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Critical Challenges. Practical Solutions.



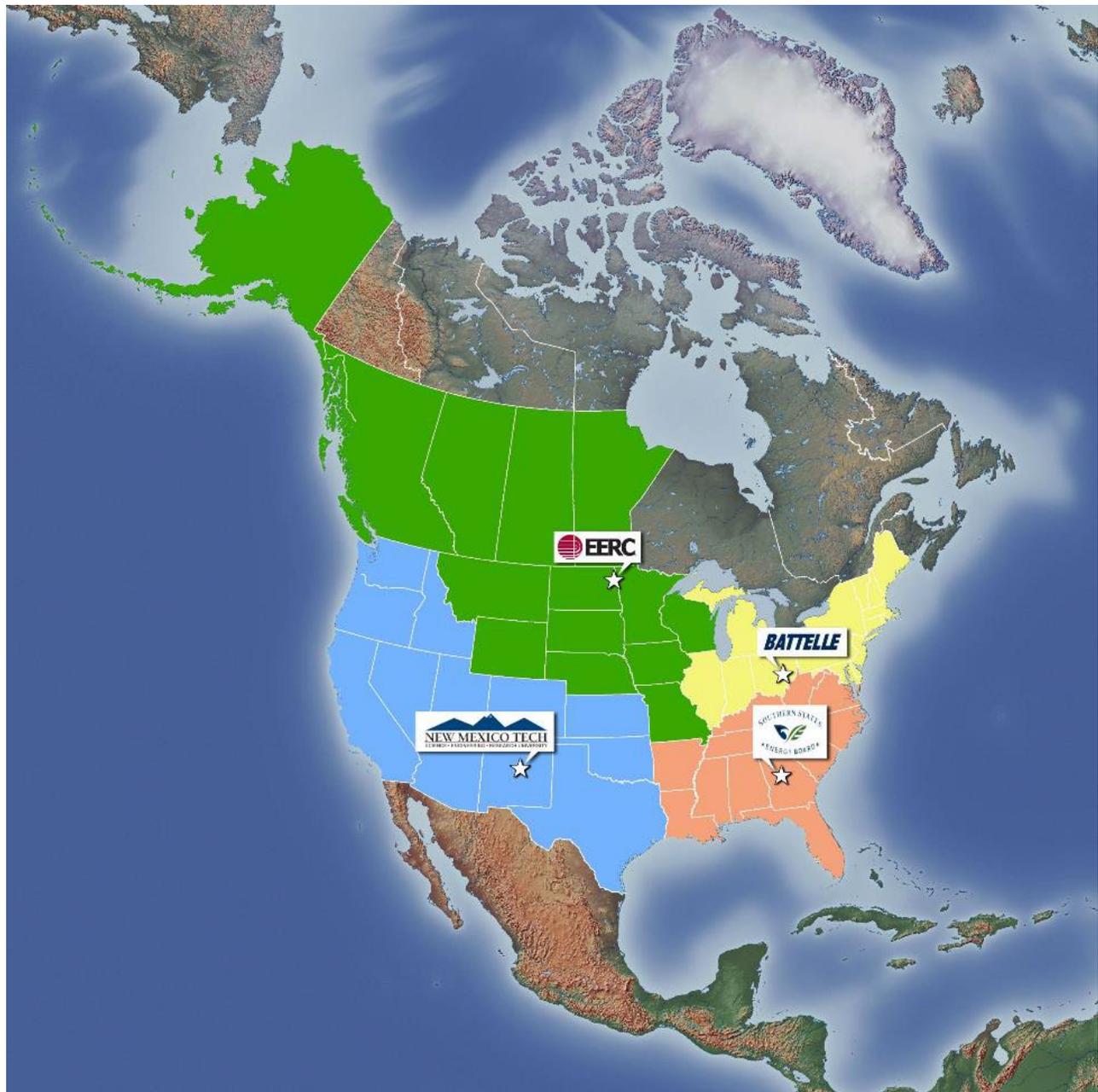
Energy & Environmental Research Center (EERC)

Plains CO₂ Reduction (PCOR) Partnership Initiative to Accelerate Carbon Capture, Utilization, and Storage Deployment (FE0031838)

U.S. Department of Energy
National Energy Technology Laboratory
Carbon Management Research Project Review Meeting
August 6, 2024

Kevin C. Connors
PCOR Partnership Project Manager

REGIONAL INITIATIVE



PCOR PARTNERSHIP

2003–2005 – PCOR Partnership: Characterization

2005–2008 – PCOR Partnership: Field Validation

2007–2019 – PCOR Partnership: Commercial Demonstration

2019–2024 – PCOR Partnership Initiative: Commercial Deployment

2024–2034 – PCOR: Sustained Commercial Deployment



U.S. DEPARTMENT OF
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NATIONAL
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LABORATORY



Institute of Northern Engineering
University of Alaska Fairbanks



UNIVERSITY
OF WYOMING
School of
Energy Resources



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Image credit – EERC

0 500 1,000
kilometers



PCOR PARTNERSHIP

The PCOR Partnership addresses regional capture, transport, use, and storage challenges facing commercial carbon capture and storage (CCS)/carbon capture, utilization, and storage (CCUS) deployment. The PCOR Partnership focuses on:

- Strengthening the technical foundation for geologic CO₂ storage and enhanced oil recovery (EOR).
- Advancing capture technology.
- Improving application of monitoring technologies.
- Promoting integration among capture, transportation, use, and storage industries.
- Facilitating regulatory frameworks.
- Providing scientific support to policymakers.
- Engaging the public through outreach and education.



Our partners inform our priorities.

