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

August 1, 2018

Ms. Karlene Fine
Executive Director
ATTN: Renewable Energy Program
North Dakota Industrial Commission
600 East Boulevard Avenue
State Capitol, 14th Floor
Bismarck, ND 58505-0840

Dear Ms. Fine:

Subject: EERC Proposal No. 2018-0128 Entitled "Integrated Carbon Capture and Storage for North Dakota Ethanol Production – Phase III"

The Energy & Environmental Research Center (EERC) of the University of North Dakota (UND) is pleased to submit an original and one copy of the subject proposal. Also enclosed is the $100 application fee.

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 make the requested grant.

If you have any questions, please contact me by telephone at (701) 777-5013 or by e-mail at kleroux@undeerc.org.

Sincerely,

Kerryanne M. Leroux
Senior Chemical Engineer
Oilfield Operations Team Lead

Approved by:

Thomas A. Erickson, CEO
Energy & Environmental Research Center

KML/kal

Enclosures

Renewable Energy Program

North Dakota Industrial Commission

Lead Organization: EERC – University of North Dakota

Cost-Share Partners: Red Trail Energy, LLC; U.S. Department of Energy

Other Project Partners: Trimeric Corporation

Application

Project Title: Integrated Carbon Capture and Storage for North Dakota Ethanol Production – Phase III

Applicant: Energy & Environmental Research Center, University of North Dakota

Principal Investigator: Kerryanne M. Leroux

Date of Application: August 1, 2018

Amount of Request: $500,000

Total Amount of Proposed Project: $2,650,000

Duration of Project: 18 months

Point of Contact (POC): Kerryanne M. Leroux

POC Telephone: (701) 777-5013

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

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ABSTRACT

The Energy & Environmental Research Center (EERC) proposes to conduct the third phase (Phase III) of a multiphase research and development effort to create the first integrated carbon capture and storage (CCS) system in ND for the reduction of carbon emissions from ethanol production and capitalize on evolving low-carbon fuel (LCF) markets. Using the Red Trail Energy (RTE) facility near Richardton, ND, as a case study, the EERC assessed the technical and economic prefeasibility of integrating CCS with ethanol production (Phase I) and resolved uncertainties related to regulatory, processing, and financial stipulations (Phase II). The proposed Phase III project will initiate field research plans developed during Phases I and II. CO_2 capture process designs will be prepared to provide the foundation for a formal engineering design of the CO_2 capture system and other CCS infrastructure, building upon preliminary work conducted during prior phases. Near-surface baseline monitoring and characterization data (seismic survey) will be collected to support characterization, permitting, and operational CCS-monitoring activities in future phases. Provisional ND permitting documents for CO_2 geologic storage will be created. Evolving LCF and other incentive programs will be assessed for their financial and regulatory impact on potential CCS implementation. Execution of outreach plans created in Phase II will engage stakeholders and communities regarding CCS integration with ND ethanol production. The results of Phase III will allow project partners to move closer to creating the first integrated CCS effort in ND. **Objective:** Maximize the market potential of ND ethanol production through CCS incentive programs by developing the first integrated ND CCS effort, compliant with ND Class VI regulations. **Expected Results:** Phase III will facilitate CCS integration with ND ethanol production in collaboration with project partners and ND regulators by 1) developing a process design package for CO_2 capture integrated with ND ethanol production, 2) collecting baseline monitoring and characterization data required for permits, 3) creating preliminary ND permit applications for geologic CO_2 storage, 4) evaluating potential integration of ND regulations with out-of-state LCF markets and other incentive programs, and 5) conducting outreach regarding CCS targeted to rural western ND communities. **Duration:** 18 months. **Total Project Cost:** $2,650,000. **Participants:** EERC, RTE, Trimeric Corporation, and the U.S. Department of Energy.

PROJECT DESCRIPTION

Introduction: The Energy & Environmental Research Center (EERC) proposes to conduct the third phase (Phase III) of a five-phase research effort to develop the first integrated carbon capture and storage (CCS) facility in North Dakota (ND) to reduce CO_2 emissions, capitalize on evolving ethanol markets, and create new economic opportunities for ND. CCS is the process of capturing carbon dioxide (CO_2) from industrial sources and injecting it into suitable geologic formations, deep underground, for permanent storage. This process has been identified as an effective means of reducing the carbon intensity (CI) of fossil and renewable fuels. Prerequisites of a successful CCS effort are the identification, evaluation, and selection of an appropriate CO_2 storage complex. The storage complex must have geology capable of both accepting and containing injected CO_2 within the storage complex. In addition, the storage complex should be tectonically and hydrogeologically stable (e.g., minimal geologic faults or features with potential migration pathways) and have geologic structure or other characteristics that limit lateral movement of stored CO_2. To understand these site-specific aspects of carbon storage, diligent investigation and substantial data acquisition are required.

In 2016**,** the EERC, in partnership with the ND Renewable Energy Program (REP); ND ethanol producer, Red Trail Energy, LLC (RTE); and the U.S. Department of Energy (DOE), began pursuing CCS as a means to reduce the CI of ND ethanol production to increase the ethanol's value through low-carbon fuel (LCF) markets. The expected outcome of this multiphase effort is an integrated case study to enable the ND ethanol industry to implement CCS and capitalize on LCF markets and/or other CCS incentives. To develop such a case study, all technical aspects of CCS integration must be evaluated, the regulatory process must be navigated, design criteria for infrastructure must be established, and the commercial viability of the effort must be understood. This is best accomplished over consecutive phases (Figure 1) that allow for go/no-go decision points.

Phase I considered the RTE facility in Richardton, ND, as a preliminary case study for assessment of integrating CCS with ND ethanol production. Results indicated the technical suitability of the underlying Broom Creek Formation for geologic CO_2 storage and included generalized designs for capturing,

injecting, and monitoring CO_2 at this site (1). A high-level economic analysis showed that a favorable opportunity may exist for ND ethanol–CCS integration through LCF markets, despite significant costs estimated for CCS infrastructure installation and operation. Phase II was therefore a "go."

Figure 1. Phases and key milestones of the ethanol–CCS integration effort with go/no-go decision points between phases (*Enhancement of Carbon Dioxide Sequestration Credit, a.k.a. Section 45Q).

The Phase II project resolved knowledge gaps identified in Phase I regarding permitting requirements, CO_2 capture specifications, community outreach, and evolving LCF program requirements and other incentives (2). The EERC and RTE determined specific requirements for ND's Underground Injection Control (UIC) Class VI Program,[1] subsequently updating draft CCS and monitoring plans developed during Phase I. Characterization of RTE's fermentation-generated CO_2 stream was conducted, leading to the refinement of CO_2 capture designs and cost estimates. Detailed community outreach plans were developed to inform stakeholders and the public of future CCS activities and outcomes. The draft CCS rules from California's LCF program were evaluated and compared to ND Class VI regulations to determine potential implications for future ND efforts seeking participation in these programs. Oregon, British Columbia, and the proposed national Canadian LCF programs were investigated as well, but none have specific carbon storage requirements to date. Other incentives investigated were the Section 45Q tax credit for CO_2 storage through enhanced oil recovery (EOR) or dedicated storage. These Phase II findings resulted in a decision by RTE to apply for the next phase of CCS implementation.

[1] In April 2018 the ND Industrial Commission was granted primacy over the regulation of CO_2 injection wells (Class VI) by the U.S. Environmental Protection Agency (EPA). ND Class VI primacy reduces uncertainty for future ND CO_2 storage projects, as the ND state agency will regulate all aspects of CO_2 injection, storage, and monitoring.

Remaining phases shown in Figure 1 will complete the CCS case study for the ND ethanol industry. Specifically, proposed future phases will 1) perform characterization activities necessary to complete permits and designs for a commercial CCS effort; 2) conduct baseline monitoring, and implement a commercial operational monitoring program; 3) complete final engineering designs for the required infrastructure; 4) develop operational plans for CO_2 capture, transport, and injection; 5) acquire drilling and related Class VI permits; 6) conduct stakeholder and community outreach to promote ND CCS acceptance; and 7) build, install, and operate a CCS system integrated with ethanol production. The case study will be available to ND stakeholders via reports or other public materials generated by this program (e.g., engineering designs, public outreach packages, etc), providing an example to other ND ethanol facilities looking to establish CCS as a means of capturing incentives for production of lower-CI ethanol. In a broader sense, successful implementation of ND's first integrated CCS ethanol production facility will increase the value of ND ethanol and economically benefit the state by facilitating access to external LCF markets and/or other incentive programs that target CCS.

The proposed Phase III project will generate CO_2 capture process designs, conduct baseline monitoring and reservoir characterization, conduct outreach activities, draft permits related to the ND Class VI program, and continue assessment of evolving CO_2 markets. RTE is committed to serving as the case study and is prepared to contribute personnel and financial resources to continued development of this case study, as detailed in its letter of commitment in Appendix A. Letters of support from the ND Department of Mineral Resources and the ND Ethanol Council are also provided in Appendix A.

Objectives: Objectives for Phase III are to collect the data necessary to advance the RTE case study to the next phase of development and ultimately create the first integrated CCS facility in ND. Specifically this includes 1) generation of site-specific CO_2 capture process designs to obtain engineering design bids, 2) collection of baseline monitoring and site characterization data to determine potential future well locations, 3) creation of draft CCS ND permitting documents, 4) maintaining up-to-date understanding of requirements from evolving CO_2 markets/incentives, and 5) execution of county- and community-level outreach to support stakeholder and community acceptance of implementing an integrated CCS effort.

Methodology: Methods for Phase III are described in the following tasks.

Task 1.0 – Develop CO_2 Capture Process Design Package (PDP). A PDP will be prepared for a potential CO_2 capture facility integrated with ethanol production at the RTE site. Project partner, Trimeric Corporation (Trimeric), will generate the PDP, which includes process flow diagrams, heat and material balances, and piping and instrumentation diagrams. Trimeric will then use these data to develop facility costs and vendor recommendations.

Task 2.0 – Initiate Monitoring and Characterization Plans. Defining the natural variability of near-surface environments will assist in generating formal monitoring plans. Improving structural characterization will aid in determining potential well locations. These proposed activities reduce geologic uncertainty of the storage complex for the preparation of a compliant ND CCS permit package.

Subtask 2.1 – Near-Surface Monitoring. Periodic sampling and compositional analyses of groundwater and soil gas within the RTE study area will be conducted. Site access agreements will be completed for private water wells (up to five) and soil gas-sampling locations (up to 12). The seasonal variability in the groundwater and soil gas composition results will be determined.

Subtask 2.2 – Reservoir Characterization. This subtask will comprise all activities needed to carry out a 3-D seismic survey within the RTE study area and assess results. Landowner agreements for site access and permits through the North Dakota Industrial Commission (NDIC) will be obtained for seismic acquisition. The 3-D seismic survey will be conducted by RTE through a third-party vendor as cost share to the project. The data generated by the survey will then be interpreted by the EERC.

Task 3.0 – Prepare CCS Permit Application Package. Draft documentation will be prepared to satisfy a storage facility permit and a permit to drill (a stratigraphic test hole). The storage facility permit covers multiple design aspects such as technical evaluation, area-of-review delineation, a corrective action plan, an emergency and remedial response plan, a casing and cementing program, a testing and monitoring plan, a well-plugging plan, and a postinjection site care and facility closure plan. Pertinent storage facility permit sections will be addressed using data available. The permit to drill a stratigraphic test hole will be prepared with Phase III data such that drilling can commence at the onset of a potential Phase IV project.

