EERC

Energy & Environmental Research Center
15 North 23rd Street, Stop 9018 • Grand Forks, ND 58202-9018 • P. 701.777.5000 • F. 701.777.5181
www.undeerc.org

February 1, 2023

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

Dear Mr. Haase:

Subject: EERC Proposal No. 2023-0100 Entitled "Integrated Renewable Combined Heat and Power for Ethanol"

The Energy & Environmental Research Center (EERC) of the University of North Dakota (UND) is pleased to submit the subject proposal to the North Dakota Industrial Commission Renewable Energy Program.

Enclosed please find an original and one copy of the subject proposal along with the application fee. Please note that the enclosed check for $200 covers this application (EERC Proposal No. 2023-0100) as well as the application being submitted under EERC Proposal No. 2023-0089.

The EERC, a research organization within UND, an institution of higher education within the state of North Dakota, is not a taxable entity; therefore, it has no tax liability. The EERC is committed to completing the project on schedule and within budget should the Commission approve the requested grant.

If you have any questions, please contact me by telephone at (701) 777-5080 or by email at jstrege@undeerc.org.

Sincerely,

DocuSigned by:
80B7CE5336464B9...
Joshua R. Strege
Assistant Director for Energy Systems

Approved by:

DocuSigned by:
29499751F2B84D7...
Charles D. Gorecki, CEO
Energy & Environmental Research Center

JRS/rlo
Enclosures

c: Karen Tyler, North Dakota Industrial Commission

Renewable Energy Program

North Dakota Industrial Commission

Application

Project Title: Integrated Renewable Combined Heat and Power for Ethanol

Applicant: Energy & Environmental Research Center (EERC), University of North Dakota; EERC Proposal No. 2023-0100

Principal Investigator: Joshua R. Strege

Date of Application: February 1, 2023

Amount of Request: $450,000

Total Amount of Proposed Project: $2,250,000

Duration of Project: 18 months

Expected Start: June 1, 2023

Point of Contact (POC): Joshua R. Strege

POC Telephone: (701) 777-5080

POC Email: jstrege@undeerc.org

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

Lead Organization: EERC

Cost Share Partner: U.S. Department of Energy Office of Fossil Energy and Carbon Management

TABLE OF CONTENTS

ABSTRACT

The Energy & Environmental Research Center (EERC) proposes to develop a detailed study of how gasification-based combined heat and power (CHP) using corn stover as fuel with CO_2 capture could benefit the state's ethanol industry. CO_2 capture from fermentation is already providing financial benefit through Section 45Q tax credits for stored CO_2 and has potential for California Low Carbon Fuel Standard (LCFS) credit sales. Making the ethanol process even less carbon-intensive by replacing natural gas with renewable syngas and adding additional CO_2 capture is expected to provide additional economic benefits. To complete this study, the EERC will characterize regional corn stover for its suitability and availability as gasifier feedstock; will conduct several weeks of stover gasification under different conditions to examine the impact on CO_2 capture solvent; will develop techno-economic models of a gasification CHP integrated into an ethanol plant; and will conduct life cycle analyses of the process to estimate potential for LCFS credits. **Objective:** The goal of the proposed project is to determine the technical and economic feasibility of implementing small-scale commercial CHP using corn stover at an operational ethanol facility. **Expected Results:** By the end of the project, the EERC

expects to have a thorough working knowledge of the specific challenges and solutions to using corn stover to provide heat and power using gasification with CO_2 capture. These data will be used to develop an engineering design for a well-integrated CHP system at an ethanol plant. In turn, this engineering design will allow the EERC to estimate the economic feasibility of using renewable heat and power with CO_2 capture at a North Dakota ethanol facility, including how the reduced carbon intensity can provide additional LCFS credits and payments for CO_2 sequestration. **Duration:** 18 months, with an anticipated start date of June 1, 2023. **Total Project Cost:** $2,250,000, with $450,000 from the North Dakota Industrial Commission Renewable Energy Program and $1.8 MM from federal funding. **Participants:** EERC, U.S. Department of Energy, and Red Trail Energy.

PROJECT DESCRIPTION

Introduction: Several recent factors have driven a strong push to decarbonize ethanol facilities in North Dakota. First, the California Low Carbon Fuel Standard (LCFS) allows fuel producers with a lower carbon intensity (CI) score than conventional petroleum fuel to earn CO_2 credits for fuel sold in California (replacing petroleum), with credits averaging about $130 per tonne of CO_2 in 2022 (Californica Air Resources Board, LCFS Data Dashboard, 2023). Second, the recent Bipartisan Infrastructure Law increased the value of sequestered CO_2 from $50 to $85/tonne and converted the payout mechanism from tax credits to direct pay for the first 5 years of operation. Third, the successful capture and storage of naturally fermented CO_2 from Red Trail Energy has proven the feasibility and potential for CO_2 capture from ethanol plants in North Dakota.

