the project, and negotiations of the contract are in progress. North American Coal Corporation (NACoal), the commercial partner, will provide $45,000.

Participants: NDIC, DOE, NACoal, IES, and the EERC.

PROJECT SUMMARY

This project involves development of a technological process to make high-grade graphite as an important value-added product from North Dakota (ND) lignite or lignite coal waste (LCW) and from ND lignite-derived coal tar pitch (CTP). The graphite made from each process will be further functionalized and used to fabricate a fast-charging (FC) lithium ion battery (LIB) anode prototype. A techno-economic analysis will be performed to determine the competitiveness of the proposed technology with currently available options for synthetic graphite (SG) and FC LIB anodes and the feasibility for subsequent scaleup and commercialization.

The scope of work comprises seven steps: 1) project management, planning, and reporting activities, spanning the entire project duration; 2) ND lignite coal or LCW upgrading; 3) processing of ND lignite-derived CTP; 4) carbonization of upgraded coal and CTP; 5) graphitization; 6) preparation and testing of the LIB anode prototype; and 7) techno-economic analysis.

If this technology advances to the commercial phase, it is anticipated that an opportunity opens for ND to create a value-added high-grade graphite product that has a high demand in multiple industries such as EVs, LIBs, aluminum production, nuclear power generation, etc. The market for these industries is growing at a fast pace, and it is conceivable that some may be attracted to open new facilities in ND to be located close to the production of high-grade graphite. Ultimately, this creates more economic opportunities for ND coal communities and moves closer to U.S. independence from foreign sources of synthetic graphite (SG). A successful implementation of this project could also assist, in some measure, in enhancing, preserving, and protecting ND's lignite industry as well as advancing/sustaining economic growth by providing a path for new opportunities for lignite markets in other industrial sectors mentioned above.

The work proposed herein will be performed as a collaborative effort between the University of North Dakota (UND) Energy & Environmental Research Center (EERC) and Institute for Energy Studies (IES), with financial support from the U.S. Department of Energy (DOE), North American Coal

Corporation (NACoal), and the North Dakota Industrial Commission (NDIC) through its Lignite Research, Development and Marketing Program.

PROJECT DESCRIPTION

Introduction

The EERC has several decades of lignite coal research and development (R&D) experience dating back to the 1980s. Combining this historical experience with its recent advances in coal-to-graphene conversion, the EERC, in collaboration with IES, proposes to develop a technology capable of converting ND lignite and LCW (primarily overburden and fines) to high-grade graphite for producing a FC LIB anode that is competitive in terms of cost and performance with existing graphite in the large and growing LIB electrode market. Although the focus of this project will be on the LIB market, the produced high-grade graphite can also be used in other industrial sectors such as in electronics, steel, aluminum production, grid-level energy storage, and nuclear energy generation.

The global graphite market was valued at $14.3 billion in 2019 and is expected to reach $21.6 billion by 2027 (Allied Market Research, 2021), with synthetic graphite (SG) holding the largest market share over natural graphite because of the increase in steel and battery industry demand for the manufacture of electrode materials. Concurrently, the market size for LIBs has also skyrocketed because of rapidly increasing demands in broad application areas such as electric vehicles (EVs), consumer electronics, and grid-level energy storage. For example, the U.S. market size in 2020 for LIB anode materials was 150,000 tons, which represents 25% of the global market size and >90% of which is graphite (BTR China, 2019). This presents a significant opportunity for traditional coal communities where coal-derived graphite (CDG) could provide a big boost to the economy in the era of dwindling coal power generation.

ND has the largest lignite coal deposit in the world, with approximately 25 billion tons that is economically minable through surface operations from within 1800 ft deep (Murphy, 2019). Based on annual production from the five state mines, the amount of lignite waste as overburden and coal fines is estimated to be ~17.8 million tons per year (see Background section). Adding this waste fraction to the nearly 31 million tons per year of regular combustion-grade lignite presents a significant resource that can be converted using EERC-developed methods to valuable products such as high-grade graphite.

Although the lignite industry has played a key role in sustaining ND's economy for many decades, a shifting energy generation paradigm from coal power plants to renewable sources creates economic challenges for traditional coal and power plant communities that see a shift in the prevailing job skills and may have little flexibility to adapt to the changes. To address these challenges, innovative solutions to extract the full economic value from coal-derived materials via transformative research for technologies that can convert coal and/or CW streams to valuable products such as graphite are needed. The proposed project seeks to develop one such innovative solution to convert ND lignite coal and coal waste into high-grade graphite, which will be used to fabricate a FC LIB anode prototype to demonstrate a potential application of the lignite-derived graphite in energy storage.

Objectives

The overall objective of the proposed project is to develop an approach to synthesize high-grade CDG from ND lignite or LCW and from ND lignite-derived CTP. The graphite made from each process will be further functionalized and utilized to fabricate a FC LIB anode prototype. A techno-economic analysis will be performed to determine the competitiveness of the proposed technology with currently available options for SG and FC LIB anodes. A successful implementation of this project will also assist in enhancing, preserving, and protecting ND's lignite industry as well as advancing/sustaining economic growth by providing a path for new opportunities for lignite markets in other industrial sectors, which is a key objective of NDIC's LRP.

Overview of Proposed Technology

The proposed technology involves the transformation of lignite coal or LCW via two process paths (Figure 1). Path A involves coal or CW upgrading, carbonization, and graphitization to obtain SG. The

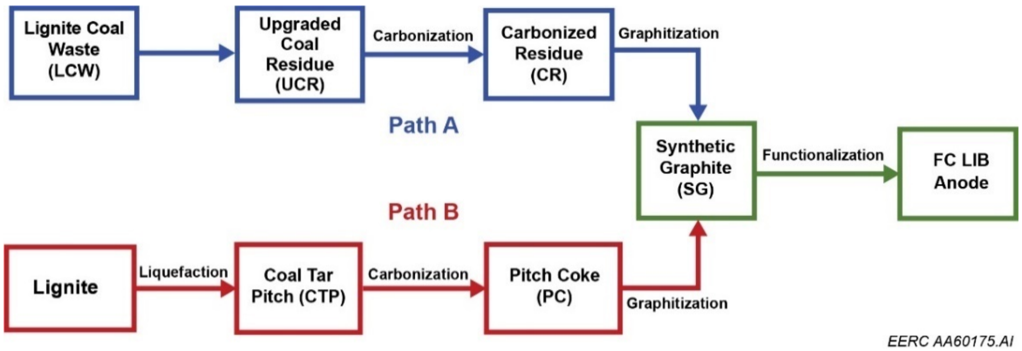

Figure 1. Schematic representation of graphite production paths from coal and CW.

CW-upgrading step will utilize physical cleaning methods developed at the EERC to produce ultraclean coal residue with <0.5 wt% ash. The ultraclean coal residue will be further treated in an autoclave reactor with proprietary chemical reagents (patent application filed) to remove or significantly reduce the heteroatom content and produce an upgraded coal residue (UCR), followed by carbonization to a carbonized residue (CR) and graphitization to SG. Path B will proceed by coal liquefaction to produce CTP, CTP carbonization to pitch coke (PC), and PC graphitization to SG.

The SG produced from Paths A and B will each be functionalized and used to fabricate a FC LIB anode prototype. In addition, a techno-economic analysis will be performed to determine the competitiveness of the proposed technology with currently available options for SG and FC LIB anodes. A successful completion of the proposed effort will validate a technological process that advances the science of lignite utilization toward other non-electric power applications, thus fulfilling NDIC's objective of preserving and expanding the lignite industry market opportunities.

Scientific and Technical Merit

Novelty of Proposed Research Over State of the Art. The proposed research concept possesses some advantages over current state-of-the-art (SOTA) approaches for CDG. It has been reported that good graphite candidates for LIB applications have small particle sizes of 10–20 µm or preferably 1–5 µm and spherical morphologies that are also isotropic in nature (Cai et al., 2020). These properties are achievable in lignite coals because the aromatic subdomains are strengthened during the graphitization process as opposed to higher-ranked coals that often form flake graphite from naturally formed 2D graphitic layers.

However, removal of coal-borne impurities is critical to being able to make a high-quality graphite because the impurities can disrupt the microstructural ordering required in high-grade graphite. Limiting the heteroatom content facilitates formation of mesophase residue, an important precursor to the graphitization process. Staged thermal treatments ensure controlled release of volatile matter (VM), prevent runaway reactions, and provide adequate residence time for improved strengthening of the fixed carbon precursors for graphite, i.e., taking care of the important thermodynamics of the process.

Several other parameters set this concept apart from current SOTA. Lignite-derived graphite tends to form spherical particles, unlike conventional graphite, which forms flakes due to preferred orientation along the (002) plane. These properties result in a higher-quality graphite with better performance in LIB applications than conventional flake graphite. Compared to conventional anisotropic graphite flakes, spherical particles have FC/discharging capability, higher packing density, higher specific capacity and energy density, and lower specific surface area (Cai et al., 2020). Unlike other SOTA processes that make conventional graphite anodes, the proposed project targets the more advanced functionalized LIB product with greater market potential and utilizes ND lignite coal or CW resources. These steps together constitute a fundamental and comprehensive approach that addresses R&D issues of the proposed process, with additional consideration for the intended application requirements. This differs from current SOTA and most literature studies, which may look at just graphite applications or just coal to graphite, with the missing linkage between coal properties, graphite properties, and application requirements.

Fundamental Aspects of Graphitization and Feasibility. Graphite is a highly crystalline carbonaceous material that exists as a naturally occurring mineral in the earth's crust or a synthetic material made in the laboratory under given conditions. The high degree of crystallinity of graphite, unlike coal, is known to be associated with the perfect ordering of the microstructural domains and the graphitic layers (Atria et al., 2002). Therefore, synthetic methods that yield high-quality graphite must ensure the process lends itself to improved ordering and strengthening of the microstructural domains. Previous studies have shown that the quality of SG is highly dependent on temperature, where temperatures lower than 2500°C often produce lower structural ordering compared to thermal treatment at about 2800°C (Atria et al., 2002;

Xing et al., 2018). This is consistent with the formation of high-quality turbostratic graphene, a 2D subdomain of graphite, at about 2727°C (Luong et al., 2020). Atria et al. (2002) also showed that heating to about 2900°C did not yield any significant improvement in the graphitizability of anthracite. These previous studies suggest an optimum graphitization temperature of about 2800°C under inert atmosphere. To achieve the required optimum temperatures for graphitization, a graphitization furnace, up to 3000°C (see Figure 2), was purchased for the graphene project and will be a critical piece of equipment for R&D on the proposed process. This furnace will greatly enhance the chances of getting a high-quality graphite.

