



October 29, 2019

Ms. Karlene Fine
Executive Director
North Dakota Industrial Commission
State Capitol, 14th Floor
600 East Boulevard Avenue, Department 405
Bismarck, ND 58505-0840

Dear Ms. Fine:

Subject: Quarterly Report Entitled "State Energy Research Center"
Contract No. SERC 2019-01; EERC Fund 24107

Attached is a copy of the subject project status report for the period of July 1 through September 30, 2019.

If you have any questions, please contact me by phone at (701) 777-5053, by fax at (701) 777-5181, or by e-mail at terickson@undeerc.org.

Sincerely,

A handwritten signature in black ink, appearing to read "T. Erickson for", is written over a horizontal line.

Thomas A. Erickson
Director of State Energy Research Program
and Interim VP for IP & Technology
Commercialization

TAE/rl0

Attachment



STATE ENERGY RESEARCH CENTER

Quarterly Project Status Report

(for the period of July 1, 2019, through September 30, 2019)

Prepared for:

Karlene Fine

North Dakota Industrial Commission
State Capitol, 14th Floor
600 East Boulevard Avenue, Department 405
Bismarck, ND 58505-0840

Contract No. SERC 2019-01

Prepared by:

Thomas A. Erickson
Scott C. Ayash

Energy & Environmental Research Center
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October 2019

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STATE ENERGY RESEARCH CENTER
Quarterly Progress Report
July 1 – September 30, 2019

EXECUTIVE SUMMARY

Over the last quarter, the Energy & Environmental Research Center (EERC) initiated the State Energy Research Center (SERC). An initial round of proposals was considered and ten projects chosen for advancement. These projects are in the early stages but are already showing great benefit. The summer Energy Hawks Program led nine students through a packed 10 weeks of education and research, resulting in three concept projects focused on supporting the state of North Dakota. Additionally, an education and outreach collaboration program was launched to bring together the strengths of all of the North Dakota institutions of higher education to provide the resources necessary to create knowledgeable citizens and stakeholders.

INTRODUCTION

SERC was established through Bill 2249 of the North Dakota 66th Legislative Assembly. The legislation included \$5 million of funding per biennium to fulfill three objectives: 1) conduct exploratory, transformational, and innovative research of technologies and methodologies that facilitate the prudent development and clean and efficient use of the state's energy resources; 2) provide greater access to energy experts for timely scientific and engineering studies to support the state's interests; and 3) educate stakeholders on issues related to the state's energy resources through public outreach. These objectives are being executed through three corresponding tasks:

- Task 1 – Perform Exploratory Research for North Dakota Energy
- Task 2 – Provide Prompt Expertise for North Dakota
- Task 3 – Advocate and Educate Through Outreach

The following represents the activity of SERC for this quarter. Note: Because of the potential opportunities for intellectual property development, technical activities are only presented at a high level to avoid negating the opportunity to protect it in the future.

HIGHLIGHTS AND ACCOMPLISHMENTS DURING REPORTING PERIOD

Task 1

Multiple projects are being conducted through this task, each focused on early-stage, exploratory energy research topics applicable to North Dakota, e.g., coal, oil and gas, wind, solar, and biofuels. Projects are selected by the EERC based on their potential to positively impact North Dakota, its industries, and its citizens. Research is focused on technology and strategy development that will ultimately lead to commercial application with public and private

sector partners. Specific activities may involve other institutions of higher education in North Dakota as needed to achieve success.

Significant Task 1 accomplishments during the reporting period included the following:

- The first internal solicitation for SERC projects was successfully conducted. Twenty-six proposals that included scope of work, time line, and budget were written and submitted by EERC researchers for consideration of SERC funding. Each proposal was reviewed and evaluated by a team of five EERC personnel. Ten proposals were ultimately selected for SERC funding. The selected projects each had a start date of August 19. An overview of the ten current SERC projects, as well as specific activities conducted on each during the reporting period, are presented below.