While the Red Trail Energy project has successfully demonstrated commercial CO_2 capture from the plant's fermenters, CO_2 is generated from multiple locations in ethanol plants, and additional capture is possible. However, whereas the fermenter CO_2 is relatively pure and needs only to be dried and compressed, CO_2 emissions from other units (such as boilers and driers) are dilute and require additional separation. Moreover, while the CO_2 from the fermenter is derived from corn and is largely renewable, other CO_2 sources are normally derived from natural gas or other fossil fuels. New approaches to provide steam, drying, and CO_2 capture are required to further reduce the CI score of North Dakota's ethanol facilities.

One option to provide a renewable natural gas replacement is biomass gasification. Ethanol plants are naturally located close to farmers growing corn, and past experience at the Energy & Environmental Research Center (EERC) has shown that corn stover can be readily gasified using technology such as a fluidized-bed gasifier (Stanislowski, 2022). Syngas generated in the gasification process can be fed to a microturbine or reciprocating engine to generate electrical power, and the waste heat from the process can be used to generate steam or to provide drying. With proper engineering design, this overall combined heat and power (CHP) process can be integrated into the ethanol plant for maximum efficiency. For processes that require significant electrical power, such as CO_2 compression, CHP using gasification can be more attractive than using combustion because of the potential for high power-to-heat ratios (DOE, 2017). Another advantage of gasification over combustion is that CO_2 can be captured using less energy-intensive processes. In combustion, CO_2 from the flue gas is usually captured using amine-based solvents. These amine-based solvents must be heated to high temperatures to recover the CO_2, then cooled again for capture. With pressurized gasification units, physical solvents can be used to absorb the CO_2 at pressure, and the CO_2 can then be recovered by reducing pressure and gently heating the physical solvent. Typical commercial physical solvent are blends of dimethyl ethers of polyethylene glycol, or DEPG.

Although there is significant potential for gasification-based CHP to benefit ethanol plants, an integrated CHP system has yet to be proven. Under an initial project funded through the State Energy Research Center (SERC), the EERC is currently completing a preliminary high-level study into the feasibility of different CHP options for ethanol plants. The proposed work will build on this initial SERC effort to better identify the challenges and solutions to gasifying corn stover to provide renewable CHP for an ethanol facility.

Objectives: The goal of the proposed project is to determine the technical and economic feasibility of implementing small-scale commercial CHP using corn stover feedstock at an operational industrial facility to validate a reduced-CI ethanol fuel applicable for low-carbon fuel programs. Specific objectives include the following:

- Complete a resource characterization study to determine the availability and suitability of corn stover for gasification-based CHP at an ethanol facility.
- Develop the data necessary to conduct a techno-economic analysis through pilot-scale testing.
- Evaluate the economic feasibility of CHP deployment, including techno-economic estimates of installation and operating costs, as well as identify potential revenue, such as carbon credits and carbon markets.
- Conduct life cycle assessments (LCAs) of gasification-based CHP to estimate CI score and possible benefit for LCFS credits.

80% cost share for the project will be provided by the U.S. Department of Energy (DOE) – Office of Energy and Carbon Management (FECM), with the remaining 20% share requested through NDIC's Renewable Energy Program.

Methodology: The project will be organized into four tasks. The task structure is identical to that in the matching proposal being submitted to FECM.

Task 1 – Project Management and Reporting –This effort is expected to require significant oversight by EERC personnel throughout the project duration to coordinate each part of the overall study so that results from each task best inform the next. Task 1 will include all reporting to project sponsors, including quarterlies and the final report. Results will be provided in project meetings to NDIC and will be shared at one or more technical conferences.

Task 2 – Biomass Characterization – Initial work under a SERC-funded study has identified some of the challenges that corn stover could present for a gasification-based CHP facility. Under Task 2, the EERC will procure corn stover from a regional source. The stover will be dried and processed as needed to be suitable for feeding into a gasifier. Any unique challenges with feedstock processing will be noted, and these data will be used to guide the engineering design efforts around fuel handling. In addition, the stover will be characterized for its fuel properties using proximate/ultimate analysis and for its ash composition using x-ray fluorescence (XRF). The XRF in particular will help to inform the team on optimal gasifier operation. Biomass can contain high levels of alkali material, which lowers the melting temperature of ash and can lead to sticky agglomerations that plug up gasifiers, leading to shutdowns and excessive maintenance. Additives such as kaolin are known to help reduce the tendency of alkali to cause agglomerations, but fuel additives present additional operational cost. XRF analysis is important to help predict ash melting temperatures and to determine optimum dosing of kaolin or other additives. Additionally, ash melting behavior will be directly tested using slag viscosity measurements.

In parallel with fuel characterization, the EERC also proposes to assess the regional availability and storage options for corn stover. The amount of stover that can be taken off the field will be dependent on regional soil conditions, which vary from the eastern to the western portion of the state. Moreover, while ethanol plants operate year-round, stover is only generated during harvest and must be stored if it is to be used as fuel for a CHP system. The EERC will study regional options for harvest and storage, including drying needs and the impacts of long-term field storage on stover's quality as a gasifier fuel.

