EERC
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University of North Dakota
15 North 23rd Street, Stop 9018 • Grand Forks, ND 58202-9018 • P. 701.777.5000 • F. 701.777.5181
www.undeerc.org

August 1, 2017

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. 2017-0139 Entitled "Integrated Carbon Capture and Storage for North Dakota Ethanol Production – Phase II"

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/bjr

Enclosures

Renewable Energy Program

North Dakota Industrial Commission

Lead Organization: EERC Energy & Environmental Research Center®

Cost-Share Partners:

Other Project Partners: TRIMERIC CORPORATION

Application

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

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

Principal Investigator: Kerryanne M. Leroux

Date of Application: August 1, 2017

Amount of Request: $345,000

Total Amount of Proposed Project: $690,000

Duration of Project: 9 months

Point of Contact (POC): Kerryanne M. Leroux

POC Telephone: (701) 777-5013

POC Email: kleroux@undeerc.org

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 a second phase (Phase II) of research to investigate integrating carbon capture and storage (CCS) at a ND ethanol facility (Red Trail Energy [RTE], located in Richardton, ND) to reduce CO_2 emissions associated with ethanol production. The proposed Phase II project will build on the previous EERC study, which successfully assessed the technical and economic pre-feasibility of integrating CCS with ethanol production, using the RTE facility as a case study location (Phase I). Continued collaboration with authorities for ND Class VI (CO_2 geologic storage) permitting and West Coast low-carbon fuel (LCF) programs will provide detailed insight into unprecedented regulatory and marketing pathways currently under development. Further refinement of the technical requirements and related economics for CCS implementation based on these new insights will improve the pathway toward commercial success in ND, especially for renewable energy production. Regional assessment results generated during the Phase I effort will also be used to develop a detailed community outreach plan, which will prepare ND ethanol producers for stakeholder involvement and communication with the public regarding potential CCS operations. Overall, continuation of this effort will assist in providing a competitive market advantage to ND ethanol producers through generation of reduced-carbon ethanol that capitalizes on LCF programs in other states.

Objective: To reduce knowledge gaps in regulatory, processing, and financial requirements and thus encourage investment toward integrating commercial CCS with ND ethanol production in order to realize CO_2 market credits from LCF programs. **Expected Results:** This proposed work will generate: 1) permitting pathways for implementing CCS in ND, 2) up-to-date qualification requirements for LCF programs, 3) site-specific data leading to reduced uncertainty and closed knowledge gaps, 4) updated Phase I project designs, 5) improved economics, and 6) a community outreach plan.

Duration: 9 months. **Total Project Cost:** $690,000. **Participants:** EERC, RTE, Trimeric Corporation, and the U.S. Department of Energy.

PROJECT DESCRIPTION

Introduction: The Energy & Environmental Research Center (EERC), in partnership with the North Dakota (ND) Renewable Energy Program (REP); North Dakota ethanol producer Red Trail Energy, LLC (RTE); and the U.S. Department of Energy (DOE), completed a study in May 2017 (hereafter referred to as Phase I), which successfully assessed the technical and economic pre-feasibility of carbon capture and storage (CCS) implementation at a ND ethanol facility (1). The Phase I study considered CO_2 capture and transport, site characterization, geologic modeling and simulation, project risk assessment, and a life cycle analysis (LCA). Results indicated that commercial implementation of CCS at the RTE facility is technically viable and may be economically favorable through low-carbon fuel (LCF) programs being developed in California and Oregon. A field implementation plan (FIP) developed during Phase I included conceptual CO_2 capture system and pipeline designs; a permitting plan for CO_2 injection in ND; an assessment of anticipated qualification requirements for developing LCF programs; a preliminary monitoring, verification, and accounting (MVA) program; designs for monitoring and injection wells; and site characterization and testing plans. Although Phase I results supported the economic viability of CCS for ND ethanol producers through LCF programs, knowledge gaps exist, particularly with regard to 1) regulatory compliance, 2) site-specific data, and 3) public outreach.

The U.S. Environmental Protection Agency (EPA) has granted ND preliminary approval in the matter of primacy for Class VI (CO_2 injection) well permitting. ND is the first state to be granted this privilege, and advancing with CO_2 storage under a state-regulated paradigm is unprecedented. Therefore, collaboration with the ND Department of Mineral Resources (DMR) is needed to identify the specific criteria necessary to comply with ND's Class VI regulations. In addition, CCS guidelines for compliance with LCF programs, specifically the California Air Resources Board (ARB) and the Oregon Department of Environmental Quality (DEQ), remain in the early stages of development, resulting in uncertainty in the technical requirements for approval.[1] These unknown requirements from ARB/DEQ (e.g., potentially

[1] Although CCS is not yet included in the ARB/DEQ LCF programs, efforts are being made to incorporate pathway approvals to account for carbon storage, particularly via saline formation injection (1). For example, the ARB

significant monitoring) may impact the economic feasibility of integrating CCS into ND ethanol production. Formal engagement (face-to-face meetings, Webinars, public hearings, phone calls, etc.) was established with both ARB and DEQ during Phase I regarding incorporation of CCS into their respective LCF programs (2, 3). This engagement should continue throughout their rule-making process to represent ND ethanol producers' interests. DMR, ARB, and DEQ have expressed interest in and a willingness to continue collaboration in support of the ND ethanol CCS effort (see Appendix A for a letter of support from DMR).

The chemistry of the CO_2 stream is a key piece of site-specific data which can have wide-ranging impacts on infrastructure design and operation, such as the addition of technology capable of removing oxygen from the gas stream to avoid pipeline corrosion issues. Additionally, impurities may initiate precipitation and/or dissolution reactions in the reservoir, affecting injectivity. Phase I efforts collected gas composition data sufficient for early infrastructure designs; however, to advance capture, transport, and injection system designs beyond the conceptual stage, a more comprehensive baseline sampling program at the RTE facility is needed to account for operational variability inherent in the ethanol production process. These results will convey design and potential cost considerations to other ND ethanol producers.

Experience has shown that early, proactive public outreach with stakeholders is key to the success of first-of-its-kind infrastructure development. The Phase I work focused only on the technical and economic suitability of CCS implementation at RTE. As such, an evaluation is necessary to determine the level and type of outreach efforts needed to support future CCS development at RTE, in turn providing an example to other ND ethanol producers.

recently released (May 2017) summary and concept papers outlining their preliminary guidance for CCS integration into their LCF program, with plans to release final drafts of their preliminary guidance in the latter half of 2017 for potential approval by mid-2018. Oregon has not yet put forth preliminary guidance for CCS integration into its pathway approvals. Therefore, it is currently unknown what will be incorporated into the final programs and whether the pathway provisions will conflict with ND regulations.

In light of the above knowledge gaps and remaining research needs, the EERC proposes a Phase II effort, which will build upon the Phase I investigation and provide investment confidence in moving forward with an in-depth site characterization and engineering effort. The RTE site will again be used as the case study location for expanding on the Phase I effort.

Objectives: Specific objectives for Phase II include 1) establishing the permitting pathway for geologic storage of CO_2 for a ND ethanol producer, 2) understanding the ARB and DEQ LCF program approval pathways for CCS (and any anticipated future guidelines), 3) collecting and analyzing gas composition data, 4) refining the Phase I project design, 5) improving the Phase I economic analysis, and 6) developing a community outreach plan for a CCS project at the RTE facility.

Methodology: The RTE ethanol facility produces approximately 64 MMgal of ethanol and 180,000 tons of CO_2 annually from the fermentation process. Phase I efforts indicated the Broom Creek and the overlying shales and salts of the Opeche, Piper, and Swift Formations are expected to make an excellent storage complex; however, some knowledge gaps exist (1). The following proposed scope of work will address knowledge gaps related to regulatory compliance, site-specific data, and public outreach.

