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Critical Challenges.

Practical Solutions.



Energy & Environmental Research Center (EERC)

SUBTASK 1.3 – INTEGRATED CARBON CAPTURE AND STORAGE FOR NORTH DAKOTA ETHANOL PRODUCTION

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National Energy Technology Laboratory

Mastering the Subsurface Through Technology Innovation, Partnerships and Collaboration:
Carbon Storage and Oil and Natural Gas Technologies Review Meeting

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Critical Challenges. **Practical Solutions.**

PRESENTATION OUTLINE

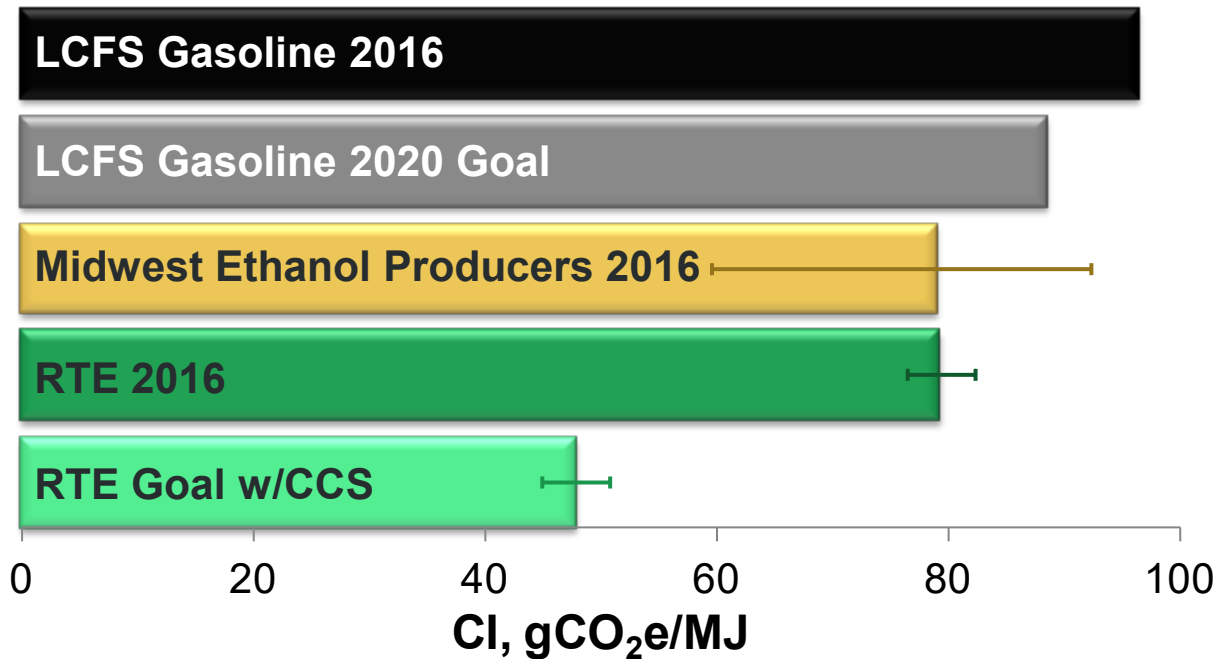
- Technical Status
 - Background
 - Scope of work
 - Activity results
- Accomplishments to Date
- Lessons Learned
- Synergy Opportunities
- Project Summary



Image Credit: Red Trail Energy

TECHNICAL STATUS – BACKGROUND

Current and Projected Carbon Intensity (CI) by Fuel Type



Source: California Air Resources Board (July 2016)

- Carbon capture and storage (CCS) can maximize CI-based carbon credits.
- Pacific Coast carbon markets:
 - California’s Low Carbon Fuel Standard (LCFS) Program
 - Oregon’s Clean Fuels Program (CFP)
 - British Columbia’s Renewable and Low Carbon Fuel Requirements Regulation

TECHNICAL STATUS – CASE STUDY

- Red Trail Energy, LLC (RTE)
 - Ethanol facility in western North Dakota
 - Current distribution to Pacific Coast
- Carbon capture potential
 - 163,000 tonnes of CO₂ annually from fermentation
 - Nearly pure CO₂ stream
- Geologic storage potential
 - Broom Creek Formation
 - 6400 ft directly below RTE facility, ~300 ft thick