Task 3 – Gasification – The EERC will use existing pilot-scale facilities to study gasifier and carbon capture performance when using 100% corn stover as a fuel. Corn stover that was dried and processed under Task 2 will be fed to a pressurized fluidized-bed gasifier to generate syngas. Based on studies completed under Task 2, kaolin or other additives may be blended with the stover to reduce the potential for agglomeration. The syngas will be cleaned to remove particulates and any traces of sulfur, shifted to convert most of the carbon monoxide to CO_2, and then passed through the EERC's carbon capture system. A commercially available solvent based on a mixture of dimethyl ethers of polyethylene glycol (DEPG) will be used to remove >90% of the CO_2.

The EERC will study both oxygen-blown and air-blown gasification of corn stover. In large-scale commercial gasifiers, fuel is gasified using purified oxygen mixed with steam to provide maximum efficiency. In smaller gasifiers, the cost of air separation to provide oxygen becomes prohibitive, and most small units are air-fired. National Energy Technology Laboratory (NETL) is actively researching new technologies to reduce the cost of small-scale air separation specifically to encourage more efficient small-scale gasification and has reported several recent successes (Dou, 2022; Singh, 2022). Because small-scale oxygen-blown gasification could become more attractive in the near future, it is worth comparing gasifier performance with both air and oxygen to study expected performance for CHP. In both cases, the CO_2 capture solvent will be exposed to syngas for periods of up to 200 hours. These tests will determine the impact of biomass-derived impurities on carbon capture performance and how these might differ when using oxygen versus air. Previous carbon capture testing at the EERC with coal and biomass blends (Stanislowski, 2022) showed that there were no major showstoppers observed when utilizing biomass as a feedstock, but longer-duration testing would enable the team to evaluate long-term impacts and, ultimately, the economics of the system.

Syngas will be sampled at various locations using Fourier transform infrared (FTIR) spectrometry and Dräger tubes to measure concentrations of organic tar components entering and leaving the carbon capture unit. This information will help to determine whether different components are accumulating in the CO_2 capture solvent, are passing through with the syngas, or are ending up in the CO_2 stream and might need to be removed before the CO_2 can be compressed and transported. Solvent samples will be taken throughout each week of testing and analyzed using gas chromatography coupled to mass spectrometry (GC–MS). The EERC has used GC–MS in the past to qualitatively monitor the buildup of tar components in CO_2 capture solvent. Based on past experience, the EERC will better develop this analytical method to help quantify the amount of tar accumulating in the solvent. This method development will provide a useful technique for future studies of the long-term impacts of different fuels on CO_2 capture solvent.

Task 4 – Integration Studies and Techno-Economic Analysis – Task 4 will develop a design for a fully integrated CHP system at an ethanol plant. The study will estimate the high-level technical and economic feasibility of such a system and will provide an LCA of a proposed CHP system design.

The overall design will be based on findings from Tasks 2 and 3 regarding fuel processing, gasifier performance, CO_2 capture performance, long-term impacts of biomass tar on CO_2 solvent and potential mitigation strategies, and needs at the ethanol plant. It is expected that the design will be sized to provide all electrical power needed for CO_2 compression, both from the CO_2 capture unit and also from the ethanol plant's fermenter. Initial designs from the EERC's SERC study predict that a CHP facility of this size will require only a portion of the stover available from corn harvest, though this will depend on findings from Task 2 regarding how much stover can be taken off the field in different areas of the state.

Although a very high-level technical model was developed under the SERC study, this model did not account for actual gasifier performance, for feedstock handling, or for how the heat and power generated at a CHP plant would actually be integrated into an ethanol facility. Under Task 4, the EERC will use plant information provided by Red Trail Energy to design an integrated CHP system. It is anticipated that such a system would include some syngas offtake for direct firing, a gas turbine or reciprocating engine for generating power from the bulk of the syngas, a heat recovery steam generator for generating steam from the hot engine exhaust, and steam offtake at different temperatures and pressures depending on the specific needs of different unit operations.

Once the technical design is completed, it will be used to conduct an LCA in accordance with NETL guidelines. An additional LCA assessment will be conducted using the California Greenhouse Gas, Regulated Emissions, and Energy Use in Transportation (CA-GREET) model, helping to provide insight into how a gasification-based renewable CHP system with CO_2 capture might provide eligibility for LCFS credits to an ethanol facility.

Anticipated Results: The final product will be a techno-economic analysis and feasibility-level review of this integrated renewable CHP project with a road map for potential implementation.

Facilities: The EERC's pressurized fluidized-bed gasifier (Figure 1) has been successfully operated on dozens of fuels for over more than 15 years of operation, and the CO_2 capture system has been operated for thousands of hours on a wide variety of syngas compositions. The gasifier and capture system were previously operated for short durations on 100% biomass feeds and on blends of up to 50% corn stover with coal. As such, the EERC is very confident in the capabilities of this system to gasify corn stover and to capture CO_2. Previous work has already identified the major concerns to CO_2 capture solvent performance that were observed over shorter durations, so the team is fully prepared on what data to gather and on what forms of degradation to expect during longer-term operation.