Critical Minerals Assessment of North Dakota Shales

This project is characterizing North Dakota shale materials to determine their potential as a source of rare-earth elements (REEs). The concentrations of REEs and several other critical minerals present in North Dakota shales will be determined. The goals of this project are to 1) identify shale resources in the state of North Dakota that have elevated levels of critical minerals and 2) better understand the thermal maturity and depositional environment of the source rock using the identified critical minerals.

Activities for this project during the reporting period included:

- Following discussions with the North Dakota Geological Survey (NDGS), it was decided that the EERC will accompany NDGS on a trip to collect shale outcrop samples. The shale samples will be analyzed later in the project. A trip is currently scheduled for late October or early November.

Evaluation of High-Value Solid Carbon Products from North Dakota Coal and Gas Resources

This study aims to develop a potential lignite-to-graphene (L2G) technology. The L2G process will focus on evaluating options to improve North Dakota lignite coal through EERC-developed advanced cleaning methods and novel transformations to upgrade the cleaned product into an enhanced lignite graphene precursor, which will then be used to make graphene.

Activities for this project during the reporting period included:

- Equipment necessary to conduct this work was prepared. Existing equipment was modified, and select pieces of new equipment were acquired.
- Specific coal samples that will be used to conduct the planned experiments were selected. The samples are in the process of being acquired.

Power Production and Distribution Resilience to Electromagnetic Pulses

The goal of this project is to develop a pathway to identify and address weaknesses in power production and distribution caused by naturally occurring electromagnetic pulses (EMPs) in North Dakota. This goal will be met by conducting a literature search to acquire information on the current status of EMP protection and legislation; developing a database of technologies currently in use; and engaging with researchers at the University of North Dakota (UND), the Grand Forks Air Force Base, and representatives from North Dakota utilities to determine a hierarchy of needs and identify areas of EMP susceptibilities.

Activities for this project during the reporting period included:

- A two-page fact sheet describing the project was developed and used to facilitate conversations with utilities and other attendees of the Lignite Energy Council Fall Conference, held October 3 in Bismarck, North Dakota.
- A literature review of known EMP susceptibilities and risks, protection options, and legislation/regulation was completed.
- Discussions were held with representatives of utilities (North Dakota and Nebraska), Midcontinent Independent System Operator, Inc. (MISO), and the Grand Forks Air Force Base to gather information on vulnerabilities to EMPs and current preventative measures.

Identification of the Most Efficient and Least Cost Process for Conversion of Wellhead Gas to Transportable Liquid Products

Direct synthesis of methane to methanol is an example of a process that, once fully developed, could be a game changer for Bakken flaring reduction. This project will identify technology options for single-stage catalysis of methane or associated gas to liquid products. Many potential routes and end products will be initially considered, but focus will be placed on the highest-value end products and simple processes that have shown promise in the laboratory.

Activities for this project during the reporting period included:

- The criteria for a literature review were established. Literature review is under way.

Evaluation of Energy Storage Technologies and the Benefit to North Dakota Utilities

Energy storage is a key element in the modern energy supply process. Energy storage systems intake excess or wasted energy and store it until it is needed, at which time the stored energy is then released from the system and utilized. This project will review energy storage technologies, concepts, and current research. Select promising technologies will be modeled to evaluate theoretical energy capacities and energy recovery efficiencies.

Activities for this project during the reporting period included:

- A literature review of previously published papers was performed, and a list of existing energy storage technologies was created. This includes technologies that have been applied at a commercial scale. A draft overview report of these technologies was started.
- A representative of MISO was contacted to discuss this project. Conversations with MISO will be critical to understanding the challenges and opportunities for implementing large-scale energy storage.

Solvent Extraction of Rare-Earth Elements from Lignite Coal In Situ

Previous work has shown that acid solvents can be effective at REE extraction from coals and coal ashes. The goal of this proposed project is to demonstrate that in situ removal of REEs from lignite coal seams is an effective way to produce REEs in an environmentally sound manner. A series of bench-scale tests using the EERC's subsurface extractive test system will be conducted to generate subscale test data and assess conceptual process designs.

Activities for this project during the reporting period included:

- Began compiling a list of potential in situ extraction techniques for REEs. Potential environmental concerns associated with these techniques were also examined.
- The technique for creating and storing coal plugs for the laboratory testing was refined. Because of the delicate nature of some of the coal samples, this process must be executed carefully to preserve the plug for testing.