PCOR PARTNERSHIP – NEW PARTNERS

2022 New Partners

- Air Products
- Alaska Asia
- Alaska DNR
- Aramco Americas
- Bakken Energy
- Barr Engineering
- BKV Corporation
- Carbon Alpha
- Cerilon (ND Ventures)
- CO2SeQure
- DarkVision Technologies
- Devon Energy
- Enbridge
- Enerplus
- GLJ
- Halliburton
- Hess
- Hydrogen Naturally
- Liberty Media
- Marathon Petroleum Corporation
- Neset Consulting
- Paragon Geophysical Services
- Rainbow Energy
- RITE
- SimTech
- Stryde
- Tallgrass Energy
- TERRACOH
- White Rock Oil and Gas

2023 New Partners

- Avalon International Corporation
- Bank of North Dakota
- ConocoPhillips
- Delta Constructors
- Emerson Automation Solutions
- Frontier Carbon Solutions
- Goodnight Midstream
- Hitachi Industrial Equipment & Solutions America
- Hunting Energy Services
- Ikon Science
- Marubeni-Itochu Tubulars America
- OLI Systems
- Paragon Geophysical Services
- Retract
- Rock Flow Dynamics
- Stress Engineering Services
- Subsurface AI
- Sumitomo
- WOGCC

2024 New Partners

- Heidelberg Materials
- Mitsui E&P USA LLC
- Meriden Carbon

REGIONAL CCUS ACTIVITY



Active and Developing CCUS Projects in the PCOR Partnership Region

- Active Capture
- ▲ Active Injection
- Developing Capture

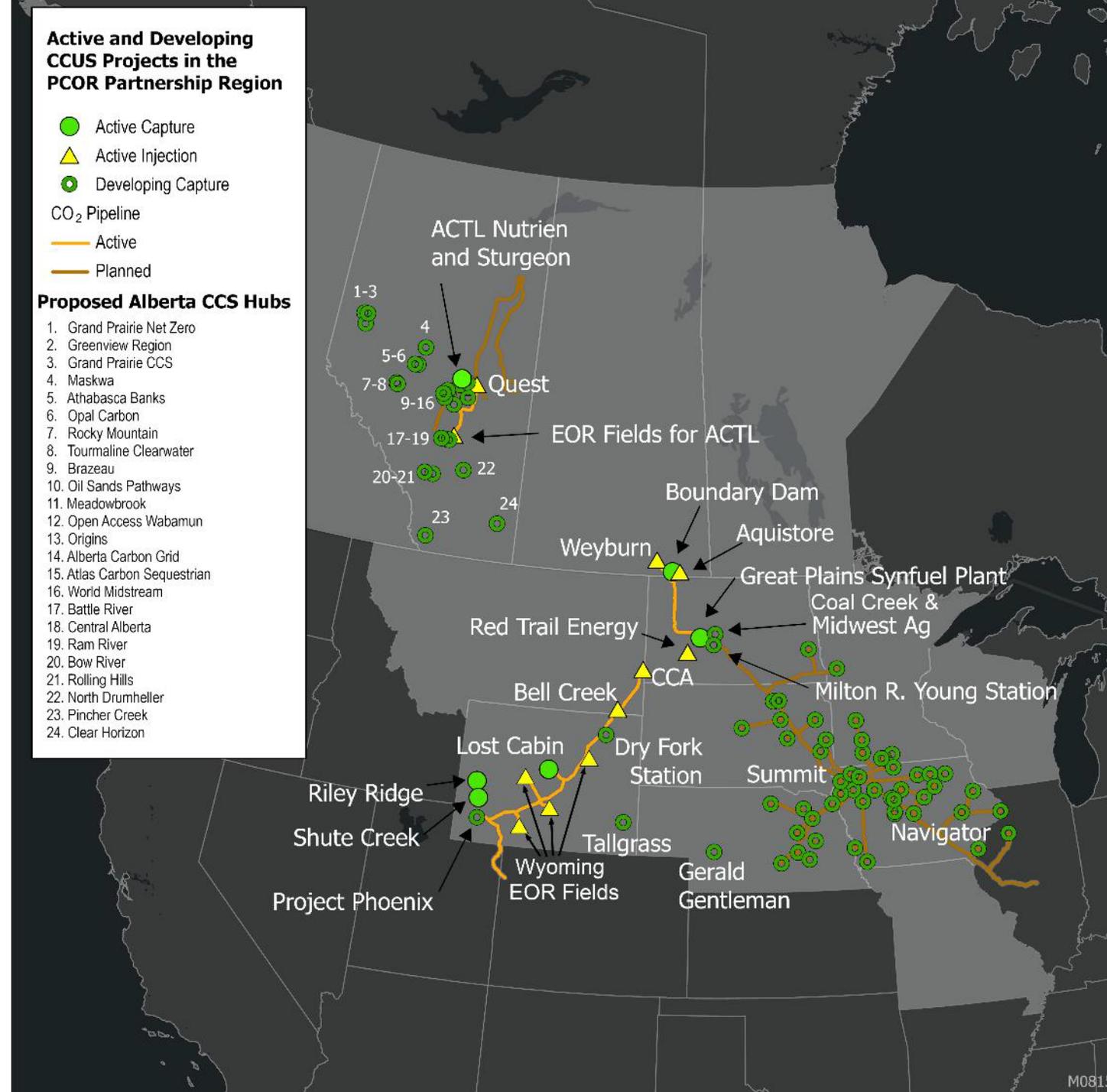
CO₂ Pipeline

— Active

— Planned

Proposed Alberta CCS Hubs

1. Grand Prairie Net Zero
2. Greenview Region
3. Grand Prairie CCS
4. Maskwa
5. Athabasca Banks
6. Opal Carbon
7. Rocky Mountain
8. Tourmaline Clearwater
9. Brazeau
10. Oil Sands Pathways
11. Meadowbrook
12. Open Access Wabamun
13. Origins
14. Alberta Carbon Grid
15. Atlas Carbon Sequestrian
16. World Midstream
17. Battle River
18. Central Alberta
19. Ram River
20. Bow River
21. Rolling Hills
22. North Drumheller
23. Pincher Creek
24. Clear Horizon



2023 AND 2024 HIGHLIGHTS

- PCOR Partnership annual meeting held in Grand Forks, North Dakota, (2023) and upcoming in Bismarck, North Dakota (2024).
- Regulatory Roundup meetings held in Deadwood, South Dakota, (2023) and upcoming in Bismarck (2024).
- Technical Advisory Board meetings held in Washington, D.C., (2023) and upcoming in Bismarck (2024).
- Continued collaboration with University of Alaska Fairbanks (UAF) and University of Wyoming.
- Field efforts continued at the Red Trail Energy CCS site.
- Seven quarterly *PCOR Pioneer* newsletters have been provided to partners.
- All DOE contractual deliverables have been met!
- Several white papers and products have been published.