Resources: Red Trail Energy will provide information on its ethanol plant and the specific requirements for CO_2 capture from its fermenter (see letter of support in Appendix A). This information will be used to design the integrated CHP system to optimize how each stream can be best used in an existing ethanol facility using CO_2 capture.

Techniques to Be Used, Their Availability and Capability: The Aspen software package proposed for Activity 4 is an industry-standard tool used to model complex reactor systems. This software includes built-in modules to accurately model CO_2 capture performance. The EERC has used Aspen to conduct numerous techno-economic assessments of CO_2 capture performance with more than 15 years of experience and is well-versed in the approaches to accurately size, model, and cost major process

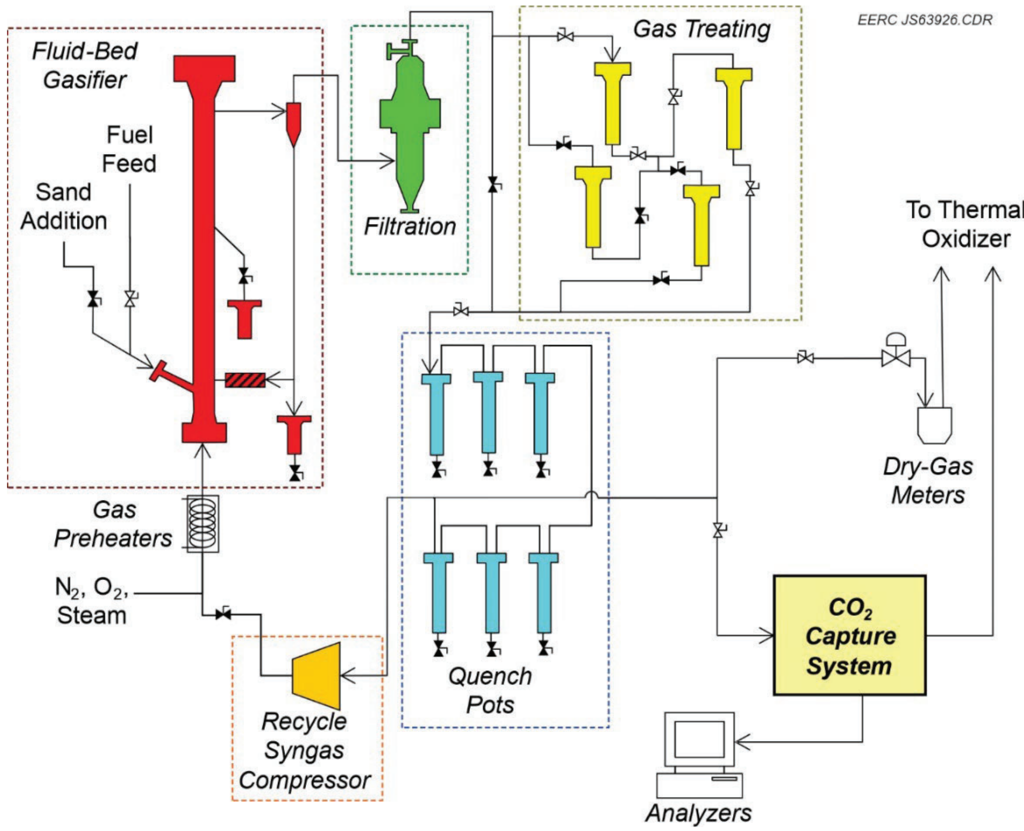


Figure 1. Projected process layout of the 10-lb/hr HPFBG.

equipment. For the full techno-economic assessment, the EERC will rely on standard approaches used in DOE baseline studies on CO_2 capture to estimate the full cost of capture.

The approach used for the LCA is a standard methodology adopted by NETL, and additional simulations used to assess carbon intensity for LCFS credits will use the CA-GREET model. The EERC team has significant experience using these models to conduct LCAs of CO_2 capture processes at Red Trail Energy and other facilities.

Environmental and Economic Impacts while Project Is Underway: The gasifier system has a well-demonstrated capability to capture particulate matter, residual sulfur, produced water, and tar compounds. All process water, solid waste, and air emissions will be treated and handled in accordance with local, state, and federal regulations and will be in compliance with the University's current permit to operate with the state. In terms of economic impacts, the project will directly leverage $1,800,000 in additional federal dollars and is expected to lead to future work with the state's ethanol industry.

Ultimate Technological and Economic Impacts: This project will provide a roadmap for implementing gasification-based renewable CHP at a North Dakota ethanol facility. The report will also help to define how the state's ethanol industry can monetize additional LCFS credits and other incentives for CO_2 capture and storage.