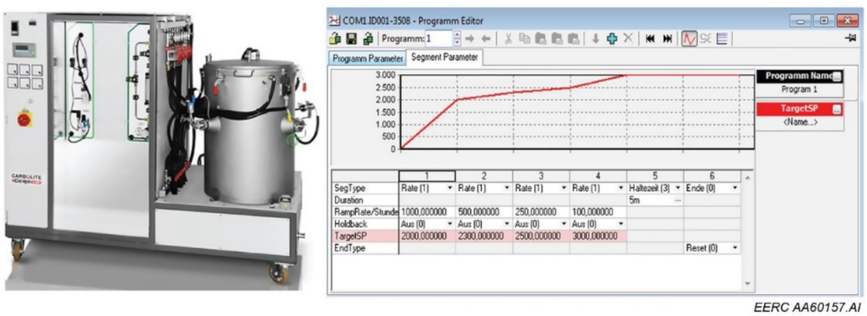

Figure 2. Existing graphitization furnace (left) and screenshot (right) of software program at the 3000°C set point at the EERC.

Other characteristics that play an important role in the graphitizability of coal or CW materials include inorganic impurities that produce ash, heteroatoms, and VM content. The ash-producing impurities tend to distort structural ordering of the crystalline microstructures in graphite (Nyathi et al., 2013). Heteroatoms such as oxygen, sulfur, or nitrogen form isotropic bridged structures that are not mesophase in nature and so hinder the graphitizability of the coal or CW material. VM is mostly made of aliphatic moieties and lacks the condensed aromatic ring structures that are critical building blocks for graphitic layers in graphite. Consequently, to make high-grade graphite from coal or CW, these challenges must be addressed to improve the graphitizability of the resulting CW residue. The proposed concept establishes a concrete plan to address all of these challenges and to significantly increase the chances of successfully making high-grade graphite from ND lignite coal or LCW.

Coal or CW upgrading is a key part of the proposed concept and will be accomplished using proprietary methods developed at the EERC. Carbonization of UCR and PC will be performed under controlled, staged-temperature regimes to facilitate strengthening of the carbon graphitic layers and alignment of microstructural subdomains for development of the high crystallinity needed for high-grade graphite. High-quality graphite is required to form a high-quality FC LIB anode. During staged temperature carbonization, the evolved VM content will be condensed and collected by a fabricated cold trap system to determine the potential for additional useful by-products. A similar staged temperature regime will be followed for CTP carbonization. The fundamental scientific basis of this concept, discussed above, coupled with the engineering expertise at the EERC and IES suggest a highly feasible concept with a great chance of success.

Methodology

To achieve the objective of the project, the methodology comprises seven tasks that are described in detail below.

Task 1.0 – Project Management and Planning. The EERC will manage and direct the project in accordance with the stated objectives to meet all technical, schedule, and budget requirements. All project activities will be led and coordinated by the EERC with the aim to effectively accomplish the work. The EERC will ensure that project plans, results, and decisions are appropriately documented and project reporting and updating requirements are satisfied. Any modifications to the project timetable, technical approach, cost, or scope of work after award will be considered in consultation with the project sponsors to accurately reflect the current status of the work being performed.

Task 2.0 – Coal Upgrading: Lignite. Coal or CW samples will be upgraded using proprietary methods developed in previous projects at the EERC. The raw coal or CW samples will be crushed to about –30 mesh (≤595 μm) and cleaned by specific gravity separation techniques to remove coal-borne inorganic minerals. Additional chemical agents such as strong acids and bases will be utilized after physical cleaning to achieve ultraclean coal residues. The clean coal residue will be further reacted in an autoclave with proprietary reagents to remove or significantly reduce the heteroatom content. The UCR will be characterized by various analytical techniques.

Task 3.0 – Coal-Derived Tar Pitch. Multiple 1-pound batches of CTP produced from ND lignite coal characterized for ash content, carbon content, and softening point will be procured from a vendor with a proprietary technology. Based on the characterization results, the best candidate suitable for producing LIB anode-grade graphite will be selected for further processing to PC and to graphite. Sample characterization will be performed using standard test methods and analytical techniques.

Task 4.0 – Carbonization

Subtask 4.1 – Upgraded Coal or Coal Waste Carbonization. The upgraded coal or CW samples will be carbonized at high temperature in two stages. In the first stage, the samples will be heated under inert atmosphere with argon to a temperature of about 500°C for about 1 hour. For the second stage, the temperature will be increased to about 1000°C and held steady for another 1 hour. In both stages, volatile fractions released will be condensed and collected in the condensate trap. Noncondensable gases released will be collected using gas bags and analyzed by gas chromatography.

Subtask 4.2 – CTP Carbonization. Carbonization of CTP will be performed under different conditions to find the best-quality PC for graphitization. Key PC performance metrics (morphology retention, residual carbon content, surface area, and porosity) will be evaluated as a function of temperature (300°–1100°C), time (1–12 hours), multistage heat treatment, and atmosphere (vacuum, N_2, or Ar). Taguchi orthogonal array built-in Minitab software will be used to design optimization experiments of these factors and investigate interactions between them. Samples will be characterized by standard analytical techniques.

Task 5.0 – Graphitization. The carbonized residues obtained in Task 4.0 will be graphitized in Task 5.0. Additional heat treatment at ~1500°C will be performed to further strengthen the residues before graphitization. The final heat-treated residue will be graphitized in a graphitization furnace at ~2800°C. The graphite samples obtained will be characterized by standard analytical techniques. A quality-controlled, commercially available graphite sample will be analyzed for comparison with the graphite samples made in this study.

Task 6.0 – Production and Testing of LIB Anode Prototype

Subtask 6.1 – Functionalization of Coal-Derived Graphite. In this subtask, the functionalization process will be optimized to prepare fast-charging graphite (FCG) from the graphite produced in Task 5.0 based on primary and secondary particle sizes, spheritic morphology, surface area, and d-spacing. The relevant experimental design method and the characterization methods in Subtask 4.2 will be applied.

Subtask 6.2 – Electrochemical Performance Testing. The synthesized FCG composite anodes will be tested for electrochemical performance relative to a commercial anode as the benchmark. Current densities and specific capacities will be calculated based on the mass of the target compound of the electrode. Cycle life will be evaluated using a three-electrode system for cyclic voltammetry (CV) and electrochemical impedance spectroscopy (EIS) tests. Coin-type and full-size cylindrical cells will be fabricated and tested.

Task 7.0 – Economic Feasibility Analysis. An economic analysis will be performed to determine the overall process feasibility by developing a process model in Aspen software. All process input/output parameters determined from Tasks 2.0–6.0 will be assessed and used for process modeling in Aspen Plus and Aspen Process Economic Analyzer.

ANTICIPATED RESULTS

The anticipated results from this project include a high-grade graphite from ND lignite or LCW and ND lignite-derived CTP with spherical particle morphologies, <0.2 wt% ash, and high crystallinity. The graphite made from each process will be further functionalized and utilized to fabricate a FC LIB anode prototype that can deliver a charging rate of >370 mAh/g, which is currently obtained in commercial graphite anodes. A report of the techno-economic feasibility of the technological process will also be produced as an appendix to the final project report.

FACILITIES AND RESOURCES

This project will take advantage of the exceptional laboratory facilities and analytical capabilities available at both the EERC and IES.

EERC Research Complex

The EERC currently occupies a research complex consisting of 254,000 square feet of laboratories, fabrication facilities, technology demonstration facilities, a specialized machine shop, and offices. It houses eight analytical laboratories dedicated to research on coal combustion and utilization; coal by-product utilization; water resource characterization; conventional/unconventional petroleum resources; alternative fuels; environmental chemistry; and carbon capture, utilization, and storage.

IES Battery Assembly and Test Center

IES and Clean Republic LLC jointly operate a battery assembly and test center where fabrication of battery test articles of various sizes from small coin-type to full-size cylindrical cells and up to 48-V battery packs can be made.

TECHNIQUES TO BE USED

The EERC and IES have several advanced analytical equipment and analysis techniques suitable for the proposed activities. A summary of key analytical techniques/equipment available for this project includes field-emission scanning electron microscopy (FESEM), x-ray fluorescence (XRF) spectroscopy, Fourier transform infrared (FTIR) spectroscopy, a Raman spectrometer for various chemical analyses; x-ray diffraction (XRD) for determination of graphite crystallinity and properties; various high-temperature furnaces and a special graphitization furnace with an upper limit of 3000°C for carbonization and graphitization; proximate/ultimate/CHN analyzers, a thermogravimetric analyzer (TGA) for coal properties determination; a surface area analyzer for graphite particles surface area measurements; inductively coupled plasma–optical emission spectroscopy (ICP–OES) for trace element detection; and an electrochemical testing workstation and a battery-testing system for testing of the anode prototype. The purchase of a safety chamber for battery FC testing is proposed. The EERC has extensive modeling and simulation capabilities. The scientific research staff members are equipped with high-end workstation computers.

ENVIRONMENTAL, TECHNOLOGICAL, AND ECONOMIC IMPACT

The environmental impact of the project is expected to be minimal because all project activities will be performed at EERC and IES laboratories on the UND campus, where all laboratory experimental procedures undergo an internal environmental compliance review to ensure compliance with North Dakota Department of Health policies and applicable national regulations.