Task 4.0 – Evaluate Economic Viability. The status of LCF programs and other evolving incentives will be assessed. A cost-benefit analysis will be performed to determine the impact of CCS-related incentives and/or LCF programs with CCS integration. Requirements from LCF/incentive programs and how they can potentially be incorporated into ND CCS permits will be evaluated to inform how ND regulators might enable participation in out-of-state programs.

Task 5.0 – Execute Public Outreach Plan. Public outreach will provide informational and educational materials related to the proposed characterization and monitoring activities as well as support local public acceptance of a potential ND CCS effort. Specific stakeholder groups will be targeted for engagement such as landowners and residents, local and regional officials, and educators.

Task 6.0 – Management and Reporting. This task includes managing project activities and ensuring coordination and planning of the project with participants and sponsors (see the Management section for more detail). A final report will be prepared to disseminate Phase III results.

Anticipated Results: Phase III will advance the first ND CCS effort toward commercial implementation. The expected results of the proposed work are 1) a CO_2 capture PDP integrated with ND ethanol production, 2) baseline monitoring and characterization data required for permits, 3) preliminary ND permit applications for geologic CO_2 storage, 4) potential for integration of ND regulations with out-of-state LCF markets and other incentive programs, and 5) active outreach regarding CCS targeted to rural western ND communities. These packages will be developed in collaboration with project stakeholders and ND regulators, facilitating CCS implementation for ND ethanol production.

Facilities and Resources: The proposed work will be performed at the EERC in Grand Forks, ND; the RTE site near Richardton, ND; and Trimeric in Buda, TX. Trimeric is a firm of chemical process engineers with vast experience, expertise, and software tools focused on large CO_2 purification and compression facilities. RTE will provide access for site-related work: near-surface monitoring (soil gas sampling), storage complex characterization (e.g., seismic data acquisition), and outreach activities. Seismic survey activities will be completed using experienced contractors, with EERC oversight. The EERC engineering and scientific research staff is equipped with state-of-the-art analytical, modeling, and

engineering facilities to conduct the proposed monitoring, characterization, permit, and outreach activities. The EERC project team has high proficiency with industry-standard geologic modeling, simulation, and seismic data-processing software and database capabilities for managing high-volume data. The EERC is committed to providing the personnel and resources to effectively conduct all proposed activities. The EERC has ample experience with CCS research and commercialization and currently leads the Plains CO_2 Reduction (PCOR) Partnership, one of seven DOE-funded Regional Carbon Sequestration Partnerships, which includes over 120 partners developing and demonstrating technologies for geologic CO_2 storage (3–9). This expertise will be applied to the RTE effort, providing data, guidance, and practical experience with CCS, all necessary to undertake commercial-scale CO_2 storage efforts. For example, the EERC has been involved with permits, design, acquisition, process, and interpretation of several conventional 2-D and 3-D seismic surveys as well as the development of new seismic techniques and strategies for CCS characterization (10–12).

Techniques to Be Used, Their Availability, and Capability: Trimeric will develop the PDP, as outlined in Task 1.0, using industry-standard process simulation tools. Trimeric has nearly a decade of experience as process engineering lead supporting the first ethanol facility to successfully capture, inject, and geologically store CO_2 (located in Decatur, IL).

The EERC will lead monitoring and characterization activities. Proposed groundwater- and soil gas-monitoring activities include meter readings on location as well as sample collection for a full suite of laboratory analyses through several seasons to establish natural water and soil gas conditions. The acquisition of 3-D seismic data entails laying out an array of surface receivers and generating seismic waves using one or more vibroseis trucks; the data collected are then processed via software and interpreted to characterize the geologic structure. Both the EERC and RTE will ensure industry-standard and permit-compliant practices are conducted.

RTE will lead all outreach activities and be the “public face” of the Phase III program. The outreach plan developed (2) with significant RTE input will be used as the basis for stakeholder engagement activities, production and dissemination of informational materials, a system to track engagement

activities and acquire feedback, and frequent assessment of progress. The proposed project will also leverage the EERC's PCOR Partnership outreach experience, e.g., public Web site development, social media, broadcast documentaries, workshops, and stakeholder engagement.

Environmental and Economic Impacts while Project Is under Way: The proposed work is primarily an engineering, permitting, and outreach package with select field elements (surface characterization and near-surface monitoring). These field activities will follow industry-standard techniques with established safety protocols. The seismic survey and near-surface sampling activities will be conducted at the RTE site. Impacts of the seismic survey are expected to be limited to minor, temporary surface disturbances on lands primarily owned by RTE. Existing wells and nonpermanent probes will be used for the near-surface sampling, resulting in nominal impacts; no permanent equipment will be installed. Analyses of collected groundwater and soil gas samples will be conducted at EERC laboratories. In addition, the use of federal funding requires that all proposed activities comply with the National Environmental Policy Act.

Ultimate Technological and Economic Impacts: The proposed Phase III project will provide ND renewable or biofuel facilities with a blueprint for navigating ND UIC Class VI regulations and benefiting from evolving LCF markets and federal incentives. This will position the ND ethanol industry as a national leader in developing reduced-carbon ethanol with a strategic first-to-market advantage over other states. Additional revenue paid through these programs will directly benefit ND communities in the vicinity of potential CCS efforts through increased tax revenue and new job opportunities for construction and operation of the expanded RTE facility. If other ND renewable energy or biofuel producers also implement CCS, the economic benefits will be available in those areas. Finally, under the right conditions, captured CO_2 can be sold to ND oilfield operators for CO_2 EOR, expanding economic benefits to stakeholders in the ND oil industry as well.

Why the Project Is Needed: ND has a well-timed opportunity to gain a competitive advantage in LCF markets and other incentives (e.g., Section 45Q). North Dakota has an established ethanol industry, suitable geology, and UIC Class VI primacy. Phase III activities will continue development of a case study for ND ethanol producers or other industries, providing a detailed example for implementing CCS

in ND. The EERC's experience with commercial CCS implementation (1–9, 13–20) will be applied to the proposed ND effort, ensuring the project's goals are successfully met.

STANDARDS OF SUCCESS

The ND renewable energy and agriculture industries will directly benefit from the continuation of this program through the proposed project. If ND can produce a lower-carbon ethanol by implementing CCS at production facilities, industry in the state may be able to take advantage of sizable market incentives currently being developed on the West Coast. Evolving federal incentives for CCS, such as Section 45Q, may also provide economic support for implementation. Although ethanol production is commonplace in the Great Plains, the geology of western ND is highly suitable for storing commercial volumes of anthropogenic CO_2, potentially allowing ND ethanol producers an advantage over ethanol producers in other states. This could incentivize the growth of biofuel production in western ND and, thus, agricultural feedstocks throughout the state as well as create new jobs for short-term construction and installation and for long-term implementation, operation, and maintenance of CCS installations.

This project will result in the data necessary to advance the case study toward the first commercial ND CCS integration with ND ethanol production that is compliant with evolving CO_2 incentives and market opportunities. The final report for this project will provide ND ethanol producers with 1) a CO_2 capture system PDP applicable to an ethanol facility, 2) baseline monitoring and characterization data for permitting needs, 3) preliminary ND CCS permit packages and up-to-date requirements for CO_2 markets/incentives, and 4) community outreach materials for stakeholder and public activities to promote acceptance of CCS implementation in ND. Each of these incremental steps is necessary to complete all the stages for commercial-scale integration of CCS with ethanol production in ND.

BACKGROUND/QUALIFICATIONS

The EERC has proven expertise related to laboratory analyses, CCS implementation, and public outreach (1–4, 9, 15–20). Numerous CCS monitoring and characterization techniques (e.g., near-surface, seismic) have been developed, field-tested, and/or validated by the EERC at demonstration and commercial CO_2 storage sites throughout the PCOR Partnership region for several completed and ongoing CO_2 storage

demonstration projects (2, 13-14, 21–24). The EERC has also conducted regional characterization specific to the Williston Basin for CO_2 storage (25–28). The EERC geophysics team has experience acquiring, processing, and interpreting seismic data, including specialized processing and interpretation of time-lapse data for site characterization and monitoring at CO_2 EOR and dedicated storage sites (10–12). Through the PCOR Partnership Program, the EERC is a leading source for CCS public knowledge by providing information and materials to over 1500 teachers, placing materials in 217 libraries, and coproducing award-winning documentaries telecast in 34 states and four Canadian provinces (29).

Project partners include RTE and Trimeric, both of which were involved in Phases I and II. RTE is a ND-based investor group that operates the Richardton corn-based ethanol production facility. Trimeric has direct experience with designing and implementing CO_2 capture systems for a variety of industrial applications and expertise in the use of process simulation tools for supercritical CO_2 system design (30).

Personnel: Ms. Kerryanne Leroux, EERC Senior Chemical Engineer, will continue to serve as principal investigator (PI), having successfully conducted Phases I and II. Ms. Leroux currently leads teams of scientists and engineers who focus on integrating CCS systems with fossil energy, such as EOR and coal-generated electricity as well as renewable energy. Technical abilities include assessment of CO_2 capture technologies and transportation, implementing and evaluating near-surface and downhole monitoring concepts for large-scale carbon storage, and techno-economic evaluation of CCS applicability for state and federal incentive programs. Ms. Leroux has also participated in research projects focused on coal, natural gas, petroleum, biomass, energy storage, biorefineries, biodiesel, ethanol, and butanol. Ms. Leroux's areas of interest and expertise include resource and life cycle assessments; process design and demonstration/commercial-scale testing; statistical interpretation, data processing, and modeling; and technical feasibility, economic analysis, and market evaluation.

Mr. Charles Gorecki, Director of Subsurface R&D at the EERC, will serve as the project advisor. He has served as the PI/project manager on several projects, including projects funded by DOE, the International Energy Agency Greenhouse Gas R&D Programme, and private industry. Currently, Mr. Gorecki manages the multimillion-dollar, multiyear, multidisciplinary PCOR Partnership Program. In

addition, he oversees five other DOE research projects aimed at advancing CO_2 storage technology, demonstrating his ability to effectively manage multiple large-scale, multiyear projects.

Resumes of all key personnel from the EERC, RTE, and Trimeric can be found in Appendix B.

MANAGEMENT

Ms. Leroux has significant experience managing diverse and complex technical projects, including management of Phases I and II, and providing valuable results on schedule and on budget. She will have the overall responsibility for the project and will communicate regularly with all project partners and participants. She will also be responsible for contractual reporting to all project partners.

Planning meetings, conference calls, Webinars, and regular e-mail communication will ensure coordination of all project partners and minimize risk. Internal review meetings will also be conducted regularly to ensure that all project activities are completed in a timely manner, according to the project schedule. Progress reports and a final report at project completion will be prepared.

TIMETABLE

The proposed scope of work is an 18-month project (Figure 2). Initiation of the proposed work is contingent upon the execution of a mutually negotiated agreement with each project sponsor. Quarterly progress reports will be submitted 30 days following the end of each calendar quarter.