Why the Project Is Needed: Several factors are converging to create a unique opportunity for North Dakota ethanol producers to benefit from reducing their carbon intensity: the increase in Section 45Q tax credits to $85/tonne of CO_2; the LCFS credits available for renewable fuels; in-depth of knowledge in CO_2 storage opportunities within the state; and the success of the initial CO_2 capture effort at Red Trail Energy's ethanol facility. Adding a renewable CHP facility to an ethanol plant would further reduce the greenhouse gas (GHG) emissions associated with ethanol production, qualifying fuels for higher LCFS credits and providing direct pay benefits for CO_2 sequestration under Section 45Q of the U.S. Tax Code. Choosing gasification as the base process for CHP would provide more power output to drive CO_2 compression than would a combustion-based CHP facility, and for an oxygen-blown gasification process, using precombustion CO_2 capture would require less energy than using postcombustion CO_2 capture. However, to date, no publicly available data are known to be available on the long-term impacts of biomass impurities on precombustion CO_2 capture solvents. Actual gasification testing is necessary to determine the real-world feasibility of a gasifier-based renewable CHP technology at ethanol plants. The optimum approach to fully integrating a CHP facility into an ethanol plant will depend on the outcomes of gasifier testing, and a detailed techno-economic assessment is warranted to better understand the costs and complexity of installing such a system.

STANDARDS OF SUCCESS

The project will be considered successful if it can provide a profitable design to integrate renewable CHP with carbon capture into existing ethanol facilities in North Dakota. A further standard of success is to provide sufficient gasifier operating data to guide and validate the CHP facility design. If these standards are met, the final product can be used by the ethanol industry as the basis for detailed engineering that would lead to construction and implementation, ultimately leading to increased profitability for the state's ethanol industry.

BACKGROUND/QUALIFICIATIONS

The project will be led by Mr. Joshua Strege, who will also lead the techno-economic modeling under Task 4. Mr. Strege is the EERC's leading technical expert in Aspen software and has been responsible for techno-economic analyses of various renewable projects, including the initial SERC study on integrating CHP into ethanol facilities. He will be assisted on Task 4 by Mr. Chris Beddoe, who will lead the LCA efforts. Mr. Beddoe has used NETL's models as well as CA-GREET for LCA studies at the EERC, including work done in support of Red Trail Energy. Biomass processing and gasification work will be led by Dr. Michael Swanson, who has more than 30 years of experience in the design, fabrication, and operation of pilot-scale gasification equipment. Dr. Swanson led the design and construction of the EERC's fluidized-bed gasifier and has overseen operation of this equipment on every project since it was first installed. Full resumes for all key personnel are provided in Appendix B.

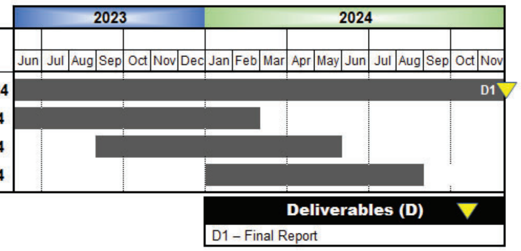
MANAGEMENT

The EERC maintains an in-house technical support team to monitor progress related to project deliverables, schedule, and spending. The project manager will hold regular meetings with the project team and will be assisted by a designated research manager to track progress and communicate with project partners.

TIMETABLE

This project is proposed to be performed over an 18-month period, with an anticipated start date of June 1, 2023. Quarterly progress reports will be submitted within 30 days after the end of each calendar quarter.

	Start Date	End Date
Task 1.0 – Project Management and Reporting	**6/1/23**	**11/30/24**
Task 2.0 – Biomass Characterization	**6/1/23**	**2/29/24**
Task 3.0 – Gasification	**9/1/23**	**5/31/24**
Task 4.0 – Integration Studies and Techno-Economic Analysis	**1/1/24**	**8/31/24**



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BUDGET

The total estimated cost for the proposed work is $2,250,000, as shown in Table 2. The EERC requests $450,000 from the Renewable Energy Program to be matched with $1,800,000 from the U.S. Department of Energy Office of Fossil Energy and Carbon Management. A letter of support is provided in Appendix A. Budget notes can be found in Appendix C.

If less funding is available than requested, then depending on the amount, the EERC would most likely propose to reduce the amount of gasifier testing. This would affect results on the long-term impacts of biomass firing on CO_2 capture solvent but would retain enough funding to complete the techno-economic study and LCA.

TAX LIABILITY

The EERC is a business unit within UND, which is a state-controlled institution of higher education and is not a taxable entity; therefore, the EERC has no tax liability.

