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

May 28, 2021

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

Dear Ms. Fine:

Subject: EERC Proposal No. 2021-0186 Entitled "Hydrogen Energy Development for North Dakota"

The Energy & Environmental Research Center (EERC) is pleased to submit this proposal following the directive set forth in Section 15 of Senate Bill 2014 of the Sixty-Seventh Legislative Assembly of North Dakota, as signed into law by Governor Burgum.

Enclosed please find an original and one copy of the subject proposal along with a check for $100. The EERC, a research organization within the University of North Dakota, an institution of higher education within the state of North Dakota, is not a taxable entity; therefore, it has no tax liability.

This transmittal letter represents a binding commitment by the EERC to complete the project described in this proposal. If you have any questions, please contact me by telephone at (701) 777-5273, by fax at (701) 777-5181, or by e-mail at cwocken@undeerc.org.

Sincerely,

DocuSigned by:
Chad Wocken
4A1E2E3014A6467...

Chad A. Wocken
Assistant Director, Clean Energy Solutions

Approved by:

DocuSigned by:
29499751F2B84D7...

Charles D. Gorecki, CEO
Energy & Environmental Research Center

CAW/rlo

Enclosures

c/enc: Lynn Helms, North Dakota Industrial Commission
Brent Brannan, Oil and Gas Research Council

Oil and Gas Research Program

North Dakota

Industrial Commission

Application

Project Title: Hydrogen Energy Development for North Dakota

Applicant: Energy & Environmental Research Center

Principal Investigator: Chad A. Wocken

Date of Application: May 28, 2021

Amount of Request: $500,000

Total Amount of Proposed Project: $500,000

Duration of Project: 2 years

Point of Contact (POC): Chad A. Wocken

POC Telephone: (701) 777-5273

POC E-Mail Address: cwocken@undeerc.org

POC Address:

15 North 23rd Street, Stop 9018

Grand Forks, ND 58202-9018

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ABSTRACT

Objective: The Energy & Environmental Research Center (EERC) proposes to perform a study that directly addresses Section 15 of Senate Bill 2014 of the Sixty-Seventh Legislative Assembly of North Dakota, specifically, "OIL AND GAS RESEARCH FUND - EXEMPTION - ENERGY AND ENVIRONMENTAL RESEARCH CENTER - STUDY OF HYDROGEN. Pursuant to the continuing appropriation in section 57-51.1-07.3 and notwithstanding any policies developed by the oil and gas research council requiring matching funds, the industrial commission shall use $500,000, or so much of the sum as may be necessary, from the oil and gas research fund to contract with the energy and environmental research center for a study regarding the development and implementation of hydrogen energy in the state. The study must include a plan for the development and implementation of hydrogen energy and must include consideration of existing resources, methods of production and delivery, and potential uses of hydrogen. The study may include estimates of the cost and timeline to develop infrastructure for hydrogen energy and the use of public and private partnerships to assist in the development of infrastructure for hydrogen energy. During the 2021-22 interim, the energy and environmental research center shall provide at least one report to the legislative management regarding the study."

Expected Results: This project will provide a pathway for the development of a hydrogen economy in North Dakota by producing a road map that assesses opportunities and challenges for hydrogen energy in the state. Consideration will also be given to opportunities for hydrogen-based product export.

Duration: The project duration is 24 months (July 1, 2021, to June 30, 2023). A road map for development and implementation of hydrogen energy will be reported by December 31, 2022.

Total Project Cost: $500,000

Participants: EERC researchers will actively engage industry, state leaders, and other stakeholders, leveraging expertise and existing relationships to gather information needed to develop a hydrogen road map for North Dakota's hydrogen economy.

PROJECT DESCRIPTION

The EERC proposes to address Section 15 of Senate Bill 2014 of the Sixty-Seventh Legislative Assembly of North Dakota as signed into law by Governor Burgum, specifically, "Pursuant to the continuing appropriation in section 57-51.1-07.3 and notwithstanding any policies developed by the oil and gas research council requiring matching funds, the industrial commission shall use $500,000, or so much of the sum as may be necessary, from the oil and gas research fund to contract with the energy and environmental research center for a study regarding the development and implementation of hydrogen energy in the state. The study must include a plan for the development and implementation of hydrogen energy and must include consideration of existing resources, methods of production and delivery, and potential uses of hydrogen. The study may include estimates of the cost and timeline to develop infrastructure for hydrogen energy and the use of public and private partnerships to assist in the development of infrastructure for hydrogen energy. During the 2021-22 interim, the energy and environmental research center shall provide at least one report to the legislative management regarding the study."

The proposed study will develop a road map that assesses opportunities and challenges for hydrogen production from fossil and renewable resources, infrastructure requirements for storage and distribution, and end uses. The study will characterize existing hydrogen energy systems, identify near- and long-term opportunities for expansion, and explore factors that can promote or hinder growth. Consideration will also be given to opportunities for the export of hydrogen-based products.

Objectives: This project will provide a pathway for the development of a hydrogen economy in North Dakota by producing a road map that assesses opportunities and challenges for hydrogen energy production, storage, infrastructure, and use in the state. The EERC proposes to directly address the intent of Section 15 of Senate Bill 2014 of the Sixty-Seventh Legislative Assembly of North Dakota, the text of which is provided in full in the previous sections (Abstract and Project Description).

To achieve the project goal, the EERC will use its technical experts and engage stakeholders to gather information and assess the technical, economic, environmental, and regulatory factors influencing hydrogen energy development in North Dakota.

Methodology: The EERC will conduct a literature review, communicate with stakeholders across the supply chain, perform computational modeling, and develop economic data to inform the development of a hydrogen economy in North Dakota. The EERC will create a road map for hydrogen energy in the state, to include an assessment of regional feedstocks and logistics, hydrogen demand, conversion technologies, purification, storage and distribution infrastructure, and end uses. The EERC will explore niche opportunities for hydrogen energy in North Dakota and strategies to leverage existing infrastructure to expand the scale, application, and geographic reach of a North Dakota hydrogen economy.

Hydrogen technologies provide an opportunity to transform our energy economy and leverage both fossil and renewable energy resources to provide an energy carrier (hydrogen) with end-use applications that are efficient and free of combustion-based emissions. The technologies needed to employ hydrogen-based energy span the entire supply chain; therefore, the study will assess the dependencies and identify pathways that are relevant to North Dakota resources, infrastructure, and uses:

- The study will review North Dakota feedstock (quantity and quality) and conversion pathways relevant to supporting a hydrogen economy. Assessment of scale must include both economy of scale for production/conversion technologies as well as availability of feedstock (electrolysis of water; reforming of methane and gaseous hydrocarbons; gasification of coal, biomass, and waste).
- Hydrogen demand is a critical aspect of the proposed study and will include an assessment of current, near-term, and long-term projections for hydrogen from multiple sectors.