The anticipated long-term economic impacts of this project are related to the potential creation of a viable path for an important value-added high-grade graphite product from ND lignite which when commercialized will create opportunities for new lignite markets in other non-electric power industrial sectors such as electronics, EVs, LIBs, aluminum production, nuclear power generation, grid-level energy storage, etc. These new opportunities will in turn help to create an economic boost to local coal communities in ND and provide a solution that can be exported to other coal communities around the country. The creation of a FC LIB anode material will provide a viable path to meet the demands of a fast-growing LIB market and EVs by utilizing ND lignite-derived graphite. The short-term economic impacts are limited to this funding being an important investment in an important research effort with the potential for significant long-term outcomes and helping to provide/sustain employment for the people working on the project. Sustaining employment for the project participants will in turn sustain their spending power in local communities, thus providing some economic benefits in the local communities.

The successful development and commercialization of CDG technologies, particularly based on ND lignite, which is the largest lignite reserve in the world, will create a significant scientific and economic impact on the utilization of coals not only for ND but nationally and globally. Such a development will not only help to fulfill the growing demand for graphite for the battery industry and other industrial applications but can help attract some new industries to ND which will be of great benefit to the ND economy.

WHY THE PROJECT IS NEEDED

North Dakota has about 25 billion tons of untapped, economically minable lignite reserves that are the main source of coal for ND's lignite-based energy industry. Because of the shifting energy generation paradigm, where renewable energy continues to replace coal power generation, economic challenges will arise for traditional coal and power plant communities. To address these challenges, innovative solutions to extract the full economic value from coal-derived materials via transformative research for technologies that can convert coal and/or CW streams to valuable products such as graphite are needed. Thus the research proposed herein is needed to help advance the proof-of-concept ideas toward commercialization, which will potentially attract new industries into the state.

STANDARDS OF SUCCESS

The project will be carried out over a period of 3 years and the standards of success are described and/or explained below.

Measurable Deliverables

1) Production of up to 3 lb of UCR
2) Production of at least 1.5 lb of carbonized UCR
3) Production of at least 0.5 lb of carbonized CTP
4) Production of up to 0.5–1.0 lb of CDG for LIB fabrication with <0.2 wt% ash

Method for Measuring Success

The amounts of produced intermediate products and final graphite products mentioned above will be reported in subsequent quarterly reports to NDIC. The ash content of the final products will be measured using standard ASTM International methods.

Value to North Dakota

This project will result in the development of a product that is highly marketable in multiple industrial sectors, with the potential to significantly expand the utilization of ND lignite and lignite market opportunities.

Utilization of Project Results by Public and Private Sectors

The produced high-grade graphite and subsequently the FC LIB will be utilized by both public and private sectors because of the wide range of applications of graphite across multiple industries such as EVs, LIBs, grid energy storage, etc.

Potential Commercial Use of Project's Results

The results of this project will be useful for further development of commercialization pathways by potential commercial entities.

Education, Research, Development, and Marketing of ND's Lignite Resources

The final report will be a valuable education resource for students and other researchers seeking further development of this process or for research and development of alternative methods aimed at preserving and expanding the marketability of ND lignite resources.

Preservation of Existing Jobs and Creation of New Jobs

This project will help sustain the jobs of project participants as well as sustaining a small number of indirect jobs for people who provider services to project participants like in a grocery store, gas station, etc. In the long-term, potential new jobs will be created if the technology matures enough to be commercialized.

Satisfying the Purposes Established in the Mission of the LRP Program

This project aims to make a high-grade graphite product from ND lignite and then use the produced graphite to make a LIB anode prototype. The graphite produced can be used by many other industrial sectors and the LIB will be applicable to the EVs and energy storage applications. Both market sectors will potentially result in greater use of lignite resources which will fulfill one of the key purposes in the mission of the LRP program, which is to enhance, preserve and/or expand the market options for ND lignite.

Reporting on Project Success

Reporting of project success will be done on a quarterly basis, and a final project report will be issued at the end of the project. In addition, periodic meetings via Webinars and/or online conference calls with NDIC will arranged to provide updates on the successful progression of the project.

BACKGROUND

The EERC has several decades of lignite coal R&D experience dating back to the 1980s. Specifically, the experience with coal beneficiation techniques such as froth flotation, float–sink, acid cleaning, and chemical fractionation methods demonstrated over the years (O'Keefe et al., 1993; Benson and Holm, 1985; Musich et al., 1994) will be relevant for the current project. While the goal for these past efforts was to produce beneficiated coal products that are more environmentally friendly for power generation, this experience is expected to be utilized in fine-tuning and to further develop the cleaning of lignite for the purpose of making high-quality graphite. Recent advances on the EERC's coal-to-graphene conversion process have opened new opportunities to create high-value carbon products from ND lignite. To continue along this line of research, the EERC, in collaboration with IES, proposes to develop a technology capable of converting ND lignite coal or CW to high-quality graphite for producing FC LIB electrode material that is competitive in terms of cost and performance with existing graphite in the large and growing LIB electrode market.

Coal Utilization Challenges/Opportunities in a New Energy Generation Paradigm

Although the ND lignite industry has been a significant contributor to the state's economy for many decades, a shifting energy generation paradigm creates economic challenges for traditional coal and power plant communities that see a shift in the prevailing job skills and may have little flexibility to adapt to the new changes. To address these challenges, DOE, pursuant to the Presidential Executive Order 14008 of January 27, 2021, is seeking innovative solutions to extract the full economic value from coal-derived materials by funding transformative research for technologies that can convert coal and/or CW streams to valuable products such as graphite. The commercialization of these novel technologies will provide alternatives for economic revitalization and environmental justice for traditional coal and power plant communities not only in ND but across the entire United States. This government objective also happens to align with NDIC's goal to preserve, protect, and expand lignite opportunities for the ND lignite industry.

To convert ND lignite to high-quality graphite, a few lignite-related challenges must be addressed. Primarily, the ash, VM, and heteroatom (O, N, S) content must be reduced significantly to improve the chances of making good-quality graphite out of lignite or LCW. With seed funding from the state through the ND State Energy Research Center (SERC) and continued funding from DOE, the EERC has successfully developed methods to address all three of these challenges. Preliminary results (Figure 3) show excellent ash reductions on lignite coal for an unoptimized method that was initially aiming for a target residual ash content of 3 wt%. Additional upgrading to curtail heteroatom content yielded an oxygen content reduction of about 24% on lignite. It is expected that further improvements to this method will produce ultraclean coal residues needed for the proposed graphite-making process. The residual sulfur content of 0.38 wt% obtained for upgraded lignite in EERC studies is already at the recommended cutoff of 0.4 wt% residual sulfur in graphite that is typically used for high-power and ultrahigh-power applications such as industrial electrodes for aluminum production (Reid, 2018). It is expected that additional fine-tuning will lead to further reductions in sulfur content below 0.38 wt% to result in better-quality lignite-derived graphite. An initial attempt at graphitization of the coals has produced promising results, shown in Figure 4, compared to the results of other coal ranks and a reference graphite sample. These initial results point to a great chance of success in the proposed project to further improve the quality of the graphite for high-end applications such as for FC LIB anodes.

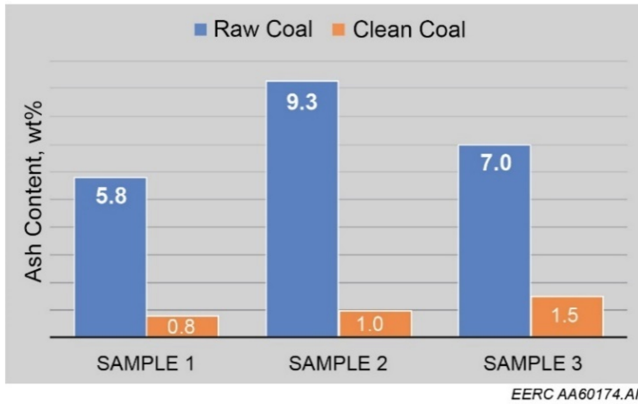

Figure 3. Ash content of raw and clean lignite coal samples.

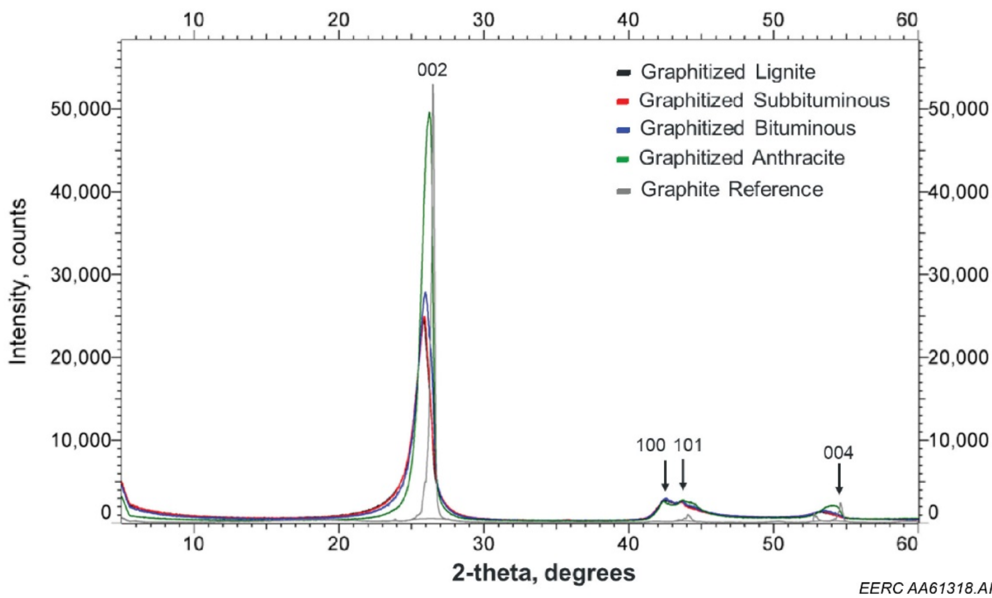

Figure 4. XRD diffractograms of graphitized coals compared to that of a reference graphite.