2023 Annual Meeting



2023 REGULATORY ROUNDUP

- Pore space law
- Long-term liability
- Class VI primacy
- Regulatory program implementation
- Pathways to permit approval
- Policy/regulatory barriers

Regulatory Roundup Meeting
Deadwood, South Dakota
July 2023



CCUS MEETING HELD

- UAF, Alaska and North Dakota legislators, and regulatory staff held a CCUS meeting in Bismarck (December 2023).
- Meeting included discussion on CCUS and associated policies prior to 2024 legislative session.
- North Dakota invitees included the EERC, North Dakota Lignite Energy Council, Department of Mineral Resources Oil and Gas Division.
- Site tours held of the Blue Flint Ethanol plant and Coal Creek Station (coal-fired electric generating plant).



Blue Flint Ethanol Plant Tour



CCUS Legislator Discussion

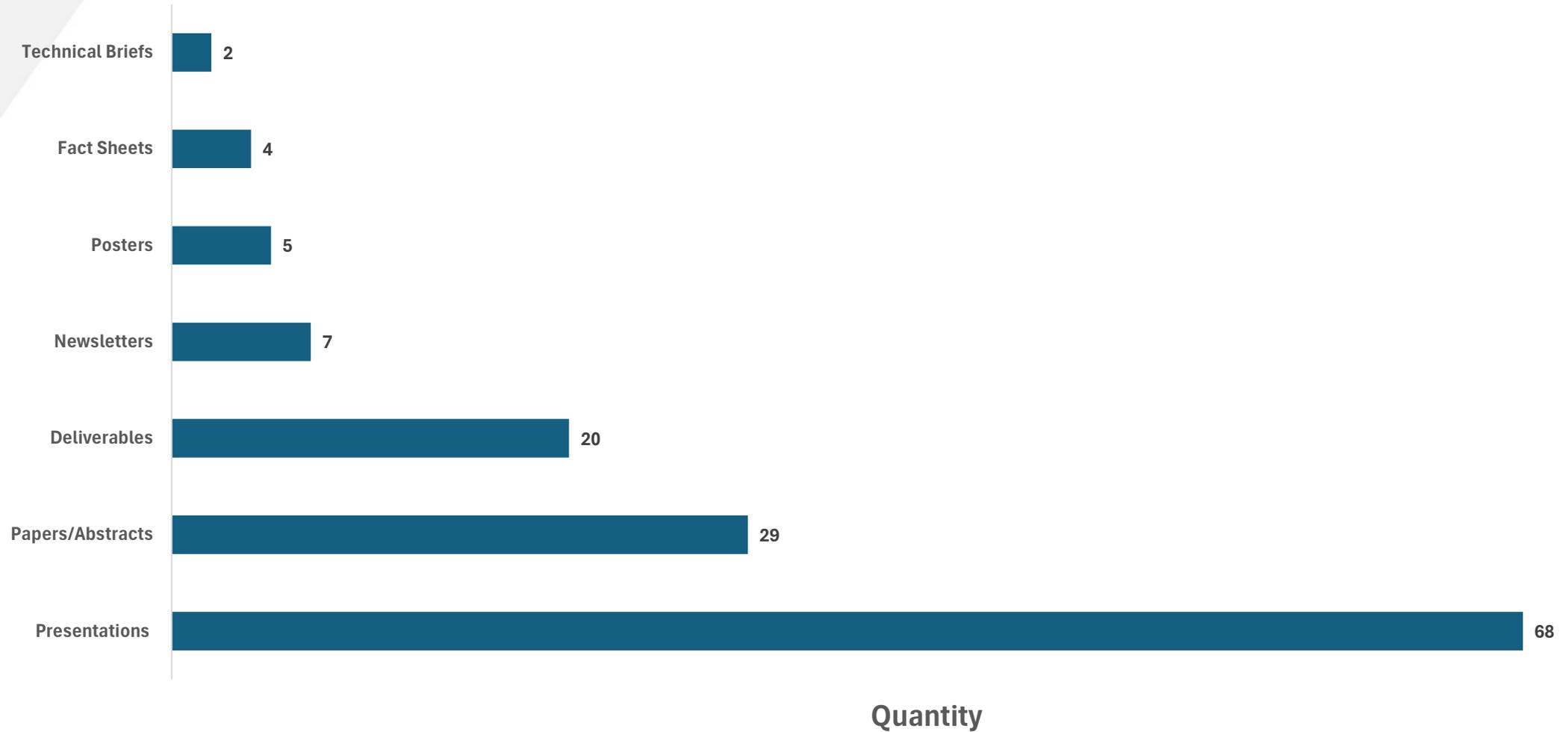


Blue Flint Ethanol Injection Site Tour



Coal Creek Station Tour

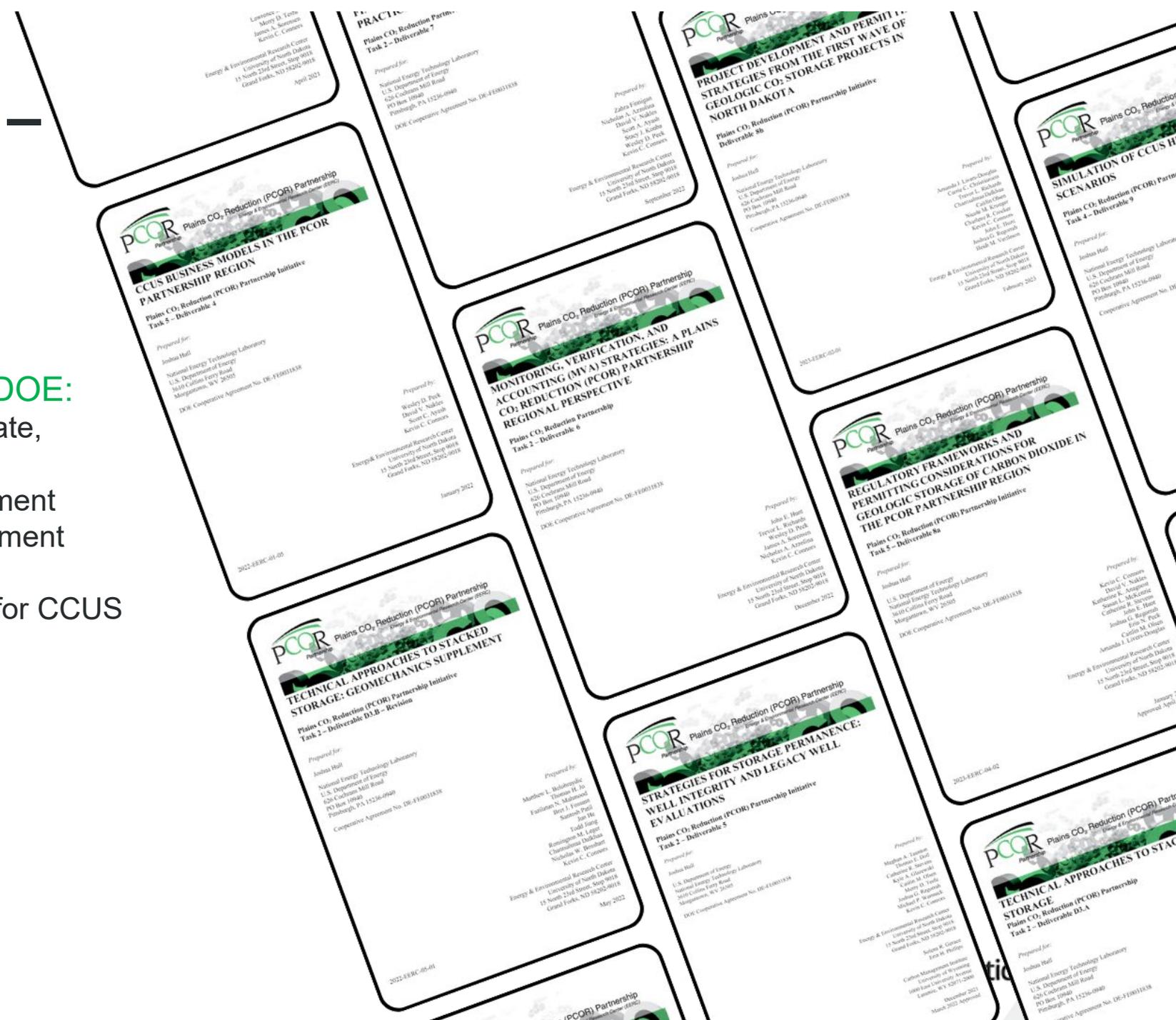
PCOR PARTNERSHIP PRODUCTS



TOPICAL REPORTS – DELIVERABLES

Recently submitted deliverables to DOE:

- D11 – Basement Faulting and Stress State, Induced Seismicity
- D12 – Regional Socioeconomic Assessment
- D13 – Regional Business Model Assessment
- D15 – PCOR Partnership Atlas
- D16 – Enabling Sustainable Monitoring for CCUS
- D17 – PCOR Road Map



DEMONSTRATING NOVEL MONITORING TECHNIQUES AT AN ETHANOL 180,000-MT/YR CCS PROJECT IN NORTH DAKOTA

RED TRAIL ENERGY (RTE) STORAGE FACILITY SITE

MAPPED SASA* ARRAYS DEPLOYED ON-SITE

HISTORICAL ANALYSIS OF SENTINEL1 SATELLITE DATA

KEY TAKEAWAYS

- The North Dakota Administrative Code (NDAC) provides for regulatory certainty by formalizing the process for...
- Incentive programs such as the Internal Revenue Service (IRS) Section 45Q tax credits and Low Carbon Fuel Standard (LCFS) protocols are driving the localization of CCS investment in North Dakota.

FIRST WAVE OF INCENTIVE-DRIVEN CCS PROJECTS IN NORTH DAKOTA

KEY TAKEAWAYS

- The North Dakota Administrative Code (NDAC) provides for regulatory certainty by formalizing the process for...
- Incentive programs such as the Internal Revenue Service (IRS) Section 45Q tax credits and Low Carbon Fuel Standard (LCFS) protocols are driving the localization of CCS investment in North Dakota.