Task 1.0 – Establish Permitting Pathways. This task will 1) work with DMR to establish the appropriate compliance criteria for a Class VI injection well permit under ND primacy and 2) continue collaboration with ARB and DEQ to understand qualification requirements for their respective LCF programs using CCS as a means to reduce CO_2 emissions.

Subtask 1.1 – ND Class VI Program. A preliminary permitting plan was developed in Phase I, with the assumption that ND would attain Class VI primacy. As it is likely ND will be granted primacy by October 2017, this subtask will generate a detailed pathway for compliance with ND Class VI guidelines and regulations. For example, specific data needs and monitoring requirements will be defined for CCS implementation at the RTE facility. ND's pore space amalgamation rules and their application to CO_2 storage will also be examined.

Subtask 1.2 – LCF Programs. Engagement with ARB and DEQ began in Phase I. Discussions with these groups will continue as part of this subtask. The EERC and RTE will work with ARB and DEQ to

stay abreast of program requirements for out-of-state participants (e.g., ND ethanol producers) as they continue to evolve. Compatibility of these LCF programs with ND regulations will also be assessed.

Subtask 1.3 – Update Phase I FIP. Permitting time lines and activities outlined in the previously developed FIP will be revised if needed. These revisions will integrate guidance from DMR and will address items such as site characterization, baseline data acquisition, permitting, site preparation, and operation. This effort will also incorporate guidance, as appropriate, from ARB and DEQ regarding their emerging LCF programs.

Task 2.0 – Update Infrastructure Design. The focus of this task is to reduce uncertainty in the designs of capture technology, pipeline, and injection wells through sampling and analysis of fermenter gas. The Phase I LCA will be updated as needed.

Subtask 2.1 – Collect and Analyze Fermentation Exhaust Gases. A gas-sampling program including location(s) and method(s) will be outlined, and gas samples will be acquired periodically from the RTE facility throughout the fermentation cycle(s) to define variability in the CO_2 stream. The samples will undergo compositional analysis.

Subtask 2.2 – Modify Design. The RTE gas composition measured in Subtask 2.1 will be used to inform and revise project infrastructure design. Compatibility of the analyzed gas composition with specific construction materials will be examined, and additional infrastructure designs will be considered if necessary (e.g., technology for oxygen removal). Energy consumption (and utility infrastructure upgrade costs, if applicable) will be estimated for any design changes.

Subtask 2.3 – Refine LCA. The results of Subtasks 1.2 and 2.2 will be used to refine the Phase I LCA

Task 3.0 – Update Economic Analysis. Cost estimates developed in Phase I, will be revised based on the outcomes of Tasks 1.0 and 2.0 to incorporate changes necessitated by regulatory compliance and/or gas composition analyses. The economic analysis will also include items not considered during Phase I, such as electrical upgrade costs and ancillary storage expenses (as applicable). All updated cost estimates will be incorporated within a revised economic assessment.

Task 4.0 – Develop Community Outreach Plan. This task will assess the population characteristics in and around the RTE site to develop a project-specific outreach plan. The plan's objectives will be to evaluate public perception of CCS, inform/educate decision makers and the general public, and identify and mitigate stakeholder concerns. The plan may include details such as types and/or number of stakeholder meeting(s) as well as concepts for outreach materials tailored for targeted stakeholder groups. These efforts will provide a model for outreach that can be applied at other facilities and, when carried out, will contribute to public understanding and acceptance of CCS implementation in ND.

Task 5.0 – 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 comprehensive report will be prepared to include the results of the Phase II efforts.

Anticipated Results: The expected results of this proposed work are 1) permitting pathways for implementing CCS in ND, 2) up-to-date qualification requirements for ARB and DEQ LCF programs, 3) site-specific data leading to reduced uncertainty and closed knowledge gaps, 4) updated Phase I project design, 5) improved economic analysis, and 6) a community outreach plan. Overall, the Phase II work is an essential component of determining the feasibility of implementing CCS at ND ethanol facilities.

Facilities and Resources: The majority of work will be performed at the EERC, a research complex consisting of 254,000 square feet of laboratories, fabrication and technology demonstration facilities, and offices, located in Grand Forks, ND. For nearly 70 years, the EERC has conducted research, testing, and evaluation of fossil and renewable fuels, emission control technologies, and CCS technologies. The engineering and scientific research staff is equipped with state-of-the-art analytical, modeling, and engineering facilities to address a wide variety of energy and environmental research topics. The EERC is committed to providing all necessary personnel and resources to effectively conduct the activities outlined in this proposal. The project team will also have at its disposal specialists in media relations, graphics, editing, and Web programming.

Techniques to Be Used, Their Availability, and Capability: Techniques, workflows, and designs developed during Phase I will be available and used for proposed Phase II activities. The Phase I FIP will be expanded and updated as appropriate based on the results of the proposed activities.

The EERC has state-of-the-art analytical equipment for identifying and quantifying a variety of gas-phase process streams, including stationary and field-portable refinery gas analyzers that use multiple capillary and packed columns to identify and quantify several gas-phase constituents. The EERC has many years of experience analyzing and quantifying gas-phase constituents, specifically gases associated with CO_2 capture, speciation, and storage, using industry-standard procedures.

Project partner Trimeric Corporation contributed to the Phase I efforts by developing a process design basis for a conceptual capture system at the RTE facility. Trimeric will participate in Phase II by supporting the gas sampling and analyses and infrastructure design update activities. If design changes are necessary, Trimeric will employ established methods for a budgetary (±10%) cost estimate of the capture, compression, and dehydration facilities. Trimeric has access to extensive in-house data sets containing actual costs for various commercial capture system components that can be used for the proposed project.

The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model was developed by the Argonne National Laboratory and is the backbone to calculate a fuel's CO_2 emissions using an LCA approach (4–6). Both ARB and DEQ have modified versions of GREET, which are designed to support their respective LCF programs. The EERC has experience using the GREET model, as well as the ARB version, which was used during Phase I to estimate CO_2 emissions for CCS implementation at a ND ethanol facility (1, 7). These tools will be available to the project team and used to generate revised LCA results.

Environmental and Economic Impacts While Project Is under Way: The proposed work is primarily a paper study, with a minor laboratory component of gas sample analysis. These analyses will follow industry-standard techniques and will be conducted in laboratories with established safety protocols. The EERC and/or other project partners plan to visit the RTE site to examine existing facilities and collect gas samples required for compositional analysis. No negative environmental or economic impacts are

expected from the proposed project. 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 information generated by the proposed project will provide ND ethanol producers with a case study to navigate ND Class VI regulations and respond to evolving LCF program requirements. Ultimately, this will help position the ND ethanol industry as a national leader in developing reduced-carbon ethanol and provide strategic market advantage over other states. In addition, ND ethanol producers will gain a precedent for the steps necessary to design, permit, and install a CCS system under ND governance.

Why the Project Is Needed: ND has a well-timed opportunity to gain a competitive advantage in the carbon markets of LCF programs, as it has both an established ethanol industry and highly suitable geology in the western half of the state for CO_2 storage on a commercial scale. ND primacy could allow for more timely CO_2 storage permitting (compared to EPA) to coincide with the current development of CCS approval pathways within LCF programs. The EERC and RTE have established engagement with DMR, ARB, and DEQ, which will continue, setting a precedent for ND ethanol producers or others seeking to implement CCS in ND. Phase II efforts will build upon the successes of Phase I findings to further close identified knowledge gaps for the ND ethanol industry on public engagement, specific regulatory requirements, implementation costs, and potential economic benefits of CCS integration.