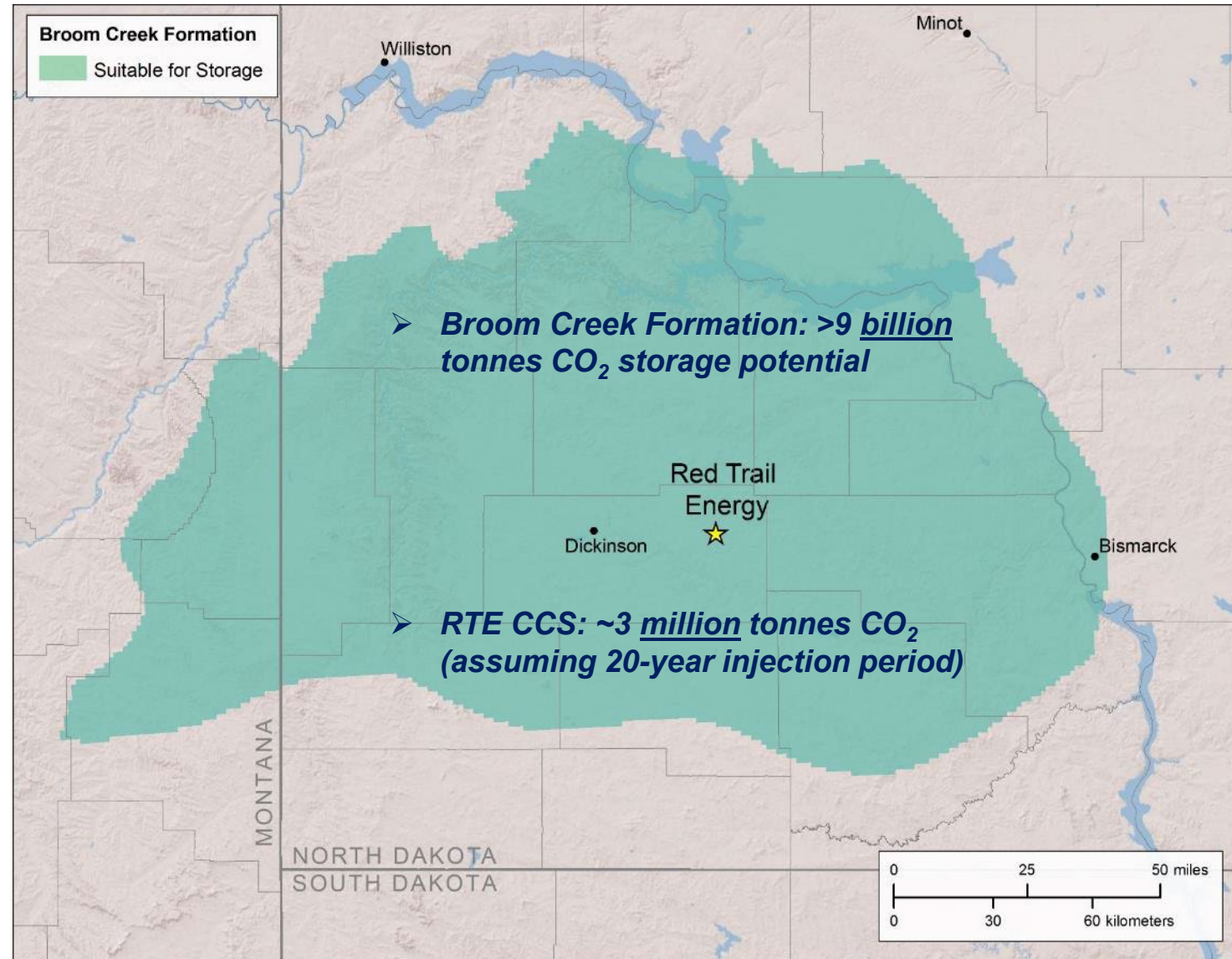
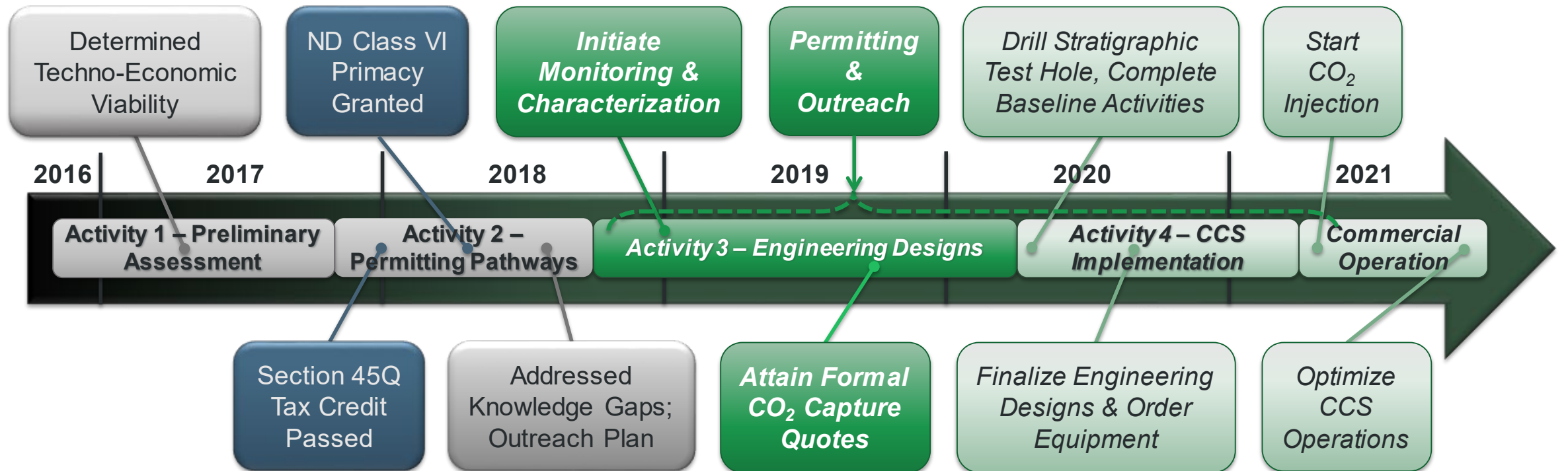