GREAT PLAINS CO2 SEQUESTRATION PROJECT

SUMMIT CARBON SOLUTIONS

COAL CREEK STATION

MIDWEST AGENERGY

RED TRAIL ENERGY

PROJECT TUNDRA

CONFERENCE POSTERS



A QUANTITATIVE APPROACH FOR DEMONSTRATING PLUME STABILIZATION UNDER CCS POLICY FRAMEWORKS

KEY TAKEAWAYS

- The use of a quantitative approach for demonstrating plume stabilization under CCS policy frameworks...

RECOMMENDED APPROACH

GEOLOGIC MODEL USED FOR CASE STUDY

PLUME METRIC

QUANTITATIVE STABILIZATION

CO2 AREAL CHANGES OVER TIME

LOW-ENVIRONMENTAL-IMPACT MONITORING OF CO2 USING SEISMIC METHODS IN NORTH DAKOTA

KEY ELEMENTS

GOAL

RESEARCH PARTNERSHIP

SEISMIC MONITORING

DATA ANALYSIS

CO2 TRANSPORTATION INFRASTRUCTURE WITHIN THE UNITED STATES AND CANADA

USA - 7270 km (4517 mi) | Canada - 680 km (424 mi)

ANNOUNCED LINES - USA | ANNOUNCED LINES - CANADA

ROUTE - FROM HILKESBIE TO BAKER, MT

Pipeline Investigation - Review of Line Sizing and Effect of Pump Stations on a Theoretical CO2 Pipeline

RESULTS

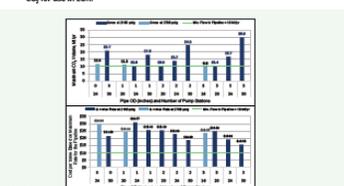


There is ~9630 km (5985 mi) of CO2 pipeline in North America, totaling a maximum capacity of 2.2 Mtpy.

Additional pipelines are planned in the United States and Canada but are not shown on this map.

CO2 flowlines are not shown on this map.

The current network of existing CO2 pipelines is primarily used to transport CO2 for use in EOR.



RESULTS

Increasing the size of pipe provided more flow rate through pipeline:

- Some pipelines may require higher pipe and flange pressure ratings (ANSI 1500 vs. ANSI 900) for the desired flow rate and limiting the OD of the pipeline.
- Adding pump stations increased the capacity of the pipeline and downsized the OD of the pipeline.
- The addition of pump stations along the pipeline can reduce the OD of the pipeline while increasing flow.
- However, the purchase cost and the operating cost of the pumps over the life of the project need to be reviewed to determine if the addition of pumps are economically justified with the reduction of line OD.
- Steel pricing, cost of pumps, and delivery time can drive the decision on how the pipeline is constructed.

