April 25, 2017

Ms. Karlene Fine  
Executive Director  
North Dakota Industrial Commission  
State Capitol, 10th Floor  
600 East Boulevard Avenue  
Bismarck, ND 58505-0310

Dear Ms. Fine:


Attached is the subject report for the period of January 1, 2017, through March 31, 2017, that shows the progress that has been made with partners of this project.

Thank you for funding this work. If you have any questions, please contact me by phone at (701) 777-5013 or by e-mail at kleroux@undeerc.org.

Sincerely,

[Signature]

Kerryanne M. Leroux  
Senior Chemical Engineer, Oilfield Operations Team Lead

KML/kal  
Attachment
INTEGRATED CARBON CAPTURE AND STORAGE FOR NORTH DAKOTA ETHANOL PRODUCTION

Quarterly Progress Report

(for the period of January 1, 2017, through March 31, 2017)

Prepared for:

Karlene Fine

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

Project Period: November 1, 2016 – May 31, 2020
Contract No. R028-039

Prepared by:

Kerryanne M. Leroux

Energy & Environmental Research Center
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Grand Forks, ND 58202-9018

April 2017
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INTEGRATED CARBON CAPTURE AND STORAGE FOR NORTH DAKOTA ETHANOL PRODUCTION

ACCOMPLISHMENTS

Major Goals of the Project

The ultimate goal of this effort is implementation of a small-scale (<200,000 metric tons, or tonnes, CO₂ per year) commercial carbon capture and storage (CCS) system at an industrial fuel production facility to generate a reduced-carbon ethanol fuel applicable for low-carbon fuel programs. To achieve that goal, the Energy & Environmental Research Center (EERC), in partnership with the U.S. Department of Energy (DOE); North Dakota ethanol producer, Red Trail Energy (RTE); and the North Dakota Industrial Commission (NDIC), is conducting a study to determine the technical and economic feasibility of implementing commercial CCS at a North Dakota ethanol production facility and proximate geologic injection site.

Accomplishments under These Goals (for the reporting period)

Specific objectives are to 1) assess the technical feasibility of carbon capture at a North Dakota ethanol facility and subsequent geologic CO₂ storage at a proximate site; 2) develop a field implementation plan (FIP) determining the design and implementation steps needed to install a CCS system; and 3) evaluate the economic feasibility of CCS deployment, including installation and operating costs as well as potential revenue from low-carbon fuel markets and/or tax incentives to assess the benefits to North Dakota ethanol producers.

Feasibility Study

This technical evaluation assesses the feasibility of carbon capture at an industrial fuel production facility and subsequent geologic CO₂ storage at the RTE site. Activities include preliminary evaluations for a CO₂ capture system, site characterization, geologic modeling and simulation, risk assessment, and a life cycle analysis (LCA).

Significant accomplishments for Subactivity 1.1 during the reporting period include the following.

CO₂ Capture

- Conducted sampling of the generated CO₂ stream at the RTE facility to determine design requirements for capture or infrastructure systems, specifically for potential O₂ removal. Based on the geology data currently available, the CO₂ stream content remains appropriate for injection into a saline formation (injection-grade) without O₂ removal.
**Site Characterization**

- Evaluated the existing site characterization data available for both the surface and subsurface environment in the vicinity of the RTE ethanol facility for use in subsequent geologic modeling. Data collection (well, depth, formation tops, well logs, and core analysis) was focused on regional wells that penetrate the target Broom Creek Formation.
- Collected data to assess the sealing formations and screen for geologic hazards, such as faults.
- Assessed the surface environment to identify land use, sensitive areas, and local population characteristics.
- Evaluated the number of and type of existing groundwater wells and other non-oil and gas wells. A sufficient number of groundwater wells are present in the area to facilitate a groundwater-monitoring program (see Figure 1).

![Figure 1. Surface features at the RTE site.](image)
Geologic Modeling and Simulation

- Created 27 static model scenarios to address the ranges for thickness, porosity, and permeability identified in the site characterization activity. General properties incorporated were thick zones of high porosity and permeability and the presence of competent upper and lower sealing formations.
- Created 18 simulation models, from the original 27 static models.
  - Simulations derived from each model were used to estimate injection pressure, pressure buildup within the reservoir, and the distribution of CO₂ at the completion of the injection period.
  - Evaluation of estimated pressure from CO₂ injection determined the pressure plume (i.e., the footprint of the pressure differential in the injection horizon necessary to lift a column of fluid) would be substantially smaller than the injection fluid plume. Thus the lateral extent of the CO₂ plume will dictate area of review (AOR) rather than the size of the pressure plume.
- Conducted a sensitivity analysis on estimated wellhead pressures required for CO₂ injection to calculate compression output requirements for capture facility design.

Risk Assessment

- Conducted a screening-level risk assessment (SLRA) via a workgroup session with the EERC and RTE teams on January 18, 2017.
  - Evaluated 34 technical risks associated with CO₂ supply, injectivity, storage capacity, containment, and induced seismicity.
  - Assessed 17 external or commercials risks associated with ethanol and CCS policy, the uncertainty surrounding policies that are under development, and a recent change in federal administration.
- Began a subsequent quantitative risk assessment to integrate the results from the geologic modeling and simulations described previously to better quantify potential technical risks.