Image Credit: Energy & Environmental Research Center (modified from Peck and others, 2014)

PROJECT Status (*Proposed Timeline*)



TECHNICAL STATUS – ACTIVITY 1

PRELIMINARY ASSESSMENT

1. Feasibility study
2. Field implementation plan (FIP)
3. Economics analysis
4. National Risk Assessment Partnership (NRAP) validation
5. Outcome assessment

➤ Conclusions

- Technically viable: estimated 40%–50% net CO₂ emissions reduction.
- May be economically viable through low-carbon fuels programs or other incentives.

SUBTASK 1.3 - INTEGRATED CARBON CAPTURE AND STORAGE FOR NORTH DAKOTA ETHANOL PRODUCTION

ABSTRACT
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), conducted a preliminary assessment for integrating small-scale carbon capture and storage (CCS) at an industrial ethanol production facility near Richardson, North Dakota.

This preliminary assessment included a technical evaluation of CCS implementation at the RTE site, development of a provisional field implementation plan (FIP), and economic analysis. Results indicated that commercial CCS is a technically and economically viable option for the significant reduction of CO₂ emissions from ethanol generation at the RTE facility.

The RTE facility produces approximately 163,000 tonnes of CO₂ annually from the ethanol fermentation process. If a CCS project is implemented, the RTE site could store approximately 3.2 million tonnes of CO₂ during a 20-year period of injection.

TECHNICAL AND ECONOMIC FEASIBILITY

Reservoir Simulation
Reservoir simulations were used to estimate minimum CO₂ injection pressure requirements, the extent of pressure buildup within the reservoir (pressure plume), and the lateral distribution of CO₂ saturation extent (CO₂ plume). Simulation results suggest a potential CO₂ plume diameter of approximately 1.4 to 2.0 miles after 20 years of injection at the RTE site.

Economic Analysis
A preliminary economic assessment was conducted for CCS implementation at the RTE site to evaluate potential costs. Results of this analysis support ethanol CCS as an economically viable option for the RTE facility.

Life Cycle Analysis (LCA)
Results of a LCA suggest that implementing CCS at the RTE facility could reduce the net CO₂ emissions by 40%–50%. This reduction in CO₂ emissions results in an ethanol product with a greatly reduced carbon intensity (CI) value. Validation of CCS to reduce the CI value of ethanol production may allow producers to expand marketability of their fuel within developing low-carbon fuel programs such as those in California and Oregon.

FIELD IMPLEMENTATION PLAN
An FIP was developed that includes the design and installation of infrastructure necessary for the capture and secure storage of CO₂ at the RTE site. The FIP consisted of the activities necessary to implement CO₂ geologic storage at the RTE site and estimate future costs:

- CO₂ capture and transport
- Plans for CO₂ injection permitting
- Ethanol CCS pathways for low-carbon fuel programs
- MVA program
- Designs for monitoring and injection wells
- Well characterization and testing plan

The RTE FIP includes designs for both a Class VI injection well and a dedicated monitoring well.

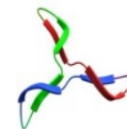
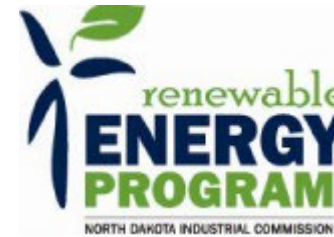
Future Activities

- Attain pathway approvals for implementing CCS into low-carbon fuel programs.
- Ongoing communication with North Dakota Industrial Commission to permit a monitoring well and a Class VI injection well.
- Collect pertinent data needed to refine engineering designs of capture system such as current flow rates and CO₂ stream composition.
- Update LCA model, where applicable, as low-carbon fuel pathways develop and details become publicly available.
- Refine economic analysis to incorporate financial details such as interest rates, market changes, pore space payers, etc.
- Develop and execute a community outreach plan to educate/inform the North Dakota public about CCS.
- Drill a stratigraphic test well to gather site-specific geologic data to improve the geologic model and AOR predictions.