  - Near-term opportunities for both petroleum and renewable fuel production, chemical manufacture, and export using existing pipeline infrastructure
  - Long-term opportunities for fuel cell-powered vehicles and fuel cells used for small-scale distributed power and utility-scale electrical generation

- Hydrogen end uses are varied, and differing levels of purification are necessary depending upon the application. The study will assess a variety of hydrogen uses and the processing and/or purification needed to support those uses:
  - Proton exchange membranes (PEMs) (transportation or stationary power)
  - Natural gas/hydrogen mixtures
  - High-temperature fuel cells for power and heat
  - Hydrogen for petroleum and renewable fuel (diesel and jet) production
  - Ammonia synthesis for fertilizer and as an energy storage medium
- Hydrogen storage, distribution, and dispensing infrastructure requirements vary widely in scale and magnitude and are influenced by production strategies, uses, and commercial penetration. Additionally, infrastructure buildout is challenged by the “chicken or the egg” dilemma. The study will investigate opportunities to advance production, infrastructure, and end use in a collaborative way:
  - Geologic storage is necessary to support robust and resilient energy supply and offset cyclical demand profile.
  - Engineered hydrogen storage is needed to facilitate hydrogen utilization statewide.
  - Hydrogen transport by truck and pipeline facilitates widespread utilization.
  - Ammonia as an energy storage and energy transportation medium.
  - Stepwise, incremental expansion may be needed to accommodate the large geography of North Dakota.

- Prior work by a variety of groups including the EERC, the U.S. Department of Energy (DOE) Hydrogen and Fuel Cell Technology Office, Fuel Cell & Hydrogen Energy Association, and others provides a starting point for this study. Public/private partnerships, trade/industry organizations, and previous demonstration projects will be evaluated relative to the needs for North Dakota.

Anticipated Results: The result of this effort will be a report that provides a road map of opportunities and challenges for hydrogen energy in North Dakota, an outline of strategies for expanding hydrogen energy in North Dakota, and summaries of economic and environmental impacts hydrogen energy use can have on North Dakota. Specific study outcomes may include:

1) Identification and quantification of scale:
    - Magnitude of hydrogen production possible from North Dakota resources.
    - Projected hydrogen demand from multiple sectors near-term (example: fuels/refining, chemical manufacture).
    - Projected hydrogen demand from multiple sectors long-term (example: transportation, fuel cell power).
    - Storage and transport infrastructure needed to support statewide hydrogen utilization.
    - Impacts of hydrogen-based energy use on emissions (example: increased emissions from fossil-based hydrogen production or reduced emissions from reduction of fossil fuel combustion).
2) Notional timeline and costs for commercial deployment of various hydrogen energy technologies/ approaches:
    - Hydrogen production systems may include gasification, reforming, electrolysis, etc.
    - Hydrogen uses may include fuels and chemicals, energy carriers like ammonia, PEM vehicle fleet, utility-scale electricity production from hydrogen, etc.

- Hydrogen storage and distribution infrastructure such as pipelines, geologic storage, or distributed systems.

3) Assessment of approaches that can facilitate growth of a hydrogen economy (new economic development) that is supportive and value-added to existing industries such as agriculture, oil and gas, electrical generation, renewable energy, electrical grid management, etc.

The EERC anticipates that findings from this study will result in identification of pilot- or demonstration-scale projects that can de-risk commercial deployment of hydrogen technologies and systems and identify policy that can reduce risk and/or enable or incentivize investment and promote public/private partnerships seeking to promote hydrogen-based energy.

Facilities: The EERC employs a multidisciplinary staff of over 200 and has 254,000 square feet of state-of-the-art offices, laboratories, and technology demonstration facilities. EERC engineering and scientific research staff members are equipped with state-of-the-art analytical, modeling, and engineering facilities, which enable us to address a wide variety of energy, environmental, and mineral resource research topics. The EERC houses eight analytical laboratories dedicated to research, including water resource characterization; conventional and unconventional petroleum resources; environmental chemistry; and carbon capture, utilization, and storage.

Environmental and Economic Impacts while Project Is under Way: The proposed project is an engineering and modeling study. No environmental impacts are anticipated, and economic impacts consist of the labor expenditure required to perform the study.

Ultimate Technological and Economic Impacts: A primary purpose of the study is to assess the potential technological and economic impacts of hydrogen energy development and deployment in North Dakota. Hydrogen is currently used in several industrial settings (Figure 1), most notably in crude oil refining for motor fuels and in the manufacture of ammonia. Economic hydrogen production from North Dakota's