STANDARDS OF SUCCESS

This project will result in a comprehensive final report consisting of permitting/approval pathways, refined designs and economics for incorporating CCS with ethanol production, and a community outreach plan addressing ND CCS. The generated report will provide ND ethanol producers with up-to-date knowledge of 1) the ND permitting and LCF program approval processes for CCS as they apply to ethanol production, 2) the potential economics of incorporating this business model into existing facilities with on-site geologic storage potential, and 3) public outreach and education approaches regarding CO_2 geologic storage specific to rural ND communities. These deliverables will also advance the state of knowledge of CCS and carbon markets in general for ND.

The ND renewable energy and agriculture industries will both directly benefit from the continuation of this proposed effort. 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. While ethanol production is commonplace in the Great Plains, the geology of western ND is a highly suitable location 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, operations, and maintenance of CCS installations.

BACKGROUND/QUALIFICATIONS

The EERC successfully carried out the Phase I study and is ideally suited to conduct the proposed scope of work to achieve the expected results. The EERC led the Partnership for CO_2 Capture (PCO_2C) for 8 years, a partnership with DOE and over 25 industry partners to test and compare capture technologies and continues to perform CO_2 capture research for various clients (8–12). The EERC, therefore, has the data, resources, knowledge, and expertise to facilitate integration of a conceptual CCS system design into a facility to derive optimal economic and environmental benefit. In addition, the EERC leads the Plains CO_2 Reduction (PCOR) Partnership, one of seven Regional Carbon Sequestration Partnerships (RCSPs) managed by DOE, which includes over 120 partners developing and demonstrating technologies for geologic CO_2 storage (13–19). Through the PCOR Partnership, the EERC has proven expertise regarding laboratory analyses, risk assessment, MVA, LCA, and public outreach (13, 14, 20–26). The EERC has also, permitted, designed, drilled, and completed over one dozen wells for characterization and monitoring of CCS validation and demonstration projects. The proposed project will also leverage the EERC's PCOR Partnership outreach efforts, which have been active in the region since 2003. These efforts feature project-focused outreach (e.g. public website development, social media, broadcast documentaries, workshops, and stakeholder engagement) as well as broadly focused general outreach on CCS.

Project partners include RTE and Trimeric, both of which were involved in Phase I. RTE is a ND-based investor group that operates the Richardton corn-based ethanol production facility, the proposed project study site. Trimeric has nearly a decade of experience as process engineering lead supporting the first ethanol facility to successfully capture and store CO_2 (located in Decatur, IL). Trimeric has direct experience with designing and implementing CO_2 capture, dehydration, and compression systems for a variety of industrial applications, including ethanol production as well as expertise in the use of process simulation tools to design systems for handling supercritical CO_2 (27).

Personnel: Ms. Kerryanne Leroux, EERC Senior Chemical Engineer, Oilfield Operations Team Lead, will continue to serve as principal investigator (PI). Ms. Leroux currently leads a team of scientists and engineers that successfully conducted the Phase I effort, in addition to implementing and evaluating MVA concepts for large-scale (>1 million tons per year) CO_2 storage and enhanced oil recovery operations as part of the PCOR Partnership Bell Creek project. Ms. Leroux has provided technical support for near-surface and downhole MVA as well as CO_2 capture technologies, transportation, and trading and commercial markets. Ms. Leroux has also participated in several research projects focused on coal, natural gas, petroleum, biomass, energy storage, biorefineries, biodiesel, ethanol, and butanol. Ms. Leroux's principal areas of expertise include resource assessments and LCAs; process design; pilot- and demonstration-scale testing; statistical interpretation, data processing, and modeling; 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, 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 the Phase I effort, 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 occur to ensure coordination of all project partners and minimize risk. Internal review meetings will also be conducted regularly to further ensure that all project activities are completed in a timely manner, according to the project schedule. Progress reports will be prepared with updated results as well as a final report at project completion.

TIMETABLE

The proposed scope of work is a 9-month effort (Figure 1). 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 at the end of each calendar quarter.

BUDGET

The estimated cost for the proposed effort is $690,000, as shown in Table 1. This proposal requests $345,000 from REP. Matching funds of $145,000 in-kind will be provided by RTE. The EERC, through its Fossil Energy Cooperative Agreement with DOE under the task for Carbon Storage Research and Development, will provide $200,000 in cash. Letters of commitment are provided in Appendix B. Budget justification can be found in Appendix C. If less REP funding is available, adjustments to scope and/or participating companies would need to be considered.

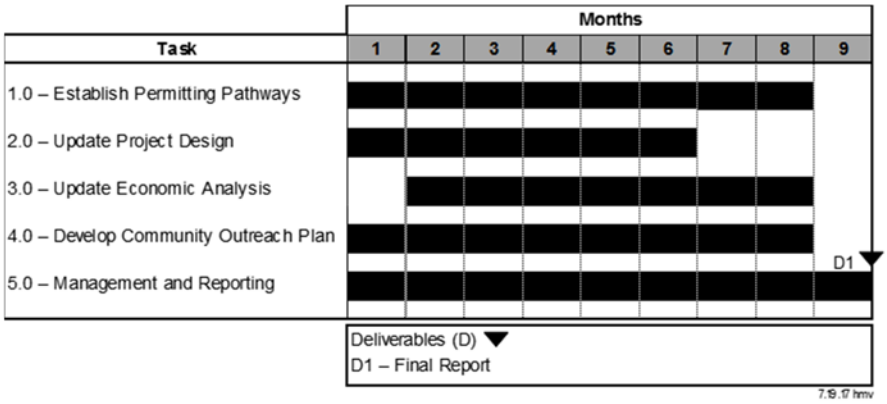

Figure 1. Project schedule.

Table 1. Budget

Project Associated Expenses	NDIC Share (Cash)	RTE Share (In-kind)	DOE Share (Cash)	Total Project
Labor	$192,929	$ –	$128,550	$321,479
Travel	$13,431	$ –	$ –	$13,431
Supplies	$499	$ –	$979	$1,478
Consultant – Trimeric Corporation	$15,000	$ –	$ –	$15,000
Other*	$680	$ –	$321	$1,001
Laboratory Fees and Services				
Process Chemistry & Development Lab	$6,096	$ –	$ –	$6,096
Graphics Services	$ –	$ –	$3,040	$3,040
Shop & Operations	$600	$ –	$ –	$600
Facilities and Administrative	$115,765	$ –	$67,110	$182,875
In-kind Cost Share – RTE	$ –	$145,000	$ –	$145,000
Total Project	$345,000	$145,000	$200,000	$690,000

* May include costs such as food, printing, communications, or other miscellaneous expenses.

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

TRIMERIC CORPORATION

July 28, 2017

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. 2017-0139 Entitled "Integrated Carbon Capture and Storage for North Dakota Ethanol Production – Phase II"

I am writing to confirm Trimeric Corporation's commitment to provide technical support for the feasibility 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 2.0 – Update Infrastructure Design and Task 3.0 – Update Economic Analysis of the proposed scope of work. Specifically, in Task 2.0 Trimeric will work with EERC to develop a sampling and analysis plan for the CO_2 stream that would feed the capture system, review the analytical results from the gas sampling program, and then refine the initial cost estimate for CO_2 purification and compression based on the results of the gas sampling program. This will include any additional equipment that is required to further treat the feed stream to make it suitable for injection.. Cost estimations for the modified design will be provided to the EERC and incorporated into Task 3.0.
Over the course of the 9-month project, we estimate approximately 85 labor hours of effort will be required to complete these tasks, with a cost estimate of $15,000.