Image Credit: Energy & Environmental Research Center

TECHNICAL STATUS – ACTIVITY 2 DETAILED PATHWAY

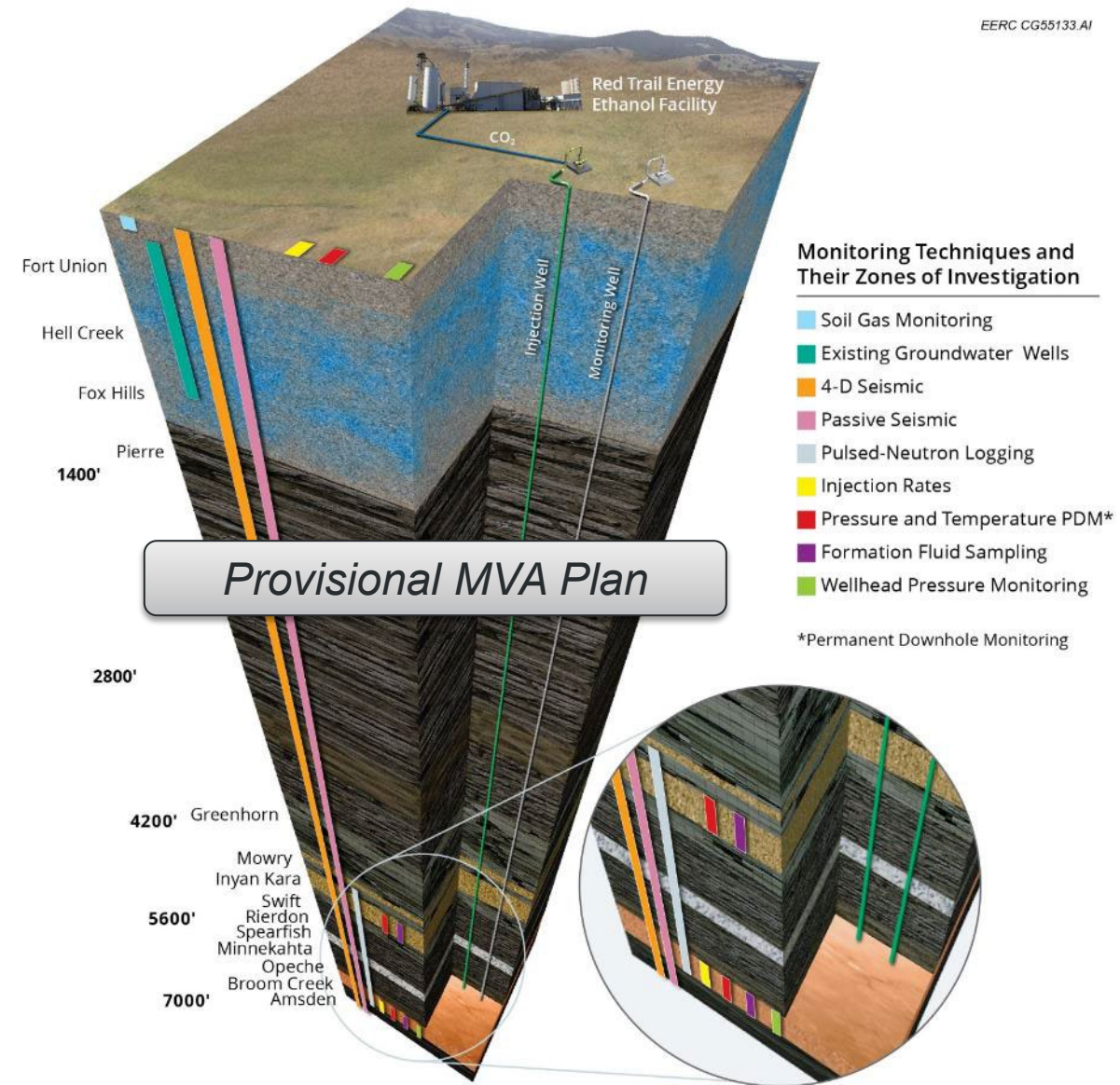
1. Establish permitting pathways
2. Update infrastructure design
3. Update economic analysis
4. Develop community outreach plan
5. Outcomes assessment