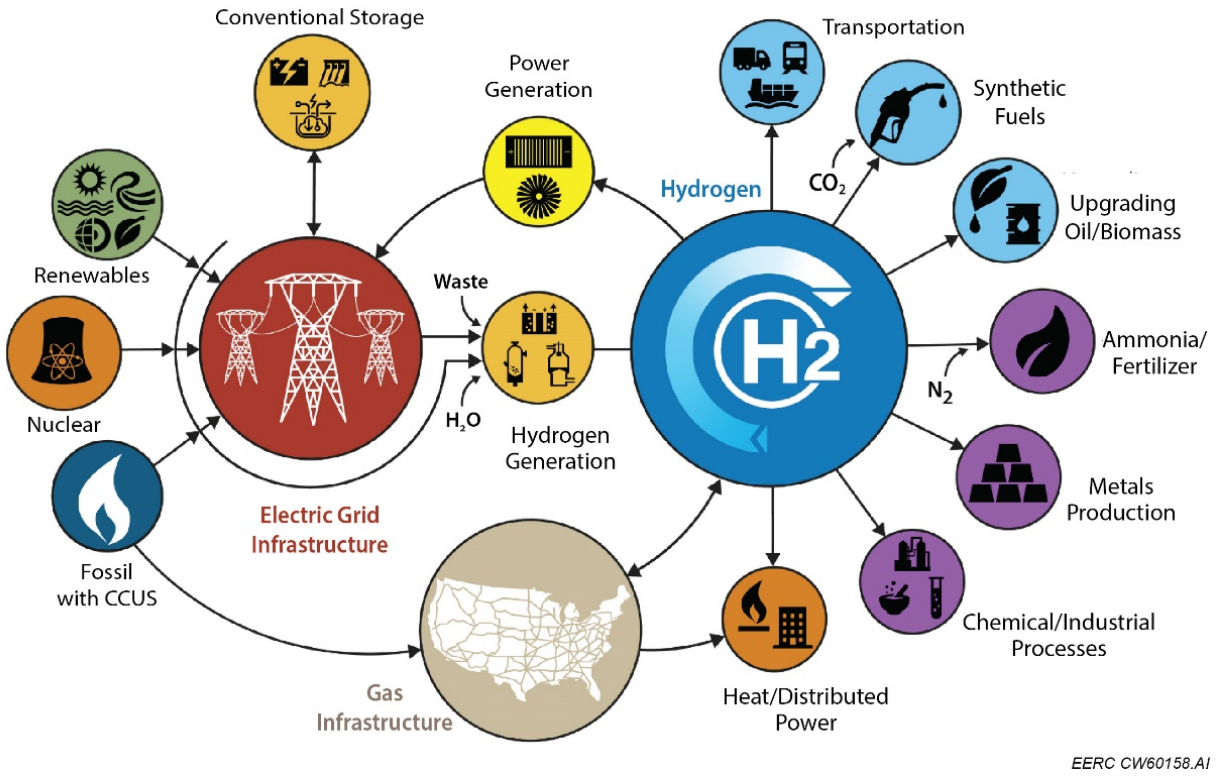
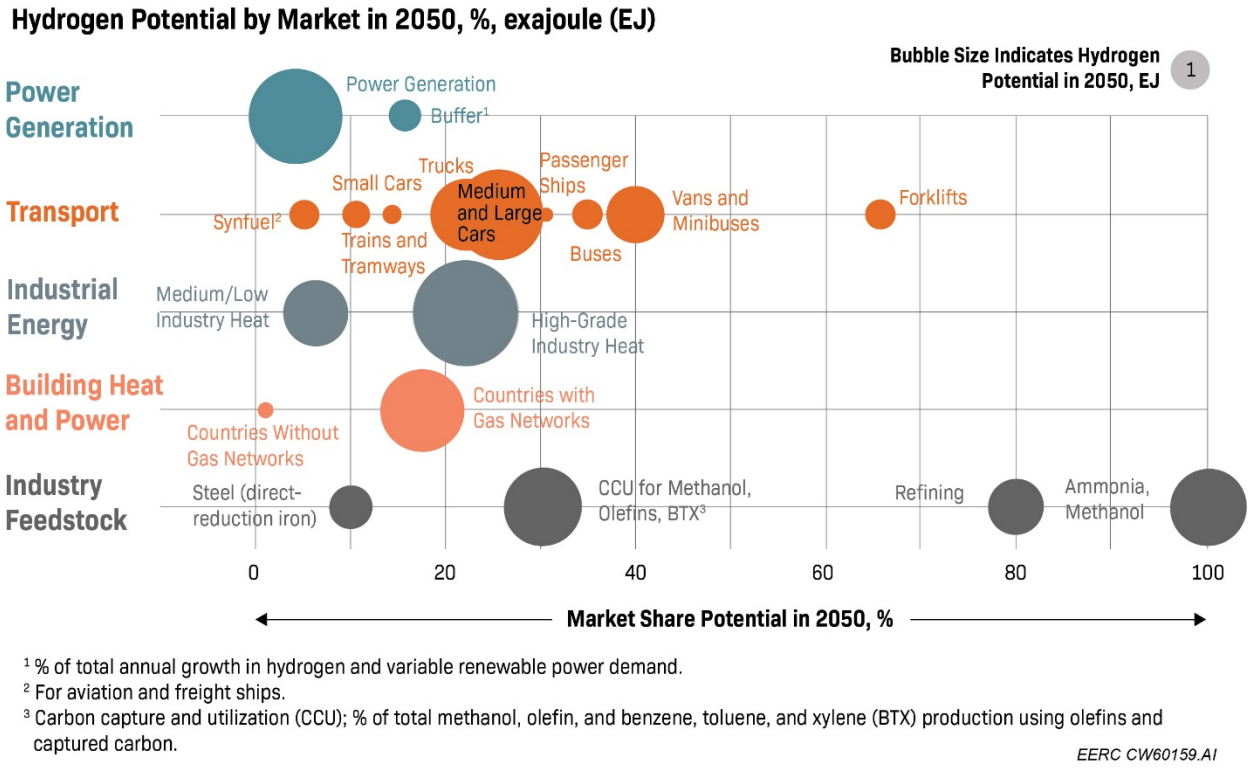


Figure 1. Conceptual hydrogen applications (DOE hydrogen program plan). CCUS stands for carbon capture, utilization, and storage.

abundant resources, specifically, natural gas, coal, biomass and agricultural residue, and electricity from fossil and renewable resources, would provide significant economic development. Additional economic impacts may be seen from the use of hydrogen in the manufacture of petroleum and renewable fuels, ammonia, and petrochemical production and as a fuel in transportation and stationary power fuel cells.

DOE's study, "Hydrogen Strategy, Enabling a Low-Carbon Economy," provides a projection for global hydrogen use in several sectors through 2050. Figure 2 provides a graphical summary of the hydrogen markets within several industrial sectors.

Why the Project Is Needed: Clean energy production and use have moved center stage, as evidenced by corporate environmental sustainability goals and mounting environmental, social, and governance (ESG) pressure from lenders and investors. North Dakota has abundant fossil and renewable energy resources. A hydrogen-based energy system can leverage these resources while enabling greater energy efficiency,



[1] % of total annual growth in hydrogen and variable renewable power demand.
[2] For aviation and freight ships.
[3] Carbon capture and utilization (CCU); % of total methanol, olefin, and benzene, toluene, and xylene (BTX) production using olefins and captured carbon.

EERC CW60159.AI

Figure 2. Global potential for future use of hydrogen (USDOE_FE_Hydrogen_Strategy_July2020.pdf [energy.gov]).

fewer environmental impacts, and reduced greenhouse gas emissions on the path to a lower carbon intensity for North Dakota.

Energy production is the largest sector of North Dakota's economy; we export almost six times the amount of energy consumed. Currently, about 95% of this energy is derived from fossil fuels at a time when customer preferences are moving toward low-carbon energy sources.

Hydrogen can be produced from a multitude of fossil and renewable resources and emits no carbon at the point of use. These features can enable North Dakota to maintain and grow its status as a major energy-producing state, and with carbon capture, improved efficiency, and agricultural practices, significant improvements in carbon reduction can be achieved.