CONFIDENTIAL INFORMATION

No confidential information is included in this proposal. It is expected that some of confidential data may be provided by Red Trail Energy to develop the technical and LCA models. Project reports will

Table 1. Budget Breakdown

Project Associated Expense	NDIC Share (Cash)	DOE Share (Cash)	Total Project
Labor	$285,421	$834,308	$1,119,729
Travel	$0	$7,895	$7,895
Supplies	$0	$6,400	$6,400
Communications	$0	$81	$81
Printing & Duplicating	$0	$170	$170
Freight - Corn Stover	$0	$5,000	$5,000
Laboratory Fees & Services			
EERC Natural Materials Analytical Research Lab	$0	$1,716	$1,716
EERC Combustion Test Service	$0	$18,749	$18,749
EERC Particulate Analysis Lab	$0	$35,154	$35,154
EERC Process Chemistry & Development Lab	$0	$5,107	$5,107
EERC Fuel Preparation Service	$0	$7,258	$7,258
EERC Continuous Fluidized-Bed Reactor Service	$0	$156,492	$156,492
EERC Document Production Service	$0	$18,300	$18,300
EERC Shop & Operations	$7,592	$30,088	$37,680
EERC Technical Software Fee	$0	$55,944	$55,944
EERC Engineering Services Fee	$5,000	$9,391	$14,391
Total Direct Costs	$298,013	$1,192,053	$1,490,066
Facilities & Administration	$151,987	$607,947	$759,934
Total Project Costs	**$450,000**	**$1,800,000**	**$2,250,000**

summarize model results such that meaningful data can be extracted without compromising the underlying confidential design information provided by Red Trail Energy.

PATENTS/RIGHTS TO TECHNICAL DATA

It is not anticipated that any patents will be generated during this project. The rights to technical data generated will be held jointly by the EERC and project sponsors.

STATE PROGRAMS AND INCENTIVES

A listing of EERC projects funded by NDIC in the last 5 years can be found in Appendix D.

REFERENCES

All references cited are in Appendix E.

APPENDIX A

LETTERS OF SUPPORT

January 26, 2023

Mr. Joshua Strege
Assistant Director for Energy Systems
University of North Dakota
Energy & Environmental Research Center
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018

Subject: EERC Proposal No. 2023-0100, "Integrated Renewable Combined Heat and Power for Ethanol"

Dear Mr. Strege:

This letter is in response to the Energy & Environmental Research Center (EERC) request for participation in the subject project as proposed to the North Dakota Industrial Commission Renewable Energy Program.

The proposed effort aims to study the technical and logistical issues related to using crop residues such as corn stover as a renewable fuel for combined heat and power (CHP) systems at an ethanol facility and how such a CHP system could be used to provide power for CO_2 capture. Red Trail Energy is pleased to offer support for this effort by providing the EERC with operational and design data from our ethanol plant in Richardton, North Dakota. This data will be used to develop and validate process models of how such a CHP system could be best integrated with the ethanol plant to optimize efficiency.

Should you have any questions, please do not hesitate to contact me at kent@redtrailenergy.com Again, we express our support of the proposed project and look forward to working with the EERC on this project.

Sincerely,

Kent Glasser
Plant Manager
Red Trail Energy

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January 30, 2023

Mr. Reice Haase
Deputy Executive Director
North Dakota Industrial Commission
ATTN: Renewable Energy Program
State Capitol – 14th Floor
600 East Boulevard Avenue, Department 405
Bismarck, ND 58505-0840

Dear Mr. Haase:

Subject: Cost Share for EERC Proposal No 2023-0100, Entitled "Integrated Renewable Combined Heat and Power for Ethanol"

The Energy & Environmental Research Center (EERC) is conducting complementary research and development efforts under a multimillion-dollar 10-year Cooperative Agreement with the U.S. Department of Energy (DOE) entitled "Joint Program on Research and Development for Fossil Energy-Related Resources." Through this joint program, nonfederal entities can team with the EERC and DOE on projects that address the goals and objectives of DOE's Office of Energy and Carbon Management.

The proposed project to the North Dakota Industrial Commission (NDIC) Renewable Energy Program is a viable candidate for funding under the EERC–DOE National Energy Technology Laboratory Program. Therefore, the EERC intends to secure $1,800,000 of cash cost share for the proposed project through its Cooperative Agreement with DOE, providing that NDIC commits $450,000 of cash cost share.

Proposals submitted to DOE by EERC under this program receive expeditious consideration, and the success rate is traditionally very high. However, there is no guarantee of approval.

As a cosponsor of the project, DOE would require access to all data generated and a royalty-free right to practice. However, certain project details can often be held confidential for some period of time.

Initiation of the proposed work is contingent upon the execution of a mutually negotiated agreement between the EERC and each of the project sponsors.

If you have any questions, please contact me by phone at (701) 777-5157 or by email at jharju@undeerc.org.

Sincerely,

DocuSigned by:
John Harju
34253F4468294EF...
John A. Harju
Vice President for Strategic Partnerships

JAH/rlo

c: Karen Tyler, North Dakota Industrial Commission

APPENDIX B

RESUMES OF KEY PERSONNEL

JOSHUA R. STREGE
Assistant Director for Energy Systems
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, North Dakota 58202-9018 USA
701.777.5080 (phone), 701.777.5181 (fax), jstrege@undeerc.org

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 L. SWANSON
Distinguished Engineer, Fuels Conversion
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
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Principal Areas of Expertise
Dr. Swanson's principal areas of interest and expertise include integrated gasification combined cycle (IGCC), pressurized fluidized-bed combustion (PFBC), hot-gas cleanup, coal reactivity in low-rank coal (LRC) combustion, supercritical solvent extraction (SFE), and liquefaction of LRCs.