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

Sincerely,

Kevin Fisher, P.E.
Vice President
Trimeric Corporation

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July 31, 2017

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 2017-0139, Entitled "Integrated Carbon Capture and Storage for North Dakota Ethanol Production – Phase II"

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 Program entitled "Integrated Carbon Capture and Storage for North Dakota Ethanol Production – Phase II" is a viable candidate for funding under this program. Therefore, the EERC has secured $200,000 of cash cost share for the proposed project through its Cooperative Agreement with DOE, providing that NDIC commits $345,000 of cash cost share and Red Trail Energy provides $145,000 of in-kind contribution.

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

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

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

Sincerely,

John A. Harju
Vice President for Strategic Partnerships

JAH/bjr

RED TRAIL ENERGY, LLC

"Our Farms, Our Fuel, Our Future"

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

July 28, 2017

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. 2017-0139 Entitled "Integrated Carbon Capture and Storage for North Dakota Ethanol Production – Phase II"

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 CO2 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 in-kind contributions including technical support for Task 1.0 – Establish Permitting Pathways, Task 2.0 – Update Infrastructure Design, Task 3.0 – Update Economic Analysis, and Task 4.0 – Develop Community Outreach Plan. Specifically, RTE's in-kind match funding will consist of contributing to the following subtasks:

- Subtask 1.1 – North Dakota Class VI Program: RTE will engage with the North Dakota Department of Mineral Resources as the authority on CO2 injection and storage permitting to determine specific criteria for compliance with state and federal regulations.
- Subtask 1.2 – Low-Carbon Fuel Programs: RTE will continue collaboration with California and Oregon program authorities, advocating for requirements that are compatible with North Dakota regulations.
- Subtask 2.1 – Collect and Analyze Fermentation Exhaust Gases: RTE will work with the project team on developing a gas-sampling program, providing engineering support and guidance to define variability in composition of the CO2 stream generated at the RTE facility.
- Task 3.0 – Update Economic Analysis: RTE will help quantify the value of any new or modified implementation costs based on the findings from Tasks 1.0 and 2.0.
- Task 4.0 – Develop Community Outreach Plan: RTE will work with the project team to identify characteristics specific to rural North Dakota communities, identify potential stakeholders, and provide or garner lessons learned from previous outreach activities in the region.

Over the course of the 9-month project, RTE anticipates its consultants and employees will spend a cumulative of about 700 hours on these activities at a rate of approximately $200/hr for a total in-kind

value of $145,000, including potential travel expenses. 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 collaborate with REC, the EERC, the U.S. Department of Energy, and Trimeric Corporation on this Phase II study toward implementation of CCS at a North Dakota ethanol production facility.

Sincerely,

Gerald Bachmeier
CEO

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 28, 2017

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

Subject: EERC Proposal No 2017-0139, Entitled "Integrated Carbon Capture and Storage for North Dakota Ethanol Production – Phase II"

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 June 21, 2013 the NDIC submitted an application to the U.S. Environmental Protection Agency (EPA) for Class VI Primacy. EPA signed a proposed federal rule to approve the State of North Dakota's application for regulatory primacy over Class VI injection wells on May 8, 2017. The application has since been published in the federal register, open to a 60-day public comment period, and is now being reviewed by EPA with finalization expected later this year. Upon final approval the NDIC's Oil and Gas Division will become the primary regulatory authority for Class VI injection wells 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

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
Phone: (701) 777-5013, Fax: (701) 777-5181, E-Mail: kleroux@undeerc.org

Principal Areas of Expertise

Ms. Leroux's principal areas of interest and expertise include renewable, alternative, and fossil energy and chemicals production; fossil industry monitoring, verification, and accounting (MVA) method assessment; resource and life-cycle assessments; process design; pilot- and demonstration-scale testing; statistical interpretation, data processing and modeling; 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 a team of scientists and engineers implementing and evaluating MVA concepts for large-scale (>1 million tons per year) CO_2 storage and enhanced oil recovery (EOR) operations. Ms. Leroux has provided technical support for near-surface and downhole monitoring related to associated CO_2 storage with regard to commercial EOR as well as CO_2 capture technologies, transportation, and trading and commercial markets. Ms. Leroux's responsibilities include serving as a principal investigator or project manager on assigned tasks; 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 as contractually required; and collecting, reducing, analyzing, and interpreting data and ensuring quality control of personal 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 CO_2 storage associated with commercial EOR, 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.

Relevant Publications

Leroux, K.M., 2017, Integrated carbon capture and storage for North Dakota ethanol production: Presentation for the Low Carbon Fuels Program, California Air Resources Board, Sacramento, California, January 30, 2017.

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Kay, J.P.; Azenkeng, A.; Fiala, N.J.; Jensen, M.D.; Laumb, J.D.; Leroux, K.M.; McCollor, D.P.; Stanislowski, J.J.; Tolbert, S.C.; Curran, T.J. *Subtask 2.18 – Advancing CO_2 Capture Technology: Partnership for CO_2 Capture (PCO_2C) Phase III*; Final Report (July 1, 2013 – March 31, 2016) for U.S. Department of Energy National Energy Technology Laboratory Cooperative Agreement No. DE-FC26-08NT43291 and multiclients; EERC Publication 2016-EERC-03-13; Energy & Environmental Research Center: Grand Forks, ND, March 2016.

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Leroux, K.M.; Strege, J.R. *Chippewa Valley Ethanol Company (CVEC) Resource Assessment and Syngas Feasibility Study*; Final Report for Chippewa Valley Ethanol Company; EERC Publication 2012-EERC-12-16; Energy & Environmental Research Center: Grand Forks, ND, Dec 2012.

Jensen, M.D.; Pavlish, B.M.; Pei, P.; Leroux, K.M.B.; Steadman, E.N.; Harju, J.A. Estimating the Cost to Capture, Compress, and Transport CO_2 from Stationary Sources in the PCOR Partnership Region. Poster presented at the 9th Annual Carbon Capture & Sequestration Conference, Pittsburgh, PA, May 10–13, 2010.

Jensen, M.D.; Pavlish, B.M.; Pei, P.; Leroux, K.M.B.; Steadman, E.N.; Harju, J.A. *Regional Emissions and Capture Opportunities Assessment – Plains CO_2 Reduction (PCOR) Partnership (Phase II)*; Value-Added Report for U.S. Department of Energy National Energy Technology Laboratory Cooperative Agreement No. DE-FC26-05NT42592; EERC Publication 2010-EERC-08-15; Energy & Environmental Research Center: Grand Forks, ND, Dec 2009.

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Schmidt, D.D.; Leroux, K.M.B. *North Dakota Forest Service Fuels for Schools Feasibility Studies;* Final Report (July 1, 2005 – June 30, 2006) for North Dakota Forest Service; EERC Publication 2006-EERC-06-07; Energy & Environmental Research Center: Grand Forks, ND, June 2006.

CHARLES D. GORECKI
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Energy & Environmental Research Center (EERC), University of North Dakota (UND)
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Principal Areas of Expertise
Mr. Gorecki's principal areas of interest and expertise include personnel and project management, reservoir engineering, 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). Through the PCOR partnership program, Mr. Gorecki has successfully overseen the execution of field activities including well drilling and completion, infrastructure development, monitoring systems deployment and operation, and the coordination of staff during these operations.

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 CO_2, and CO_2 EOR. Mr. Gorecki also manages a group of more than 50 scientists and engineers at the EERC, focused on all aspects of research related to geologic, subsurface and environmental systems.

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 carbon capture and storage. 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 carbon capture and storage.