Coal Waste Resources and Opportunity for North Dakota

There are five coal mines, six power plants, and two polygeneration facilities in ND. The coal production, power plants served, estimated CW as a fraction of total production, and township communities that serve the mines and plants are shown in Table 1. The Dakota Gasification Company (DGC) uses only coarser coal particle sizes (~3/8 inch) from Freedom Mine for gasification, and roughly 40% of the 15 million tons (Mt)/year produced (i.e., 6 Mt) is rejected as coal fines (CF). With the high-ash, low-Btu weathered overburden coal (WOC) produced at each mine, an estimated yearly total CW resource of ~17.8 Mt is anticipated (Table 1).

Table 1. North Dakota Coal Mines, Power Plants, and CW Resources

Name	Annual Production, Mt	Power Plant(s)	Coal Waste Fraction, Mt	Township/Community
Beulah Mine	0.5	HS	0.2	Beulah
Coyote Creek Mine	2.5	CS	1.0	Beulah
Center Mine	4.5	MRYS	1.8	Center
Falkirk Mine	8.1	CCS	2.8	Underwood
Freedom Mine	15	DGC, AVS, LOS	12.0	Beulah

HS – Heskett Station, CS – Coyote Station, MRYS – Milton R. Young Station, CCS – Coal Creek Station, AVS – Antelope Valley Station, and LOS – Leland Olds Station.

Although some fraction of CF is used at AVS, the overall CW resource is still significant and can be used as a feedstock for value-added products while also providing economic benefit to local coal/power plant communities. In this proposal, CF and WOC are collectively called CW, which will be used as feedstock to produce high-quality graphite.

Technical Barriers to Coal-Derived Graphite Technologies

The major challenge with CW that limits its use for power generation or for other applications is associated with the high content of coal-borne impurities. WOC tends to be enriched in inorganic minerals from soil contamination and other organics that have not been coalified, in addition to the higher heteroatom content resulting from oxidation. The ash content of WOC is typically higher (~5.5%) than that of regular combustion-grade coal (~4.6%) for ND lignite. CF also tends to have a higher ash content (~10.1%) because of preferential segregation of pyritic and other heavier mineral components during processing. The heating value of CF is also greatly reduced, which is partly why it is not suitable for combustion in power plants. Despite these challenges, the coal-upgrading methods developed at the EERC have proven to significantly improve the quality of lignite, as mentioned above, and will be applied to improve the quality of CW as a graphite precursor. It is anticipated that remaining technological barriers to commercialization of this graphite-making technology are as great as those involved in making high-grade graphite. Conceptually, it can be done in two or three main process steps which can be integrated relatively easily within a 3–5-year time frame, depending on availability of additional funding.

Coal-Derived Graphite Anodes for LIB

Graphite produced mostly from natural sources has been the SOTA anode material for commercial LIBs since the 1990s because of high LIB storage capacity (372 mAh/g), low cost, and excellent cycling life. However, the graphite anode still has challenges associated with the poor charging rate capability of the current LIBs (Cai et al., 2020). Although progress is being made to develop alternatives such as a silicon anode, graphite anode advantages suggest that graphite will remain a dominant anode material for commercial LIBs for the foreseeable future. With increasing demand for graphite electrodes for the large LIB market in EVs, natural graphite resources are increasingly limited and often exist in foreign countries. This creates an opportunity for development of domestic CDG technologies to fill the need while also creating economic revitalization impacts in traditional coal and power plant communities in ND and other regions of the United States.

Current Efforts at the EERC and IES

The EERC and IES are currently working on several DOE-funded projects that provide prior experience and capabilities to pursue CDG technologies. For example, the EERC is working on developing a process for making graphene from lignite and other U.S. domestic coals. Additional projects currently ongoing at IES are focused on the development of lignite-derived advanced Si/graphite anodes for LIB (DE-FE-0026825/S00045) and additional preliminary studies on developing FC LIB cathode materials from lignite, sponsored by NDIC and Clean Republic (a LIB producer). These previous and ongoing efforts by the EERC and IES are expected to provide a solid foundation for success in the proposed project.

QUALIFICATIONS

Dr. Alexander Azenkeng, EERC Assistant Director for Critical Materials, will be the lead principal investigator (PI) and lead Tasks 1.0, 4.1, and 5.0. Dr. Azenkeng has an academic background in physical chemistry and has been project manager for numerous EERC research activities, including several funded by DOE. He has 13 years of experience with characterization and assessment of coal materials and recently has been leading EERC efforts to make high-value materials from coal and coal-derived products.

Dr. Xiaodong Hou, IES Research Assistant Professor, will serve as co-PI and lead Task 3.0, Subtask 4.2, and Task 6.0. Dr. Hou is a materials chemist with over 15 years of experience in advanced functional materials, including 7 years of experience in development of coal-derived materials for LIBs.

Mr. Nicholas Stanislowski, EERC Research Scientist, will lead Task 2.0. Mr. Stanislowski has a B.Sc. degree in Geology, and he has experience in coal beneficiation/upgrading, coal conversion and other chemical processes, and predicting the fate of materials in chemical systems.

Mr. Joshua Strege, EERC Assistant Director for Energy Systems, will lead Task 6.0. Mr. Strege leads the process engineering team in process modeling and techno-economic analysis efforts across applied research projects encompassing CO_2 capture and transport, advanced power cycle technology development, and other energy conversion technologies.

Mr. Jason Laumb, EERC Director of Advanced Energy Systems Initiatives, will serve as a project advisor. Mr. Laumb has 20 years of experience in coal science, techno-economic modeling, environmental control systems, supercritical CO_2 power cycles, and advanced gasification technologies.

Dr. Michael Mann, Chester Fritz Distinguished Professor of Chemical Engineering, Associate Dean for Research for the College of Engineering and Mines, will serve as a project advisor. Dr. Mann has over 35 years of experience in the energy field, including a wide range of conventional and renewable energy technologies.

NACoal is a commercial owner of three lignite mines in ND and will provide the coal or CW samples needed for the proposed work.

Resumes of key personnel are included in Appendix B.

VALUE TO NORTH DAKOTA

The primary value of this project to ND includes 1) keeping coal mines operational and providing an economic boost to coal communities by producing a high-value product such as graphite from lignite or LCW, 2) creating a FC LIB anode material to meet the demands of a fast-growing LIB market from ND lignite, and 3) creating opportunities for U.S. independence from foreign sources of SG by making the SG from ND lignite. In addition, successful implementation of this project could enhance, preserve, and protect ND's lignite industry as well as advance/sustain economic growth via new opportunities for lignite markets in nonenergy sectors such as the electronics industry and high-energy-storage applications.

MANAGEMENT

The overall management of this project will involve several components, including proper organization of all project activities, roles and responsibilities of project participants, a clear decision-making and communication strategy, management of risks, and evaluation points to be used to ensure that the project is meeting its schedule and objectives. These components are described in detail below.

Organization of Project Activities

Organizational Chart. The core project team (Figure 5) comprises UND EERC and IES, DOE, and project partners NDIC, through its Lignite Research, Marketing and Development Program, and NACoal. The PIs, key task leads, and project advisors identified in the organizational chart will work together to ensure the scope of work is fully implemented.

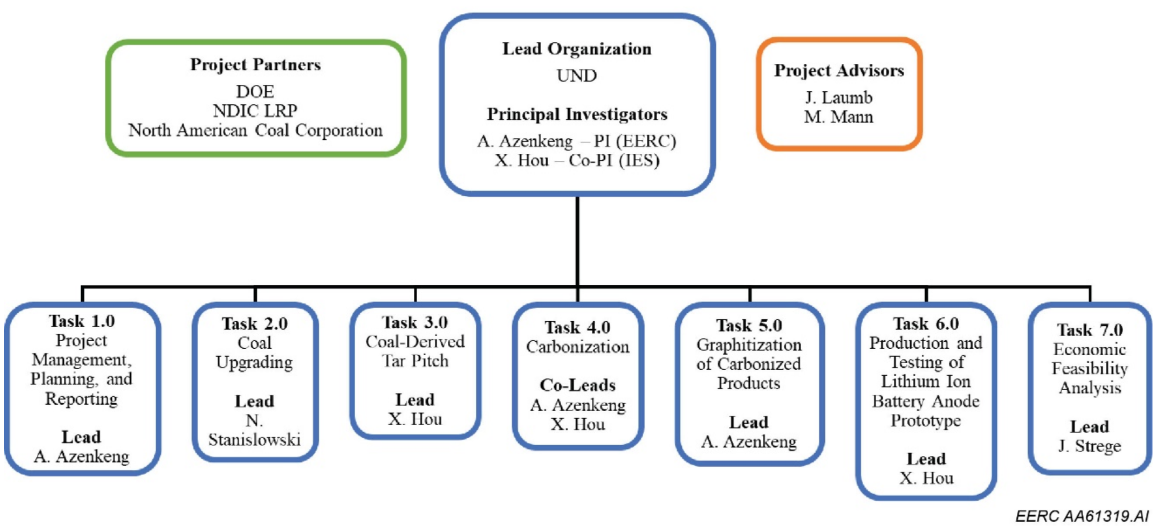

Figure 5. Project organizational chart.

Roles and Responsibilities of Participants. The EERC will be responsible for overall project management and reporting. The PIs will oversee the technical aspects of the project for the various tasks shown in Figure 4, in addition to working with the project advisors and task leads to ensure proper implementation of the project scope of work and objectives. The PIs will maintain regular communications to discuss any technical challenges, find mitigation strategies, and coordinate any potential intellectual property that may ensue from the work. NDIC and NACoal are cash cost-share partners that will contributed $500,000 and $45,000, respectively.

Decision-Making and Communication Strategy. Several strategies will be put in place to ensure effective communication during the implementation of the proposed scope of work. Project update meetings will be held on a regular basis to ensure that the project's objectives are progressing according to schedule. NDIC will receive regular quarterly updates/reports of project accomplishments, challenges, and any variance from the project objectives. In addition, the EERC and IES are both UND campus departments which further facilitates communication.