Education and Training
Ph.D., Energy Engineering, University of North Dakota, 2000. Dissertation: Modeling of Ash Properties in Advanced Coal-Based Power Systems.
M.B.A., University of North Dakota, 1991.
M.S., Chemical Engineering, University of North Dakota, 1982.
B.S., Chemical Engineering, University of North Dakota, 1981.

Research and Professional Experience
2022–Present: Distinguished Engineer, Fuels Conversion, EERC, UND.

2004–Present: Adjunct Professor, Chemical Engineering, UND.

1999–2022: Principal Engineer, Fuels Conversion, EERC, UND. Dr. Swanson is currently involved in the demonstration of advanced power systems such as IGCC and PFBC focused on hot-gas cleanup issues.

1997–1999: Research Manager, EERC, UND. Dr. Swanson managed research projects involving the demonstration of advanced power systems such as IGCC and PFBC focused on hot-gas cleanup issues.

1990–1997: Research Engineer, EERC, UND. Dr. Swanson was involved with the demonstration of advanced power systems such as IGCC and PFBC focused on hot-gas cleanup issues.

1986–1990: Research Engineer, EERC, UND. Dr. Swanson supervised a contract with the U.S. Department of Energy (DOE) to investigate the utilization of coal–water fuels in gas turbines, where he designed, constructed, and operated research projects that evaluated the higher reactivity of low rank coals in short-residence-time gas turbines and diesel engines.

1983–1986: Research Engineer, EERC, UND. Dr. Swanson designed, constructed, and operated SFE and coal liquefaction apparatus; characterized the resulting organic liquids and carbonaceous chars; and prepared reports.
1982–1983: Associated Western Universities Postgraduate Fellowship, DOE Grand Forks Energy Technology Center, Grand Forks, North Dakota. Dr. Swanson designed and constructed an SFE apparatus.

Publications
Dr. Swanson has authored or coauthored numerous professional publications.

CHRISTOPHER J. BEDDOE
Senior Research System Engineer
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Principal Areas of Expertise
Mr. Beddoe's principal areas of interest and expertise include measurement system analysis and design, development of control systems, fabrication, computer programming, and automation, life cycle analysis and air dispersion modeling.

Education and Training
B.S., Mechanical Engineering, University of North Dakota, 2007.
Proficient in the use of 2-D and 3-D AutoCad; Pro-Engineer; Solid Works; ANSYS; MATLAB; C++; Java and G-code for CNC operations; Microsoft Office Suite; MS Macros; Visual Basic; and various communications protocols.

Research and Professional Experience
2021–Present: Senior Research System Engineer, EERC, UND. Mr. Beddoe supports testing, engineering design, fabrication, management, and support of EERC laboratory, pilot, and field systems related to the production, combustion, and gasification of fuels, preparing research proposals, interpreting data, writing reports and papers, presenting project results to clients, and presenting papers at national and international conferences.

2018–2021: Senior Research Engineer and Manager, Applied Geology Laboratory (AGL), EERC, UND. Mr. Beddoe's responsibilities include working in collaboration with subject matter experts, principal investigators, and EERC leadership to prepare proposals and develop and pursue new business opportunities; management of the Applied Geology Laboratory; close coordination of research efforts with personnel and laboratories to ensure successful project completion on-time, on-budget, and within clients expectations; ensuring proper operation of laboratory systems and that laboratory data and results are of excellent quality and integrated with the theoretical, modeling, and field components of EERC research efforts; ensuring laboratory safety and updating/maintaining laboratory testing and safety procedures; developing and expanding research efforts and laboratory capabilities, particularly in the areas of CO_2 enhanced oil recovery (EOR), CO_2 storage, unconventional hydrocarbon recovery, natural resource management, critical resource characterization and recovery, geologic and synthetic materials characterization, and environmental aspects of energy management; and mentoring staff and colleagues and promoting professional development, education, and training opportunities.

2011–2018: Research Engineer, EERC, UND. Mr. Beddoe's responsibilities included development of precision measurement and control systems for material testing in the AGL, modifying existing equipment, designing and building new parts and equipment, developing new standard operating procedures (SOPs) and training/supervising technical staff, testing and calibrating transducers and measurement system, and analyzing and interpreting raw data.

2007–2009: Manufacturing Process Engineer, Hutchinson Technology Inc. Mr. Beddoe was responsible for developing and qualifying new precision measurement and manufacturing equipment and processes, supervising technical staff, reviewing and signing off on proposed changes to measurement systems, coordinating equipment for repairs, interfacing between managers, designers and machinists developing new equipment, and led projects organizing efforts for as many as 12 people.