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PCOR Partnership
Plans CO₂ Reduction (P) OR Partnership

U.S. Incentives to Capture and Store CO₂ Fact Sheet

Practical, Environmentally Sound CO₂ Sequestration

Section 45Q of the U.S. Internal Revenue Code was first introduced in 2002 as part of the Energy Improvement and Extension Act. This section, referred to as the 45Q tax credit, incentivizes investment and development in carbon capture, utilization, and storage (CCUS) projects. Since 2002, the code has been updated and expanded, allowing more projects to qualify for the tax credit.

2005 Energy Improvement and Extension Act offered \$50 per tonne of stored CO₂ for dedicated geologic storage projects and \$35 per tonne for CO₂ utilization projects with associated storage. Dedicated storage projects include methane from a mine, reformer and gas processor, associated storage projects most often reference enhanced oil recovery operations.

2018 Bipartisan Budget Act (BBA) expanded Section 45Q to provide \$50 per tonne of stored CO₂ (CC₂), the Internal Revenue Code uses carbon oxide, which includes CO₂, for dedicated storage and \$35 per tonne for associated storage. The BBA reduced the 15 million tonne CO₂ storage cap from the 2008 act but specified that the 45Q tax credit must be claimed over a 12-year period and that construction or operation must begin prior to 2025.

2022 Inflation Reduction Act (IRA) expanded on the BBA and raised the credit available to \$100 per tonne of carbon oxide stored for dedicated storage and \$60 per tonne for associated storage. The IRA also implemented a 30-year option for qualifying facilities, reduced the carbon capture threshold requirement to 1.0 million tonnes, and extended the deadline to begin construction by January 1, 2025. The major enhancements to 45Q in the IRA are summarized in Table 1. These changes, in government and education under the inflation-reduction-act-2022.

Storage Type	Pre-IRA (2002-2021)	IRA (2022-2025)	IRA (2026-2032)	IRA (2033-2042)	IRA (2043-2052)
Dedicated Storage	\$50	\$100	\$100	\$100	\$100
Associated Storage	\$35	\$60	\$60	\$60	\$60

45Q Tax Credit Enhancements Through the IRA of 2022

Who Receives the Tax Credit?
The 45Q tax credit is granted to the taxpayer, generally the operator of the carbon capture and storage project, who contractually ensures secure geologic storage of the CO₂. After the first five years of receiving the credit, the operator and the taxpayer may transfer the credits to an unrelated party in exchange for only cash.

45Q Incentive

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Fact Sheet

Practical, Environmentally Sound CO₂ Sequestration

Carbon Storage Monitoring, Verification, and Accounting (MVA)

Carbon storage is a process that injects captured volumes of carbon dioxide (CO₂) deep underground via one or more injection wells. Carbon storage may be a primary or secondary objective of project operators, but both primary (dedicated saline storage) and secondary (associated with CO₂ enhanced oil recovery (EOR), EOR) efforts result in the safe and permanent storage of CO₂. MVA refers to the set of actions that operators take to monitor injection operations, verify the CO₂ is stored safely, and account for project-related CO₂.

MVA Methods and Environments

Generally, monitoring environments can be divided into three broad categories from top to bottom: 1) atmosphere, 2) near surface (from surface to lowest underground source of drinking water (USDW)), and 3) deep subsurface (from below lowest USDW to the storage reservoir). Each environment requires its own set of MVA methods to effectively measure CO₂ volumes and fulfil project goals.

Standard MVA Methods	Environments
<ul style="list-style-type: none"> Distance Monitoring <ul style="list-style-type: none"> • Satellite remote • Aerial monitors • Heat monitors CO₂ Accounting <ul style="list-style-type: none"> • Mass balance • Inert gases • Pressure Active Monitoring <ul style="list-style-type: none"> • CO₂ flow rate • Gas rate data • Geophysical data • Seismic (LGR) 	<ul style="list-style-type: none"> Atmosphere Near Surface Deep Subsurface Above-Zone Monitoring

MVA Rules and Regulations

- Maintain an approved testing and monitoring plan as required by the CO₂ injection well permitting authority.
- Report CO₂ emissions and stored CO₂ volumes to the proper authorities (e.g., U.S. Environmental Protection Agency Greenhouse Gas Reporting Program).
- Ensure compliance with MVA incentive programs and/or carbon markets (e.g., low-carbon fuel markets or tax incentive programs).

Why Does MVA Matter?

MVA

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Fact Sheet

Practical, Environmentally Sound CO₂ Sequestration

Demonstrating CO₂ Storage in the PCOR Partnership Region

The Plans CO₂ Reduction (PCOR) Partnership is in its 20th year of collaboration with public and private partners to demonstrate the permanent, safe, and practical underground storage of carbon dioxide (CO₂) from industrial facilities—carbon capture, utilization, and storage or CCUS.

- In Phase I of the program (2002 to fall 2009), we focused on characterizing the stationary CO₂ emission sources as well as the geological storage layers suitable for CO₂ storage in the PCOR Partnership region.
- In Phase II (fall 2009 to fall 2019), the PCOR Partnership completed four subsurface field validation tests.
- The multi-faceted Phase III program, active through December 2018, was built around commercial-scale demonstrations and unprecedented collaboration at the local, regional, and cross-border levels.
- The PCOR Partnership Initiative (2019-2024) is focused on identifying and addressing regional storage and transportation challenges facing the commercial deployment of CCUS.

PCOR PARTNERSHIP REGION

PHASE I Characterization
PHASE II Field Validation
PHASE III Commercial Demonstration
INITIATIVE Commercial Deployment

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ENHANCED OIL RECOVERY FOR LONG-TERM CO₂ STORAGE

Technical Brief

Making Safe, Practical Carbon Capture, Utilization, and Storage Projects a Reality

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EOR Storage

OUTREACH

PCOR PARTNERSHIP ATLAS

6TH EDITION REVISED | 2024

U.S. DEPARTMENT OF ENERGY | **NELAP NATIONAL ENERGY LABORATORY** | **EERC UNIVERSITY OF NORTH DAKOTA** | **PCOR Partnership**