The opportunity for North Dakota lies in its natural resources and existing infrastructure capable of producing, storing, and distributing hydrogen at a cost-competitive scale. Agricultural resources and

fossil fuels can provide feedstock for hydrogen production. Renewable wind and solar systems, coal, and natural gas-generated electricity, along with North Dakota's abundant water resources, can produce hydrogen from water electrolysis. When coupled with carbon capture, significant decarbonization can also be achieved, enabled by geologic resources capable of storing both CO_2 and product hydrogen.

North Dakota's existing natural gas pipelines can transport blends of natural gas and low-carbon hydrogen to demand centers across the country. Further, access to large-scale storage for hydrogen can compensate for short-term or seasonal variability in hydrogen demand (fuel and chemical manufacture) and production from intermittent wind and solar electric systems.

The study, directed by the Sixty-Seventh Legislative Assembly, will provide a road map outlining opportunities and impacts of the development and implementation of hydrogen energy in the state.

STANDARDS OF SUCCESS

A successful hydrogen energy study will characterize existing hydrogen production and demand in North Dakota, describe opportunities for innovative and cost-effective development and implementation, and identify actions that may promote and/or incentivize hydrogen energy development.

A key measure of success will be the delivery of a project report that contains the findings described above. Success will also be measured by adhering to the project plan and deliverables.

BACKGROUND/QUALIFICATIONS

The EERC is a high-tech, applied research center at the University of North Dakota with over 60 years of industry and government collaboration on hydrogen technology development. In 2004, DOE designated the EERC the National Center for Hydrogen Technology® (NCHT®), which has housed research initiatives focused on techno-economic studies, technology development, and pilot- and demonstration-scale testing. EERC experience includes hydrogen production from fossil and renewable resources via conventional and novel/innovative gasification, reforming, and electrochemical technologies; development of patented processes for producing hydrogen from liquid feedstocks at high pressure;

hydrogen separation and purification through conventional and emerging technologies, both pressure-driven and electrochemical; hydrogen utilization via direct combustion, conversion to fuels and chemicals, and oxidation in fuel cells for electricity generation; extension of novel, proprietary EERC bonding technologies to join high-temperature, hydrogen-compatible materials that enable more efficient hydrogen and power production; and development of tools to increase efficiency and reliability of gasification systems through improved fuel selection and preparation, among others.

The EERC's expertise across all energy sectors, and strong relationships with North Dakota industry, state agencies, and academic organizations provide the collaborative relationships needed to perform this broad-reaching study and identify ways to benefit those impacted by hydrogen.

Personnel: The project team has decades of experience working on projects involving hydrogen production, engineered systems and infrastructure, geologic storage, and use. Resumes of key personnel are provided in Appendix A. Chad Wocken, EERC Assistant Director for Clean Energy Solutions, will serve as Project Manager. Other key EERC personnel include Chris Martin, Principal Engineer for Advanced Thermal Systems; Josh Strege, Assistant Director for Energy Systems; Ted Aulich, Principal Process Chemist for Fuels and Chemicals; Steve Schlasner, Senior Engineer; Bruce Folkedahl, Senior Research Engineer; and Arash Abarghani, Research Scientist.

MANAGEMENT

The EERC manages over 200 contracts a year, with more than 1300 clients in 53 countries. Systems ensure that projects are managed within budget, schedule, and scope. Mr. Wocken will oversee the project and be responsible for project coordination, guidance, and supervision to ensure consistent progress and adherence to budget and schedule constraints. EERC leadership team will provide management assistance. Quarterly progress reports will be submitted to NDIC 30 days after the end of each calendar quarter. At least one report will be provided to legislative management, NDIC, and the Oil and Gas Research Council by December 31, 2022, summarizing the results of the proposed study.

TIMETABLE

This proposed project duration is 24 months, beginning July 1, 2021, and ending June 30, 2023.

BUDGET

The total estimated cost for the scope of work is $500,000. The budget provided in the table was developed based on estimates to perform the scope of work and experience with similar projects. Cost share is not proposed as prescribed in Senate Bill 2014. Budget notes are included in Appendix B.

Project Associated Expense	NDIC Share (Cash)
Labor	$299,186
Travel	$1,228
Supplies	$1,000
Communications	$500
Printing & Duplicating	$967
Food	$990
Laboratory Fees & Services	
EERC Graphics Services	$2,186
EERC Technical Software Fee	$21,600
EERC Engineering Services Fee	$3,469
Total Direct Costs	$331,126
Facilities & Administration	$168,874
Total Project Costs	**$500,000**

CONFIDENTIAL INFORMATION

There is no confidential information included in this proposal.

TAX LIABILITY

The University of North Dakota, EERC, is a state-controlled institution of higher education and is not a taxable entity. It has no tax liability to the state of North Dakota or any of its political subdivisions.

PATENTS/RIGHTS TO TECHNICAL DATA

No patentable technologies are expected to be created during this work.

STATUS OF ONGOING PROJECTS

The EERC's ongoing NDIC projects funded through the Oil& Gas Research Program as listed below and are current on all deliverables.

Project Title	Contract Award No.
NDIC Emerging Issues	G-000-004
iPIPE: The Intelligent Pipeline Integrity Program	G-046-88
Underground Storage of Produced Natural Gas – Conceptual Evaluation	G-049-092
Improving EOR Performance Through Data Analytics and Next-Generation Controllable Completions	G-050-97
PCOR Partnership Initiative to Accelerate CCUS Deployment	G-050-96
Produced Water Management Through Geologic Homogenization	G-051-101
Bakken Production Optimization Program 3.0	G-051-98

APPENDIX A

RESUMES OF KEY PERSONNEL

CHAD A. WOCKEN
Assistant Director for Clean Energy Solutions
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, North Dakota 58202-9018 USA
701.777.5273 (phone), 701.777.5181 (fax), cwocken@undeerc.org

Principal Areas of Expertise

Mr. Wocken's principal areas of research include developing alternative fuel and chemical processes and innovative energy technologies. Currently, he leads projects focused on developing and advancing alternative chemical and fuel production processes at the bench, lab, and pilot scale and optimizing processes associated with oil and gas production and midstream operations. In addition, Mr. Wocken manages a group of researchers and a lab facility containing batch and continuous reactor systems capable of testing a variety of thermochemical processes.

Qualifications

B.S., Chemical Engineering, University of North Dakota, 1994

Professional Experience

2001–Present: EERC, UND.

Assistant Director for Clean Energy Solutions (September 2019–Present). Mr. Wocken leads a multidisciplinary team of engineers and scientists focused on applying scientific principles to address the challenges to energy production. His team's applied research activities include process modeling; engineering studies; and technology evaluation and development at the bench, pilot, and demonstration scale. Mr. Wocken has over 25 years of experience spanning work in oil and gas production, fuel processing, electricity generation, emission control, environmental remediation, and process engineering. Drawing on his engineering training and diverse experience, he enjoys defining problems and developing innovative solutions to promote clean energy solutions.