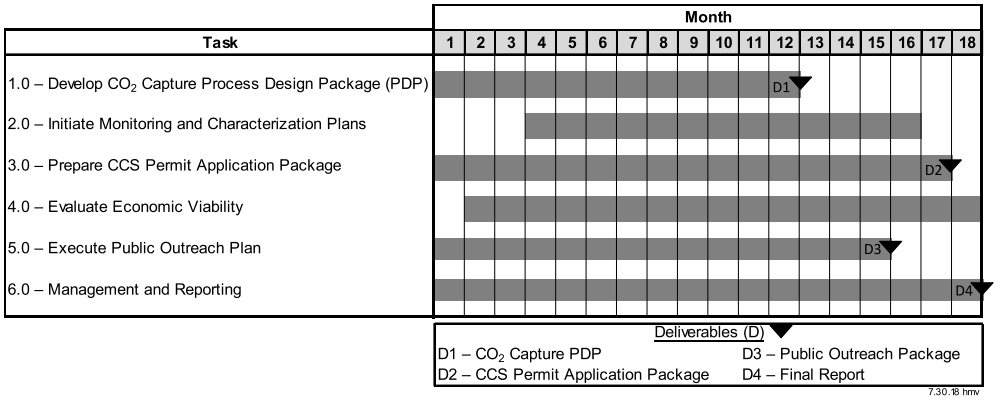

Figure 2. Project schedule.

BUDGET

The estimated cost for the proposed project is $2,650,000, as shown in Table 1. The EERC requests $500,000 from REP. Matching funds of $1,750,000 will be provided by RTE, including $950,000 cash

and at least $800,000 in-kind ($500,000 for the seismic survey and $300,000 of RTE labor). An additional $400,000 of cash will be provided as matching funds through the EERC's Fossil Energy Cooperative Agreement with DOE under the Carbon Storage Research and Development task. Letters of commitment are provided in Appendix A. Budget justification can be found in Appendix C. If less REP funding is available, adjustments to scope and/or participating companies will need to be considered.

Table 1. Budget Breakdown

Project Associated Expense	NDIC Share (Cash)	Red Trail Share (Cash/In-Kind)	DOE Share (Cash)	Total Project
Labor	$324,833	$443,246	$133,393	$901,472
Travel	$6,801	$16,050	$5,488	$28,339
Supplies	$0	$3,655	$3,152	$6,807
Repairs	$0	$0	$4,680	$4,680
Contractor-Trimeric	$0	$79,003	$0	$79,003
Communications	$99	$759	$40	$898
Printing & Duplicating	$173	$1,233	$103	$1,509
Food	$0	$850	$0	$850
Professional Development	$0	$40	$0	$40
Laboratory Fees & Services				
Analytical Research Lab	$0	$43,200	$517	$43,717
Process Chemistry & Development Lab	$0	$0	$8,791	$8,791
Graphics Services	$320	$23,412	$6,592	$30,324
Shop & Operations Fees	$0	$0	$2,700	$2,700
Research Information Service	$0	$2,554	$0	$2,554
Outside Laboratory Fees	$0	$0	$98,925	$98,925
Freight	$0	$0	$1,400	$1,400
Facilities & Administration	$167,774	$335,998	$134,219	$637,991
In-Kind Cost Share-Red Trail Energy	$0	$800,000	$0	$800,000
Total Project Costs	$500,000	$1,750,000	$400,000	$2,650,000

TAX LIABILITY

The EERC is a special research center 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.

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.

REFERENCES

All references cited are in Appendix D.

APPENDIX A

LETTERS OF COMMITMENT AND SUPPORT

RED TRAIL ENERGY, LLC

"Our Farms, Our Fuel, Our Future"

PO Box 11 Richardton, ND 58652 (701)-974-3308 FAX (701)-974-3309

July 30, 2018

Ms. Kerryanne Leroux
Senior Chemical Engineer, Oilfield Operations Team Lead
Energy & Environmental Research Center
University of North Dakota
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018

Dear Kerryanne:

Subject: EERC Proposal No. 2018-0128 Entitled "Integrated Carbon Capture and Storage for North Dakota Ethanol Production – Phase III"

Red Trail Energy (RTE) is excited to continue working with the Energy & Environmental Research Center (EERC) on the proposed subject project submitted to the North Dakota Renewable Energy Council (REC). RTE operates a corn-based ethanol production facility located near Richardton, North Dakota, producing approximately 64 MMgal/yr of ethanol and generating 180,000 tons of CO_2 annually. We look forward to the results of this proposed work, anticipated to provide key regulatory and scientific data to make informed investment decisions regarding implementation of carbon capture and storage (CCS) as a means for reducing the carbon footprint of ethanol production.

RTE will be providing support via cash and in-kind contributions. In-kind match funding includes technical support for proposed Tasks 1–5. Specifically, RTE's in-kind support will consist of contributing to the following activities:

- Task 1.0 – Develop CO_2 Capture Process Design Package (PDP): RTE will provide technical support regarding current RTE facility processing data to the project team to assist with development of the PDP.
- Task 2.0 – Initiate Monitoring and Characterization Plans: RTE will provide access for any site-related work, including near-surface monitoring (soil gas sampling) and reservoir characterization (seismic data acquisition) and support, as appropriate, toward contacting owners of affected water wells or land(s). RTE will also contract the seismic survey and subsequent data collection and processing.
- Task 3.0 – Prepare CCS Permit Application Package: RTE will engage with the North Dakota Department of Mineral Resources as the authority on CO_2 injection and storage permitting to participate in drafting required permits for compliance with state regulations.
- Task 4.0 – Evaluate Economic Viability: RTE will continue collaboration with California and Oregon low-carbon fuel program authorities, advocating for requirements that are compatible with North Dakota regulations.
- Task 5.0 – Execute Public Outreach Plan: RTE will lead all outreach activities, including but not limited to involvement in stakeholder engagement activities, dissemination of informational materials, acquiring

feedback, and assessment of progress. RTE will also provide any needed site access for outreach activities such as meeting rooms, tours, etc.

Over the course of the 18-month project, RTE anticipates its employees will spend a cumulative 1500 hours on these activities at a rate of approximately $200/hr for a total in-kind value of $300,000. In addition, a minimum $500,000 will be spent on the design and execution of a seismic survey, for a total in-kind contribution of at least $800,000. A cash contribution of $950,000 will also be provided should the project be awarded for a match totaling $1,750,000. All contributions are contingent upon award and approval by RTE's Board of Directors. It is understood that this cost share will also be applied to a U.S. Department of Energy (DOE) proposal; therefore, RTE certifies that its cost-share funding will comprise nonfederal dollars and will not be used as federal match on any other project. RTE will report actual in-kind cost share to the EERC on a regular basis to be determined at the time of contract negotiations.

We are pleased to continue collaboration with REC, the EERC, DOE, and Trimeric Corporation on this Phase III study toward demonstration of CCS implementation at a North Dakota ethanol production facility.

Sincerely,

Gerald Bachmeier
Chief Executive Officer
Red Trail Energy, LLC

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

August 1, 2018

Ms. Karlene Fine
Executive Director
North Dakota Industrial Commission
600 East Boulevard Avenue
State Capitol, 14th Floor
Bismarck, ND 58505-0840

Dear Ms. Fine:

Subject: Cost Share for EERC Proposal No. 2018-0128, Entitled "Integrated Carbon Capture and Storage for North Dakota Ethanol Production – Phase III"

The Energy & Environmental Research Center (EERC) is conducting complementary research and development efforts under a multimillion-dollar, 5-year Cooperative Agreement with the U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL) 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 Fossil Energy.

The proposed project to the North Dakota Industrial Commission (NDIC) Renewable Energy Council, entitled "Integrated Carbon Capture and Storage for North Dakota Ethanol Production – Phase III," is a viable candidate for funding under this program. Therefore, the EERC has secured $400,000 of cash cost share for the proposed project through its Cooperative Agreement with DOE, provided that NDIC commits $500,000 of cash cost share and Red Trail Energy provides $1,750,000 of cash and in-kind contributions.

As a cosponsor of the project, DOE will 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.

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

Sincerely,

John A. Harju
Vice President for Strategic Partnerships

JAH/bjr

July 30, 2018

Kerryanne Leroux
Senior Chemical Engineer, Oilfield Operations Team Lead
Energy & Environmental Research Center
University of North Dakota
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018

Dear Kerryanne:

Subject: EERC Proposal No. 2018-0128 Entitled "Integrated Carbon Capture and Storage for North Dakota Ethanol Production – Phase III"

I am writing to confirm Trimeric Corporation's commitment to provide technical support for the pre-engineering design of a CO_2 capture and transport system for the subject project, which is being proposed by the Energy & Environmental Research Center (EERC) and Red Trail Energy (RTE) to the North Dakota Industrial Commission's Renewable Energy Council (REC) and the U.S. Department of Energy (DOE).

Trimeric is an engineering firm with a technical staff made up exclusively of chemical process engineers with a vast range of experience and expertise regarding purification, compression, dehydration, and other processing of CO_2. We have supported several large CO_2 compression and purification facilities that purify CO_2 either by simple dehydration or through liquefaction and then distillation.

We will bring this experience to bear to help complete Task 1.0 – Draft CO_2 Capture Process Design Package (PDP) of the proposed scope of work. Trimeric will develop a PDP for an RTE CO_2 capture facility, necessary to advance the project on to an implementation phase. The package includes the development of process simulation and process engineering design, such as process flow diagrams, heat and material balances, and piping and instrument diagrams. Trimeric will then use these data to develop facility costs and recommend vendors. The outcome of this task will be all documentation and cost estimates needed to pursue formal engineering bids for installation of the CO_2 capture system to proceed with detailed engineering design.

Over the course of the 12-month project, we estimate approximately 415 labor hours of effort will be required to complete these tasks, with a cost estimate of $79,003.

We are pleased to continue collaboration with REC, the EERC, RTE, and DOE on this Phase III study toward implementation of carbon capture and storage at a North Dakota ethanol production facility.

Sincerely,

Joe Lundeen, P.E.
Vice President
Trimeric Corporation

Oil and Gas Division

Lynn D. Helms - Director Bruce E. Hicks - Assistant Director

Department of Mineral Resources

Lynn D. Helms - Director

North Dakota Industrial Commission

www.dmr.nd.gov/oilgas/

July 31, 2018

Mr. Gerald Bachmeier
CEO
Red Trail Energy, LLC
3682 Highway 8 South
PO Box 11
Richardton, ND 58652

Subject: EERC Proposal No. 2018-0128, Entitled "Integrated Carbon Capture and Storage for North Dakota Ethanol Production – Phase III"

Dear Gerald,

The North Dakota Industrial Commission's (NDIC's), Department of Mineral Resources (DMR), Oil and Gas Division is pleased to provide Red Trail Energy (RTE) with this letter of support for your efforts regarding the investigation of commercial geologic storage of carbon dioxide (CO_2) in North Dakota.

North Dakota has promulgated a comprehensive set of regulations for all aspects of CO_2 injection and storage operations as part of the North Dakota Underground Injection Control (UIC) Class VI Program. On April 10, 2018 North Dakota became the first state in the Nation to receive Class VI primacy approval from the U.S. Environmental Protection Agency (EPA). On April 24, 2018 North Dakota's Class VI primacy became effective upon EPA final rule publication in the federal register. The final approval issued by EPA grants the NDIC's Oil and Gas Division primary regulatory authority for all Class VI injection well activities in North Dakota.