PCOR PIONEER

ANNUAL MEETING – 20 YEARS OF THE PCOR PARTNERSHIP

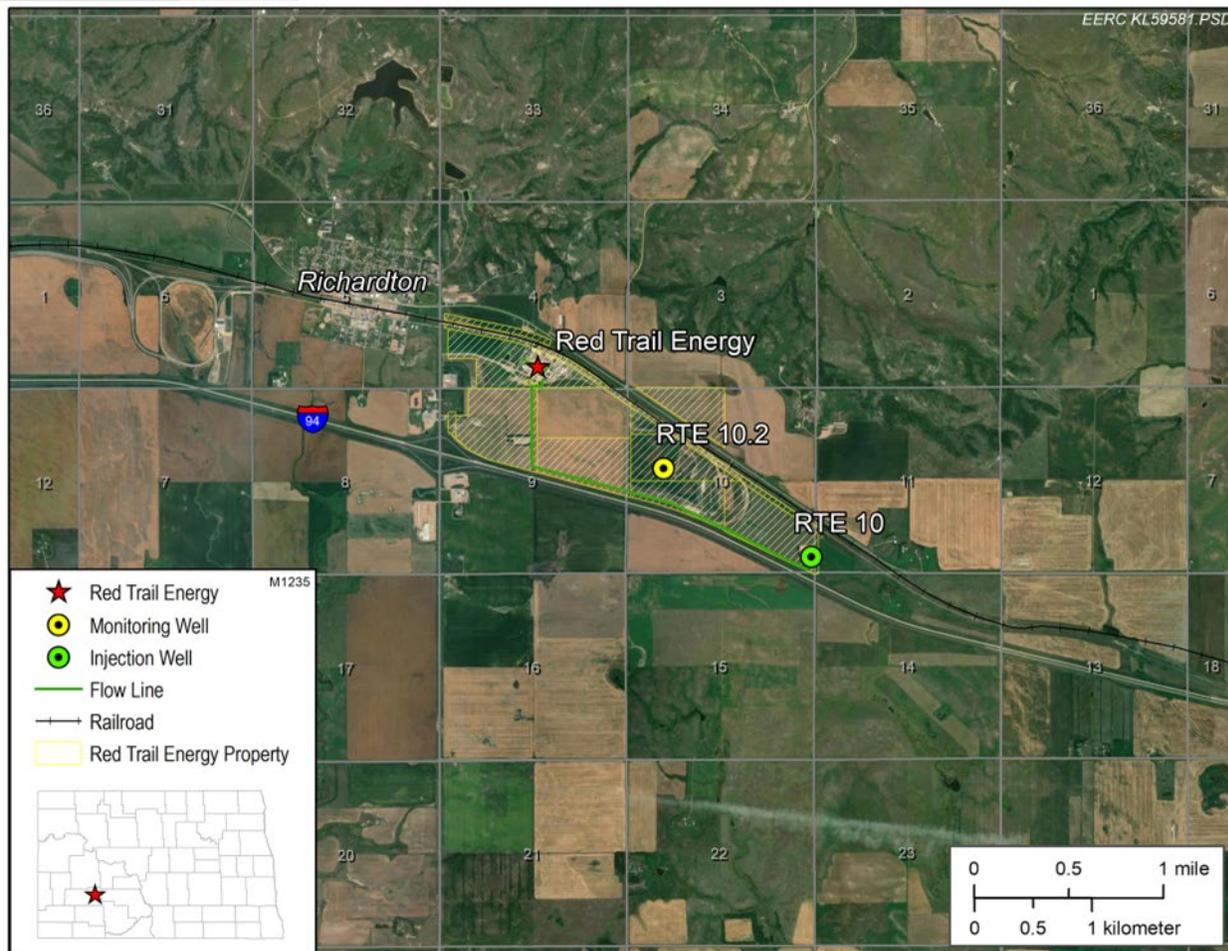
20 years!

Early 140 partners gathered at the **EERC** in Grand Forks, North Dakota, on February 27, 2023, for the PCOR Partnership Annual Meeting. The 2-day event featured a regular technical tour (see article below), followed by a full day of informal discussions, expert presentations, and an award ceremony (see article below). Throughout the event were the numerous opportunities for networking and collaboration focused on advancing projects.

The diversity of the partnership, comprising the CCUS industry, service providers, technology providers, government agencies, engineering consulting firms, and more, meant there was no shortage of talk on all aspects of the CCUS industry. With 62 different organizations represented at the meeting, the diversity continues to climb. In just the past 4 years, the PCOR Partnership has welcomed new partners. (The latest partners to join are listed later in this news article). Building upon the 20-year solid foundation constructed of regional collaboration—the very backbone of the PCOR Partnership—shows that we are achieving our goal of accelerating the commercialization of CCUS.

750 Atlases have been distributed!

PCOR HIGHLIGHT – RED TRAIL ENERGY CCS PROJECT

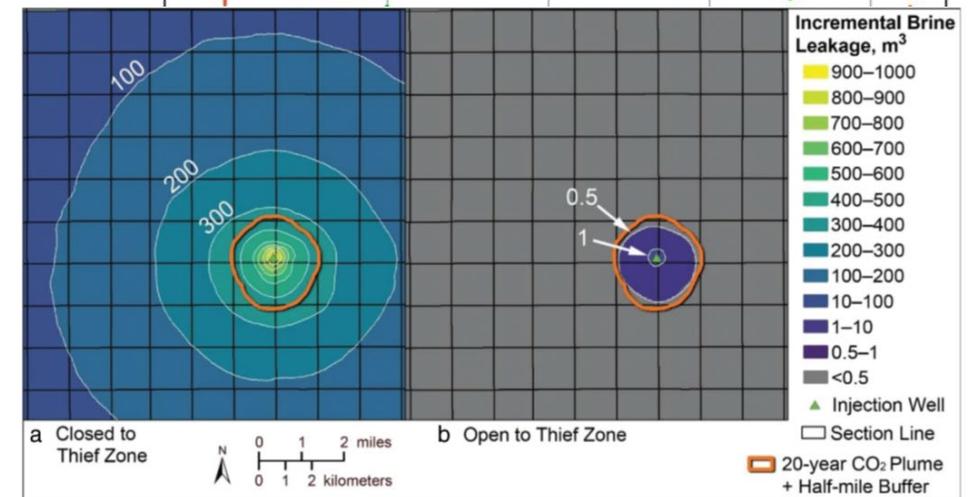
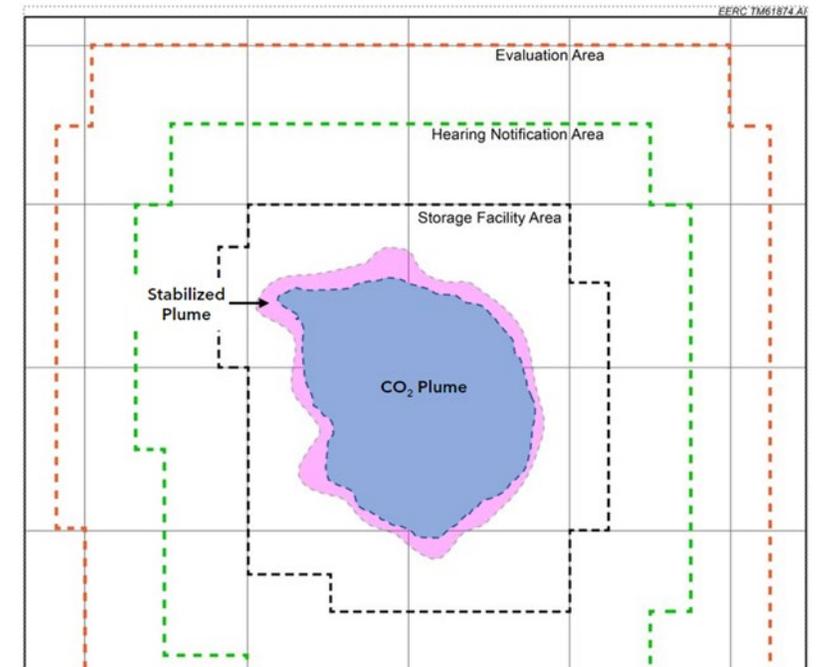