2006: Engineered Surfaces Center, Grand Forks, North Dakota. Mr. Beddoe worked in a small team responsible for the design, modeling, and fabrication of a vibration isolation table, began design of a rolling contact fatigue test machine, and worked as a laboratory assistant for metallurgical testing.

Publications
Mr. Beddoe has coauthored several professional publications.

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

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.

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.

Freight – Corn Stover: Estimated cost for receiving the feedstock based on historical costs.

Operating Fees: Operating fees generally include EERC recharge centers, outside laboratories, and freight.

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

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

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

Technical software fees are for the use of ASPEN modeling software.

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.

APPENDIX D

EERC PROJECTS FUNDED BY THE NORTH DAKOTA INDUSTRIAL COMMISSION IN THE LAST 5 YEARS

EERC PROJECTS FUNDED BY THE NORTH DAKOTA INDUSTRIAL COMMISSION IN THE LAST 5 YEARS

Project Name	Start Date	End Date	Total Contracted
Bakken Production Optimization Program 2.0	11/01/16	05/31/20	$6,000,000.00
Initial Engineering, Testing, and Design of a Commercial-Scale CO_2 Capture System	09/01/17	12/31/19	$3,200,000.00
FERR 1.3 – Integrated Carbon Capture and Storage for North Dakota Ethanol Production	11/01/17	07/31/18	$345,000.00
iPIPE: The intelligent Pipeline Integrity Program	04/01/18	12/31/23	$2,600,000.00
Economic Extraction and Recovery of REES and Production of Clean Value-Added Products from Low-Rank Coal Fly Ash	06/16/18	02/15/20	$30,000.00
Low-Pressure Electrolytic Ammonia Production	06/16/18	06/30/22	$437,000.00
FERR 1.3 – Integrated Carbon Capture and Storage for North Dakota Ethanol Production	12/01/18	05/31/20	$500,000.00
State Energy Research Center	07/01/19	06/30/27	$20,000,000.00
Underground Storage of Produced Natural Gas – Conceptual Evaluation and Pilot Project(s)	06/01/19	06/30/23	$3,500,000.00
Assessment of Bakken and Three Forks Natural Gas Compositions	11/01/19	06/19/20	$300,650.00
Improving EOR Performance Through Data Analytics and Next-Generation Controllable Completions	01/27/20	09/30/24	$500,000.00
Wastewater Recycling Using a Hygroscopic Cooling System	01/31/20	09/30/22	$100,000.00
PCOR Partnership Initiative to Accelerate CCUS Deployment	02/01/20	09/30/24	$2,000,000.00
PCOR Partnership Initiative to Accelerate CCUS Deployment	02/01/20	09/30/24	$2,000,000.00
FERR 3.2 – Produced Water Management Through Geologic Homogenization, Conditioning, and Reuse	02/01/20	01/31/22	$300,000.00
Bakken Production Optimization Program 3.0	05/01/20	04/30/23	$6,000,000.00
EERC Technical Support for RTE CCS Activities – November 1, 2019	06/01/20	11/30/21	$500,000.00
Flue Gas Characterization and Testing	07/01/20	11/30/21	$3,741,450.00
Laboratory-Scale Coal-Derived Graphene Process	09/01/20	04/30/23	$162,500.00
Hydrogen Energy Development for North Dakota	07/01/21	06/30/23	$500,000.00
Ammonia-Based Energy Storage Technology	04/01/21	03/31/23	$101,390.00
Field Study to Determine the Feasibility of Developing Salt Caverns for Hydrocarbon Storage in Western North Dakota	07/01/21	06/30/23	$11,900,000.00
Williston Basin CORE-CM Initiative	02/01/22	05/31/23	$750,000.00
Front-End Engineering and Design for CO_2 Capture at Coal Creek Station	02/01/22	08/31/23	$7,000,000.00
Unitized Legacy Oil Fields: Prototypes for Revitalizing Conventional Oil Fields in North Dakota	07/01/21	06/30/24	$3,000,000.00
iPIPE 2.0: The intelligent Pipeline Integrity Program	01/01/22	12/31/23	$400,000.00
Advanced Processing of Coal and Waste Coal to Produce Graphite for Fast-Charging Lithium-Ion Battery	02/01/22	01/31/25	$500,000.00
Liberty H_2 Hub Front-End Engineering and Design	11/01/22	10/31/24	$10,000,000.00

APPENDIX E

REFERENCES CITED

REFERENCES CITED

California Air Resources Board. LCFS Data Dashboard. https://ww2.arb.ca.gov/resources/documents/lcfs-data-dashboard, accessed January 2023.

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Dou, J.; Krzystowczyk, E.; Li, F. *Radically Engineered Modular Air Separation System with Tailored Oxygen Sorbents.* Final Report for U.S. Department of Energy. April 2022.

Singh, R. *High Selectivity and Throughput Carbon Molecular Sieve Hollow Fiber Membrane-Based Modular Air Separation Unit for Producing High Purity O_2.* Project Review Meeting for U.S. Department of Energy National Energy Technology Laboratory. May 2, 2022.