Risk Management Plan

During the project, the risk factors identified in Table 2 will be continually analyzed and appropriate measures taken to address any perceived risks as necessary. Effective communication with

Table 2. Perceived Risks and Mitigation Strategies

Perceived Risk	Risk Rating			Mitigation/Response Strategy
	Probability	Impact	Overall	
Financial Risks:				
Insufficient Cost-Share Acquisition	Low	High	Med.	Agree to cost-share terms with cost-share partners (NDIC, NACoal) and DOE prior to start of project.
Budget Insufficient to Complete Project	Low	High	Med.	PIs will work with task leads to ensure priority is given to schedule and use of allocated hours.
Cost/Schedule Risks:				
Equipment Cost Shortage	Low	High	Low	Budgets are based on preacquired quotations to mitigate this issue.
Missed Schedule Due Dates	Low	Med	Low	Pay close attention to project timelines regularly.
Technical Risks:				
%Carbon	Med.	High	Med.	Removal of the heteroatoms, VM, and ash and graphitization at >2800°C are crucial.

Continued . . .

Table 2. Perceived Risks and Mitigation Strategies (continued)

Perceived Risk	Risk Rating			Mitigation/Response Strategy
	Probability	Impact	Overall	
Technical Risks:				
%Ash	High	Med.	Med.	Upgrading coal and producing ultralow ash tar pitch are key mitigation strategies and postgraphitization purification.
Surface Area	Low	Med.	Low	Optimizing the functionalization and graphitization processes will mitigate this issue.
Extent of Graphitization	Low	Med.	Low	Graphitization at temperatures >2800° will mitigate the issue.
Tap Density	Low	Med.	Low	No significant deviation expected from that of previous studies based on physical and chemical properties.
Low Initial Specific Capacity at 0.1C	Low	Med.	Low	A conservative target has been set on this attribute; optimizing the graphitization and functionalization processes will mitigate this issue if it occurs.
Low ICE (initial coulombic efficiency)	Low	Med.	Med.	Preliminary tests have reached the target >90%. It will be mitigated by adjusting the surface area and particle size.
Poor Cycling Life (80% capacity retention)	Med.	High	Med.	The strategies above for low ICE also mitigate this issue. Tuning the microstructures by optimizing the synthetic conditions will greatly alleviate this issue.
Pressing Density	Low	Med.	Low	No significant deviation expected from that of previous studies based on physical and chemical properties.
Capacity Retention at 1C and 2C charge rate	Low	High	Med.	Preliminary results are close to this goal and optimizing the functionalization process will further mitigate this issue.
Resource Risks:				
Lab Equipment Failure	Low	Med.	Low	Coordinate with laboratory manager and other project teams to schedule laboratory analysis.
Management Risks:				
Schedule or Cost Overruns	Low	High	Med.	Hold regular meetings to ensure project priorities and milestone due dates are kept.
Loss of Project Personnel Due to Health Issues	Low	High	Low	Ensure that project goals, milestones, and schedule are communicated to task leads and all researchers regularly. Designate and train an assistant to the PIs.
Planning and Oversight Risks:				
Missed Milestone Due Dates	Low	Low	Low	Project advisor helps ensure proper oversight of overall project activities.
EH&S Risks:				
Release of Hazardous Effluents	Low	High	Low	The EERC maintains a safety office with personnel trained to advise and handle hazardous waste based on standards. Periodic trainings will be conducted.
External Factor Risks:				
Delays in Equipment/Supplies Shipments	Low	High	Low	Ensure equipment/supplies are ordered with enough time to mitigate unanticipated delays.

project team members will be key to early identification of risks and a timely discussion of mitigation strategies with the DOE project manager and NDIC. A preliminary list of the perceived risks associated with completing the project is summarized in Table 2 and will be continually addressed and updated during the project.

Evaluation Points

The evaluation point (milestone) log for the project is organized by task and includes planned completion dates and verification methods, as shown in Table 3. The assumed start date for the project is February 1, 2022, and the project will span a period of 36 months. If the actual project start date happens to be earlier or later, this table and the project timetable will be updated accordingly. The verification methods will include providing data and reports to project sponsors, in addition to meetings held at periodic points to provide detailed updates of the findings and future directions. The evaluation points are also marked in the project timetable in Figure 3.

Table 3. Project Milestones (Ms)

Task/ Subtask	Milestone Title	Planned Completion Date	Verification Method
2.0	M1 – Completion of Coal Upgrading	9/30/2022	Produce about 2 lb of product and reported in subsequent quarterly report
3.0	M2 – Completion of Coal-Derived Tar Pitch	9/30/2022	Produce about 2 lb of product and reported in subsequent quarterly report
4.1	M3 – Completion of Upgraded Coal Carbonization	2/28/2023	Produce about 1.5 lb of product and reported in subsequent quarterly report
4.2	M4 – Completion of Coal Tar Pitch Carbonization	2/28/2023	Produce a minimum of 1 lb of product and reported in subsequent quarterly report
5.0	M5 – Completion of Graphitization	7/31/2023	Produce a minimum of 0.5 lb of product and reported in subsequent quarterly report
6.1	M6 – Completion of Functionalization of Coal-Derived Graphite	7/31/2024	Provide characterization data in subsequent quarterly report
6.2	M7 – Completion of Electrochemical Performance Testing	10/31/2024	Validate 1C and 2C tests and reported in subsequent quarterly report
7.0	M8 – Completion of Economic Feasibility Analysis	11/30/2024	Produce an economic assessment and reported in subsequent quarterly report

TIMETABLE AND DELIVERABLES

The timetable for each task is summarized in Figure 6 and includes a link between the scope and schedule, as well as the corresponding start and completion dates. The main deliverables for this

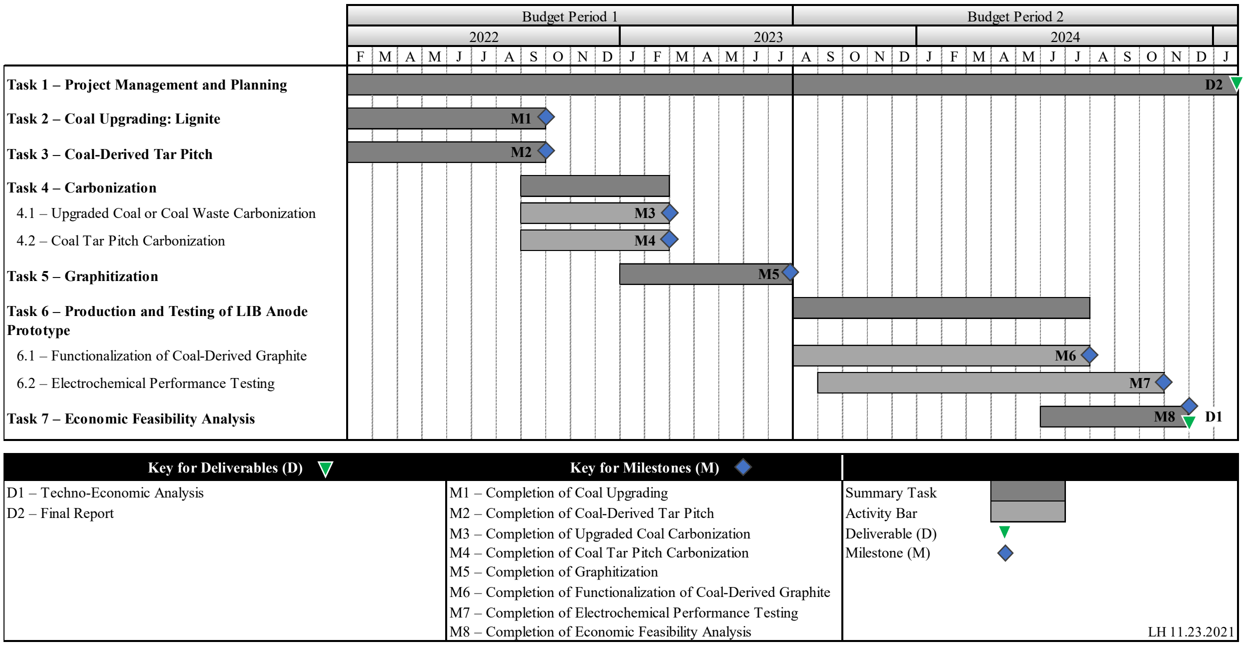

Figure 6. Project timetable.

include the project final report and a report of the techno-economic feasibility analysis, which will be provided as an appendix to the final report. Both reports will be submitted at the end of the project.

BUDGET AND MATCHING FUNDS

The total estimated cost for this project is $1,545,000, provided in Table 4. DOE will provide funding in the amount of $1,000,000. NDIC and NACoal will provide $500,000 and $45,000 of cash cost share, respectively. A safety chamber costing about $16,400 will be purchased with part of DOE funding and used for testing of the FC LIB anode prototype. Letters of commitment for the cost-share providers can be found in Appendix A. Budget notes can be found in Appendix C.

Table 4. Budget Breakdown

Project Associated Expense	NDIC Share (Cash)	Federal U.S. DOE Share (Cash)	North American Coal Share (Cash)	Total Project
Labor	$234,915	$388,479	$26,841	$650,235
Travel	$13,467	$12,034	$0	$25,501
Equipment > $5000	$0	$16,400	$0	$16,400
Supplies	$5,000	$112,011	$0	$117,011
Consultant - Dennis James Consulting, LLC	$0	$30,000	$0	$30,000
Communications	$30	$20	$0	$50
Printing & Duplicating	$30	$41	$0	$71
Laboratory Fees & Services				
EERC Natural Materials Analytical Research Lab	$52,380	$60,463	$0	$112,843
EERC Analytical Research Lab	$4,037	$8,074	$0	$12,111
EERC Process Chemistry & Development Lab	$1,674	$10,605	$0	$12,279
EERC Graphics Services	$1,971	$2,850	$0	$4,821
EERC Shop & Operations	$0	$0	$0	$0
EERC Software Solution Services	$0	$0	$0	$0
EERC Technical Software Fee	$11,600	$0	$0	$11,600
EERC Engineering Services Fee	$6,021	$3,070	$1,284	$10,375
IES Sample Preparation Equipment	$0	$2,000	$0	$2,000
IES Ultimate Analysis	$0	$4,500	$0	$4,500
IES Thermogravimetric Analyzer (TGA)	$0	$4,000	$0	$4,000
IES X-ray Fluorescence Spectroscopy	$0	$1,900	$0	$1,900
IES X-ray Diffractometer	$0	$2,800	$0	$2,800
IES Scanning Electron Microscope	$0	$4,500	$0	$4,500
IES BET Surface Area Analyzer	$0	$2,800	$0	$2,800
IES Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES)	$0	$2,200	$0	$2,200
IES Electrochemical Workstation	$0	$5,200	$0	$5,200
IES Battery Testing System	$0	$24,000	$0	$24,000
Total Direct Costs	$331,125	$697,947	$28,125	$1,057,197
Facilities & Administration	$168,875	$302,053	$16,875	$487,803
Total Project Costs	**$500,000**	**$1,000,000**	**$45,000**	**$1,545,000**

TAX LIABILITY

The EERC and IES are departments within UND, which is a state-controlled institution of higher education and is not a taxable entity; therefore, it has no tax liability.