The North Dakota regulations meet or exceed EPA Class VI requirements, addressing some factors that fall outside the scope of EPA and the federal UIC program (e.g., pore space ownership, project certification, long-term liability of stored CO_2, etc.). Therefore, North Dakota's Class VI UIC program is tailored specific for North Dakota and RTE has the opportunity to be the first to apply for a Class VI permit in North Dakota. For North Dakota ethanol facilities seeking to implement carbon capture and storage (CCS) in particular, reporting and validation options may be available to coordinate with approval pathways from out-of-state low-carbon fuel programs.

We are thus supportive of RTE's project and look forward to working with RTE on the specifics of a North Dakota Class VI permit application. The NDIC looks forward to engaging with RTE and the Energy & Environmental Research Center (EERC) of the University of North Dakota on generating a path forward that further supports low-carbon energy production in North Dakota.

Sincerely,

Kevin C. Connors
CCS Supervisor

North Dakota Ethanol Council

July 30, 2018

Mr. Gerald Bachmeier
CEO
Red Trail Energy, LLC
3682 Highway 8 South
PO Box 11
Richardton, ND 58652

Dear Gerald:

Subject: EERC Proposal No. 2018-0128, Entitled "Integrated Carbon Capture and Storage for North Dakota Ethanol Production – Phase III"

The North Dakota Ethanol Council (NDEC) is pleased to provide Red Trail Energy (RTE) with this letter of support for its efforts to investigate the commercial geologic storage of carbon dioxide (CO_2) generated during the production of ethanol in North Dakota. The project proposed by the Energy & Environmental Research Center (EERC) offers a route to expanded opportunities for the state's renewable energy industries.

Ethanol is a critically important piece of the state's energy production for multiple reasons. Not only do the five North Dakota ethanol plants have the capacity to produce 520 million gallons of ethanol annually for use as fuel but, in addition, the ethanol industry is a large contributor to the state's economy. The ethanol industry contributes $623 million annually to the state's economy and an additional $11 million in state and local tax revenues each year. Our state continues to investigate long-term strategies that incorporate all energy resources—traditional and emerging—to meet the nation's growing energy demand in an environmentally responsible manner, and this project will further that aim.

NDEC looks forward to engaging with both RTE and the EERC to generate a path forward that further bolsters low-carbon energy production in North Dakota. We are pleased to support the exciting opportunities the proposed project will bring to both the state of North Dakota and the nation in resolving our energy challenges.

Sincerely,

Deana Wiese

Deana Wiese
Executive Director

1605 E. Capitol Avenue
PO Box 1091 • Bismarck, ND 58502
701.355.4458 • 701.223.4645 (fax) • www.ndethanol.org

APPENDIX B

RESUMES OF KEY PERSONNEL

KERRYANNE M. LEROUX
Senior Chemical Engineer, Oilfield Operations Team Lead
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, North Dakota 58202-9018 USA
701.777-5013 (phone), 701.777.5181 (fax), kleroux@undeerc.org

Principal Areas of Expertise

Ms. Leroux's principal areas of interest and expertise include fossil, alternative, and renewable energy and chemicals production systems; CO_2 storage monitoring, verification, and accounting (MVA) methods; resource and life cycle assessments; process design and integration; pilot-, demonstration-, and commercial-scale testing; statistical interpretation, data processing, and modeling; and technical feasibility, economic analysis, and market evaluation.

Qualifications

M.S., Chemical Engineering, University of North Dakota, 2001.
B.S., Chemical Engineering, University of North Dakota, 1999.

Professional Experience

2015–Present: Senior Chemical Engineer, Oilfield Operations Team Lead, EERC, UND. Ms. Leroux leads teams of scientists and engineers integrating carbon capture and storage (CCS) systems with fossil and renewable energy, such as enhanced oil recovery (EOR), coal-generated electricity, and ethanol fuel production. Specific technical support has included assessment of CO_2 capture technologies and transportation; implementing and evaluating near-surface and downhole MVA concepts for large-scale (>1 million tons/year) carbon storage; and techno-economic evaluation of CCS applicability for state and federal CO_2 reduction incentive programs. Ms. Leroux's main responsibilities include serving as a principal investigator or project manager; providing project support and guidance and regularly assessing activities and progress; effectively reporting results and conclusions of research activities to clients through technical reports, publications, papers, posters, and personal communication; and collecting, reducing, analyzing, and interpreting data and ensuring quality control of project work.

2001–2015: Research Engineer, EERC, UND. Ms. Leroux has researched coal, natural gas, petroleum (diesel, gasoline), biomass (wood, agricultural residues, grasses/straws, municipal solid waste [MSW]), combustion, gasification, syngas clean-up (tars, membrane separation), catalysis (steam methane reforming, water–gas shift, Fischer–Tropsch), cogeneration/combined heat and power, fuel cells, electrolysis, energy storage, wind hybrid systems, biorefineries, pyrolysis, bio-oil, biodiesel, ethanol, butanol, hydrogen, ammonia, biogas and landfill gas, and densification (pellets, torrefaction). Ms. Leroux has also provided technical support for management of solid waste (MSW and inert waste recycling and reduction), water (drinking water and wastewater treatment, processing water management [e.g., cooling water systems], flood mitigation), and CO_2 (near-surface groundwater and soil gas monitoring related to EOR-associated storage, capture technologies, transportation, trading and commercial markets).

1999–2001: Graduate Research/Education, Department of Chemical Engineering, UND. Ms. Leroux's work on two-phase flow models for low-pressure systems continued scarce research of pressure gradient models for various regimes, including a deriving model and writing a simulation program for annular flow and identified parameters for significance of liquid vaporization and acceleration. She also revised an air/water simulation program for hydrogen pressure drop, accommodating NASA's interest, and altered parameters within a model applicable to all flow regimes for gradient estimation particular to stratified flow. In addition, she designed experiments for an industrial setting and performed statistical analysis of collected data.

Publications and Presentations

Has coauthored numerous professional publications.

CHARLES D. GORECKI
Director of Subsurface R&D
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, North Dakota 58202-9018 USA
701.777.5355 (phone), 701.777.5181 (fax), cgorecki@undeerc.org

Principal Areas of Expertise
Mr. Gorecki's principal areas of interest and expertise include enhanced oil recovery (EOR), unconventional oil and gas research, and the geologic storage of CO_2.

Qualifications
B.S., Geological Engineering, University of North Dakota, 2007.

Professional Experience
2015–Present: Director of Subsurface R&D, EERC, UND. Mr. Gorecki is responsible for developing and managing programs and projects focused on conventional, unconventional, and enhanced oil and gas production; the geologic storage of CO_2; geothermal; and other energy and environmental research. He currently serves as the Program Manager for the Plains CO_2 Reduction (PCOR) Partnership, one of seven regional partnerships funded by the U.S. Department of Energy's (DOE's) National Energy Technology Laboratory Regional Carbon Sequestration Partnership Program. The PCOR Partnership Program is a three-phase, multiyear, multimillion-dollar program, focused on assessing the technical and economic feasibility of capturing and storing CO_2 emissions from stationary sources in the northern Great Plains and adjacent area. Under this program, Mr. Gorecki leads a multidisciplinary team of researchers working primarily on developing monitoring, verification, and accounting concepts and technologies for large-scale CO_2 storage (>1 million tons per year) in deep saline formations and oil fields and the characterization of the geologic formations in the PCOR Partnership region in preparation for the implementation of the commercial deployment of carbon capture and storage (CCS).

In addition to the PCOR Partnership Program, Mr. Gorecki also manages or oversees projects related to CO_2 storage capacity estimation, novel reservoir surveillance and CO_2 storage monitoring techniques, and unconventional oil and gas resource modeling, characterization, and testing. He has also led several other national and international projects associated with CO_2 storage, the nexus of water and CCS, and CO_2 EOR.

2011–2015: Senior Research Manager, EERC, UND. Mr. Gorecki was the manager of the PCOR Partnership and the technical lead for the Bell Creek CO_2 EOR field demonstration. Mr. Gorecki led the geologic modeling and simulation efforts for the EERC as well as national and international efforts associated with the nexus of water and CCS. He led efforts focused on developing storage capacity estimates and methodologies for deep saline formations and hydrocarbon reservoirs. In addition, Mr. Gorecki has led and worked on detailed site characterization, modeling, risk assessment, and monitoring activities for both EOR projects and

CO_2 storage operations in deep saline formations. He participated in several expert review committees and was involved in developing a methodology for estimating CO_2 storage capacity in deep saline formations, oil and gas reservoirs, and shale formations for DOE.

2010–2011: Research Manager, EERC, UND. Mr. Gorecki led the modeling and monitoring and Water Working Group tasks for Phase III of the PCOR Partnership Program. He led the EERC's geologic modeling efforts, coordinating a multidisciplinary team to develop detailed geologic models and run predictive simulations for CO_2 storage, CO_2 EOR, and unconventional oil and gas plays. Mr. Gorecki was also the facilitator of the Regional Carbon Sequestration Partnership Water Working Group, where he led discussion on the nexus of water and CCS.

2007–2010: Research Engineer, EERC, UND. Mr. Gorecki worked with the PCOR Partnership at the EERC to develop models to describe the behavior of CO_2 prior to injection into saline formations and oil fields. Mr. Gorecki led a joint venture funded by the IEA Greenhouse Gas R&D Programme and DOE to develop storage capacity/ resource coefficients to determine CO_2 storage capacity/resource estimates in saline formations. As a result of Mr. Gorecki's work in developing storage capacity/resource estimates, he served on the expert review panel on the U.S. Geological Survey's CO_2 Capacity Methodology; advised and helped to develop methodologies for the North American Energy Working Group's CO_2 storage capacity efforts between the United States, Canada, and Mexico; and advised the DOE National Energy Technology Laboratory on the third edition of the Carbon Sequestration Atlas of the United States and Canada.

Professional Memberships
American Association of Petroleum Geologists, 2009–Present
Society of Petroleum Engineers, 2007–Present
Member of European Association of Geoscientists and Engineers, 2014–Present

Publications and Presentations
Mr. Gorecki has authored and coauthored many papers and given presentations on a variety of topics associated with CO_2 EOR and CO_2 storage in the United States and throughout the world.

JOHN A. HAMLING
Principal Engineer, Oilfield Operations Group Lead
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, North Dakota 58202-9018 USA
701.777.5472 (phone), 701.777.5181 (fax), jhamling@undeerc.org

Principal Areas of Expertise

Mr. Hamling has over 10 years of combined experience in unconventional oil and gas development, enhanced oil recovery (EOR), and carbon capture, utilization, and storage (CCUS). He is a Principal Engineer at the EERC, where he integrates science and operations to catalyze pioneering solutions for geologic CO_2 utilization and the exploration, development, and production of oil and gas in unconventional plays.

Mr. Hamling's areas of expertise include development, implementation, and oversight of surface, near-surface, deep subsurface, and reservoir characterization and surveillance programs for geologic CO_2 storage and EOR. His experience includes well-logging principals and applications; well drilling, well completions; wellbore integrity; risk assessment; logistics; well stimulation and enhanced recovery in tight oil plays; and health, safety, and environmental (HSE) programs.

Mr. Hamling has served as project manager (PM), principal investigator (PI), and task lead for several multiyear, multimillion-dollar research and demonstration projects. He leads the data analytics, operations, and reservoir surveillance groups at the EERC as well as several adaptive multidisciplinary project teams. These activities encompass both contract research as well as several strategic partnership programs between the state of North Dakota, the U.S. Department of Energy (DOE), and private industry designed to propel the development and implementation of approaches that benefit practical energy development. In addition, he is an Adjunct Lecturer in the Department of Petroleum Engineering at UND.