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

Relevant Publications

Leroux, K.M., Klapperich, R.J., Azzolina, N.A., Jensen, M.D., Kalenze, N.S., Bosshart, N.W., Torres Rivero, J.A., Jacobson, L.L., Ayash, S.C., Nakles, D.V., Jiang, T., Oster, B.S., Feole, I.K., Fiala, N.J., Schlasner, S.M., Wilson IV, W.I., Doll, T.E., Hamling, J.A., Gorecki, C.D., Pekot, L.J., Peck, W.D., Harju, J.A., Burnison, S.A., Stevens, B.G., Smith, S.A., Butler, S.K., Glazewski, K.A., Piggott, B., and Vance, A.E., 2017, Integrated carbon capture and storage for North Dakota ethanol production: Final report (November 1, 2016 – May 31, 2017) for North Dakota Industrial Commission and Red Trail Energy, Grand Forks, North Dakota, Energy & Environmental Research Center, May.

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Gorecki, C.D., Liu, G., Bailey, T.P., Sorensen, J.A., Klapperich, R.J., Braunberger, J.R., Steadman, E.N., and Harju, J.A., 2013, The role of static and dynamic modeling in the Fort Nelson CCS Project: Energy Procedia, v. 37, p. 3733–3741.

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Liu, G., Gorecki, C.D., Bremer, J.M., Klapperich, R.J., and Braunberger, J.R., 2015, Storage capacity enhancement and reservoir management using water extraction—four site case studies: International Journal of Greenhouse Gas Control, v. 35, p. 82–95.

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Principal Areas of Expertise
Mr. Hamling's principal areas of expertise include development, implementation, and oversight of surface, near-surface, deep subsurface, and reservoir characterization and monitoring programs for CO_2 storage and enhanced oil recovery operations. His expertise also includes reservoir measurement and well-logging principles and applications and the development, design, and implementation of new approaches that benefit the exploration, development, and production of oil and gas in unconventional reservoirs.

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
Mr. Hamling is a Principal Engineer who has over 10 years of experience in the oil and gas, enhanced oil recovery (EOR), and carbon capture, utilization, and storage (CCUS) industry. At the EERC, he leads the data analytics, operations, and reservoir surveillance groups focused on development, design, and implementation of approaches that benefit the exploration, development, and production of oil and gas and geologic CO_2 storage. Mr. Hamling serves as project manager and principal investigator, leading multidisciplinary teams and overseeing several U.S. Department of Energy multiyear, multimillion-dollar research projects and strategic partnerships, including the Plains CO_2 Reduction (PCOR) Partnership's Bell Creek project as well as projects related to novel automated geophysics techniques, intelligent reservoir surveillance systems, active reservoir management, tight oil EOR, and well stimulation in unconventional reservoirs. He served as PI and PM for a variety of complex DOEsponsored CCS projects including the DOE Phase 1 project entitled "Developing and Validating Pressure Management and Plume Control Strategies in the Williston Basin Through a Brine Extraction and Storage Test." This project included a design and implementation plan for a field validation of engineering strategies for managing formation pressure as well as predicting and monitoring differential pressure plume movement in the subsurface. The plan incorporated a testbed for evaluation of brine treatment technologies that may be capable of treating high-TDS extracted water for beneficial use as a means of managing and reducing extracted brine disposal volumes. Through these activities, Mr. Hamling has led all aspects of the design, planning, coordination, drilling, well logging, coring, well testing, completion, instrumentation, and workover operations of multiple deep wells for monitoring, injection, and production purposes.

PCOR Partnership Bell Creek Project Task Lead for Well Drilling and Completion and Operation Monitoring and Modeling and Assistant Task Lead for Site Characterization and Modeling. Mr. Hamling managed all aspects of design, preparation, service provider coordination, budget preparation, drilling, testing, data interpretation, on-site management, and completion of six new wells that were successfully drilled between December 2011 and April 2013 as part of the PCOR Partnership's study to demonstrate CO_2 storage potential in clastic formations in association with CO_2 EOR. Activities included

the acquisition of 64 pulsed-neutron logs, installation of a permanent 50-level multicomponent geophone array, acquisition of a +40-square-mile baseline and subsequent repeat 3-D seismic surveys, vertical seismic profile (VSP) surveys in two wells, collection of over 200 feet of 4-inch-diameter core, collection of 70 sidewall cores, installation of casing-conveyed pressure and temperature gauges and a distributed temperate system, casing-conveyed perforation, and acquisition and interpretation of a full suite of modern high-resolution well log data in multiple wells. Mr. Hamling has led all aspects of MVA for the PCOR Partnership Bell Creek project, which has been active since 20009. Mr. Hamling's experience with project management and field operations, including well drilling and completion techniques, downhole logging technologies, coring, and MVA, will be directly applicable to the proposed project.

Schlumberger Wireline Engineer. 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 a health, safety, and environmental (HSE) officer, loss prevention team lead, and explosives and radiation safety officer for wellsite activities.

Relevant Publications

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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.

Relevant Publications

Leroux, K.M., Klapperich, R.J., Azzolina, N.A., Jensen, M.D., Kalenze, N.S., Bosshart, N.W., Torres Rivero, J.A., Jacobson, L.L., Ayash, S.C., Nakles, D.V., Jiang, T., Oster, B.S., Feole, I.K., Fiala, N.J., Schlasner, S.M., Wilson IV, W.I., Doll, T.E., Hamling, J.A., Gorecki, C.D., Pekot, L.J., Peck, W.D., Harju, J.A., Burnison, S.A., Stevens, B.G., Smith, S.A., Butler, S.K., Glazewski, K.A., Piggott, B., and Vance, A.E., 2017, Integrated carbon capture and storage for North Dakota ethanol production: Final report (November 1, 2016 – May 31, 2017) for North Dakota Industrial Commission and Red Trail Energy, Grand Forks, North Dakota, Energy & Environmental Research Center, May.

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Principal Areas of Expertise

Ms. Jensen's principal areas of expertise include carbon capture and CO_2 transport infrastructure, high-pressure/high-temperature processes, production of fuels from coal and renewables, waste cleanup technologies, adsorption system design and operation, low-temperature plasma technologies, photocatalytic processes, statistical experimental design, and system modeling.

Education and Training

B.S., Chemical Engineering, University of North Dakota, 1983.
B.A., Anthropology, University of North Dakota, 1978.

Professional Experience

2011–Present: Senior Chemical Engineer, CO_2 Capture and Infrastructure Engineering Team Lead, EERC, UND. Ms. Jensen's responsibilities include supervising a team of engineers and scientists who perform research in the areas of CO_2 capture, compression, and transport via pipeline as well as document surface facility design at regional CO_2 storage sites. Specific activities in this area include matching CO_2 capture technologies with utility and industrial sources, suggesting appropriate compression technologies, and developing theoretical pipeline networks to optimize the transport of the CO_2 for storage or beneficial use. Ms. Jensen and her team also perform life cycle analyses of products to determine their carbon intensities. The engineering team studies and evaluates coal combustion, water treatment, and photocatalytic processes and develops carbon management plans. Ms. Jensen assists with the advancement and demonstration of advanced compression processes and advises on direct liquefaction projects. She works to develop fuels from biomass or CO_2. Ms. Jensen designs, develops, operates, and/or evaluates complex processes and equipment, including CO_2 capture systems. She develops statistically designed experimental matrices; tracks, reduces, and interprets data generated during research projects; and derives empirical models describing system behavior. Ms. Jensen develops integrated, multiproject programs to meet both the immediate and long-term needs of clients; prepares or assists with the preparation of proposals and supporting documentation; develops comprehensive QA/QC plans; and prepares patent applications. Her project management activities include detailed program planning; scheduling of equipment and personnel; budget monitoring; maintenance of project schedules, dissemination of research results through reports, papers, and presentations; and communication with clients.