CONFIDENTIAL INFORMATION

The proposed work does not contain any confidential information.

APPENDIX A

LETTERS OF SUPPORT

October 4, 2021

SENT VIA ELECTRONIC MAIL

Sheryl A. Eicholtz-Landis
University of North Dakota
15 North 23rd Street, Stop 9018
Grand Forks, North Dakota 58202-9018
slandis@undeerc.org

SUBJECT: Selection of Application for Negotiation Under Funding Opportunity Announcement Number DE-FOA-0002405 titled "Advanced Coal Waste Processing: Production of Coal-Enhanced Filaments or Resins for Advanced Manufacturing and Research and Development of Coal-Derived Graphite"

Application: Advanced Processing of Coal and Coal Waste toProduce Graphite for Fast-Charging Lithium Ion Battery Anode, Alexander Azenkeng, 13376938

Dear Sheryl A. Eicholtz-Landis:

We are pleased to provide this update on your application. The Office of Fossil Energy and Carbon Management within the Department of Energy (DOE) has completed its evaluation of your application submitted in response to the subject Funding Opportunity Announcement (FOA). The application below has been recommended by the Office of Fossil Energy and Carbon Management 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**.)

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. Your organization will be notified of the announcement and provided a link there-to, via a subsequent email to this letter.

Please note: The Office of Fossil Energy and Carbon Management has determined that awards selected under this FOA will be required to incorporate an Environmental, Safety, and Health (ES&H) Analysis for Products Proposed to be Manufactured into the project objectives. No additional funding for this requirement will be added to the project.

The recipient will identify ES&H requirements for any products proposed to be manufactured, based on anticipated effects on the environment, safety, and human health in the following situations:

- **Receiving, storage, handling, and use of raw materials to manufacture products**

- **Shipping to customer locations and handling of manufactured products at customer locations**
- **Field modification and installation (e.g., cutting, drilling, finishing, etc.) of manufactured products**
- **Long-term use of the manufactured product in residential, commercial, and industrial settings.**
- **Demolition, removal, and recycling/disposal as applicable at the end of the manufactured product's useful life.**

Should this change result in your organization not wishing to execute a project, please email the Contract Specialist identified below no later than October 11, 2021 to indicate your desire to withdraw from this FOA.

Receipt of this letter does not authorize the applicant 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.

The award negotiation process may take up to 90 days. The applicant 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 October 18, 2021**:

- Pre-Award Information Sheet (available at https://netl.doe.gov/node/5719)
- Updates (if applicable) to the Environmental Questionnaire form provided as part of your original application

Please provide the requested documents to the attention of Erin Lugas, who is the Contract Specialist from the Acquisition group handling the administrative portion of your application. Erin Lugas can be reached at 412-386-9152 or erin.lugas@netl.doe.gov. Michael Fasouletos is the NETL 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 Reichl
Contracting Officer
Finance and Acquisition Center

cc: FOA File
aazenkeng@undeerc.org
Michael.fasouletos@netl.doe.gov
Erin.Lugas@netl.doe.gov

NORTH AMERICAN COAL CORPORATION

CARROLL L. DEWING
Vice President – Operations

Telephone: 701-323-3392
E-Mail: carroll.dewing@nacoal.com

May 21, 2021

Dr. Michael D. Mann
Distinguished Professor, Chemical Engineering Executive Director, Institute for Energy Studies
University of North Dakota
Collaborative Energy Center, Room 246 2844 Campus Road, Stop 8153
Grand Forks, ND 58202-8153

Re: Letter of Support for UND proposal titled "Lignite-derived graphite for fast-chargeable Li-ion battery anodes" in response to DE-FOA-0002405

Dear Mike:

North American Coal Corporation (NACoal) is interested in supporting UND's application to DOE for developing Lithium Ion Battery Anode Materials from lignite coals. We believe your project could help open new markets for the lignite industry and provide our economy with useful, low cost carbon products.

NACoal is the largest lignite producer in the United States and one of the top 10 coal producers in the United States. We mine and market coal for use in power generation, SNG production, activated carbon production, as well as, providing selected value-added mining services for other natural resources companies. Our corporate headquarters are in Plano, Texas, near Dallas, and we operate surface coal mines in North Dakota, Mississippi, Texas, New Mexico, and Louisiana.

NACoal is pleased to provide a total cost-share of up to $45,000, over the 3-year term of the project, subject to project award by US Department of Energy and final review.

Best of luck on your application.

Very truly yours,
THE NORTH AMERICAN COAL CORPORATION

Carroll L. Dewing
Vice President – Operations

APPENDIX B

RESUMES OF KEY PERSONNEL

DR. ALEXANDER AZENKENG
Assistant Director for Critical Materials
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, North Dakota 58202-9018 USA
701.777.5051 (phone), 701.777.5181 (fax), aazenkeng@undeerc.org

Principal Areas of Expertise

Dr. Alexander Azenkeng is Assistant Director for Critical Materials at the EERC, where he applies chemistry principles to studies involving multiple research portfolios, including computational simulations to elucidate reaction mechanisms of coal combustion and chemical processes at the molecular level; chemical transformations in low-rank coal upgrading; coal–biomass gasification technologies; characterization of materials by spectroscopic and microscopic techniques; CO_2–amine reaction chemistry of CO_2 capture, utilization, and sequestration (CCUS) technologies; reservoir geochemistry of CO_2 sequestration; nuclear magnetic resonance (NMR) spectroscopy study of unconventional oil and gas reservoirs; improved methods for extraction and isolation of critical minerals (rare-earth elements [REEs] and platinum group metals [PGMs]) from coals; and development of approaches for production of high-value carbon materials such as graphene and graphite from coal feedstocks.

Education and Training

Ph.D., Theoretical Physical Chemistry, University of North Dakota, 2007.
Dissertation: Theoretical Studies of Low-Lying Electronic States of Lithium, Titanium, and Mercury Compounds; supervised by Prof. Mark R. Hoffmann.
M. Sc., Chemistry, University of Buea, Cameroon, 1998.
Thesis: Preparation of Iron (III) and Nickel (II) Oxide Thin Films from the Corresponding Metal Acetylacetonates via Pyrolysis.
B.Sc., (magna cum laude) Chemistry, University of Buea, Cameroon, 1996; with professional minor in Chemical Processing Technology.

Research and Professional Experience

May 2021–Present: Assistant Director for Critical Materials, EERC, UND. Dr. Azenkeng's current research interests include development of approaches for making high-value products (graphene and graphite) from coal, critical mineral research for REEs and PGMs, carbon capture technologies for coal combustion and gasification systems, and carbon storage/sequestration in geological sinks.

2008–April 2021: Senior Research Scientist, EERC, UND. Dr. Azenkeng applied chemistry principles to studies involving multiple research portfolios, including chemical analysis of materials by SEM, material corrosion evaluation in oil and gas applications, CO_2 capture using aqueous amine solvents, CO_2 sequestration in geologic formations, and chemical transformations in low-rank coal upgrading. He was involved in developing analytical approaches to better characterize organic shale and tight rock formations for potential CO_2 storage and improved methods for analyzing rare-earth elements (REEs) in coals, geologic samples, and produced water from oil and gas operations.

2007–2008: Temporary Researcher, EERC, UND. Dr. Azenkeng's work focused on NO_x emission control technologies, CO_2 capture technologies, and gasification technologies.

2005–2007: Graduate Research Assistant, EERC, UND. Dr. Azenkeng's work focused on quantum mechanical modeling of Hg oxidation reactions on activated carbon surfaces.

Professional Activities

Member, Microscopy Society of America, 2010–Present
Member, North Dakota Academy of Sciences, 2004–Present
Member, American Chemical Society, 2002–Present

Publications and Presentations

Books and Book Chapters

Ralston, N.V.C.; Azenkeng, A.; Raymond, L.J. Mercury-Dependent Inhibition of Selenoenzymes and Mercury Toxicity. In *Methylmercury and Neurotoxicity*; Ceccatelli, S., Aschner, M., Eds.; Current Topics in Neurotoxicity 2; Springer: New York, 2012; pp 91–99.

Peer-Reviewed Publications

Azenkeng, A.; Mibeck, B. A.F.; Kurz, B. A.; Gorecki, C. D.; Myshakin, E. M.; Goodman, A. L.; Azzolina, N. A.; Eylands, K.E.; Butler, S.K.; Sanguinito, S. An image-based equation for estimating the prospective CO_2 storage resource of organic-rich shale formations. *International Journal of Greenhouse Gas Control* **2020**, *98*, 103038.

Laumb, J.D.; Glazewski, K.A.; Hamling, J.A.; Azenkeng, A.; Watson, T.L. Wellbore Corrosion and Failure Assessment for CO_2 EOR and Storage: Two Case Studies in the Weyburn Field. *International Journal of Greenhouse Gas Control* **2016,** *54*, 479–489.