Qualifications

B.S., Mechanical Engineering, University of North Dakota, 2007.
Associate of Science, Associate of Arts, Williston State College, 2004.
Certified Engineer in Training (EIT)

Professional Experience

2012–Present: Principal Engineer, Oilfield Operations Group Lead, EERC, UND. Mr. Hamling currently serves as PM, PI, and task lead for several multiyear, multimillion-dollar projects, where he leads a multidisciplinary team of scientists and engineers working to develop and implement monitoring, verification, and accounting (MVA) concepts for large-scale (>1 million tons per year) CO_2 storage and EOR operations. He also works with a multidisciplinary team in the development, design, and implementation of new approaches that benefit the economic exploration, development, and production of oil and gas.

2017–Present: Adjunct Lecturer, Department of Petroleum Engineering, UND.

2011–2012: Research Manager, EERC, UND. Mr. Hamling's responsibilities included managing characterization and monitoring research activities and operations for large-scale (>1 million tons per year) combined EOR and CO_2 storage projects for the Plains CO_2 Reduction (PCOR) Partnership. He also led various research activities related to oil and gas production, infrastructure, and development from unconventional reservoirs.

2009–2011: Research Engineer, EERC, UND. Mr. Hamling's focus was on the design and implementation of new approaches that benefit the exploration, development, and production of oil and gas and with the PCOR Partnership, where he evaluated the potential for CO_2 storage in geologic formations. Specific responsibilities included field operations design, deployment, and interpretation relating to oilfield technologies applicable to the CO_2 capture and storage (CCS) industry; laboratory functions relating to the Applied Geology Laboratory (AGL); data analysis; regulatory compliance; and communication of operations between service providers, management teams, industry partners, and governmental organizations. Additional responsibilities included investigation and/or demonstration of techniques and/or technologies that can enhance oil and gas production or economically benefit the oil and gas industry while reducing the environmental footprint of drilling and production operations.

2007–2009: Reservoir Evaluation Engineer; HSE Representative; and Loss Prevention Team Leader, Reservoir Evaluation segment, Schlumberger Limited. Mr. Hamling was responsible for providing tailored geophysical solutions for specific and unique oilfield applications, executing basic and advanced reservoir evaluations utilizing real-time wellbore measurement technologies, reservoir pressure and fluid sampling, and interpretation of reservoir measurement data. In this role, Mr. Hamling designed and oversaw all aspects of openhole and cased-hole logging operations for over 300 wells in both conventional and unconventional oil and gas plays. He also served as an HSE officer, loss prevention team lead, and explosives and radiation safety officer for wellsite activities.

2004–2007: Student Research Scientist/Engineer, EERC, UND. Mr. Hamling was responsible for conducting research related to the development of new methods to join high-temperature, creep-resistant alloys and advanced processing and manufacture techniques for silicon carbide ceramic composites; materials testing in accordance with ASME (American Society of Mechanical Engineers), ASTM International, and ISO (International Organization for Standardization) standards; analyzing scanning electron microscopy micrographs; designing and fabricating composite micrometeorite shielding; and literature and patent review.

Professional Activities

Society of Petroleum Engineers International Williston Basin Section – have continuously served as a section officer and board member since 2012. Positions include Acting Chairperson, Vice-Chairperson, and Communications Chairperson.

Served as PCOR Partnership representative on the writing committee for two U.S. Department of Energy Regional Carbon Sequestration Partnership (RCSP) Program BPMs entitled *Best Practices for Monitoring, Verification, and Accounting of CO_2 Stored in Deep Geologic Formations – Version 3* and *Best Practices for Operating Carbon Storage Projects*.

Publications and Presentations

Has authored and coauthored numerous technical publications.

RYAN J. KLAPPERICH
Senior Hydrogeologist
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, North Dakota 58202-9018 USA
701.777.5000 (phone), 701.777.5181 (fax), rklapperich@undeerc.org

Principal Areas of Expertise

Mr. Klapperich's principal areas of interest and expertise focus on CO_2 enhanced oil recovery (EOR) and storage, including geologic site characterization, monitoring program assessments, design and implementation of near-surface monitoring programs, and interpretation of monitoring data. Other areas of interest include hydrogeology, geographic information systems (GIS), CO_2 sequestration, and related environmental issues.

Qualifications

M.S., Geology, University of North Dakota, 2008.
Graduate Certificate, Geographic Information Science, 2007.
B.S., Geology, University of North Dakota, 2005.
B.A., Honors Program, University of North Dakota, 2005.

Professional Experience

2009–Present: Senior Hydrogeologist, EERC, UND. Mr. Klapperich works with the Oil and Gas Group and the Plains CO_2 Reduction (PCOR) Partnership at the EERC, where he is actively involved in many site characterization and CO_2-monitoring activities including the following:

- Served as the co-principal investigator (PI) on a project principally funded by the IEA Greenhouse Gas R&D Programme (IEAGHG) focused on understanding the use of active reservoir management (ARM) schemes to enhance CO_2 storage and reduce monitoring, verification, and accounting (MVA) costs.
- Serves as the Co-PI on the recently awarded brine extraction and storage test (BEST) project, which will demonstrate the use of ARM techniques to improve reservoir storage potential in saline formations with CO_2 storage potential.
- Serves as the task lead for the PCOR Partnership's Water Working Group, a working group comprising members of the U.S. Department of Energy's (DOE's) Regional Carbon Sequestration Partnership (RCSP) Program focused on developing an understanding and solutions for issues at the nexus of carbon capture and storage (CCS) and water.

2007–2009: Laboratory Technician, North Dakota Geological Survey Core and Sample Library, Grand Forks, North Dakota. Mr. Klapperich's responsibilities included staging and taking digital photographs of core sample inventory; processing and manipulating digital photographs; updating, cataloging, and reboxing core and sample inventory; cutting unprocessed cores into slabs; processing and cataloging new inventory; assisting clients with retrieving and handling samples; and operating a forklift.

2006–2007: Research Assistant, Geology and Geological Engineering, UND. Mr. Klapperich's responsibilities included refining new analytical laboratory procedures, performing analytical procedures in the Environmental Analytical Research Laboratory, and analyzing collected data; performing literature reviews and preparing materials for grant submissions, progress reports, and presentations/publications; maintaining proper quality control and quality assurance while working as a team member with other students and lab personnel; and provided tours of exhibits in Leonard Hall.

2005–2006: Teaching Assistant, Department of Geology and Geological Engineering, UND. Mr. Klapperich's responsibilities included preparing brief introductory lectures, administering weekly quizzes and makeup sessions, preparing course materials such as hand specimens or handouts, maintaining course grades, and assisting with student inquiries for a physical geology laboratory course as well as providing tours of exhibits in Leonard Hall.

Professional Memberships
Society of Petroleum Engineers, 2009–present
American Geophysical Union, 2007–2009

Publications and Presentations
Has authored or coauthored several technical publications.

SHAUGHN A. BURNISON
Principal Geophysicist, Geophysics Team Lead
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, North Dakota 58202-9018 USA
701.777.5366 (phone), 701.777.5181 (fax), sburnison@undeerc.org

Principal Areas of Expertise
Mr. Burnison's research objectives include the application of geophysics in creative ways for monitoring, verification, and accounting of CO_2 storage and enhanced oil recovery operations. His interests also include using geophysics and well-logging principals toward the efficient development of unconventional petroleum reservoirs such as North Dakota's Bakken Formation.

Qualifications
M.S., Exploration Geophysics, Stanford University, 1989
B.S., Geological Engineering, University of Minnesota, 1981

Professional Experience:
2012–Present: Principal Geophysicist, Geophysics Team Lead, EERC, UND. Mr. Burnison leads a diverse team that is working with passive microseismic data collection, processing, and analysis; 4-D seismic analysis in the presence of CO_2 injection; and unique seismic data-processing methods for fixed-source and fixed-receiver array geometries. He is the principal investigator for a scalable, automated, semipermanent seismic array (SASSA) project that uses the seismic method in an unconventional manner to track subsurface CO_2 plume migration and the principal investigator on a project to investigate CO_2 plume migration using the Krauklis wave.

2010–2011: Project Controls/Earned Value Consultant, SLAC National Accelerator Laboratory. Mr. Burnison assisted preparing the schedule and cost estimate for the "Linac Coherent Light Source – II" project, a $400M addition to the world's brightest hard x-ray laser. Scheduling development was done using Primavera P6 and costing using Deltek COBRA.

2007–2010: Senior Scientist – Program Management, NSTec. Mr. Burnison maintained and improved the Nevada Test Site Environmental Management Program's Risk Management Plan, identifying risks and computing impacts using Oracle Primavera Risk Analysis Monte Carlo software. He designed and updated the monthly project metrics for senior management and posted project financial and schedule data to the federal project management system.

2005–2007: Field Lead – Environmental Restoration, NSTec. Mr. Burnison planned, coordinated, and directed field activities. He was an Occupational Safety and Health Administration (OSHA) supervisor under 40 Code of Federal Regulations 1910 and 830 and has 40-hr HAZWOPER credentials.

2003–2005: Task Manager – Environmental Restoration, Bechtel, Nevada. Mr. Burnison

managed projects, tracked earned value, and managed compliance at the Nevada Test Site for the Environmental Restoration Project for over 20 postclosure sites.

2002–2003: Contract Auditor – Logistics Analyst, Innovative Logistics, Inc., McLean, VA. Mr. Burnison performed complicated reconciliations and financial analyses at the direction of the CFO employing Excel, Access, Deltek GCS, and Cognos Impromptu tools working independently in support of a large government contract closeout; created reports for in-house clientele using Business Intelligence tools to enhance analysis; and worked shifts as part of a team on a 24/7 operation to produce a crucial daily deliverable report and management tool.

1994–2001: Investment Manager, Bali, Indonesia/Alexandria, VA. Mr. Burnison was a self-employed investment manager actively managing personal portfolios of stock investments and controlled costs, taxes, and market actions with financial management software.

1996: Consulting Geophysicist, Robertson Research International, Islamabad, Pakistan. Mr. Burnison initiated client relationships in Pakistan for an embryonic technical joint venture between British and Pakistani geophysical processing companies, trained local technical staff in digital processing theory, and designed and implemented production procedures for a start-up seismic data-processing center.

1992–1994: Geophysicist – Data Processing and Special Projects, Halliburton Geophysical Services, Jakarta, Indonesia. Mr. Burnison's responsibilities included serving as a geophysical guru for local office staffed with expatriate and Indonesian professionals serving national and major oil company clientele, performing wavelet analysis, designing filters, establishing parameters for key projects, performing exotic processing–seismic inversions and prestack depth migrations, and designing land and marine 3-D seismic surveys to meet bid specifications.

1989–1992: Geophysicist – Data Processing and Data Collection, Halliburton Geophysical Services, Beijing and Ningxia Province, PRC. Mr. Burnison was a geophysicist for a local office staffed with expatriate and Chinese professionals, while ensuring the quality of geophysical data processing and data collection for a remote joint venture computing center and Gobi desert-based data collection crew, establishing data collection parameters based on modeling and field testing, designing data-processing procedures, and training Chinese technical staff.