Waste Utilization for Bio-Based Alternatives to Chemicals and Fuels

Hydrothermal liquefaction has proven to be an effective method for conversion of waste feedstock to useful bio-based intermediates. This project will analyze opportunities to repurpose waste from industrial and municipal sources in North Dakota through conversion via hydrothermal liquefaction. The goal of the project is to generate data to support the concept of creating bio-based intermediates using a North Dakota waste stream that could be used as renewable alternatives to petro-derived chemicals and fuels.

Activities for this project during the reporting period included:

- A literature review was conducted to determine potential feedstocks and the feasible operating conditions for testing the hydrothermal liquefaction process.

Crude Oil Swelling with Injected Rich Gas and CO₂ as a Potential Mechanism for Enhanced Oil Recovery in the Bakken

Injecting Bakken rich gas and/or CO₂ captured from industrial sources to achieve even a 1% increase in recoveries would yield over a billion barrels of additional oil. The EERC has shown that both rich gas and CO₂ can solvate Bakken crude oil and recover oil from Bakken rock samples. However, a major EOR mechanism—i.e., crude oil swelling—has not yet been studied. The purpose of this project is to determine the volumetric swelling that occurs with CO₂ and rich-gas hydrocarbons at different pressures and reservoir temperatures and thus better understand the effect of crude oil swelling on EOR success in the Bakken.

Activities for this project during the reporting period included:

- The initial design of the experimental setup was created. Required hardware (fittings, etc.) needed for the experiment were acquired. The experimental system was set up.
- The pressure, volume, temperature (PVT) cell for the experiment was calibrated, and initial CO₂ injection tests were conducted. Two types of Bakken crude oil were tested to determine swelling at various pressures. Preliminary results were generated.

Enhancing Reservoir Productivity Through a New Hydraulic Fracturing Approach

Optimizing hydraulic fracture spacing by accounting for stress shadow development has the potential to increase stimulated reservoir volume and formation productivity in both the short and long term. This project is focused on understanding the impact of stress shadows on hydraulic fracture effectiveness. An improved method to hydraulic fracturing design that considers the effect of reservoir properties and principal stresses (or stress shadow) will be investigated.

Activities for this project during the reporting period included:

- Initial computer models were constructed using XSite software. These initial models are being used to determine the optimum model size needed to realistically represent fracture spacing.

Bench-Scale Extraction of Rare-Earth Elements from Lignite Coal Ash

Previous work has identified coal and coal by-products as a potential source for REEs. The goal of this project is to demonstrate at the bench scale a novel, economically viable, and environmentally benign process for extracting and concentrating REEs from low-rank coal (LRC) ash. Methods of REE extraction and concentration will be developed or improved to take advantage of unique properties of LRC fly ash, such as by altering the mineralogy to improve REE mobilization and solubility.

Activities for this project during the reporting period included:

- The process of engaging a graduate student to assist with the project began.
- Initial sample solutions of REEs extracted from LRC ash were prepared using techniques developed in previous work at the EERC. The preparation of these initial samples represent a unique REE extraction process with the potential to dramatically lower the cost of REE extraction from LRC ash material. All of the prepared samples were sent to UND's Metal Analysis Core Facility for analysis.

Task 2

This task allows quick and efficient access to energy experts from the EERC for timely scientific and engineering studies to support the state's interests. Through this task, the State Energy Research Center has the ability to both react to, and proactively address, issues that have the potential to impact the state's energy (and other, if appropriate) industries. All projects conducted through this task are at the discretion of the North Dakota Industrial Commission NDIC.

At this time, limited conversations have occurred, but no projects have been initiated through this task.

Task 3

This task consists of outreach activities to advocate for, and educate about, North Dakota's energy industries. Work conducted under this task will involve a variety of outreach tools and activities that may include fact sheets; training workshops; websites; on-site tours and presentations to school and community groups; and participation in international, national, and regional trade press, television, radio, peer-reviewed literature, interviews, and conference presentations. Two specific activities are the Energy Hawks and Energy Outreach Collaboration Programs.