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

Conference and Other Presentations

Azenkeng, A.; Mibeck, B.A.F.; Eylands, K.E.; Butler, S.K.; Kurz, B.A.; Heebink, L.V. Advanced Characterization of Unconventional Oil and Gas Reservoirs to Enhance CO_2 Storage Resource Estimates – Organic Structure and Porosity of Organic-Rich Shales. Presented at Mastering the Subsurface Through Technology Innovation, Partnerships & Collaboration: Carbon Storage & Oil & Natural Gas Technologies Review Meeting, Pittsburgh, PA, Aug 1–3, 2017.

Klenner, R.C.L.; Braunberger, J.R.; Sorensen, J.A.; Eylands, K.E.; Azenkeng, A.; Smith, S.A. A Formation Evaluation of the Middle Bakken Member Using a Multimineral Petrophysical Analysis Approach. Paper presented at the SPE/AAPG/SEG Unconventional Resources Technology Conference, Denver, CO, Aug 25–27, 2014; URTeC Paper No. 1922735.

Laumb, J.D.; Azenkeng, A.; Heebink, L.V.; Jensen, M.D.; Raymond, L.J. CO_2 Utilization Technologies for Lignite-Based Generation. Poster Abstract in *Proceedings of Air Quality IX: An International Conference on Environmental Topics Associated with Energy Production*; Arlington, VA, Oct 21–23, 2013.

Laumb, J.D.; Kay, J.P.; Holmes, M.J.; Cowan, R.M.; Azenkeng, A.; Heebink, L.V.; Hanson, S.K.; Jensen, M.D.; Letvin, P.A.; Raymond, L.J. Economic and Market Analysis of CO_2 Utilization Technologies – Focus on CO_2 Derived from North Dakota Lignite. *Energy Procedia* **2013**, *37*, 6987–6998.

Laumb, J.D.; Kay, J.P.; Holmes, M.J.; Cowan, R.M.; Azenkeng, A.; Heebink, L.V.; Hanson, S.K.; Jensen, M.D.; Letvin, P.A.; Raymond, L.J. Economic and Market Analysis of CO_2 Utilization Technologies – Focus on CO_2 Derived from North Dakota Lignite. Paper presented at the 11th International Conference on Greenhouse Gas Control Technologies (GHGT-11), Kyoto, Japan, Nov 18–22, 2012.

Azenkeng, A. Development of an Improved CCSEM Technique for Quantitative Coal Mineralogy. Presented at the 28th Annual International Pittsburgh Coal Conference, Pittsburgh, PA, Sept 12–15, 2011.

Technical Reports

Azenkeng, A. *Evaluation of Lime Kiln Ash Ring Samples for Environmental Energy Services, Inc.*; Final Report for Environmental Energy Services, Inc.; EERC Publication 2018-EERC-08-03; Energy & Environmental Research Center: Grand Forks, ND, Aug 2018.

Azenkeng, A.; Kurz, B.A.; Gorecki, C.D. *An NMR-Based Method for Fluid Typing and Proportion Estimation for the Potential for CO_2 Storage or CO_2 EOR in the Middle Bakken Formation*; Final Report included in *Subtask 4.1 – Strategic Studies* Final Report (Aug 10, 2015 – May 31, 2017) for U.S. Department of Energy National Energy Technology Laboratory Cooperative Agreement No. DE-FE0024233; EERC Publication 2017-EERC-05-13; Energy & Environmental Research Center: Grand Forks, ND, May 2017.

Azenkeng, A.; Pavlish, B.M.; Lentz, N.B.; Galbreath, K.C.; McCollor, D.P. *Feasibility of Hydrothermal Dewatering for the Potential to Reduce CO_2 Emissions and upgrade Low Rank Coals*; Final Report (June 25, 2008 – Dec 31, 2009) for the University of Wyoming; EERC Publication 2010-EERC-02-02; Energy & Environmental Research Center: Grand Forks, ND, Feb 2010.

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XIAODONG HOU, PH.D.

Education and Training

Postdoctoral, Department of Chemistry, University of North Dakota (UND), 2010–2013.
Ph.D., Polymer Chemistry and Physics, Shanghai Jiao Tong University, Shanghai, China, 2009.
M.S., Chemical Engineering, Shaanxi University of Science and Technology, Shaanxi, China, 2005.
B.S., Chemical Engineering, Shaanxi University of Science and Technology Shaanxi, China, 2002.

Research and Professional Experience

2017–Present: Research Assistant Professor, Institute for Energy Studies (IES), College of Engineering & Mines, UND. Research Interests: development of advanced materials for Li-ion batteries and coal-derived high-value carbon materials.

2014–2016: Senior Chemist/Lecturer, Advanced Material Characterization Laboratory, IES, UND. Main research interests and expertise: synthesis and characterization of advanced chemical materials, environmental sampling and analysis, and crystal structural analysis.

2013–2014: Interim Lab Director and Analytical Chemist, Environmental Analytical and Research Laboratory, UND. Principal areas of expertise: apply various spectroscopic, chromatographic, and microscopic techniques to determine the chemical components of broad environment samples.

2010–2013: Postdoctoral Research Associate, Department of Chemistry, UND. Research interests: synthesis and characterization of covalently bonded hierarchical nanomaterials.

2005–2009: Ph.D. Graduate Research Assistant, Shanghai Jiao Tong University, Shanghai, China. Research interests: synthesis and characterization of advanced inorganic nanoparticles/block copolymer hybrid materials for energy application.

Relevant Publications (selected from over 30)

Xu, S.; Zhou, J.; Wang, J.; Pathirana, S.; Oncel, N.; Pushparaj, R.; Zhang, X.; Mann, M.; **Hou, X.**, *In-situ Synthesis of Graphene-coated Silicon Monoxide Anodes from Coal-derived Humic Acid for High-performance Lithium-ion Battery*. Advanced Functional Materials, **2021**, xxx, XX. DOI: 10.1002/adfm.202101645

Hou, X.; Hou, Y.; Mann, M. *Porous Silicon/Lignite-derived Graphene Composite Anodes for Lithium ion batteries*, 36th International Battery Seminar and Exhibition, Fort Lauderdale, FL, March 24–27; Fort Lauderdale, FL, **2019**.

Patent

Xiaodong Hou. Low-cost Graphene-modified Anode Materials for Lithium Ion Batteries. Provisional Patent in process.

Synergistic Activities

- Principal Investigator: Group lead of Li-ion battery research at IES. Major active projects include " Lignite-Derived Carbon Materials for Li-ion Battery Anode,: $500,000 award by DOE NETL ACP program; "The Preparation of a High Capacity Graphene Modified Graphite/SiO_x Anode Electrode Batteries," $259,796 award by private cell manufacturer; "Porous Silicon/Lignite-

Derived Graphene Composite Anodes for Li-Ion Batteries," $369,581 award by DOE UCFER; "New Battery Charing Technology," $248,229 award by NDIC Research ND program; "Lignite-Derived Graphene/Si Anode for Li-ion Battery," $140,000 award by UND VPR Postdoctoral Program.

- Industrial collaboration: Working with multiple companies on battery R&D, including long-term collaboration with a local company, Clean Republic, since 2014.
- Invited lecture and presentations: Presents on multiple battery- and coal-relevant conferences.
- Graduate Faculty: Mentors one postdoc, four Ph.D. students, and two undergraduates on coal-derived materials for Li-ion battery research.

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Research Scientist
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Principal Areas of Expertise

Mr. Stanislowski's principal areas of interest and expertise include coal conversion; carbon capture, utilization, and storage; and data processing.

Education and Training

B.S., Geology, University of North Dakota, 2016.

Research and Professional Experience

October 2019–Present: Research Scientist, EERC, UND. Mr. Stanislowski interacts with a diverse team of scientists and engineers to address the challenges of advanced power generation and chemical processes. His work involves evaluating coal conversion and other chemical processes and predicting the fate of materials in chemical systems.

January–July 2018: GIS Analyst Intern, Johnson Outdoors Inc. (LakeMaster, Hummingbird, Minn Kota), Little Falls, Minnesota. Mr. Stanislowski operated computer programs to analyze and digitize data for creation of bathymetric maps.

Publications

Mr. Stanislowski has coauthored several publications.

JASON D. LAUMB
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Principal Areas of Expertise

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

Education and Training

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

Research and Professional Experience

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

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

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

2001–2008: Research Manager, EERC, UND. Mr. Laumb led projects involving bench-scale combustion testing of various fuels and wastes as well as a laboratory that performs bench-scale combustion and gasification testing. He served as principal investigator and managed projects related to the inorganic composition of coal, coal ash formation, deposition of ash in conventional and advanced power systems, and mechanisms of trace metal transformations during coal or waste conversion and wrote proposals and reports focused on energy and environmental research.

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

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

Professional Activities
Member, American Chemical Society

Publications
Mr. Laumb has coauthored numerous professional publications.

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Principal Areas of Expertise

Mr. Strege's principal areas of interest and expertise include biomass and fossil fuel conversion for energy production, with an emphasis on CO_2 capture and storage in power generation and in industrial applications. He is certified in Aspen Plus and Aspen HYSYS and is proficient in process modeling and techno-economic assessments. He also has significant experience in the design, fabrication, and operation of bench- and pilot-scale equipment for combustion, gasification, synthetic and renewable fuel production, and CO_2 capture.

Education and Training

M.S., Chemical Engineering, University of North Dakota, 2005. Thesis: High-Temperature Corrosion of Potential Heat Exchange Alloys under Simulated Coal Combustion Conditions.

B.S., Chemical Engineering, University of North Dakota, 2005.

Training includes project management training through PM College, Six-Sigma Green Belt, and Design Flow Technology (DFT).

Software skills include Microsoft Office suite (Excel, MS Project, Word, and Access) and advanced VBA macro programming and SQL server integration; CAD design and engineering drawing creation (PTC Creo Parametric).

Certifications include Aspen Plus- and Aspen HYSYS-certified.

Research and Professional Experience

May 2021–Present: Assistant Director for Energy Systems, EERC, UND. Mr. Strege leads a multidisciplinary team of engineers and scientists in evaluating and demonstrating energy processes from the initial modeling phase through physical testing at the bench, pilot, and demonstration scales. Specific areas of interest include CO_2 capture and transport, process modeling and techno-economic analysis, gasification and combustion technology development and demonstration, and other energy conversion technologies. Current research activities are focused on low-carbon-intensity power cycles for fossil fuel- and biomass-fired systems.