Principal Engineer, Transformational Energy Group Lead (2015–August 2019); Senior Research Manager (2009–2015); Research Engineer (2001–2009).

<u>Project/Program Management</u>

- Developed a new research program and managed the design and fabrication of a facility to test and evaluate solid-oxide fuel cells with a variety of gaseous fuels including actual syngas produced from the EERC's pilot-scale gasification systems.
- Led a process-modeling team within the EERC's Bakken Production Optimization Program, focused on applying computational modeling expertise to crude oil production processes and addressing emission reduction and gas flaring while also reducing crude oil volatility.

- Directed the EERC's associated gas-flaring mitigation activities, aiding industry partners in their efforts to identify technologies to reduce flaring. These efforts led to the creation of the Flaring Solutions Database, a clearinghouse of business and technology solutions that have the potential to utilize gas at the wellhead and reduce flaring.
- Managed a Defense Advanced Research Projects Agency (DARPA)-funded project that successfully developed technology to produce drop-in-compatible jet fuel for the military from renewable feedstock. Activities included planning work activities, developing and executing a risk-based project management plan, coordinating activities of five project partners to meet project goals, and communicating with the DARPA project manager.
- Managed the scale-up and design of a 300-barrel/day renewable fuel pilot plant capable of producing specification-compliant jet and diesel fuels from renewable oil feedstock.

Technology Development and Research

- Designed and executed an oil and gas gathering pipeline leak detection demonstration project, resulting in tangible performance improvements for three pipeline operators.
- Conducted a technical and economic assessment of alternative uses for associated gas in an effort to reduce the amount of gas being flared in the Williston Basin. Technologies evaluated included gas-processing operations to recover natural gas liquids, gas-fired power generation, transportation fuel, and traditional petrochemical unit operations.
- Performed a system-level engineering evaluation of integrated algae production at a coal-fired power plant to assess carbon uptake, emission control requirements, relative scale, and the viability of water and waste heat utilization.
- Designed, fabricated, and operated several fixed-catalyst bed reactor systems to evaluate a variety of thermocatalytic processes to produce renewable fuels and chemicals.
- Conducted testing at coal-fired power plants, and developed control technologies to reduce atmospheric emission of particulate matter, mercury, and other contaminants.

1995–2001: Project Engineer, URS/Radian International, Salt Lake City, Utah (1997–2001), and Milwaukee, Wisconsin (1995–1997).

Process Design, Operation, and Optimization

- Designed remediation systems to remove BTEX compounds and chlorinated solvents from groundwater. Project tasks included site evaluation, technology selection, system design, and creation of specifications.
- Performed start-up and long-term operations of groundwater remediation systems. Responsibilities included troubleshooting equipment/system malfunctions, process optimization, writing operations and maintenance manuals, establishing performance verification criteria, defining operational cost, and directing technicians' work.
- Conducted detailed reviews of industrial wastewater treatment systems to identify alternative treatment technologies, process optimizations, and water reuse alternatives.

Construction Oversight

- Provided on-site oversight for several construction projects consisting of mechanical equipment installation, instrumentation and process control, building and road construction, excavation, and underground utility installation. Daily responsibilities included evaluating work for conformance with construction drawings and specifications; coordinating work activities; and facilitating communication between the design firm, client, and contractors.

Project Management

- Served as project manager for several large projects that were completed successfully. Activities included developing cost proposals, managing budget and schedule, equipment and subcontractor acquisition, and maintaining effective communication with the client.

1994–1995: Process Engineer, Archer Daniels Midland, Clinton, Iowa.

Plant Operation

- Supervised operations and personnel at a wet corn mill oil extraction and refining plant. Tasks consisted of prioritizing work activities, scheduling maintenance of process equipment, monitoring product quality, and extensive system troubleshooting and failure analysis.

Publications and Presentations

Has authored or coauthored numerous publications.

DR. CHRISTOPHER L. MARTIN
Principal Engineer, Advanced Thermal Systems
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, North Dakota 58202-9018 USA
701.777.5083 (phone), 701.777.5181 (fax), cmartin@undeerc.org

Principal Areas of Expertise
Dr. Martin's principal areas of expertise include thermal energy conversion, utilization, and system analysis; mitigation of environmental effects from power generation including the prevention of air emissions from combustion and gasification systems, and the minimization of water use during energy conversion processes.

Qualifications
Ph.D., Mechanical Engineering, University of Florida, Gainesville, FL, 2004.
M.S., Mechanical Engineering, University of Florida, Gainesville, FL, 2000.
B.S., Mechanical Engineering, University of North Carolina, Charlotte, North Carolina, 1998.

Professional Employment
2020–Present: Principal Engineer, Advanced Thermal Systems, EERC, UND.

2005–2019: Senior Research Engineer, Advanced Thermal Systems, EERC, UND. Dr. Martin's responsibilities include assisting with current projects in environmentally compatible power generation, contributing to research proposals, and developing new project areas for the EERC. Notable project areas include the following:

- **Water-saving cooling technology for power plants.** The focus of these projects was a technology conceived by Dr. Martin to improve the efficiency and cost-effectiveness of dry cooling for power plants. This development effort has earned phases of state, federal and commercial support.
- **Gasification technology for nontraditional fuels.** Dr. Martin devised and evaluated gasification-based systems to recover energy from industrial and commercial solid waste streams. These efforts also include a system for high-efficiency waste processing at remote military forward operating bases.
- **Air emissions control at coal-fired utilities.** Dr. Martin managed a portfolio of emission control research projects by serving as a program area manager for the EERC's Center for Air Toxic Metals® program. He also evaluated novel emissions control technologies using laboratory, pilot plant, and field demonstrations.

2002–2005: Research Assistant, Solar Energy and Energy Conversion Laboratory, University of Florida. Dr. Martin researched the conversion of low-temperature thermal energy resources using advanced thermodynamic cycles; performed tasks needed to support research work, including the design, modification, and operation of laboratory equipment; reviewed engineering literature;

and prepared technical correspondence, including progress reports, presentations, and publications.

2001–2002: Teaching Assistant, Control Systems Laboratory, University of Florida. Dr. Martin taught lecture and laboratory components for an undergraduate control systems laboratory.

2000–2001: Design Engineer, Manufacturing Laboratories, Inc., Gainesville, Florida. Dr. Martin aided the design, manufacture, and assembly of a precision machine tool; designed machine components; prepared production drawings; and interfaced with fabricators. He also supervised machine assembly operations.