Red Trail Energy NDIC Storage Facility Permit

<i>Facility</i>	64-million-gallon dry mill ethanol production plant	
<i>Tonnage</i>	180,000 tonnes per annum	
<i>Injector Design</i>	One CO ₂ injector into single storage reservoir	
<i>Regulatory Status</i>	NDIC	Class VI permit approved Permit to Inject approved
<i>Other</i>	Support from US DOE, NDIC Renewable Energy Program, DOE-funded EERC-PCOR for storage site development and novel sustainable monitoring	

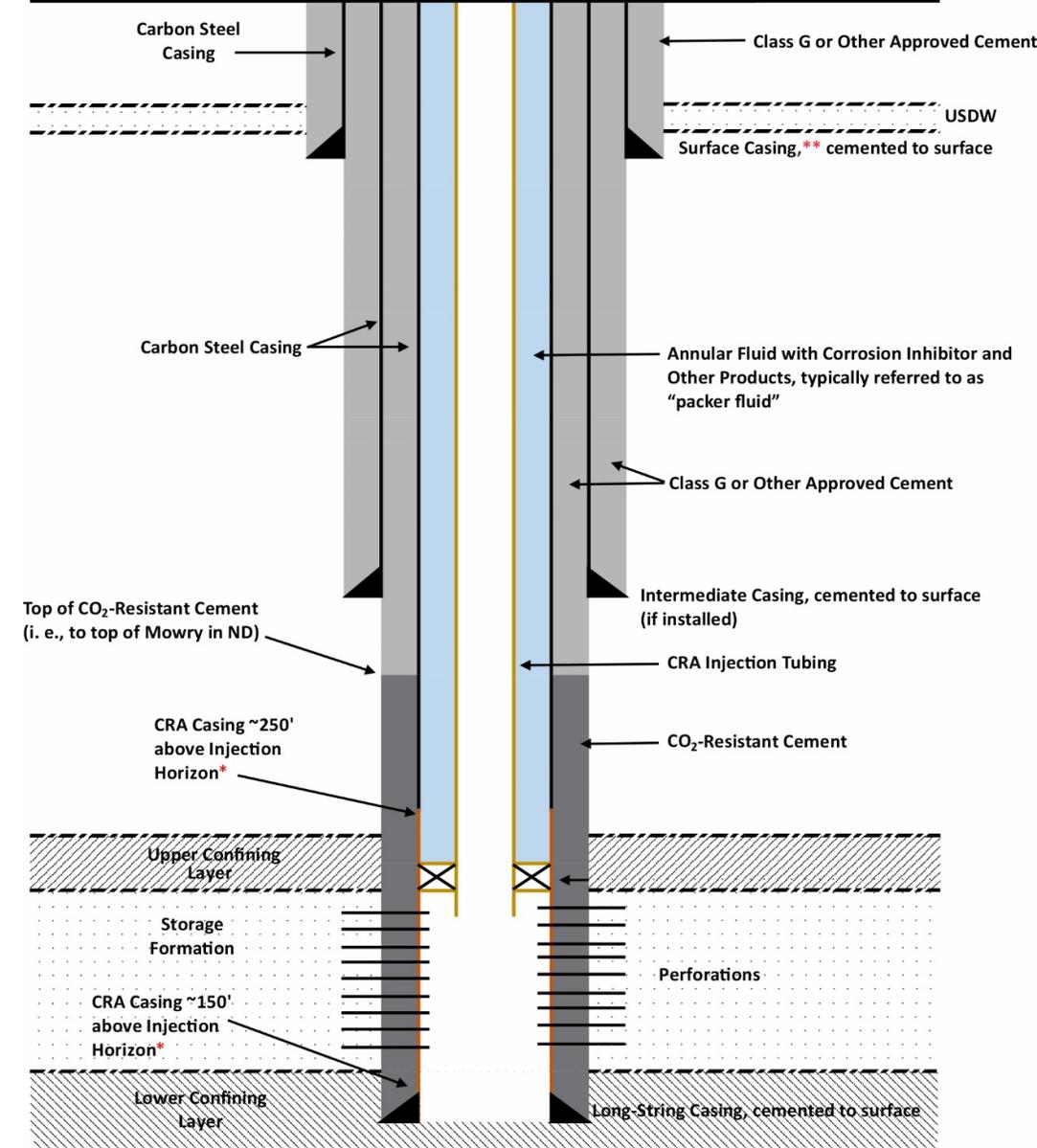
PCOR HIGHLIGHT – PLUME STABILIZATION

- The EERC, through the PCOR Partnership, conducted a study to evaluate a quantitative approach to demonstrate plume stabilization, with a theoretical case study of a CCS project in North Dakota.
- Plume stabilization is not explicitly defined by EPA rules and regulations.
 - Individual states such as North Dakota may have more rigorously defined plume stability expectations.
- Plume stabilization must be defined by the operator via multiple approaches, including risk assessment, numerical simulations, and monitoring data.
- The EERC studied applying a simplified methodology by Harp and others (2019) to calculate the time at which plume stabilization occurs.
- Plume stabilization can be found when the change in area over time slows to near zero, displaying asymptotic behavior.
 - dA/dt



PCOR HIGHLIGHT – PARTNERING WITH STRESS ENGINEERING

- Stress Engineering Services, Inc., is working as a subcontractor to provide the PCOR Partnership with basic guidelines and white papers on considerations for:
 - Selecting corrosion-resistant alloy material for CO₂ storage and utilization applications.
 - Use of carbon steel pipelines with CO₂ streams containing hydrogen sulfide (H₂S).
- The EERC has completed these white papers and guideline documents for publication.