TRIMERIC CORPORATION

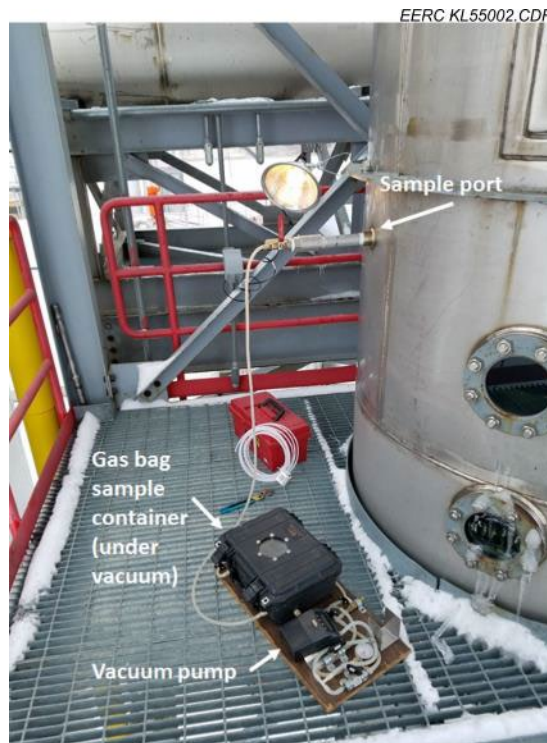
PERMITTING

- Low-carbon fuel programs
 - California LCFS, British Columbia
 - Oregon CFP, Canadian Clean Fuel Standard (proposed)
- North Dakota Class VI program
 - Primacy approved April 24, 2018
 - Discussed implementation details (e.g., pore space amalgamation)
- Updated FIP
 - Near-surface MVA (e.g., soil gas sampling/analyses)
 - Assessed California LCFS impact (e.g., ≥ 100 years postinjection monitoring)



UPDATE INFRASTRUCTURE

- Analyzed fermentation exhaust gases:
99.6–100% CO₂, 0–0.4% N₂, <100ppm O₂



- Capture modifications
 - Considered enhanced oil recovery (EOR) and food-grade CO₂ production systems
 - Path to commercialization
- Refined LCA
 - Injection-grade CO₂ product (with storage) = 40%–50% CI reduction
 - EOR- or food-grade CO₂ product (with storage) = 30%–40% CI reduction

UPDATE ECONOMICS

Expenses

- Electric upgrade for capture: 3–4 MW (nearly doubling current RTE facility)
- Pore space payment considerations: volumetric vs. pressure displacement
- California LCFS CCS requirements
 - Third-party reviews/verification
 - Expanded monitoring metrics, time frames

Incentives

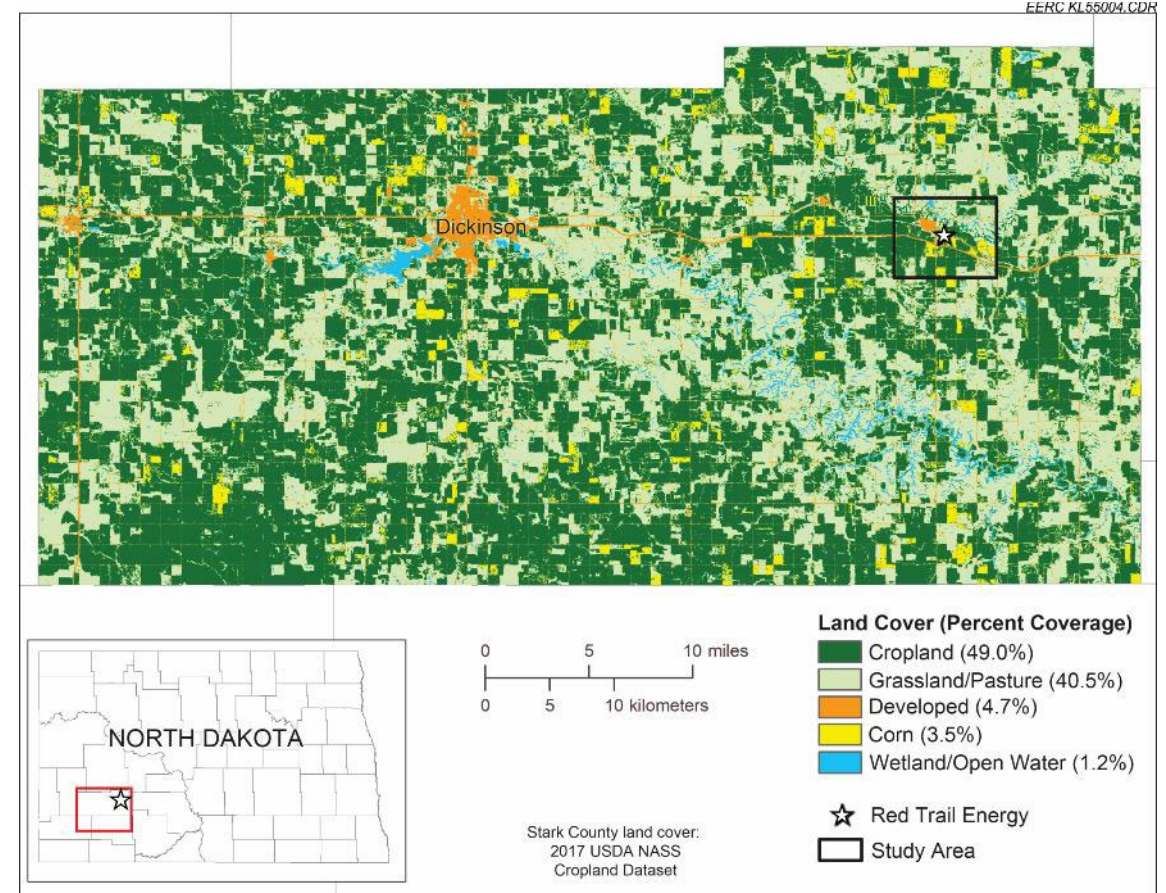
- Low-carbon fuel programs
- EOR
- Enhancement of Carbon Dioxide Sequestration Credit, a.k.a. Section 45Q