1981–1987: General Field Engineer – Openhole Well-Logging and Borehole Seismic Specialist, Schlumberger Well Services, Sacramento and Bakersfield, CA. Mr. Burnison performed openhole wireline logging on over 200 oil and gas wells in California and other states. He was directly responsible for the safety and performance of a three-man crew and a million-dollar mobile wireline unit and ensured regulatory compliance, handling and transporting explosive and radioactive materials. He specialized in borehole seismic methods, including vertical seismic profiles on land and sea.

Publications and Presentations
Has coauthored several publications.

THOMAS E. DOLL
Principal Petroleum Engineer
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, North Dakota 58202-9018 USA
701.777.5190 (phone), 701.777.5181 (fax), tdoll@undeerc.org

Principal Areas of Expertise

Mr. Doll's principal areas of interest and expertise include petroleum engineering and project, engineering, and general management. Throughout his career with oil and natural gas exploration companies, Mr. Doll has been directly responsible for the design and permitting, with various state and federal agencies, of drilling sites and wells; primary producing, secondary, and tertiary wells; facilities; and infrastructure. Mr. Doll, as Supervisor of the Wyoming Oil and Gas Conservation Commission, performed duties that included the interpretation and enforcement of statutes, rules, and regulations over oil and natural gas activities, including but not limited to, drilling, production, secondary and tertiary projects, and the plug, abandonment, and reclamation of wells, wellsites, and infrastructure. In that capacity, Mr. Doll was directly involved with the U.S. Environmental Protection Agency Underground Injection Control Program rules and permitting requirements, under Wyoming's primacy, for fresh and produced water injection and for carbon dioxide injection in enhanced oil recovery (EOR) projects. Mr. Doll drafted rules adopted by the Commission for Carbon Sequestration Financial Assurance and for Hydraulic Fracturing Disclosure, the first state to require chemical compound disclosure prior to and posttreatment.

Qualifications

B.S., Petroleum Engineering, University of Wyoming, 1971.
Registered Professional Engineer:

- Wyoming, PE 3543, February 1981
- North Dakota, PE 1829, February 1976

Professional Experience

2012–Present: Principal Petroleum Engineer, EERC, UND, Grand Forks, North Dakota. Mr. Doll's responsibilities include working under contract with the Plains CO_2 Reduction (PCOR) Partnership for carbon capture, utilization, and sequestration (CCUS) for the Cedar Creek Anticline in southeastern Montana, including project, drilling, completion, and production optimization of the Bakken Formation in North Dakota and Montana, as well as providing EERC petroleum engineering input for various projects such as the Bell Creek CO_2 EOR project.

2009–2012: Supervisor, Wyoming Oil and Gas Conservation Commission, Casper, Wyoming. Mr. Doll's responsibilities included managing a state agency with 40 employees and a biennial budget of $9.5 million. Mr. Doll authored and implemented Commission rules on well stimulation including hydraulic fracturing chemical compound disclosure; participated in a carbon sequestration financial assurance task force and authored the Commission's carbon

sequestration unitization rule to meet a legislative mandate; prepared and presented oil and natural gas information at over 60 educational forums such as professional meetings and federal and state government agency meetings, including formal testimony to the House Energy and the Environment Subcommittee and the Department of the Interior, at various public, academic, and industry forums; and enforced Commission rules and regulations through field inspections, hearings, and show cause actions to ensure compliance.

2008–2009: Independent Petroleum Engineering Consultant. Mr. Doll was recognized as an expert witness as a registered Professional Petroleum Engineer for the Wyoming Oil and Gas Conservation Commission hearings and prepared an Underground Injection Control (UIC) Permit for Wyoming Department of Environmental Quality (WDEQ) Water Quality Division (WQD) approval for a client to complete a nonhazardous waste disposal well in Crook County, Wyoming.

1997–2008: District Manager, Williams Production RMT (now WPX Energy), Gillette, Wyoming. Mr. Doll provided management, engineering, and supervision of the Powder River Basin asset, including management of the development and exploitation of coalbed natural gas resources on leasehold in the Powder River Basin, serving as Senior Petroleum Engineer; Project Manager; and Drilling, Regulatory, and Land Manager during the period and providing coordination/communication with joint venture partner counterparts for over 6600 coalbed natural gas wells producing over 505 MMcfd.

1989–1997: General Manager, Fluor Daniel (NPOSR), Inc. Mr. Doll provided general management, engineering management, and field operations management of Fluor Daniel (NPOSR) personnel and contractors of the Naval Petroleum Reserve Number 3, under contract to the U.S. Department of Energy (DOE) in Casper, Wyoming; managed all aspects of activities including conventional oil and gas production, gas reinjection for pressure maintenance, enhanced oil recovery via steamflood, polymer enhanced waterflood and fireflood operations, and directional and slant-hole drilling including a gas liquids extraction plant; and initiation of new technologies testing under typical oil field conditions through the Rocky Mountain Oil Field Testing Center (RMOTC).

1987–1989: Project Manager; TIORCO, Inc. (The Improved Oil Recovery Company), Wyoming, Montana, South Dakota, and Colorado, based in Gillette, Wyoming **(s**ee 1984–1986).

1986–1987: Independent Petroleum Engineering Consultant, Petroleum Engineering/Chemical Consultant, Gillette, Wyoming. Mr. Doll provided chemical and monitoring for wells producing up to 25% hydrogen sulfide with potential for severe tubular and surface facilities corrosion, and provided a postmortem report and to DOE via operating contractor John Brown Engineering at the Naval Petroleum Reserve No. 3 polymer augmented waterflood.

1984–1986: Project Manager; TIORCO, Inc. (The Improved Oil Recovery Company), Wyoming, Montana, South Dakota and Colorado, based in Gillette, Wyoming. Mr. Doll provided engineering supervision and technical monitoring, oversight, and reporting of chemically augmented injection projects for various independent oil companies to maximize oil recovery through cost-effective improved injectivity, sweep improvement, reduced produced water quantity, and injected water quality control.

1983–1984: Director of Engineering (Acting), DOE, Casper, Wyoming. Mr. Doll was the Acting Director of Engineering for the DOE Naval Petroleum and Oil Shale Reserves in Colorado, Utah, and Wyoming. He provided supervision/direction to three engineers and support staff at Teapot Dome Naval Petroleum Reserve No. 3 and Anvil Points Oil Shale Reserve and provided technical and engineering oversight of the operating contractor to DOE, Lawrence-Allison and Associates West (LAAW).

1983–1983: Drilling Engineer, LAAW, Casper, Wyoming. LAAW contracted to DOE to operate the Naval Petroleum Reserve No. 3 in Casper, Wyoming; provided well design and daily field engineering oversight of drilling well operation on a DOE-owned rig; and identified severe steel tool joint wear to failure caused by aluminum drill pipe in a compression–rig picked up steel drill pipe, and a shallow drilling program was initiated.

1981–1983: Petroleum Engineering Consultant, Clausen Operating Company, Douglas, Wyoming. Mr. Doll provided supervision and direction of eight on-site operations consultants for conventional oil and gas drilling, workovers, and production operations in the Powder River Basin; 18-month petroleum engineering contract to John Brown Engineering and LAAW at DOE's Naval Petroleum Reserve No. 3 for engineering design and fieldwork for injectivity testing followed up with a pilot project; and wellbore, well site, and facilities design, specification, and construction supervision and drilling supervision with resultant implementation of a polymer-augmented waterflood pilot at Naval Petroleum Reserve No. 3.

1980–1981: Petroleum Engineer, WYOCO Petroleum, Walcott, Wyoming. Mr. Doll provided engineering management and field supervision of a field supervisor and roustabout for a small independent oil and gas producer in the Southwestern Hanna Basin; evaluation of Niobrara oil shale production problems and low-Btu natural gas production problems; and provided analysis and recommendations to management.

1977–1980: Petroleum Engineer, Louisiana Land and Exploration Company, Denver, Colorado. Mr. Doll provided drilling and production engineering and field operations design, specification, implementation, and oversight in the northern Rocky Mountains and California. Tasks included preparation of AFE cost estimates and reserves estimates; well economic evaluation for proposed wells in the leasehold area, working directly with geoscientists in prospect evaluation and providing Monte Carlo economic simulations for management decision making; managed and directed consultants during wildcat drilling, providing an on-site drillstem test and logging evaluation and for long string cementing; and on-site management and direction of consultants on well completions and stimulations.

1974–1977: Petroleum Engineer, Amerada Hess Corporation, Williston, North Dakota, and Tulsa, Oklahoma, including production engineering based in Williston, North Dakota. Mr. Doll was responsible for 350 producing oil wells on the Nesson Anticline in northwestern North Dakota and drilling engineering based in Tulsa, Oklahoma. Responsible for design, implementation, oversight, and management of wildcat and infield drilling programs in the central Alberta overthrust, onshore California directional drilling, and Williston Basin field expansion in North Dakota; and reserves/reservoir engineering in Tulsa, Oklahoma, responsible for reserves reporting companywide, operated and nonoperated properties.

1971–1974: Petroleum Engineer, Halliburton Services, Rock Springs, Wyoming. Mr. Doll was responsible for engineering support to cementing, hydraulic fracture stimulation, acidization, and drillstem testing for the major service contractor in western Wyoming, northern Colorado, and eastern Utah.

Publications and Presentations
Has authored and coauthored numerous publications and presentations.

LONNY L. JACOBSON
Senior Operations Specialist
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, North Dakota 58202-9018 USA
701.777.5331 (phone), 701.777.5181 (fax), ljacobson@undeerc.org

Principal Areas of Expertise

Mr. Jacobson's principal areas of interest and expertise include drilling and completion design, optimizing wellsite layout for well servicing/completions, hydraulic fracturing techniques, logistics, field implementation planning, site management, and economic cost–benefit analysis of projects.

Qualifications

B.A., Economics, University of North Dakota, 2007.
H_2S Certification, 2014; OSHA 10-hour Hazard Recognition Training, 2013; Well Control Training, Workover and Completion, 2015.

Professional Experience

August 2015–Present: Senior Operations Specialist, EERC, UND. Mr. Jacobson's responsibilities include leading field activities for the EERC related to drilling, logging, coring, and completion. He also analyzes hydraulic fracturing practices and conducts oil and gas pipeline evaluations and inspections in conjunction with EERC oilfield projects. In addition, Mr. Jacobson performs economic evaluations (e.g., cost–benefit analysis) of projects.

2007–2015: Operation Manager/Consultant, Bonetraill Rentals, LLC, Williston, North Dakota. Mr. Jacobson's responsibilities included hydraulic fracturing procedures, workover operations, completions, drilling operations, coil tubing, wireline, installation, independent third-party inspection of gas and production water pipelines, invoicing, daily reports, and overseeing other consultants for an oilfield service company that provides services to some of the largest oilfield operations in the Williston Basin region.

Mr. Jacobson took projects from concept through to production. He worked as a site manager for over 100 workover operations and has experience working in multiple formations, including the Bakken/Three Forks, Midale, Spearfish, Dakota, Red River, and Mission Canyon. He also has experience in the completion of produced-water disposal wells in the state of North Dakota. Mr. Jacobson typically managed health, safety, and environment (HSE) during all operations, except in extreme sour/H_2S environments.