October 2019–April 2021: Principal Process Engineer, Energy Systems Development, EERC, UND. Mr. Strege led the process engineering team in process modeling and techno-economic analysis efforts across applied research projects encompassing CO_2 capture and transport, advanced power cycle technology development, and other energy conversion technologies.

2013–September 2019: Project Manager and Senior Engineer, Cirrus Aircraft. Mr. Strege's responsibilities as Project Manager included building an 80-member team to develop and manufacture composite products for small aircraft under contract with an outside client. As Senior Engineer, he led a team of engineers and technicians responsible for reducing waste, implementing root cause and corrective actions on product defects and downstream issues, and developing and implementing software solutions for improved tracking and accountability across all departments.

2005–2013: Research Engineer, EERC, UND. Mr. Strege participated in and managed several multiyear, multiclient projects aimed at researching and developing alternative energy and fuel sources. Specific projects included hydrotreating of waste vegetable oils for conversion to drop-in-compatible JP-8 jet fuel, assessing the feasibility of modern warm-gas cleanup technologies for liquid fuel synthesis via the Fischer–Tropsch process, and design and testing of cold-gas cleanup reactors for syngas. He also participated in pilot-scale studies comparing the postcombustion CO_2 capture efficiency of a variety of proprietary and conventional amine-based solvents.

2000–2005: Student Research Assistant, EERC, UND. Mr. Strege's responsibilities included design and development of instrument control software. In addition, he studied corrosion rates and mechanisms of high-temperature alloys as part of his master's research.

Publications
Mr. Strege has authored and coauthored numerous professional publications.

DR. MICHAEL D. MANN

Education and Training

Ph.D. (1997), Energy Engineering; M.B.A. (1988); M.S. (1981), Chemical Engineering, University of North Dakota (UND). B.A. (1979), Chemistry and Mathematics, Mayville State College.

Research and Professional Experience

2014–Present: Executive Director, Institute for Energy Studies (IES), UND. In addition to overall management duties, Dr. Mann's responsibilities include identifying key technical and economic barriers to development of secure, affordable, and reliable energy production technologies; identifying proposal opportunities and developing new relationships with potential partners; and drawing from resources across the UND campus, building teams to deliver the research, education, and/or public outreach required to meet the needs of these public and private partners.

2013–2014: Associate Dean, College of Engineering and Mines, UND.

2009–2013; 2018-Present: Associate Dean for Research, School of Engineering and Mines. UND.

2008: Interim Dean, School of Engineering and Mines. UND.

2006–Present: Distinguished Professor, Chemical Engineering, UND.

2005–2013: Chair, Chemical Engineering, UND.

1991–2006: Associate Professor, Chemical Engineering, UND.

2000–2005: Director, Engineering Doctoral Program.

1999–2005: Senior Research Advisor, Energy & Environmental Research Center (EERC), UND.

1994–1999: Senior Research Manager, Advanced Processes and Technologies, EERC, UND.

1985–1994: Research Manager, Combustion Systems, EERC, UND,

1982–1985: Research Engineer, Wastewater Treatment and Reuse, EERC, UND

1981–1982: Operating Contractor, EG&G, Grand Forks Energy Technology Center (GFETC).

Relevant Publications

Xu, S.; Zhou, J.; Wang, J.; Pathiran, S.; Oncel, N.; Ilango, R.; Zhang, X.; Mann, M.; Hou, X. In-Situ Synthesis of Graphene-Coated Silicon Monoxide Anodes from Coal-derived Humic Acid for High-Performance Lithium-ion Battery. Advanced Functional Materials, Research Article No. adfm.202101645R1.

Hou, X.; Hou, Y.; Mann, M.; Mann, J.; Baker, J.; A Low Cost Synthetic Procedure for High Consistent Lithium Iron Phosphate Cathode Materials; Lithium Battery Materials & Chemistries/Battery Safety; Arlington, VA, Oct 2017.

Baker, J.; Hou, Y.; Mann, M.; Mann, J.; Hou, X. Preparation of Lithium Ion Battery Cathode Composites Using Leonardite-Derived Humic Acid, 2018 Annual AIChE Conference; Pittsburgh, PA, Oct 2018.

Hou, X.; Hou, Y.; Mann, M.; Xu, S. Porous Silicon/Lignite-derived Graphene Composite Anodes for Lithium Ion Batteries; 36th International Battery Seminar and Exhibition; Fort Lauderdale, FL, March 2019.

Dale, N.N.; Mann, M.D.; Salehfar, H.; Dhirde, A.M.; Han, T. Impedance Study of a Proton Exchange Membrane Fuel Cell under Various Loading Conditions. *Journal of Fuel Cell Science and Technology* **2010**, *7*, 031010.

Xiao, F.; Bedane, A.; Zhao, J.; Mann, M.; Pignatello, J. Thermal Air Oxidation Changes Surface and Adsorptive Properties of Black Carbon (Char/Biochar). *Science of the Total Environment* **2018**.

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, Pittsburgh, PA, April 9, 2019.

Synergistic Activities

- Focused research on multidisciplinary and integrated energy and environmental projects emphasizing a cradle-to-grave approach; coupling thermodynamics with political, social, and economic factors.
- PI/Co-PI on UND's rare-earth pilot plant project, recovery of critical materials from waste and produced water, and several lithium ion battery projects.

APPENDIX C

BUDGET NOTES

BUDGET NOTES

ENERGY & ENVIRONMENTAL RESEARCH CENTER (EERC)

BACKGROUND

The EERC is an independently organized multidisciplinary research center within the University of North Dakota (UND). The EERC is funded through federal and nonfederal grants, contracts, and other agreements. Although the EERC is not affiliated with any one academic department, university faculty may participate in a project, depending on the scope of work and expertise required to perform the project.

INTELLECTUAL PROPERTY

The applicable federal intellectual property (IP) regulations will govern any resulting research agreement(s). In the event that IP with the potential to generate revenue to which the EERC is entitled is developed under this project, such IP, including rights, title, interest, and obligations, may be transferred to the EERC Foundation, a separate legal entity.

BUDGET INFORMATION

The proposed work will be done on a cost-reimbursable basis. The distribution of costs between budget categories (labor, travel, supplies, equipment, etc.) and among funding sources of the same scope of work is for planning purposes only. The project manager may incur and allocate allowable project costs among the funding sources for this scope of work in accordance with Office of Management and Budget (OMB) Uniform Guidance 2 CFR 200.

Escalation of labor and EERC recharge center rates is incorporated into the budget when a project's duration extends beyond the university's current fiscal year (July 1 – June 30). Escalation is calculated by prorating an average annual increase over the anticipated life of the project.

The cost of this project is based on a specific start date indicated at the top of the EERC budget. Any delay in the start of this project may result in a budget increase. Budget category descriptions presented below are for informational purposes; some categories may not appear in the budget.

Salaries: Salary estimates are based on the scope of work and prior experience on projects of similar scope. The labor rate used for specifically identified personnel is the current hourly rate for that individual. The labor category rate is the average rate of a personnel group with similar job descriptions. Salary costs incurred are based on direct hourly effort on the project. Faculty who work on this project may be paid an amount over the normal base salary, creating an overload which is subject to limitation in accordance with university policy. As noted in the UND EERC Cost Accounting Standards Board Disclosure Statement, administrative salary and support costs which can be specifically identified to the project are direct-charged and not charged as facilities and administrative (F&A) costs. Costs for general support services such as contracts and IP, accounting, human resources, procurement, and clerical support of these functions are charged as F&A costs.

Fringe Benefits: Fringe benefits consist of two components which are budgeted as a percentage of direct labor. The first component is a fixed percentage approved annually by the UND cognizant audit agency, the Department of Health and Human Services. This portion of the rate covers vacation, holiday, and sick leave (VSL) and is applied to direct labor for permanent staff eligible for VSL benefits. Only the actual approved rate will be charged to the project. The second component is estimated on the basis of historical data and is charged as actual expenses for items such as health, life, and unemployment insurance; social security; worker's compensation; and UND retirement contributions.

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

Equipment: Equipment to be purchased includes a safety chamber for battery testing that is required for testing of the fast-charging lithium ion battery (LIB) anode prototype.

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

Consultant: Dennis James Consulting, LLC, will be utilized to provide technical advice and consulting within its expertise in relevant fields. Additional hours are allotted for project participant coordination, project meetings, project management, and support for UND.

Subcontracts: Not applicable.

Professional Fees: Not applicable.

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

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

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

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

Operating Fees: Operating fees generally include EERC recharge centers, Institute for Energy Studies (IES) laboratories, outside laboratories, and freight.

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

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

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

Shop and operations recharge fees cover specific expenses related to the pilot plant and the required expertise of individuals who perform related activities. Fees may be incurred in the pilot plant, at remote locations, or in

EERC laboratories whenever these particular skills are required. The rate includes such items as specialized safety training, personal safety items, fall protection harnesses and respirators, CPR certification, annual physicals, protective clothing/eyewear, research by-product disposal, equipment repairs, equipment safety inspections, and labor to direct these activities. The estimated cost is based on the number of hours budgeted for this group of individuals.

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

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

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

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

Facilities and Administrative Cost: The F&A rate proposed herein is approved by the U.S. Department of Health and Human Services and is applied to modified total direct costs (MTDC). MTDC is defined as total direct costs less individual capital expenditures, such as equipment or software costing $5000 or more with a useful life of greater than 1 year, as well as subawards in excess of the first $25,000 for each award.

Cost Share: Cost share will be provided in the form of cash from the U.S. Department of Energy in the amount of $1,000,000 and North American Coal Corporation in the amount of $45,000.

APPENDIX D

REFERENCES

REFERENCES

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Benson, S.A.; Holm, P.L. Comparison of Inorganic Constituents in Three Low-Rank Coals. *Industrial & Engineering Chemistry Product Research and Development* **1985**, *24*, 145–149.

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