1985–2011: Research Engineer, EERC, UND. Ms. Jensen performed research in the areas of CO_2 capture and storage, reaction engineering, coal combustion, reburning, hazardous waste treatment, gas-phase particulate and mercury collection, photocatalytic processes, fuel production from biomass, contaminated water cleanup, and phytoremediation. She designed, developed, operated, and/or evaluated complex processes and equipment, including column CO_2 capture systems, high-pressure/high-temperature coal conversion systems, low-temperature plasma systems, and multicolumn sorption systems. She identified promising carbon sequestration opportunities by matching CO_2 capture technologies with point sources, pairing those combinations with nearby geologic sinks, and performing the preliminary compressor and

pipeline specifications. She evaluated and compared characterization, remediation, and decontamination technologies for application to waste treatment/cleanup programs. Ms. Jensen developed statistically designed experimental matrices; tracked, reduced, and interpreted data generated during research projects; and derived empirical models describing system behavior. Ms. Jensen also developed integrated, multiproject programs to meet both the immediate and long-term needs of clients; prepared or assisted with the preparation of proposals and supporting documentation; developed comprehensive QA/QC plans; and prepared patent applications. Her project management activities included detailed program planning; scheduling of equipment and personnel; budget monitoring; maintenance of project schedules, dissemination of research results through reports, papers, and presentations; and communicating with clients.

Patents

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Jensen, M.D. Risks Associated with Capture, Compression, and Transport of CO_2. Presented at the Risk Management for CCS Projects Training Seminar, Calgary, AB, May 18, 2010.

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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.

Relevant Publications
Crocker, C.R., and Daly, D.J., 2017, The Bell Creek story – CO_2 in action [DVD]: Dambach, B., and Gorecki, C.D., executive producers, Fargo, North Dakota, Prairie Public Broadcasting, and Grand Forks, North Dakota, Energy & Environmental Research Center.

Daly, D.J., and Crocker, C.R., 2017, Energy and CO_2 management—carbon capture and storage: Presented at the 2017 Lignite Education Seminar, Bismarck, North Dakota, June 13, 2017.

Daly, D.J., Crocker, C.R., and Gorecki, C.D., 2016, Regionwide outreach in a project-level world – lessons from the PCOR Partnership: Paper presented at the 13th International Conference on Greenhouse Gas Control Technologies (GHGT-13), Lausanne, Switzerland, November 14–18, 2016.

Sacuta, N., Daly, D.J., Botnen, B.W., and Worth, K., 2016, Communicating about the geological storage of carbon dioxide – comparing public outreach for CO2 EOR and saline storage projects: Paper presented at the 13th International Conference on Greenhouse Gas Control Technologies (GHGT-13), Lausanne, Switzerland, November 14–18, 2016.

Daly, D.J., Crocker, C.R., Crossland, J.L., and Gagner, K.L., 2015, Energy conservation—a household's contribution to reducing our carbon footprint: Final report (July 1, 2014 – December 31, 2015) for North Dakota Cooperative Agreement No. 3726-SEP14-EE, EERC Publication 2015-EERC-12-12, Grand Forks, North Dakota, December.

Daly, D.J., Crocker, C.R., Crossland, J.L., Gorecki, C.D., and Steadman, E.N., 2015, PCOR Partnership—multifaceted and multilevel outreach: Poster presented at the Transforming Technology Through Integration and Collaboration Carbon Storage R&D Project Review Meeting, Pittsburgh, Pennsylvania, August 18–20, 2015.

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Daly, D.J., Crocker, C.R., Crossland, J.L., Gorecki, C.D., Steadman, E.N., and Harju, J.A., 2014, Regional and project-based CCUS outreach – the PCOR Partnership experience: Poster presented at the 2014 IEAGHG Social Research Network Annual Meeting, Calgary, Alberta, January 14–15, 2014.

Daly, D.J., Crocker, C.R., Dambach, B., Pearson, B., and Anderson, D., 2014, A collaboration among Prairie Public Broadcasting, classroom teachers, and the PCOR Partnership to produce classroom-ready CCS lessons: Presented at the International Workshop on Public Education, Training, and Community Outreach for Carbon Capture, Utilization, and Storage, Decatur, Illinois, July 30, 2014.

Wade, S., Cather, M., Cumming, L., Daly, D.J., Garrett, G., Greenberg, S., Myhre, R., Stone, M., and Tollefson, L., 2014, Digital communications—status and potential applications for CCUS public outreach: Energy Procedia, v. 63, p. 7070–7086.

Daly, D.J., and Wade, S., 2013, Message mapping for CCUS outreach—testing communications through focus group discussion: Energy Procedia, v. 37, p. 7346–7352.

Daly, D.J., 2012, Best practices in public outreach – what have we learned?: Presentation and panel discussion for the Outreach and Public Engagement Workshop at the 11th Annual Conference on Carbon Capture Utilization & Sequestration, Pittsburgh, Pennsylvania, April 30 – May 3, 2012.

Daly, D.J., Bradbury, J., Garrett, G., Greenberg, S., Myhre, R., Peterson, T., Tollefson, L., Wade, S., and Sacuta, N., 2011, Road-testing the outreach best practices manual—applicability for implementation of the development phase projects by the regional carbon sequestration partnerships: Energy Procedia, v. 4, p. 6256–6262.

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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

Relevant Publications

Hamling, J.A., Klapperich, R.J., Stepan, D.J., and Jacobson, L.L., 2017, Implementing and validating reservoir pressure management strategies in the Williston Basin: Poster presented at the Carbon Capture, Utilization & Storage Conference, Chicago, Illinois, April 10–13, 2017.

Hamling, J.A., Stepan, D.J., and Klapperich, R.J., 2017, Integrating monitoring data—understanding reservoir behavior and CO_2 movement at the Bell Creek commercial CO_2 EOR project: Presented at the IEAGHG Monitoring Network Meeting, Traverse City, Michigan, June 13–15, 2017.

Klapperich, R.J., Nakles, D.V., and Gorecki, C.D., 2017, Special issue of IJGGC – nexus of water and carbon capture and storage: Plains CO_2 Reduction (PCOR) Partnership Phase III Task 14 Deliverable D106 for U.S. Department of Energy National Energy Technology Laboratory Cooperative Agreement No. DE-FC26-05NT42592, EERC Publication 2017-EERC-06-04, Grand Forks, North Dakota, Energy & Environmental Research Center, May.

Leroux, K.M., Klapperich, R.J., Azzolina, N.A., Jensen, M.D., Kalenze, N.S., Bosshart, N.W., Torres Rivero, J.A., Jacobson, L.L., Ayash, S.C., Nakles, D.V., Jiang, T., Oster, B.S., Feole, I.K., Fiala, N.J., Schlasner, S.M., Wilson IV, W.I., Doll, T.E., Hamling, J.A., Gorecki, C.D., Pekot, L.J., Peck, W.D., Harju, J.A., Burnison, S.A., Stevens, B.G., Smith, S.A., Butler, S.K., Glazewski, K.A., Piggott, B., and Vance, A.E., 2017, Integrated carbon capture and storage for North Dakota ethanol production: Final report (November 1, 2016 – May 31, 2017) for North Dakota Industrial Commission and Red Trail Energy, Grand Forks, North Dakota, Energy & Environmental Research Center, May.

Hamling, J.A., Klapperich, R.J., Stepan, D.J., Sorensen, J.A., Pekot, L.J., Peck, W.D., Jacobson, L.L., Bosshart, N.W., Hurley, J.P., Wilson IV, W.I., Kurz, M.D., Burnison, S.A., Salako, O., Musich, M.A., Botnen, B.W., Kalenze, N.S., Ayash, S.C., Ge, J., Jiang, T., Dalkhaa, C., Oster, B.S., Peterson, K.J., Feole, I.K., Gorecki, C.D., and Steadman, E.N., 2016, Field implementation plan for a Williston Basin brine extraction and storage test: Phase I topical report for U.S. Department of Energy National Energy Technology Laboratory Cooperative Agreement No. DE-FE0026160, Grand Forks, North Dakota, Energy & Environmental Research Center, April.