| Credits, \$/tonne | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026+ |
|-------------------|------|------|------|------|------|------|-------|
| Dedicated Storage | 32 | 35 | 38 | 41 | 44 | 47 | 50* |
| EOR | 20 | 23 | 25 | 28 | 30 | 33 | 35* |

* To remain constant in value for 2027 and thereafter (adjusted for inflation).

DEVELOP OUTREACH PLAN

- Social characterization: demographics, energy development, and land cover
- Outreach plan development
 - Goals and approaches
 - Implementation guidelines
 - Project partners and audiences
 - Outreach narrative, themes, and messages
 - Audience engagement strategies
 - Materials and time line
 - Tracking and assessment



ACCOMPLISHMENTS AND NEXT STEPS

- Continuing project based on favorable results from Activity 2.0.
- Potential Activities:
 - Develop CO₂ capture process design package
 - Initiate monitoring and characterization plans
 - Prepare CCS permit application package
 - Evaluate economic viability
 - Execute public outreach plan



Image Credit: Energy & Environmental Research Center

LESSONS LEARNED

- Risks are policy/program-related, not technical.



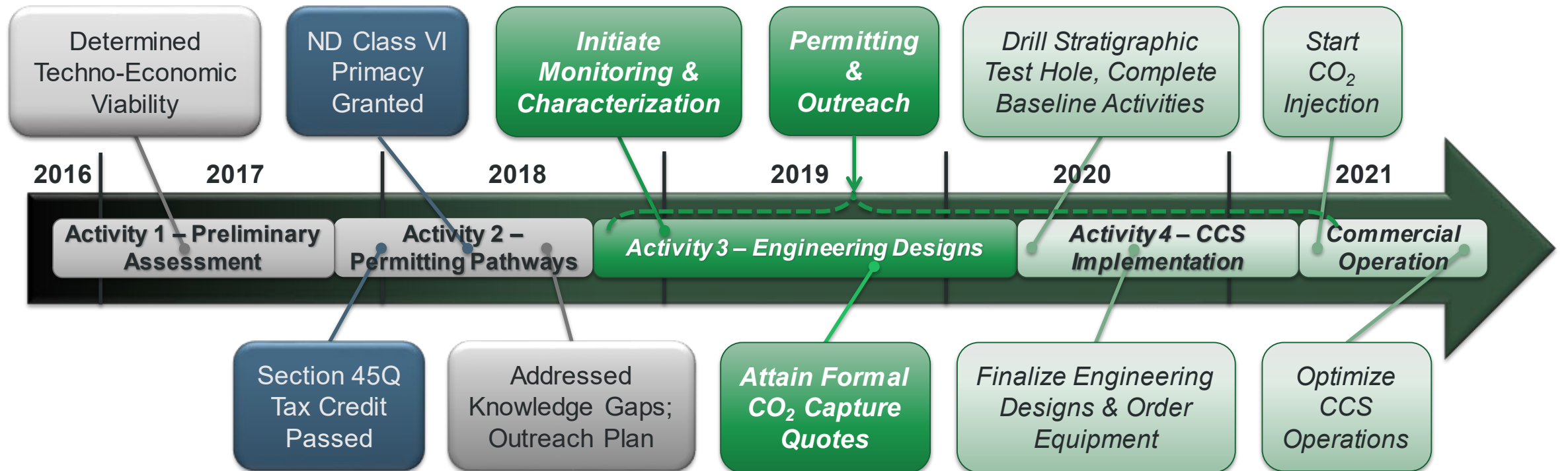
Photo by EPA

- Economic opportunities are reliant on evolving state/federal incentives.
 - Low-carbon fuel programs
 - ◆ California LCFS, Oregon CFP, etc.
 - Tax credits
 - ◆ Enhancement of Carbon Dioxide Sequestration Credit, a.k.a. Section 45Q
 - Proposed legislation
 - ◆ Carbon Utilization Act of 2018, USE IT Act

SYNERGY OPPORTUNITIES

- NETL Regional Partnerships
 - ***Plains CO₂ Reduction Partnership***
 - Midwest Geological Sequestration Consortium [Illinois State Geological Survey]
- CarbonSAFE Phase II
 - ***North Dakota Integrated Carbon Storage Complex Feasibility Study***
 - Integrated Midcontinent Stacked Storage Hub [Battelle Memorial Institute]
 - Integrated Commercial Carbon Capture and Storage Feasibility Study at Dry Fork Station [University of Wyoming]
- ***Techno-Economic Assessment of Regional Carbon Utilization Scenarios and Attendant Monitoring Technology***
- Developing and Validating Pressure Management and Plume Control Strategies in the Williston Basin Through a Brine Extraction and Storage Test (BEST)

PROJECT SUMMARY (*Potential Activities*)



CONTACT INFORMATION

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THANK YOU!