NOTES:

- Drawing is not to scale but to provide a representation for the construction of a CCS injection well.
- CRA = corrosion-resistant alloy
- Injection packer is to be installed within 50' of the top perforation.

*Indicated lengths are provided as a reference and would be defined on a project-by-project basis.

**Surface casing is required to be set 50' below lowermost source of drinking water.

PCOR PARTNERSHIP

- Building on over 20 years of applied research in CCUS.
- Active region developing commercial CCUS projects.
- Engaged and motivated partners.
- Engaged regulators.
- PCOR Partnership is a catalyst for CCUS projects in the region.
- Focused on infrastructure development strategies.
- Ethanol industry in the region accelerating CCUS.
- Expanding CO₂ EOR opportunities in the region.

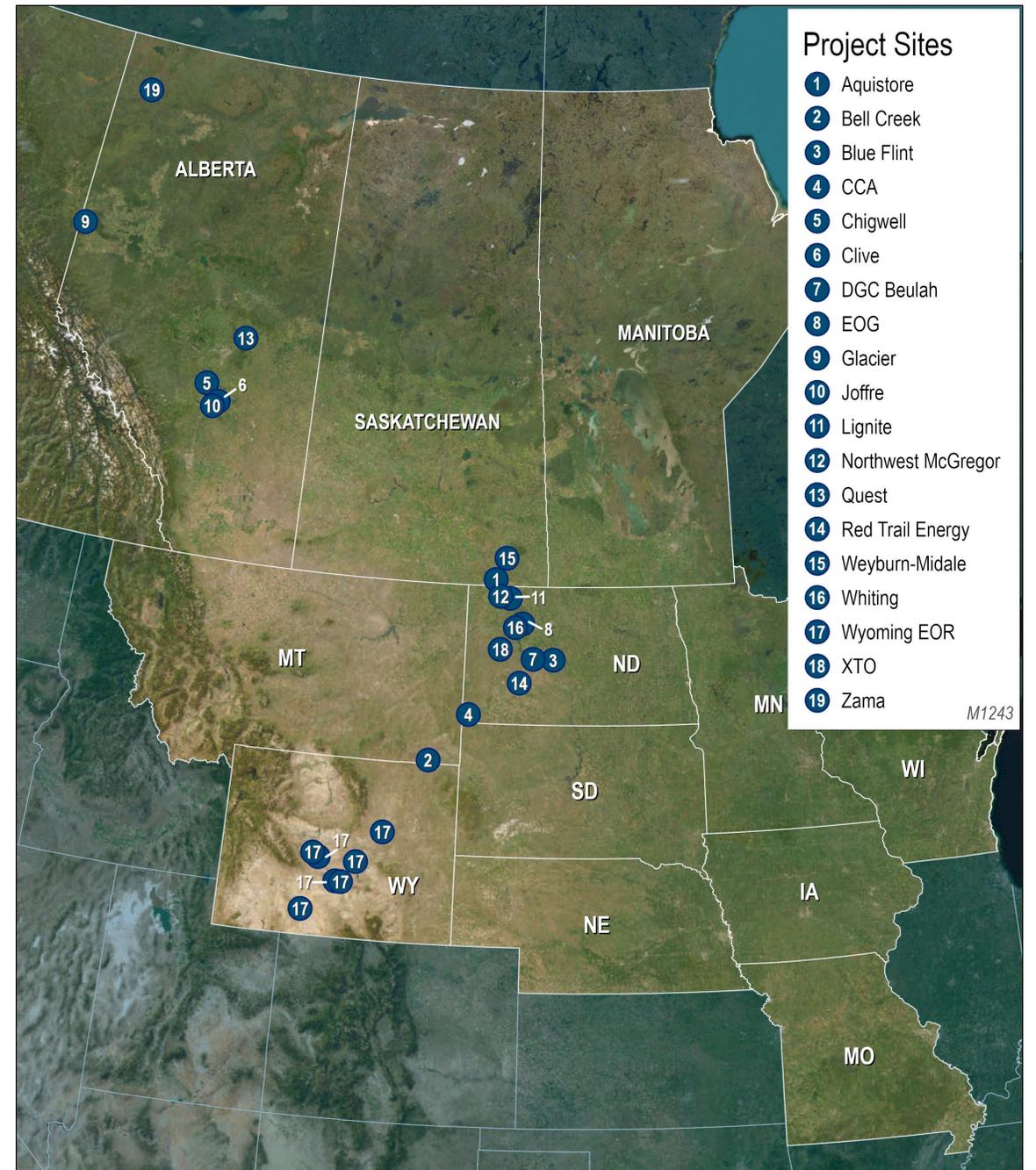


Total net CO₂ stored in PCOR Region:

170 million tonnes

Project	Net CO ₂ Stored (metric tons)
Aquistore	500,000
Bell Creek EOR	11,900,000*
Blue Flint	86,206
Cedar Creek Anticline EOR	1,600,000*
Chigwell EOR	1,600,000
Clive EOR	5,427,022
DGC Beulah	438,912
EOG Pilot	1593
Glacier	12,000
Joffre Field EOR	1,500,000
Lignite Field Test	82
Northwest McGregor Field Test	400
Quest	8,800,000
Red Trail Energy	299,145
Weyburn-Midale EOR	39,000,000
Whiting Pilot	2336
Wyoming EOR	97,000,000*
XTO Pilot	88
Zama Field Test	85,000

* Calculated estimate.





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A wide-angle photograph of a university campus at sunset. The sun is low on the left, casting a warm glow over the scene. In the foreground, there are large trees with yellowing leaves. In the background, there are several large, multi-story brick buildings, some with white accents. A parking lot with many cars is visible in the middle ground. The sky is a mix of blue and orange.

THANK YOU

Critical Challenges. Practical Solutions.

ACKNOWLEDGMENT

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