Leroux, K.M., Glazewski, K.A., Kalenze, N.S., Botnen, B.W., Stepan, D.J., Klapperich, R.J., and Hamling, J.A., 2016, Lessons learned in near-surface monitoring for large-scale CO_2 storage: Presented at the 2016 AIChE Annual Meeting, San Francisco, California, November 13–18, 2016.

Klapperich, R.J., Jensen, M.D., Stepan, D.J., Gorecki, C.D., and Nakles, D.V., 2015, Long-term protection of freshwater resources: Poster presented at the PCOR Partnership Annual Membership Meeting, Chicago, Illinois, September 16–17, 2015.

Liu, G., Gorecki, C.D., Bremer, J.M., Klapperich, R.J., and Braunberger, J.R., 2015, Storage capacity enhancement and reservoir management using water extraction—four site case studies: International Journal of Greenhouse Gas Control, v. 35, p. 82–95.

Klapperich, R.J., Liu, G., Stepan, D.J., Jensen, M.D., Gorecki, C.D., Steadman, E.N., Harju, J.A., and Nakles, D.V., 2014, IEAGHG investigation of extracted water from CO_2 storage—potential benefits of water extraction and lesson learned: Energy Procedia, v. 63, p. 7173–7186.

Liu, G., Gorecki, C.D., Saini, D., Bremer, J.M., Klapperich, R.J., and Braunberger, J.R., 2013, Four-site case study of water extraction from CO_2 storage reservoirs: Energy Procedia, v. 37, p. 4518–4525.

LONNY L. JACOBSON
Senior Operations Specialist
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
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Principal Areas of Expertise

Mr. Jacobson's principal areas of interest and expertise include optimizing wellsite layout for well servicing/completions, well design, 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, 2017; 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 designing field implementation plans and 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.

Relevant Publications

Leroux, K.M., Klapperich, R.J., Azzolina, N.A., Jensen, M.D., Kalenze, N.S., Bosshart, N.W., Torres Rivero, J.A., Jacobson, L.L., Ayash, S.C., Nakles, D.V., Jiang, T., Oster, B.S., Feole, I.K., Fiala, N.J., Schlasner, S.M., Wilson IV, W.I., Doll, T.E., Hamling, J.A., Gorecki, C.D., Pekot, L.J., Peck, W.D., Harju, J.A., Burnison, S.A., Stevens, B.G., Smith, S.A., Butler, S.K., Glazewski, K.A., Piggott, B., and Vance, A.E., 2017, Integrated carbon capture and storage for North Dakota ethanol production: Final report (November 1, 2016 – May 31, 2017) for North Dakota Industrial Commission and Red Trail Energy, Grand Forks, North Dakota, Energy & Environmental Research Center, May.

Hamling, J.A., Klapperich, R.J., Stepan, D.J., Sorensen, J.A., Pekot, L.J., Peck, W.D., Jacobson, L.L., Bosshart, N.W., Hurley, J.P., Wilson IV, W.I., Kurz, M.D., Burnison, S.A., Salako, O., Musich, M.A., Botnen, B.W., Kalenze, N.S., Ayash, S.C., Ge, J., Jiang, T., Dalkhaa, C., Oster, B.S., Peterson, K.J., Feole, I.K., Gorecki, C.D., and Steadman, E.N., 2016, Field implementation plan for a Williston Basin brine extraction and storage test: Phase I topical report for U.S. Department of Energy National Energy Technology Laboratory Cooperative Agreement No. DE-FE0026160, Grand Forks, North Dakota, Energy & Environmental Research Center, April.

DR. NICHOLAS A. AZZOLINA
Principal Hydrogeologist and Statistician
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
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Principal Areas of Expertise

Dr. Azzolina is a hydrogeologist and statistician with 20 years of industrial and consulting experience, specializing in statistical analysis and modeling of large, complex environmental data sets.

Qualifications

Ph.D., Environmental Management and Science, Carnegie Mellon University, 2015.
M.S., Hydrogeology, Syracuse University, 2005.
B.A., Geological and Geophysical Sciences, Princeton University, 1997.
Proficient in the use of:

- Microsoft Word, Excel, PowerPoint, and Access
- Visual MODFLOW and Ground Water Vistas (groundwater modeling)
- ESRI ArcMap, SEGA GIS, Visual Sample Plan (geospatial mapping)
- PHREEQC and VisualMINTEQ (geochemical reaction modeling)
- Minitab, Netica, PAST, R, and SAS (statistical modeling)

Professional Experience

December 2016–Present: Principal Hydrogeologist and Statistician, EERC, UND. Dr. Azzolina performs statistical data analyses and supports projects related to CO_2 enhanced oil recovery (EOR), CO_2 storage, unconventional oil and gas production, and chemical contamination of environmental media (soil, groundwater, and sediment). He also specializes in conducting life cycle assessments for carbon capture, utilization, and storage (CCUS) projects and leads risk assessments for CO_2 storage, EOR, and other subsurface projects.

2010–Present: Independent Consultant, The CETER Group, Inc.
2008–2010: Scientist/Project Manager, Foth, Green Bay, Wisconsin.
2005–2008: Scientist/Project Manager, The RETEC Group, Inc., Ithaca, New York.
2004–2005: Scientist, O'Brien and Gere Engineers, Inc., Syracuse, New York.
2003–2005: Research Assistant/Head Teaching Assistant, Syracuse University, Department of Earth Science, Syracuse, New York.
2000–2003: Supervisor, McMaster-Carr Supply Co., Dayton, New Jersey.
1997–2000: Senior Field Engineer, Schlumberger Oilfield Services, Edinburg, Texas.

Relevant Publications

Leroux, K.M., Klapperich, R.J., Azzolina, N.A., Jensen, M.D., Kalenze, N.S., Bosshart, N.W., Torres Rivero, J.A., Jacobson, L.L., Ayash, S.C., Nakles, D.V., Jiang, T., Oster, B.S., Feole, I.K., Fiala, N.J., Schlasner, S.M., Wilson IV, W.I., Doll, T.E., Hamling, J.A., Gorecki, C.D., Pekot, L.J., Peck, W.D., Harju, J.A., Burnison, S.A., Stevens, B.G., Smith, S.A., Butler, S.K., Glazewski, K.A., Piggott, B., and Vance, A.E., 2017, Integrated carbon capture and storage for North Dakota ethanol production: Final report (November 1, 2016 – May 31, 2017) for North Dakota Industrial Commission and Red Trail Energy, Grand Forks, North Dakota, Energy & Environmental Research Center, May.

Azzolina, N.A., Kreitinger, J.P., Skorobogatov, Y., Shaw, R.K., Mascuch, L., and Ripp, J.A., in press, Background concentrations of PAHs and metals in surface and subsurface soils collected throughout Manhattan, New York: Environmental Forensics.

Azzolina, N.A., Peck, W.D., Hamling, J.A., Gorecki, C.D., Ayash, S.C., Doll, T.E., Nakles, D.V., and Melzer, L.S., in press, How green is my oil? a detailed look at greenhouse gas accounting for CO_2-enhanced oil recovery (CO_2-EOR) sites: International Journal of Greenhouse Gas Control.