Critical Challenges. **Practical Solutions.**



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BENEFIT TO THE PROGRAM

To progress toward full-scale CCS deployment, the feasibility of a small- to medium-scale commercial (<1,000,000 metric tons of CO₂ emitted annually) geologic storage complex for CO₂ must be established. Activities outlined in the proposed approach will gather data to address both the technical and nontechnical challenges associated with establishing feasibility. The results derived from implementation of the proposed project will provide a significant contribution to DOE's Carbon Storage Program goals. Specifically, this project will support DOE Goals 1 and 2 by validating technologies that will improve reservoir storage efficiency, ensure containment effectiveness, and/or ensure storage permanence by collecting and generating fundamental geologic data from the subbasinal characterization of a potentially ideal CO₂ storage complex (Broom Creek Formation). This proposed project also includes efforts to validate risk assessment tools developed by NRAP. Goal 3, the ability to predict CO₂ storage capacity in geologic formations to within $\pm 30\%$, will be addressed by integrating characterization data derived from the proposed project into geocellular and dynamic reservoir models for a commercial-scale geologic storage complex. In addition, this project will support Goal 4 by producing information that will be useful for inclusion in DOE best practices manuals focusing on monitoring, verification, accounting, and assessment; site screening, selection, and initial characterization; public outreach; well management activities; and risk analysis and simulation.

PROJECT OVERVIEW

GOALS AND OBJECTIVES

- Goal: Implementation of a small-scale (<200,000 metric tons CO₂ per year) commercial CCS system at an industrial fuel production facility to generate a reduced-carbon ethanol fuel applicable for low-carbon fuel programs.
- Objectives
 - Develop a FIP for small-scale CCS.
 - Determine the full carbon life cycle of an industrial fuel production facility with CCS.
 - Determine the validity and pathway of using CCS to meet LCFS.
 - Validate the Broom Creek Formation, an Aeolian reservoir, as a regional target for CCS.

PROJECT OVERVIEW

SUCCESS CRITERIA

- Key activities will signify successful completion of the subtask's goals:

| Project Activity | Key Milestones | Subsequent Step |
|--|--------------------------|--------------------------------|
| 1 – Preliminary Assessment for Integrated Small-Scale CCS at an Industrial Fuel Production Facility. | FIP (M1) and LCA (M2) | Pathway for CCS implementation |
| 2 – Detailed Pathway for Integrated Small-Scale CCS at an Industrial Fuel Production Facility. | Permitting Pathways (M3) | CCS system designs |
| 3 – Engineering Designs for Integrated Small-Scale CCS System. | Site Design (M6) | CCS implementation |
| 4 – Implementation of CCS at an Industrial Fuel Production Facility. | Permitting (M7) | Commercial operation |

- Subtask will be considered successful as measured by the following:
 - Generates data that provide cost-effective value to the efforts of commercial deployment of integrated small-scale CCS systems and provide a template for implementation of similar-sized industrial CO₂ sources.
 - Described and communicated to DOE and the CCS industry along with appropriate site-specific challenges and lessons learned.

ACCOMPLISHMENTS TO DATE

Completed Deliverables

- Quarterly reports [*D2, D4–8]

**D1 quarterly not required due to final agreement delays*

- Activity 1.0 interim report [D3]
- Activity 2.0 interim report [D9]

Completed Milestones

- FIP for Integrated Small-Scale CCS Completed [M1]
- Life Cycle Analysis of an Industrial Fuel Production Facility with CCS Completed [M2]
- Pathway of Using CCS to Meet Low-Carbon Fuel Standards Completed [M3]
- Updated Infrastructure Design for an Industrial Fuel Production Facility with CCS [M4]