Significant Task 3 accomplishments during the reporting period included the following:

- *Energy Outreach Collaboration Program*
On July 31, 2019, a meeting was held to discuss opportunities for collaboration across all institutions of higher education within the state of North Dakota. The initial invitation list went to all institutions across North Dakota and were not limited to those within the State Board of Higher Education. Appendix A contains the invitation list, agenda, and notes from the meeting. Additionally, visits were made to Lake Region State College and Mayville State College to solicit their involvement in this effort and other potential opportunities.
- *Energy Hawks Summer Internship Program*
Nine students were selected in the spring of 2019 to participate in the Energy Hawks program. The nine students spent 10 weeks learning about all forms of North Dakota

energy, including a weeklong tour of western North Dakota with visits to oil and gas, coal, ethanol, hydro, and wind sites, as well as a day in Williston to discuss impacts to the community and infrastructure with the growth of the Bakken industry. The students used these experiences, as well as the opportunity to meet with energy experts throughout the program, to identify areas they believe can be improved or enhanced with further research. Three concept research projects were initiated by the students, and are summarized below.

Energy Hawks Concept Project 1: Artificial Photosynthesis: Fuel from CO₂ in North Dakota

Photosynthesis is a process whereby plants convert CO₂ with the energy of light to produce organic matter. The project investigated applying CO₂ hydrogenation, also termed artificial photosynthesis (AP), on a large scale, collocated with a fossil fuel power plant. AP will be applied to the CO₂ capture stream at facilities such as that proposed at Project Tundra or for any other concentrated CO₂ source. Mimicking natural photosynthesis on a plant scale to store and generate synthetic fuel will take advantage of excess electricity generation capacity in the state of North Dakota and can become an energy storage surrogate. This project investigated the opportunities and possible challenges of generating methanol as a synthetic liquid fuel, which is a relatively safe fuel with highly economical energy density.

Energy Hawks Concept Project 2: Harnessing Wind Energy Using Two-Way Vehicle Charging in North Dakota

Electric vehicle (EV) usage has increased recently as a result of improved technologies and lower prices. EVs reduce carbon dioxide and other emissions when used in lieu of gasoline vehicles, which is one of the most appealing factors of driving one. An additional benefit to driving an EV could be the potential to use the car's battery as electricity storage, thereby making EVs more appealing to consumers and giving the electric car more utility. This paper evaluated the concept, called bidirectional charging, to determine what challenges need to be met in order for such a system to be feasible in North Dakota

Energy Hawks Concept Project 3: Social Media: Enhancing Energy Awareness among Young Adults

Digital natives aged 16–26 believe that renewable energy sources such as solar and wind are superior for electrical generation. In actuality, renewable energy sources are unreliable as sources for electrical generation when compared with fossil fuels or nuclear energy. To ensure reliability and the continuation of vital services, an all-of-the-above approach is necessary to provide affordable access to energy. This project creates a template to use future social marketing principles to create a public information campaign that 1) provides accurate information on electrical energy consumption and the technological innovations to make electrical generation cleaner, safer, and more reliable; 2) challenges digital natives to think critically about affordable electricity and how it relates to quality of life issues; and 3) spreads energy literacy to create a path toward productive participation in subsequent conversations as informed consumers. Focusing on digital natives as the target audience will channel digital native fervor for social engagement to encourage energy literacy.

FINANCIAL INFORMATION

This project is sponsored by NDIC. Table 1 shows the proposed budget of \$5,000,000 for this project and expenses through September 30, 2019.

Table 1. Project Cost

Task	Budget	Expended	Balance
1 – Exploratory Research	\$ 3,750,000	\$ 104,529	\$ 3,645,471
2 – Prompt Expertise	\$ 500,000	\$ 1,450	\$ 498,550
3 – Advocate and Educate	\$ 750,000	\$ 59,672	\$ 690,328
Totals	\$ 5,000,000	\$ 165,651	\$ 4,834,349

PLANNED FUTURE ACTIVITIES

The following activities are planned for the next quarter.

Task 1

- A second solicitation round for proposals will be conducted.
- Work on the ten ongoing projects will continue.