Specific site management projects included the following:

- Site Manager, Sundance Energy, Inc., which included site acquisition; site management during site preparation, drilling, completion (hydraulic fracturing, drill outs/cleanouts), and flow testing; site facilities and equipment installation; daily reporting; and site restoration.

- Site Manager, Cornerstone Natural Resources, LLC, which included site management during completion (hydraulic fracturing, drillout/cleanouts), flow testing, site facilities and equipment installation, and daily reporting.

- Site Manager, Crescent Point Energy US Corporation, which included site management during completion (hydraulic fracturing, drillout/cleanouts), flow testing, and daily reporting.

Site management for these projects also included controlling site access, serving as first point of contact for on-site contractors performing work, coordinating on-site activities among all on-site contractors, scheduling equipment deliveries and services, participating in daily phone conferences, ensuring maintenance/snow removal of pad and access roads, arranging fueling services, managing on-site analysis of fluids, arranging and managing off-site analysis of fluids, and scheduling and supervising water hauling and proper disposal of fluids. Mr. Jacobson was in charge of all scheduling and work performed on-site during well activities, ensuring all testing/ work did not impact/damage the formation or future testing procedures.

2010–2011: Shop Supervisor, R&M Energy Systems, Oklahoma City, Oklahoma. Mr. Jacobson's responsibilities included manufacturing of sucker rod guides, overseeing a small work staff, maintenance of machinery, inventory, orders from different companies, and quality control procedures. Maintained the second-best profit margin in the company within the first year of operations.

2006–2006: Consultant, Bonetraill Rentals, LLC, Williston, North Dakota. Mr. Jacobson's responsibilities included hydraulic fracturing procedures, workover operations, drilling operations, daily reports, and invoicing.

Publications and Presentations
Has coauthored several technical publications.

DANIEL J. DALY
Senior Geologist/Public Outreach Specialist, Outreach Team Lead
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, ND 58202-9018 USA
701.777.2822 (phone), 701.777.5181 (fax), ddaly@undeerc.org

Principal Areas of Expertise
Developing and implementing programs to inform nontechnical audiences regarding environmental and energy issues.

Qualifications
M.S., Geology, University of North Dakota, 1984.
B.A., Earth Science, New Mexico Highlands University, 1974.

Professional Experience
1975–Present: Senior Geologist/Public Outreach Specialist, Outreach Team Lead, EERC, UND. During his tenure at the EERC, Mr. Daly has served in the following specific roles:

2003–Present: Manager, Outreach and Education, Plains CO_2 Reduction (PCOR) Partnership (Clients: U.S. Department of Energy [DOE] and more than 80 government and industry stakeholders in the United States and Canada).
1999–2008: Coordinator, Red River Valley Clean Cities Coalition (Clients: U.S. Department of Agriculture, DOE, and regional stakeholders).
2000–2003: Project Manager, Red River Geoscience Education Pilot Project (Client: National Science Foundation).
2001–2004: Task Manager, Red River Environmental Information Network (Client: U.S. Environmental Protection Agency).
1995–2003: Management Team Member, DOE Environmental Management Program (Cooperative Agreement providing technical support for the development of innovative technologies to aid in nuclear complex cleanup; Client: DOE).
1992–1995: Task Manager, national-level assessment of waste generation and shallow subsurface environmental issues related to gas industry exploration and production (Clients: GTI and DOE).
1989–1998: Task Manager, tracking and assessment of government policy and regulatory actions in support of strategic planning for the EERC.

In addition, Mr. Daly also served as a technician on several project-based appointments with the North Dakota Geological Survey, UND's North Dakota Mining and Mineral Resources Research Institute, and UND's Engineering Experiment Station.

Publications and Presentations
Has authored or coauthored eight public television documentaries on energy and environmental topics, Web materials on energy and environmental topics, project-based technical reports, and presentations for a variety of technical and nontechnical audiences.

CHARLENE R. CROCKER
Research Scientist
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, North Dakota 58202-9018 USA
701.777.5018 (phone), 701.777.5181 (fax), ccrocker@undeerc.org

Principal Areas of Expertise

Ms. Crocker's principal areas of interest and expertise span public outreach and scientific research activities. Public outreach programs have focused on fossil energy transformations, carbon dioxide emissions, water quality and use, and fish consumption advisories and include general public and K–12 education and documentary development, writing, and production. Research areas have focused on trace element emissions and control for fossil fuel combustion systems, with a particular emphasis on air pollution issues related to mercury and fine particulates. This includes developing carbon-based mercury control sorbents; mercury and halogens in coal combustion; and airborne particulate matter instrumentation. Ms. Crocker has experience in water quality monitoring, analytical methods, and education; development and implementation of fish consumption surveys; laser-induced breakdown spectroscopy (LIBS); atomic absorption spectroscopy (AAS) (flame; graphite furnace, and hydride generation); inductively coupled plasma (ICP) spectroscopy; trace element analysis of water, coal, and coal by-products; and atomic fluorescence spectroscopy (AFS).

Qualifications

B.S., Chemistry, University of North Dakota, 1994.
B.A., French, Colby College, Waterville, ME, 1986.

Professional Experience

2002–Present: Research Scientist, EERC, UND. Ms. Crocker's responsibilities include managerial and principal investigator duties for projects related to public outreach and scientific research. With respect to outreach, this included the development of public outreach programs for CO_2 sequestration, water, and fish advisories and the development of CO_2 sequestration public outreach materials, water quality education, and a water-based geoscience education program and outreach activities for middle and high school students. Research responsibilities included projects related to development of sorbents for emission control strategies in fossil fuel-fired energy systems; projects related to environmental management and air quality; collaborating with other scientists on the development of carbon-based flue gas sorbents, particulate matter (PM) sampling, evaluation of bioassessment tools, fish consumption survey development, proposal and report writing, data analysis, presentation of results, and budget tracking; developing PM-sampling protocols; and directing the activities of student assistants.

1994–2002: Research Chemist, EERC, UND. Ms. Crocker's responsibilities included managing projects relating to environmental management and air quality; collaborating with other scientists on fish consumption survey development, PM sampling, corrosion of ceramic and alloy

materials, coal ash, water purification, and surface decontamination research; proposal and report writing, data analysis, presentation of results, and budget tracking; developing PM sampling protocols; participating in development of a water-based geoscience education program and outreach activities for school children; directing activities of student assistants; developing and implementing analytical methods employing LIBS. Previous duties performed in the Analytical Research Laboratory focused on water quality and energy-related analyses. Responsibilities included preparing and analyzing ultratrace element samples in aqueous and inorganic media using AAS, ICP, and IC; recording and disseminating analytical results and quality control checks; performing research on ultratrace elemental analysis of mercury using AFS; and preparing reagents and solutions.

1993–1994: Research Assistant, EERC, UND. Ms. Crocker's responsibilities included preparing and analyzing ultratrace element samples in inorganic media; performing research on ultratrace element analysis of mercury in air using AFS; and preparing reagents and solutions.

1990: Naturalist, Deep Portage Conservation Reserve, Hackensack, Minnesota. Ms. Crocker's responsibilities included planning and conducting environmental education programs for children and adults; evaluating curriculum; and organizing lending of educational learning stations.

1988–1990: Sanctuary Manager, Wetlands, Pines & Prairie Audubon Sanctuary, Warren, Minnesota. Ms. Crocker's responsibilities included planning and conducting environmental education programs; organizing chapter meetings; publishing the Sanctuary newsletter; and performing administrative tasks.

1988: Park Ranger/Interpreter, Boston Harbor Islands State Park, Boston, Massachusetts. Ms. Crocker's responsibilities included interpreting natural and human history; developing special programs and leading walking tours of the islands; and conducting school programs.

Presentations and Publications
Has authored and coauthored over 50 publications.

GERALD BACHMEIER

3128 Bay Shore Bend SE
Mandan, ND 58554

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Qualifications Summary

An effective, driven, confident professional with extensive supervisory experience. Leadership shown in workplace as employee in upper and middle management positions. Capable of coordinating multiple projects and organizing communications to meet deadlines. A strong work ethic and ability to inspire others to reach team objectives. Respected consultant with reputation for integrity in business. Particular strengths in business development, alliance building, employee relationships, project management and cross training

Areas of Strength

DIRECTION – SUPERVISION – PROJECT ASSESSMENT – LEADERSHIP DEVELOPMENT – CONTRACT NEGOTIATION – BUSINESS DEVELOPMENT – BUSINESS ALLIANCE BUILDING- CROSS TRAINING – MARKETING

Professional Board Memberships

Chaired multiple boards involved in facility production, planning, and marketing.

- Executive Board of Renewable Products Marketing group
- President – North Dakota Ethanol Producers Association
- North Dakota Ethanol Council

Professional Experience

Chief Executive Officer

- Red Trail Energy, LLC. – Richardton, ND July 2010 – Present
  Administration of Red Trail Energy ethanol facility. Utilize expertise to oversee and manage daily operations of Plant, Lab and Financial activities. Identify opportunities for growth in the financial and production sectors. Promote positive attitudes regarding company policies, employees and customers. Maintain and monitor risk management procedures. Recommend grain policies as well as oversee and maintain all grain hedging, grain bids and grain settlement activity. Assist in hiring, supervising, and termination of employees as necessary. Strategic planning and preparation of all department budgets and financials.
  - Assess needs in staffing, policies and procedures to maximize the growth of Red Trail Energy.
  - Calculate risk and return in market, maximizing profit as markets change.
  - Communicate with total Risk Management Program.

Chief Manager

- DENCO – Morris, MN 1999 – 2010
  Administration of DENCO ethanol facility, advisor to Red Trail Energy in Richardton, ND. Coordinated activities of Plant management, Lab management, and Financial sections. Maintained employee retention program. Identified opportunities of growth as major contributor to the ethanol industry. Advocated for ethanol industry at state and federal levels. Utilized industry expertise and plant management expertise to influence construction and engineering of new generation high capacity plants. Evaluated probable success of projects brought to Greenway consulting, and instruct principles on modifications needed. Facilitated contact between interested investors, project managers and

contractor. Promote use of E-85 and higher level blends on a local and state environment.

- Designed business development plan for DENCO allowing for exit strategy and eight-fold profit for investors.
- Created Greenway Consulting and Golden Lyk subsidiary companies, creating profit for DENCO and providing training and experience for staff.
- Established contractual relationship with eleven other MN ethanol plants, creating RPMG, improving marketing and enzyme purchasing capabilities of DENCO.
- Assessed need of key staff, developed individual benefit programs resulting in highly trained and motivated staff, with excellent staff retention
- Directed leadership development events, and prioritized training, including external sources such as the Carnegie program.
- Calculate risk and return in financial markets, maximizing profits as seasons and markets change.
- Invest in internal and external projects to provide security and growth.

Plant Manager, Ethanol Marketing Manager- Milsolv Minnesota Corporation

- MORRIS AG-ENERGY COMPANY, INC. – MORRIS, MN 1990–1999
  Oversaw equipment procurement and installation during construction phase. Morris Ag- Energy representative for negotiating labor agreement with Allied Industrial Worker Union. Employee organization, hiring, termination and training. Total plant financial overview, corn procurement, chemical and energy procurement, plant process operations. Improvement of efficiency and expansion in production.
  - Improved profitability from $80,000 loss to net profit of $69,000 in one year.
  - Expanded Ethanol Marketing Division from $6 million to $47 million in three years.
  - Developed relationship with all major Refiners in the upper Midwest and West coast.
  - Negotiated contracts and developed market strategies for Milsolv and Heartland Corn Products, Winthrop MN, through start-up.