1998–2000: Research Assistant, Machine Tool Research Center, University of Florida. Dr. Martin conducted applied research in the areas of machine tool dynamics and cutting tool testing and prepared technical progress reports for industrial sponsors.

Professional Memberships
American Society of Mechanical Engineers

Publications and Presentations
Has coauthored numerous publications.

JOSHUA R. STREGE
Assistant Director of Energy Systems
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, North Dakota 58202-9018 USA
Phone: (701) 777-5080, Fax: (701) 777-5181, E-Mail: jstrege@undeerc.org

Principal Areas of Expertise

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

Qualifications

M.S., Chemical Engineering, University of North Dakota, 2005. Thesis: High-Temperature Corrosion of Potential Heat Exchange Alloys under Simulated Coal Combustion Conditions.
B.S., Chemical Engineering, University of North Dakota, 2005.
Training: Project Management training through PM College, Six-Sigma Green Belt, and Design Flow Technology (DFT).
Skills: Microsoft Office suite (Excel, MS Project, Word, and Access) and advanced VBA macro programming and SQL server integration; CAD design and engineering drawing creation (PTC Creo Parametric).
Certifications: Aspen Plus- and Aspen HYSYS-certified.

Professional Experience

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

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

2013–September 2019: Project Manager and Senior Engineer, Cirrus Aircraft. Mr. Strege's responsibilities as Project Manager included building an 80-member team to develop and manufacture composite products for small aircraft under contract with an outside client. As

Senior Engineer, he led a team of engineers and technicians responsible for reducing waste, implementing root cause and corrective actions on product defects and downstream issues, and developing and implementing software solutions for improved tracking and accountability across all departments.

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

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

Publications and Presentations

Has authored and coauthored numerous professional publications and presentations.

TED R. AULICH
Principal Process Chemist, Fuels and Chemicals
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, North Dakota 58202-9018 USA
701.777.2982 (phone), 701.777.5181 (fax), taulich@undeerc.org

Professional Experience

1989–Present, Principal Process Chemist, Fuels and Chemicals, EERC, UND.

Responsibilities

- Directs renewable/alternative energy, fuel, and chemical technology development projects worth $50,000 to $5 million, with responsibility for meeting performance, schedule, and cost targets.
- Assesses technology development project opportunities on the basis of accessible performance and quality data, commercialization potential, cost, and demonstrated strength of project team.
- Summarizes data, prepares reports, and presents findings and recommendations to internal supervisors and colleagues and external clients, project partners, review boards, and investors.
- Prioritizes, plans, and directs activities of multidisciplinary staff in executing multiple projects in varying technology segments and at various stages of development.
- Exercises leadership in strategic planning, positioning of resources, mentoring junior staff, and liaising with technical and support staff at all levels to enable optimal application of skills and resources to maintaining core business strengths and capitalizing on new opportunities.
- Generates new business by developing project concepts, assembling multipartner project teams, preparing budgets, writing proposals, and directing overall proposal preparation efforts.
- Builds and maintains productive relationships with existing and potential customers, industry partners, federal and state agencies, engineering contractors, and economic development groups.

Key Accomplishments

- Partnered with the U.S. Air Force in utilizing a test stand-mounted jet aircraft engine to assess performance and emission effects of blending biodiesel into military jet fuel.
- Designed and administered surveys of commercial ethanol and nonethanol gasolines to provide statistically defendable data for assessment of fuel-related air quality effects and health risks.
- Currently chair the Research Committee of the Governors' Ethanol Coalition, an international group dedicated to increasing the presence of ethanol in the world transportation fuel market.
- Formulated a high-performance ethanol- and biodiesel-based aviation fuel certified by the U.S. Federal Aviation Administration as an alternative to lead-containing aviation gasoline.
- Designed and conducted a North Dakota statewide ethanol plant site assessment focused on evaluation of economics-enhancing collocation opportunities with energy and ag facilities.

- Designed and conducted an economic and regulatory compliance evaluation of steam generation options for a 40–60-million-gallon/year ethanol production facility.
- Designed and conducted an emissions-, fuel economy-, and performance-based evaluation of diesel fuels blended with varying levels of biodiesel and ethanol.
- Negotiated, developed, and directed a collaboration to assess the technical and economic feasibility of bus fleet-scale hydrogen generation (from natural gas) and refueling stations.
- Designed, administered, and reported results of a commercial fuel contamination analysis that enabled resolving a legal responsibility dispute prior to trial.
- Prepared an EPA-approved quality assurance plan for a $200,000 project to optimize thermal depolymerization processes for recovery of oil refinery feedstocks from waste plastics.

1987–1989, Technical Editor, EERC, UND.
1985–1987, Analytical Chemist, EERC, UND.
1983–1985, Quality Control Manager, H.B. Fuller Industrial Coatings, St. Paul, Minnesota.

Qualifications
B.S., Chemistry, University of North Dakota, Grand Forks, North Dakota, 1986.
B.S., Biology, University of St. Thomas, St. Paul, Minnesota, 1982.

Publications and Presentations
Mr. Aulich has coauthored numerous technical reports, papers, articles, and presentations and is a coinventor on several patents.

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Principal Areas of Expertise

Dr. Schlasner's principal areas of interest and expertise include hydrogen, CO_2 capture, petroleum-refining and microbial bioprocess technologies, and advanced process control.

Qualifications

Ph.D., Chemical Engineering, Ohio State University, 1987
M.S., Chemical Engineering, Ohio State University, 1983
M.B.A., University of South Dakota, 1977
B.S., Chemical Engineering, South Dakota School of Mines & Technology, 1980
B.A., Chemistry and Mathematics, St. Olaf College, 1974
Diploma, Air War College, 1997
Diploma, Air Command and Staff College, 1993
Air University by correspondence
Professional Engineer, Ohio and Oklahoma
U.S. Department of Defense Acquisition Professional in Systems Planning, Research, Development, and Engineering, certified Level II (1995), trained Level III (2000)
Master of Process Technology, certified (1997); one of the first 18 engineers certified by Phillips
Top Secret/SBI Security Clearance, updated 2004

Professional Experience

2010–Present: Research Engineer, EERC, UND, Grand Forks, North Dakota. Dr. Schlasner works on projects related to hydrogen production technology, petroleum refinery emission control, and hot-gas filtration.

1987–2009: ConocoPhillips Company (formerly Phillips Petroleum Company), Bartlesville Technology Center, Oklahoma.

2001–2009: R&D Team Lead and Chief Engineer, CO_2 Capture/H_2 Production Team, R&D Senior Engineer, Long-Range Technology.