Azzolina, N.A., Nakles, D.V., Gorecki, C.D., Peck, W.D., Ayash, S.C., Melzer, L.S., and Chatterjee, S., 2015, CO_2 storage associated with CO_2 enhanced oil recovery – a statistical analysis of historical operations: International Journal of Greenhouse Gas Control, v. 37, p. 384–397.

Siegel, D.I., Azzolina, N.A., Smith, B.J., Perry, A.E., and Bothun, R.L., 2015, Methane concentrations in water wells unrelated to proximity to existing oil and gas wells in northeastern Pennsylvania: Environmental Science and Technology, v. 49, no. 7, p. 4106–4112.

Azzolina, N.A., Small, M.J., Nakles, D.V., Glazewski, K.A., Peck, W.D., Gorecki, C., Bromhal, G.S., and Dilmore, R.M., 2015, Quantifying the benefit of wellbore leakage potential estimates for prioritizing long-term MVA well sampling at a CO_2 storage site: Environmental Science and Technology, v. 49, no. 2, p.1215–1224.

Azzolina, N.A., Neuhauser, E.F., Finn, J.T., Crawford, T.R., Anders, K.A., Doroski, M.A., Perretta, A.C., Distler; M.A., and Heitzman, G.W., 2014, Volatile organic compounds from coal tar and soil vapor samples at manufactured gas plant (MGP) sites: Environmental Forensics, v. 15, no. 3, p. 225–233.

Azzolina, N.A., Small, M.J., Nakles, D.V., and Bromhal, G.S., 2014, Effectiveness of subsurface pressure monitoring for brine leakage detection in an uncertain CO_2 sequestration system: Stochastic Environmental Research and Risk Assessment, v. 28, p. 895–909.

MARC D. KURZ
Senior Geologist, Process Chemistry and Development Team Lead
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
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Principal Areas of Expertise

Mr. Kurz's principal areas of interest and expertise include process chemistry analytical applications, design, operation, and maintenance of laboratory- and pilot-scale reactor testing systems for biofuel development, biofuel chemistry and analysis, design and implementation of subsurface and groundwater remediation technologies, and geophysical characterization testing.

Qualifications

B.S., Environmental Geology and Technology, University of North Dakota, 1993.
Postgraduate coursework in soil sciences, groundwater remediation, global change issues, satellite image processing, and geographic information systems (GIS), 2001–2007.

Professional Experience

2010–Present: Senior Geologist, Process Chemistry and Development Team Lead, EERC, UND. Mr. Kurz coordinates and conducts the analysis of various laboratory- and pilot-scale reactor product and by-product effluents to provide data for the calculation of material balances, conversions, and product qualities in support of EERC projects. Mr. Kurz provides a variety of general and specialized analytical testing, including wet-chemical testing, thermogravimetric analysis (TGA)/differential calorimetry scanning (DSC), gas chromatography/mass spectrometry, flash point and cold-flow properties of fuels, and refinery gas analysis (RGA).

2007–2010: Research Scientist, Renewable Energy and Biofuel Technology, EERC, UND. Mr. Kurz served as a research scientist on projects related to alternative energy technologies. His primary responsibilities included conducting laboratory- and pilot-scale research experiments related to biofuel technology and operating various laboratory analytical instruments.

2000–2007: Research Scientist, Subsurface Treatment and Remediation Research, EERC, UND. Mr. Kurz served as a manager and co-principal investigator on a variety of research projects related to groundwater remediation and oil and gas industry-related issues. His responsibilities included supervision of graduate research assistants and fieldwork personnel, proposal writing, budget management, and presentation of project research at a variety of technical conferences.

1996–2000: Geologist/Research Scientist, Groundwater Remediation Program, EERC, UND. Mr. Kurz's responsibilities included researching and report writing on various remediation technologies for contaminated groundwater and soils, conducting extensive fieldwork activities, and performing analytical laboratory testing. In addition, he was involved in research related to the exploration, production, and environmental aspects of coalbed methane exploitation.

1994–1996: Research Assistant, Water and Wastewater Treatment, EERC, UND. Mr. Kurz's primary responsibilities included various field- and laboratory-based research on a variety of water and wastewater remediation projects.

Relevant Publications

Folkedahl, B.C., Wocken, C.A., Kurz, M.D., and Strege, J.R., 2013, Activity 2.3 – Production of bio-derived platform chemicals: Final report for U.S. Department of Energy National Energy Technology Laboratory Grant No. DE-FG36-08G088054, EERC Publication 2013-EERC-05-01, Grand Forks, North Dakota, Energy & Environmental Research Center, May.

Wocken, C.A., Oster, B.G., Kurz, M.D., and Aulich, T.R., 2011, Renewable oil refinery development for commercialization: Final report (July 1, 2009 – June 30, 2011) for North Dakota Industrial Commission Contract No. R004-010, EERC Publication 2011-EERC-06-22, Grand Forks, North Dakota, Energy & Environmental Research Center, June.

Pansegrau, P.D., Aulich, T.R., Wocken, C.A., Kurz, M.D., and Oster, B.G., 2010, Triacylglyceride as a feedstock for jet fuel production: Presented at the 101st American Oil Chemists' Society (AOCS) Meeting & Expo, Phoenix, Arizona, May 16–19, 2010.

GERALD BACHMEIER

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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

INTEGRATED CARBON CAPTURE AND STORAGE FOR NORTH DAKOTA
EERC PROPOSAL #2017-0139

PURPOSE	DESTINATION	NUMBER OF TRIPS	NUMBER OF PEOPLE		TOTAL
Project Kickoff Mtg.	Richardton, ND	1	3	$	855
Regulatory/Permitting	Bismarck, ND	2	4	$	3,764
Market Pathway Mtg.	Portland, OR	1	2	$	3,149
Market Pathway Mtg.	Sacramento, CA	1	2	$	3,699
Field Sampling	Richardton, ND	1	1	$	1,109
Final Report Update Mtg.	Richardton, ND	1	3	$	855
TOTAL ESTIMATED TRAVEL				$	13,431

BUDGET JUSTIFICATION

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.

Budget category descriptions presented below are for informational purposes; some categories may not appear in the budget.

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

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

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

Equipment: If equipment (value of $5000 or more) is budgeted, it is discussed in the text of the proposal and/or identified more specifically in the accompanying budget detail.

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.

Consultants: Trimeric will participate during in this project by supporting the gas sampling and analyses and infrastructure design update activities. If design changes are necessary, Trimeric will employ established methods for a budgetary (±10%) cost estimate of the capture, compression, and dehydration facilities. Trimeric has access to extensive in-house data sets containing actual costs for various commercial capture system components that can be used for the proposed project.

Professional Fees: Not applicable.

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

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

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

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

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

EERC recharge center rates are established annually.

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

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

Shop and operations recharge fees cover specific expenses related to the pilot plant and the required expertise of individuals who perform related activities. Fees may be incurred in the pilot plant, at remote locations, or in EERC laboratories whenever these particular skills are required. The rate includes such items as specialized safety training, personal safety items, fall protection harnesses and respirators, CPR certification, annual physicals, protective clothing/eyewear, research by-product disposal, equipment repairs, equipment safety inspections, and labor to direct these activities. The estimated cost is based on the number of hours budgeted for this group of individuals.

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

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

Cost Share: The EERC, through its Fossil Energy Cooperative Agreement with DOE under the task for Carbon Storage Research and Development, will provide $200,000 in cash. In addition, in-kind cost share in the amount of $145,000 will be provided in the form of services. The services provided by Red Trail Energy, LLC (RTE) will provide for more comprehensive baseline sampling efforts at the RTE facility needing to account for operation variability inherent to the ethanol production process where results will convey design and potential cost consideration to other ND ethanol producers.

APPENDIX D

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REFERENCES CITED

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