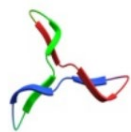
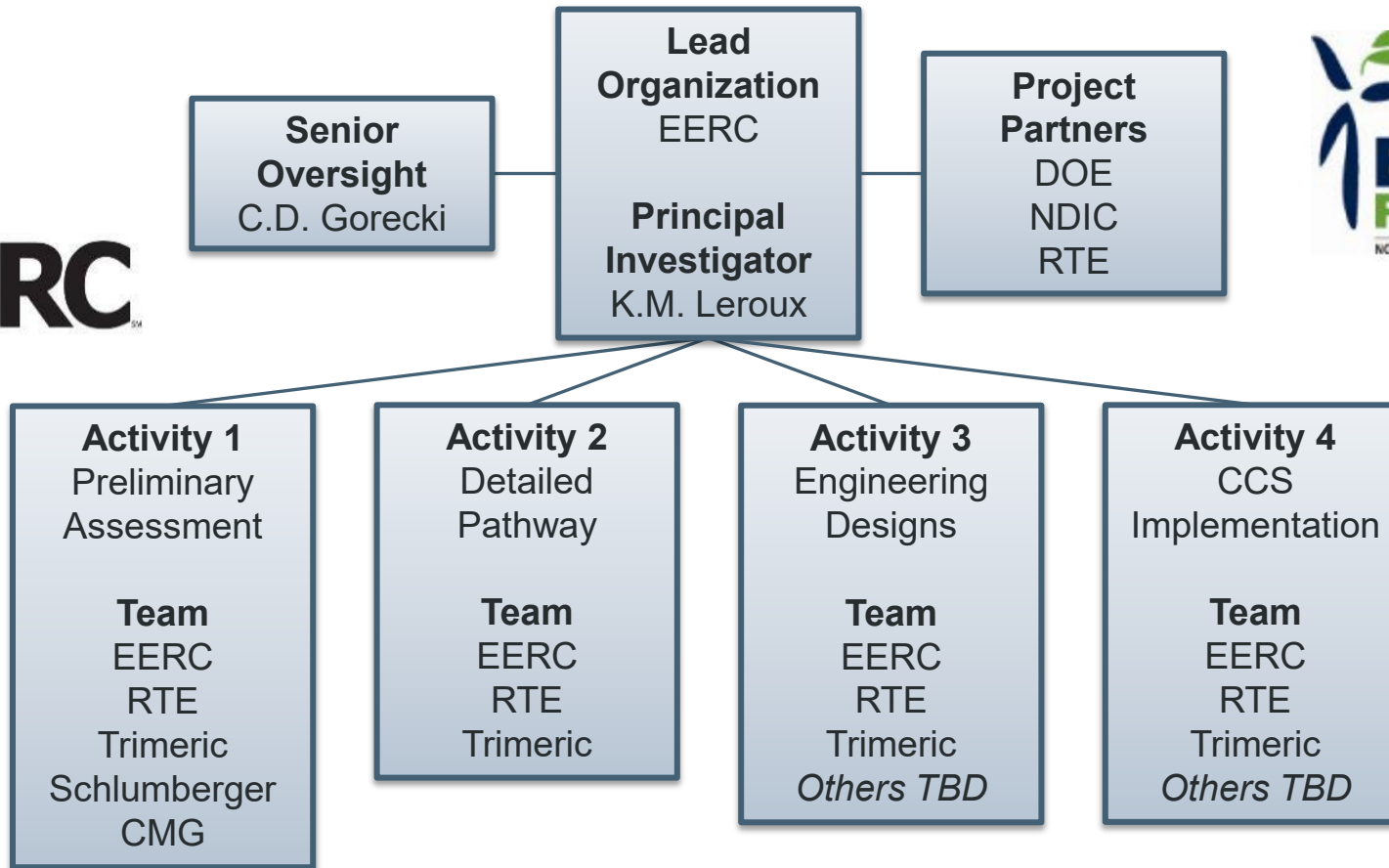
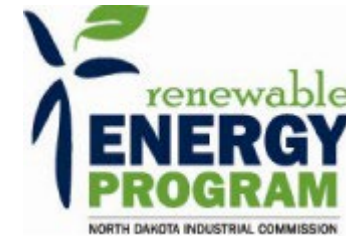


Image Credit: Energy & Environmental Research Center

ORGANIZATION CHART



U.S. DEPARTMENT OF
ENERGY



TRIMERIC CORPORATION

Schlumberger
Carbon Services



GANTT CHART (Period of Performance: 11/1/16 – 5/31/20)

| Subtask Title: Subtask 1.3 – Integrated Carbon Capture and Storage for North Dakota Ethanol Production | | | | | | | | | | | | | | | | | | | | | |
|--|------|-----|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|-----|-----|-----|-----|-----|-----|
| | 2016 | | 2017 | | | | | | | | | | | | 2018 | | | | | | |
| Activity | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul |
| 1 – Preliminary Assessment | █ | | | | | | | | | | | | | | | | | | | | |
| 2 – Detailed Pathway | | | | | | | | | | | | | | | █ | | | | | | |

| | 2018 | | | | | 2019 | | | | | | | | | | | 2020 | | | | | | |
|-------------------------|------|-----|-----|-----|-----|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|-----|-----|-----|-----|-----|--|
| Activity | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | |
| 3 – Engineering Designs | | | █ | | | | | | | | | | | | | | | | | | | | |
| 4 – CCS Implementation | | | | | | | | | | | | | | | | | | | | | | | |

Today (vertical dashed line at the start of Oct 2018)

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