1992–2001: Refinery Senior Engineer, Advanced Process Control, Sweeny Petrochemical Complex, Texas.

1991–1992: Refinery Engineer, Process/Operations, Bartlesville Corporate Engineering, Oklahoma.

1987–1991: Process Engineer, Plastics, Bartlesville Research Center, Oklahoma.
Process Automation Engineer, Advanced Composites
R&D Engineer, Advanced Composites
R&D Engineer, Biotechnology Division

1980–2004: Colonel, Directorate Senior Reservist, U.S. Air Force Reserve, Air Force Research Laboratory (AFRL), Ohio.
Lieutenant Colonel, Division Senior Reservist
First Lieutenant – Major:

- Biotechnology Project Engineer
- Nonmetallic Materials Project Engineer
- Chemical Research Officer

1974–1978: Second Lieutenant – First Lieutenant, U.S. Air Force Active Duty, 44th Strategic Missile Wing (SAC), South Dakota.

- Wing Operations Staff Officer
- Missile Combat Crew Commander
- Deputy Missile Combat Crew Commander

Professional Memberships

National Hydrogen Association, Director (2006–2007)
American Chemical Society
American Society for Microbiology
Tau Beta Pi
Beta Gamma Sigma

Publications and Presentations

Jensen, M.D.; Schlasner, S.M.; Gorecki, C.D.; Wildgust, N. *Opportunities and Challenges Associated with CO_2 Compression and Transport During CCS Activities*; Plains CO_2 Reduction (PCOR) Partnership Phase III Task 6 Deliverable D85 for U.S. Department of Energy National Energy Technology Laboratory Cooperative Agreement No. DE-FC26-05NT42592; EERC Publication 2017-EERC-06-17; Energy & Environmental Research Center: Grand Forks, ND, May 2017.

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Wocken, C.W.; Stevens, B.G.; Almlie, J.C.; Schlasner, S.M. End-Use Technology Study – An Assessment of Alternative Uses for Associated Gas; Topical Report for North Dakota Industrial Commission Contract No. G024-052; Energy & Environmental Research Center: Grand Forks, ND, Sept 2012.

Schlasner, S.M.; Almlie, J.C. *Demonstration of Pratt & Whitney Rocketdyne's Hydrogen Generator Technology – Phases I–III (Years 3–5 – Activity 3.2 – Development of a National Center for Hydrogen Technology*; Topical Report for U.S. Department of Energy National Energy Technology Laboratory Cooperative Agreement No. DE-FC26-05NT42465; Energy & Environmental Research Center: Grand Forks, ND, March 2011.

Miracca, I.; Ingvar Åsen, K.; Assink, J.; Coulter, C.; Curran, L.; Lowe, C.; Torres Moure, G.; Schlasner, S. The CO_2 Capture Project (CCP): Results from Phase II (2004–2009). *Energy Proc.* **2009**, *1* (1), 55–62.

Garland, R.; Schlasner, S.M. Hydrogen Production: Pathways and Status. Presented at the 234th American Chemical Society National Meeting, Boston, MA, Aug 19–23, 2007.

Schlasner, S.M. Design and Implementation of a Flexible, Integrable DCS Based on a Real-Time, Message-Passing Networked Operating System. In *Proceedings of the Industrial Computing Conference;* Anaheim, CA, Oct 27–31, 1991; pp 469–478.

Luli, G.W.; Schlasner, S.M.; Ordaz, D.E.; Mason, M.; Strohl, W.R. An Automatic Online Glucose Analyzer for Feed-Back Control of Fed-Batch Growth of Escherichia Coli. *Biotechnol. Techniq.* **1987**, *1*, 223–228.

Schlasner, S.M. Strohl, W.R.; Lee, W.-K. On-Line Adaptive, Optimal Control of a Fed-Batch Fermentation of Streptomyces C-5. In *Proceedings of the 1987 American Control Conference*; Minneapolis, MN, June 10–12, 1987 ("Control and Optimization of Biochemical Processes" session best paper award).

Blackwell, J.V.; Schlasner, S.M.; Jivatadavirute, W.; Strohl, W.R. Computer-Controlled Gradient Feed Process for High-Density Fermentation of an Anthracycline-Producing Streptomycete. Presented at the 87th Annual Meeting of the American Society for Microbiology, Atlanta, GA, March 1–6, 1987.

Tsai, Y.-L.; Schlasner, S.M.; Tuovinen, O.H. Inhibitor Evaluation with the Use of Immobilized Cells of Nitrobacter agilis. *Appl. Environ. Microbiol.* **1986**, *52*, 1231–1235.

Strohl, W.R.; Schlasner, S.M.; Lorenson, P.L. Microcomputer-Control of Fermentation Processes. *Biotechniq.* **1986**, *4* (4), 336–344.

Strohl, W.R.; Schlasner, S.M.; Lorenson, P.L.; Blackwell, J.V. Computer Assisted Fermentation of Microorganisms. Presented at the 1985 International High-Technology Biomedical Conference, Pharmaceutical & Toxicological Institute of the Ohio State University, Columbus, OH, Nov 3–15, 1985.

DR. BRUCE C. FOLKEDAHL
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Principal Areas of Expertise

Dr. Folkedahl's principal areas of interest and expertise include combustion and gasification processes; biomass to fuels and chemicals; development of methodologies to mitigate the effects of inorganic components on the performance of combustion, gasification, and air pollution control systems; and fuel inorganic transformations and deposition and development of predictive models to assess these processes. Dr. Folkedahl has been responsible for the development of two novel water minimization technologies for use in power generation systems. He is also interested in the study and development of high-temperature materials for aggressive environments.

Qualifications

Ph.D., Materials Science and Engineering, Pennsylvania State University, 1997.
B.S., Computer Science, University of North Dakota, 1990.

Professional Experience

2001–Present: Senior Research Engineer, Critical Materials, EERC, UND. Dr. Folkedahl's responsibilities include studies of combustion and gasification in conjunction with electricity generation; fundamental mechanisms of ash deposition, fouling, and fine particulate and aerosol formation and emission during combustion; process development for the conversion of biomass feedstocks to fuels, chemicals, and value-added products; water minimization technologies for power generation; and corrosion and development of high-temperature materials to withstand aggressive combustion environments.

2000–2001: Product Manager, 3M Industrial Mineral Products Division, Little Rock, Arkansas. Dr. Folkedahl's responsibilities included managing a crushing and screening business unit 24-hr/day, 7-day/week manufacturing operation, including hiring, training, and directing 40 employees; managing a $12,000,000 annual budget; forecasting budgets; developing and implementing cost reduction plans; and developing automated labor-reducing equipment and routines.