Task 2

- Pending a request by NDIC, a project will be initiated.

Task 3

- Over the next quarter, the guiding principles for the collaboration program will be established, and participating institutions will begin providing information and resources to be included.
- Planning for the 2020 Energy Hawks summer internship program will begin.

APPENDIX A

INVITATION LIST, AGENDA, AND MEETING NOTES

Tuesday, July 30, 2019 –
 Wednesday, July 31, 2019

Lewis & Clark/Stevens/Maximilian Meeting Rooms

Purpose:

Discuss Collaboration Activities

Tuesday, July 30

TIME	ACTIVITY	DISCUSSION LEADER(S)
6:30 p.m.	Arrive at Eagle Crest (Kings Walk Golf Course)	
6:35 p.m.	Welcome and Introductions	
7:00 p.m.	Dinner and Networking Social	
8:30 p.m.	Adjourn	

Wednesday, July 31

TIME	ACTIVITY	DISCUSSION LEADER(S)
8:30 a.m.	Arrive at the EERC	
8:35 a.m.	Overview of the EERC and State Energy Research Center	Tom Erickson
9:00 a.m.	Tour the EERC	Tom Erickson
10:30 a.m.	Break	
10:45 a.m.	Open Discussion/Round Robin	All
12:00 Noon	Business Lunch <i>[Thompson/LaVerendrye]</i>	All
1:00 p.m.	Adjourn	

EERC Contact Person: Jen Knudson, (701) 777-5130

(Invitee list on back page)

INVITEE LIST

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STATE ENERGY RESEARCH CENTER COLLABORATION MEETING SUMMARY

This first meeting of the State Energy Research Center (SERC) collaboration group was convened on the evening of July 30 and continued July 31 from 8:00 a.m. to 12:30 p.m. The agenda for the meeting is attached which also includes the institutions and personnel in attendance. Meeting materials presented are also attached. Pictures taken during the meeting can be found at www.flickr.com/gp/undeerc/1N8g58. The pictures may be freely used for any media opportunities.

The following is a summary of discussion topics and resultant action items from the meeting. Lively conversation occurred around a broad range of potential topics for collaboration (and SERC funding) including:

- 1) A summer program to provide faculty with a greater understanding of North Dakota's all-of-the-above energy model.
- 2) A multidisciplinary energy research program (similar to Energy Hawks) to be held at the EERC comprising higher education students from throughout North Dakota.
- 3) Scholarship program to support faculty and/or students in gaining hands-on experience in the energy industry.
- 4) Development and presentation of workshops and other education opportunities for students, faculty, teachers, and the general public.
- 5) Methods of creating relationships between researchers that should help in the creation of future partnerships.
- 6) Pursuit of outside funding mechanisms, such as the National Science Foundation, to enhance undergraduate research programs.
- 7) A greater connection between research and the public through presentation venues, especially focused on the western part of the state.
- 8) Identification of niche opportunities to enhance collaboration (i.e., collaboration between a few institutions related to a specific need/desired outcome).

Based on the conversation, the following action items were determined:

- 1) SERC will compile a summary of the conversation and action items to be sent to all institutions.
- 2) SERC will put together a draft plan to help organize (or virtually assemble) all energy outreach opportunities (grade school, high school, and post-high school) that exist within North Dakota to be able to provide a resource to faculty and teachers.
- 3) Each institution is asked to assign a point of contact to initially gather existing outreach information.
- 4) An Energy Outreach Collaboration (EOC) team will be formed to assess the existing data and develop a path forward to fill in any identified gaps (this effort will be funded by SERC).
- 5) Each institution should examine other ways that can create or enhance collaboration through niche opportunities or through broader statewide opportunities. Those ideas should be brought forward to Tom Erickson via a short summary document (one page).
- 6) Another high-level meeting of the overall SERC collaboration team will be held in central North Dakota following the Bison's 8th national championship celebration. This meeting would focus on the accomplishments to date of the EOC group as well as any niche initiatives launched. Discussion would also focus on additional opportunities for collaboration.

All communication for SERC should go to Tom Erickson, EERC Director of the State Energy Research Center.