Education

BISMARCK STATE COLLEGE, Bismarck, ND 1990
Associates Degree in Process Plant Technology

Dale Carnegie Graduate 1996
STATE OF MONTANA

Certified Developmental Disabilities Teaching Program 1986
COUR D' ALENE, IDAHO

Scott and Fetzer Fortune 500- Professional Sales and Management 1982

Carson High School 1972

RAY MCKASKLE, P.E., Senior Engineer
Trimeric Corporation
Buda, TX 78610

Biographical Sketch

Mr. McKaskle has over 24 years of engineering experience, including 17 years of process engineering services for clients from the oil and gas, electric power utility, coal gasification, wood products, petrochemical, and semiconductor industries. Recent project experience includes lead engineer and project manager roles for a 1,000 tonne per day (21 MMSCFD) carbon dioxide (CO_2) compression and dehydration system for a Department of Energy Regional Sequestration Partnership Phase III Demonstration project, for a 2,600 (50 MMSCFD) tonne per day CO_2 compression and dehydration system for a commercial client, and for capacity evaluations, process improvements, and expansions for an 850 tonne (16 MMSCFD) per day CO_2 compression, liquefaction, distillation, and pumping facility for a commercial client. He is also leading a multi-year effort for a U.S. oil producer to convert their fleet of drilling rigs to run on LNG in order to reduce diesel usage, which includes Life Cycle Assessment of system costs and environmental benefits.

Mr. McKaskle has performed and managed emissions testing projects at facilities across his industry experience base using standard EPA approved and specially developed testing protocols to suit the application. He has firsthand experience with numerous product flow rate and emissions measurement testing efforts and with evaluation of measurement test results.

With more than seven years of process engineering experience in the semiconductor industry, Mr. McKaskle has also developed expertise in complex troubleshooting of existing processes, process reactors, and abatement systems. He was a proven performer in systematic and statistically based troubleshooting and root cause analysis of process and reactor issues.

Education

B.S., Chemical Engineering, Oklahoma State University, 1992
Graduated in top 10% of College of Engineering

Professional Experience

Senior Engineer, Trimeric Corporation, 2005 – Present
Chemical Systems Engineer – Senior Field Process Engineer, Novellus Systems Inc., 1999 – 2005
Associate Engineer – Staff Engineer, Radian International, 1992 – 1999

Professional Registrations/Certifications

Registered Professional Engineer in Texas
Registered Professional Engineer in California

Selected Publications

McKaskle, R. and B. Piggott, "Design, Construction, and Commissioning of a New 50 MMscfd (1 Million Tonne / Year) CO_2 Compression and Dehydration Facility for EOR", Presented at Twelfth Annual Carbon Capture, Utilization & Sequestration Conference and Published in Conference Proceedings, Pittsburgh, Pennsylvania, May 14, 2013.

McKaskle, R., K. Fisher, R. Jones, S. Frailey, "Design, Startup, and Operation of a 50 MWe CO_2 Sequestration System, Presented at Eleventh Annual Carbon Capture, Utilization & Sequestration Conference and Published in Conference Proceedings, May 2012.

McKaskle, R., and A. Sexton, "Design and Performance of CO_2 Injection Equipment: MGSC Validation Phase Enhanced Oil Recovery Sites II and III", Illinois State Geological Survey, Open File Series 2012-7, 17 pp., 2012.

Finley, Robert, Kevin Fisher, Ray McKaskle, "Evaluation of CO_2 Capture Options from Ethanol Plants", Illinois State Geological Survey, DOE Award #: DE-FC26-05NT42588, 2006.

McKaskle, R., K. Fisher, A. Sexton, "Comparison of Source Specific CO_2 Capture Processes", Presented at Society of Petroleum Engineers International Conference on CO_2 Capture, Storage, and Utilization, San Diego, California, Nov. 3, 2009.

Synergistic Activities

The following items highlight Mr. McKaskle's project experience in related technical areas:

Project Manager and Lead Engineer for Design of 1,000 tonne per day CO_2 Compression and Dehydration System

- Served as project manager and lead engineer for an engineering team that designed the 1,000 tonne per day (50 MWe) CO_2 compression and dehydration system for the DOE Midwest Geological Sequestration Consortium Regional Partnership Phase III Demonstration.
- Managed the project from development of the initial design basis through commissioning, startup, 3-year injection operations completing the one million tonne injection phase of the project, and subsequent data analysis and reporting tasks.

Prepared and delivered "A New Look at Impurities in CO_2 for EOR and their Consequences" presentation at Midland CO_2 Conference on December 11, 2014

Taught course at DOE offices in Morgantown, WV on CO_2 Purification and Processing Equipment Used for Enhanced Oil Recovery in February 2013

Prepared and delivered "Comparison of Source Specific CO_2 Capture Processes" presentation at Society of Petroleum Engineers International Conference on CO_2 Capture, Storage, and Utilization in San Diego, CA on November 3, 2009

BRAD PIGGOTT, P.E., Senior Engineer
Trimeric Corporation
Buda, TX 78610

Biographical Sketch

Mr. Piggott is a chemical engineer with over 14 years of experience in diverse industries such as hydrogen production, air separation, natural gas treating, and specialty chemicals. As a process engineer, Mr. Piggott has provided services from the concept phase of a project through commissioning and start up and has specific experience commissioning, operating, and troubleshooting carbon dioxide (CO_2) compression and purification facilities. He was a lead process engineer for a 50 MMSCFD CO_2 compression and purification facility from the initial process design phase through start up and initial operation of the facility. Mr. Piggott has extensive experience specifying equipment for CO_2 service including compressors, dehydration units, and multistage centrifugal pumps. He has developed process control documentation for several dense phase CO_2 pump applications and overall control strategy documentation for CO_2 compression and dehydration facilities. He has also sized and specified relief devices in acid gas service at a wide range of pressures and designed relief device vent headers for CO_2 service. Mr. Piggott routinely develops operating procedures for new and existing process facilities and has written operating procedures for several CO_2 compression and purification facilities.

Education and Training

B.S., Chemical Engineering with a Minor in Economics, Colorado School of Mines, Golden, Colorado, 2002.

Research and Professional Experience

Senior Engineer, Trimeric Corporation, 2008-Present
Positions up to Syngas Tech Engineer, Air Liquide America, 2002-2008

Professional Registrations/Certifications

Registered Professional Engineer in Texas
Registered Professional Engineer inMississippi

Selected Publications

Marsh, M.J., J.P. Farone, B.D. Piggott, C.B. Wallace, “Evaluation, Selection, and Implementation of CO_2 Removal Technology at a Complex Gas Production Site”, Proceedings of the 60th Annual Laurance Reid Gas Conditioning Conference, Norman, Oklahoma, 21-24 February 2010, pp. 221-232.

McKaskle, R. and B. Piggott, “Design, Construction, and Commissioning of a New 50 MMscfd (1 Million Tonne / Year) CO_2 Compression and Dehydration Facility for EOR”, Presented at Twelfth Annual Carbon Capture, Utilization & Sequestration Conference and Published in Conference Proceedings, Pittsburgh, Pennsylvania, May 14, 2013.

Piggott, B., R. McKaskle, T. Kerr, A. Ryan, “Acid Gas Relief Challenges in the Natural Gas Treatment Industry”, Laurence Reid Gas Conditioning Conference, February 2016, Norman, OK, pp. 365-381.

Synergistic Activities

The following highlights Mr. Piggott's project experience in related technical areas:

CO_2 Compression and Purification

- Process engineer for 21 MMSCFD CO_2 compression and dehydration facility.
  - Sized and specified control valves.
  - Developed control system documentation for dense phase CO_2 pump.
  - Developed operating procedures for entire facility including inlet multistage blower, reciprocating compressors, dehydration unit, multistage centrifugal pump, injection pipeline, and utilities.
  - Attended Factory Acceptance Test of CO_2 dense phase pump control loops.
  - Supported start up and initial operation of facility.
- Process engineer for 42 MMSCFD CO_2 compression and dehydration facility.
  - Provided process engineering review for entire facility prior to facility start up.
  - Developed control system documentation for dense phase CO_2 pumps.
  - Sized and specified back pressure control valve for dense phase CO_2 pumps.
  - Developed operating procedures for entire facility including inlet multistage blower, reciprocating compressors, dehydration unit, multistage centrifugal pump, injection pipeline, and utilities.
- Process engineer for 50 MMSCFD CO_2 compression and dehydration facility.
  - Evaluated bids for rotating compression equipment and developed technical and economic justification for equipment selection.
    - Investigated alternate process configurations with host fertilizer facility to minimize operating costs of facility.
  - Sized and specified high pressure vent control valves and facility back pressure control valves.
  - Worked with detailed engineering firm and equipment vendors during detailed design phase, responsible for review and approval of process datasheets and vendor submissions.
  - Developed overall facility control philosophy and control documentation for entire facility and each major unit operation.
  - Developed cold weather cooling tower operating procedures.
  - Developed operating procedures for entire facility including inlet multistage blower, reciprocating compressors, dehydration unit, multistage centrifugal pump, injection pipeline, and utilities.
    - Trained facility operators.
  - Led loop check and functional test team for facility.
    - Responsible for validating control systems at facility against control system documentation.
  - Supported start up and initial operation of facility.
    - Compared actual facility performance with original process design.
- Process engineer for large enhanced oil recovery client utilizing naturally occurring CO_2.
  - Process engineering support of field compressor installation.
    - Analyzed reciprocating compressor operations at a variety of inlet conditions to set suction pressure and temperature limitations for compressor operation.
    - Sized and specified relief valves and recycle control valves for reciprocating compressor installation.
    - Developed compressor start up sequence with PLC programmer to enable safe and reliable automatic compressor startup.

APPENDIX C

BUDGET JUSTIFICATION

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 will include seismic site visits, field sampling, meetings with the North Dakota Department of Mineral Resources, community open houses, a DOE annual review meeting, and a technical conference. 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, etc., are based on historical costs. Miscellaneous travel costs may include taxis, 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.

Repairs: Factory maintenance of gas meters and YSI probes is necessary to ensure representative sampling meter readings while in the field. Costs are based on previous history.

Contractor: The EERC will contract with Trimeric Corporation in Task 1 of the project scope. Trimeric will develop a process design package (PDP) for the Red Trail Energy (RTE) CO_2 capture facility, necessary to advance the project on to an implementation phase. Project partner, Trimeric, will generate the PDP, which includes the development of process simulation and process engineering design, such as process flow diagrams, heat and material balances, and piping and instrument diagrams. Trimeric will then use these data to develop facility costs and recommend vendors. The outcome of this task will be all documentation and cost estimates needed to pursue formal engineering bids for installation of a CO_2 capture system integrated with North Dakota ethanol production to proceed with detailed engineering design and implementation. Costs are based on a quote from Trimeric.

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. Costs are based on previous history.

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. EERC laboratory and analytical recharge fees are charged on a per-sample, hourly, or daily rate. Additionally, the EERC will work with an outside laboratory to conduct isotopic analyses of gas and water samples. The estimated cost is based on a quote for three field sampling events.

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.

Freight is budgeted for sending samples to the outside laboratory for the isotopic analyses. The cost is based on previous history.

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

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