1999–2000: Senior Product Engineer, 3M Industrial Mineral Products Division, St. Paul, Minnesota. Dr. Folkedahl's responsibilities included developing ceramer-coated roofing granules, developing automated dry powder-handling system for slurry-making process, investigating the mechanism of fluorine alkalinity reduction and coating enhancement in roofing granules, and investigating mechanisms of rust formation in mild steel storage tanks for roofing granules.

1994–1998: Graduate Assistant, Pennsylvania State University, University Park, Pennsylvania. Dr. Folkedahl's responsibilities included proctoring and grading exams and teaching lab classes. Thesis work consisted of development of a neural network model of inorganic ash viscosity in high-temperature systems; development of an image analysis program to identify graphitizability of cokes; and statistical cluster analysis of the chemical composition of ash deposits in electrical generation boilers.

1989–1999: Research Scientist, EERC, UND. Dr. Folkedahl's projects and responsibilities included corrosion studies of high-temperature alloys, modeling of slag and silicate material viscosities, and crystallization studies of coal. Other responsibilities included design, development, and maintenance of analytical software; development and implementation of new analysis techniques; and operation and performance analysis with x-ray diffraction, x-ray fluorescence, scanning electron microscopy, and processing and manipulation of raw data.

Publications and Presentations

Dr. Folkedahl has authored or coauthored numerous professional publications.

DR. ARASH ABARGHANI
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Principal Areas of Expertise

Dr. Abarghani's principal areas of interest and expertise include subsurface geology, petroleum geology and engineering, organic petrology and geochemistry, and atomic force microscopy (AFM)-based nano-IR spectroscopy.

Qualifications

Ph.D., Petroleum Engineering, University of North Dakota, 2019. Dissertation: Multiscale Organic Material Characterization of the Bakken Source Rock.

M.Sc., Sedimentary Geology, School of Earth Sciences, Shahid Beheshti University of Tehran, Iran, 2000. Thesis: Geochemistry and Sedimentary Environments of the Middle-Upper Jurassic Deposits (Dalichai and Lar Formations), Northwest Iran.

B.Sc., Geology, College of Natural Sciences, University of Tabriz, Iran, 1998.

Professional Training: ANASYS Instruments NanoIR2-S AFM-IR, Nebraska Center for Materials and Nanoscience, University of Nebraska at Lincoln; organic petrography, vitrinite/bitumen reflectance measurement, Rock-Eval 6, high-frequency nuclear magnetic resonance (NMR) spectroscopy, Core Laboratories, Houston, Texas; and advanced training for E&P in frontier basins by IFP, Fugro Robertson, Total, Petronas, Repsol, CNPC, CNLC, and Schlumberger.

Software: Schlumberger Petrel, Interactive Petrophysics, Rock Works.

Professional Experience

February 2020–Present: Research Scientist, EERC, UND. Dr. Abarghani conducts laboratory analyses and interprets laboratory data to support research activities related to improved production of unconventional oil and gas reservoirs, enhanced oil recovery in unconventional and conventional formations, and subsurface storage of CO_2 and/or rich gas.

June 2019–January 2020: Research Assistant, EERC, UND. Dr. Abarghani carried out research on organic petrology and geochemistry, vitrinite and bitumen reflectance measurements, and Rock-Eval 6 pyrolysis data interpretation.

May 2017–May 2019: Research Assistant, Institute for Energy Studies, UND. Dr. Abarghani performed vitrinite reflectance and dispersed organic matter organic petrology studies using a LEICA DM 2500-P microscope equipped with J&M photometer TIDAS S MSP200, geochemical screening of Bakken source rock using SRA, major and trace element geochemistry studies using x-ray fluorescence (XRF), low-frequency NMR spectroscopy, and scanning electron microscopy (SEM).

May 2017–May 2019: Teaching Assistant, Petroleum Engineering Laboratory II, UND. Dr. Abarghani assisted with the PTRE 462 lab and was Co-Instructor for the course Shale Plays (PTRE 493).

January 2014–August 2015: Geological Software Instructor, Department of Education, Exploration Directorate, National Iranian Oil Company (NIOC), Tehran, Iran.

November 2011–August 2015: Senior Subsurface Geologist, NIOC. Dr. Abarghani located and planned exploratory wells, prepared geological forecast and completion reports, collaborated on several geological and engineering studies, research on oil and gas exploration, reservoir characterization, and stratigraphic and sedimentological investigations of petroliferous basins.

October 2001–November 2011: Wellsite Geologist, NIOC. Dr. Abarghani was responsible for all geological operations and mud-logging supervision at the wellsite location at several oil and gas fields, both onshore and offshore.

1999–2000: Research Assistant, Geochemistry Research Laboratory and Carbonates Petrology Laboratory, Department of Geology, Shahid Beheshti University of Tehran. Dr. Abarghani studied trace elements to determine their role in sedimentary and diagenetic environments using XRF, atomic absorption spectroscopy (AAS), and stable isotopes (oxygen and carbon) geochemistry.

1996–1998: Research Assistant, Sedimentology Research Laboratory, Department of Geology, University of Tabriz. Dr. Abarghani studied grain size and environmental analysis of the north Tabriz Miocene red fluvial deposits.

Professional Activities
Member, Society of Organic Petrology
Reviewer, *International Journal of Coal Geology*
Reviewer, *Fuel*

Publications and Presentations
Dr. Abarghani is the author and coauthor of several peer-reviewed papers and technical reports in leading international journals.

APPENDIX B

BUDGET NOTES

BUDGET NOTES

ENERGY & ENVIRONMENTAL RESEARCH CENTER (EERC)

BACKGROUND

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

INTELLECTUAL PROPERTY

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

BUDGET INFORMATION

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

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

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

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

Fringe Benefits: Fringe benefits consist of two components which are budgeted as a percentage of direct labor. The first component is a fixed percentage approved annually by the UND cognizant audit agency, the Department of Health and Human Services. This portion of the rate covers vacation, holiday, and sick leave (VSL) and is applied to direct labor for permanent staff eligible for VSL benefits. Only the actual approved rate will be charged to the project. The second component is

estimated on the basis of historical data and is charged as actual expenses for items such as health, life, and unemployment insurance; social security; worker's compensation; and UND retirement contributions.

Travel: Travel includes two trips to Bismarck for project review meetings**.** 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: Not applicable.

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.

Subcontracts: Not applicable.

Professional Fees: Not applicable.

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

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

Food: Expenditures for meetings with stakeholders 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: Not applicable.

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

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

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

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

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

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

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

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

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