Life Cycle Analysis

- Completed a detailed LCA to derive carbon intensity (CI) values for CCS implementation at the RTE facility, which are used to estimate carbon credits and CO₂ market value through the California Low-Carbon Fuel Standards (LCFS) Program and thus estimate potential revenue.
  - Derived CI values for RTE’s existing ethanol production using the California Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (CA-GREET) model employed by the LCFS Program.
  - Based on the LCFS methodology, the EERC used the CA-GREET model to derive CI values for a CCS operating scenario at RTE. This approach incorporated emissions associated with the operation of the designed capture facility (e.g., energy usage for dehydration and compression), as well as reduced emissions associated with geologic storage of the CO₂ stream (instead of venting to the atmosphere).
Field Implementation Plan

A FIP is being developed to describe the steps necessary to design and install infrastructure for the capture and secure storage of CO₂ at the RTE site. Activities include conceptual plant infrastructure design; a permitting plan; a monitoring, verification, and accounting (MVA) plan; well design; and well characterization and testing design.

Significant accomplishments for Subactivity 1.2 during the reporting period include the following.

Plant Infrastructure Design

- Completed conceptual infrastructure designs for capture, dehydration, compression, and transport of CO₂ based on the findings from the assessment of the CO₂ stream at the RTE facility and estimated pressure requirements for CO₂ injection into the Broom Creek Formation (schematic shown in Figure 2).
- Determined pipeline requirements based on the composition and flow rates of the CO₂ generated at RTE, as well as estimated distance to a potential injection sites.

Permitting Plan

- Investigated permitting requirements for a North Dakota Class VI CO₂ injection well, assuming North Dakota regulatory primacy is granted. Critical permitting items were identified from North Dakota Administrative Code (NDAC) Chapter 43-05-01 and North Dakota Century Code (NDCC) Chapter 38-22, should CCS be implemented at the RTE facility.
- Explored potential pathways for CCS within low-carbon fuel programs. Participated in discussions between RTE and overseeing departments for the California LCFS Program and the Oregon Clean Fuels Program (CFP), as efforts are currently under way within these programs to incorporate carbon storage, particularly via saline formation injection.¹²

MVA Plan

- Nearing completion of the preliminary MVA plan by incorporating derived data and information generated during the permitting plan and well design activities to include testing and monitoring requirements as outlined in the NDAC. Surface, near-surface, and deep subsurface monitoring approaches and techniques were considered.

¹ Peters, B. Oregon Department of Environmental Quality, personal communication, March 2017.
² Wade, S. California Air Resources Board, personal communication, Jan 2017.
Figure 2. Schematic of the RTE CO$_2$ capture and compression facility process design (image courtesy of Trimeric Corporation).
Well Design

- Nearing completion of the conceptual designs for the drilling and completion of a monitoring well and an injection well to meet regulations and provide sufficient capacity for the CO₂ injection rates as estimated from RTE generation.
  - Required materials were identified.
  - Inclusion of monitoring equipment identified in the MVA plan was considered.
  - Time lines for complete well installation were estimated.

Well Characterization and Testing Design

- Developed a site characterization plan that includes discussion of well logging, core acquisition and testing, and downhole testing for both the prospective monitoring and injection wells. The plan considered data collection and evaluations that would be most pertinent to determining optimal injection well location, refining pressure requirements for capture system design, and improving AOR estimations.

Economic Analysis

This preliminary economic assessment quantifies the costs and benefits of combining commercial CCS with ethanol production at the RTE site. Activities include estimating capital and operating expenses for CCS implementation and potential revenue through low-carbon fuel programs or other CO₂ markets.

Significant accomplishments for Subactivity 1.3 during the reporting period include the following:

- Estimated potential revenue based on the CI values calculated during LCA activities and the LCFS Program market for CO₂ credits.
- Investigated alternative markets for a CO₂ product generated at the RTE facility, such as enhanced oil recovery (EOR) or as a food-/chemical-grade source.
- Estimated capital expenses (CAPEX) and annual operating expenses (OPEX) to implement CCS at the RTE facility based on FIP designs of major components:
  - Capture infrastructure and pipeline
  - Permitting
  - Monitoring and injection wells
  - Execution of the characterization and MVA plans
- Compared estimated costs and revenue for the injection, EOR, and food-grade systems to evaluate economic benefit.

Plan for the Next Reporting Period to Accomplish the Goals

All work will be finalized during the next reporting period. To accomplish this, final geologic simulations estimating AOR after injection has ceased, the quantitative risk assessment, incorporation of any additional information available regarding the LCFS Program and CFP pathway approval process for CCS, and any necessary updates to the MVA plan will be
conducted. In addition, estimated capital and operating costs and potential revenue from applying CCS to RTE ethanol production will be refined. A final comprehensive report will be prepared to include the results of the feasibility study, details of the FIP, and outcomes of the economic analysis.

PARTNERS AND FINANCIAL INFORMATION

This project is sponsored by the NDIC Renewable Energy Program, DOE, and RTE. Table 1 shows the budget of $1,005,000 for this project and expenses through the reporting period.

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PRODUCTS

Publications, Conference Papers, and Presentations

An overview of the project effort was presented to the California Air Resources Board in relation to the LCFS program.

Web Site(s) or other Internet Site(s), Technologies or Techniques, Inventions, Patent Applications, and/or Licenses

None.

CHANGES/PROBLEMS

None.