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PCOR Partnership

Plains CO_2 Reduction (PCOR) Partnership

Fact Sheet

Practical, Environmentally Sound CO_2 Sequestration

CO_2 Sequestration Test in a Deep, Unminable Lignite Seam

From 2005 to 2009, the Plains CO_2 Reduction (PCOR) Partnership implemented a small-volume carbon dioxide (CO_2) storage test in a lignite coal seam in Burke County, northwestern North Dakota. The Lignite Test was one of the four CO_2 storage validation field projects performed during Phase II (2005–2009) of the ongoing PCOR Partnership Program.

Goals and Key Results

The project was designed to 1) demonstrate that CO_2 can be safely injected and trapped in an unminable lignite seam, 2) assess the feasibility of CO_2-enhanced methane production from lignite, and 3) evaluate a variety of operational conditions to determine their applicability to similar coal seams within the region or beyond. Results included the following:

- The first field project to inject CO_2 into a deep, unminable lignite seam in the Williston Basin.
- Demonstration of CO_2 containment within the deep, unminable lignite seam for the duration of the test.
- Successful use of a reservoir saturation tool (RST) in conjunction with crosswell seismic to help identify the location of the CO_2 plume in the lignite seam.

The project was not able to address the recovery of methane resulting from CO_2 injection in this unminable lignite seam likely because of its low methane content coupled with poorly developed permeability.

CO_2 was injected into the center well of a five-well pattern. View of the test site from the north.

Fast Facts

Location: Burke County, northwestern North Dakota

Injection Zone: 10–12-foot-thick lignite seam

Depth: 1100 feet

CO_2 Injected: approximately 90 tons

Injection Duration: 16 days

Postinjection Monitoring: 3 months

Partners: Eagle Operating, Praxair, U.S. Department of Energy, PCOR Partnership

Lessons learned provide a first step in developing best practices for drilling, completion, injection, and monitoring protocols for CO_2 storage in the region's unminable lignite seams.

Site Selection

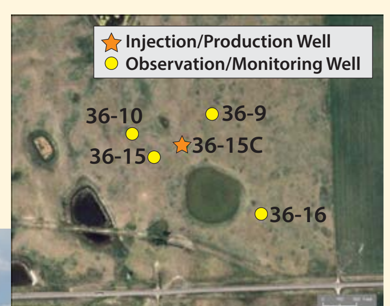
Lignite coal occurs in the PCOR Partnership region in the area comprising western North Dakota, eastern Montana, and southwestern Saskatchewan, and studies suggest the presence of coalbed methane (CBM), but no production exists. Site-screening criteria included locally continuous lignite seams with a minimum thickness of 10 feet in glaciated areas of the region, a depth below the maximum economical limit for mining, and availability of mineral rights. Several locations under state ownership met the screening criteria, and the candidate sites were then assessed using oil and gas logs, water well logs and other available data sets (e.g., gamma ray logs) with respect to geologic character and groundwater occurrence. A mineral lease was acquired for a 160-acre area northwest of Minot (Burke County, northwestern North Dakota), and local government officials and landowners were contacted. Because of the potential for economic development from CBM production, the project was given a positive reception.

Permitting

Because the project involved federal funding, the National Environmental Policy Act (NEPA) required a review to determine if an environmental assessment and environmental impact statement would be required. Because the project met the criteria for a categorical exclusion under NEPA, neither the environmental assessment nor the impact statement was required. North Dakota state requirements included the following:

- Drilling applications for each well.
- Sundry notices on a regular basis for work performed on the wells.
- A CO_2 injection application (Class II well).
- An aquifer exemption request because the intended injection zone potentially met the criteria for a potential underground source of drinking water (USDW; exemption granted with concurrence from the U.S. Environmental Protection Agency).

A well-spacing exemption was received because the four monitoring wells and the injection well were designed to fit within a single 160-acre well-spacing unit.



Drilling, coring, logging, and well completion activities prepared the site for the 16-day CO_2 injection test.

Drilling, Coring, and Well Installation

In August 2007, a group of five wells was drilled in a modified five-spot configuration within the 160-acre spacing unit. These were designated as Wells 36-9, 36-10, 36-15, 36-15C (injector well), and 36-16. The image below left shows the well pattern. The monitoring wells ranged from 288 to 920 feet from the injection well. The top third of the injection well seam was cored and tested for CO_2 and methane adsorption potential and methane content.

Immediately after drilling, the wells were cased and cemented from top to bottom to protect shallow USDWs and to isolate the injection zone. The injection and monitoring wells were then perforated at the level of the injection zone, a 10–12-foot-thick lignite coal seam sandwiched between layers of clay at a depth of approximately 1100 feet.

Preparing coal core for testing.

Well Development and Preinjection Monitoring

Permeability was lower than expected. As a result, well stimulation techniques were applied in stages of least to most aggressive to enhance connections between the wellbores. The techniques included swabbing, sonic hammer, nitrogen N-fit test, and acid treatment (in order of application). Ultimately, the N-fit test determined that the formation pressure was well below expected (345 psi vs. the calculated 470 psi), and acidizing proved the most effective in establishing communication between the wellbores and the coal seam.

Preinjection monitoring comprised three stages. Initial well monitoring characterized baseline conditions for all wells using portable field instruments to record pressure changes, fluctuations in water elevations, and the presence of gas. During well development activities, monitoring focused on analyzing fluids and gases taken from each well. Conductivity, temperature, and pH of the fluid samples were determined in the field; major cations and anions were determined in the laboratory. Gas samples were analyzed for O_2, CO_2, H_2S, and hydrocarbons including methane. Following well development, temperature and pressure sensors were attached inside the well casing at the surface, while sensors for temperature, pressure, conductivity, and pH were deployed inside the well casing just above the seam perforations. RST logs characterized the geology and fluids in proximity to the wells, and crosswell seismic surveys were conducted between Wells 36-9 and 36-15 and Wells 36-16 and 36-10 to characterize the geologic layers as well as fluids and gases.

CO_2 Injection

Food-grade CO_2 (99.9% pure) supplied by Praxair was shipped from Wyoming to the injection site by rail and truck. Approximately 90 tons of CO_2 was injected during a 16-day period in March 2009. A proprietary nontoxic tracer was added to the CO_2, which was injected at pressures ranging from 605 to 770 psia (gaseous and liquid injection). The low permeability of the coal impeded injection. The minimum pumping rate of the Praxair skid was found to exceed the injection rate accepted by the coal seam, and as a result, injection had to be started and stopped, resulting in nine cycles of reservoir pressure buildup and decline.

CO_2 was injected into the lignite bed for 16 days.

Postinjection Monitoring

The 90-day monitoring period focused on characterizing the fate of the injected CO_2. No CO_2 or tracer was detected in the monitoring wells. RST detected the injected CO_2 gas at the injection well, and crosswell seismic between monitoring wells and crossing at the injection well identified the configuration of the plume. Sensors in monitoring wells detected a decrease in temperature and a slight increase in pressure—this was interpreted as indirect evidence of the approach of the CO_2 plume.

Postinjection monitoring activities continued for 90 days. Two of the activities were gas sampling and crosswell seismic tomography to track CO_2 movement deep underground.

Observations

The project occurred in a relatively uninvestigated section of the geologic column—below commonly used drinking water aquifers and above layers containing recoverable oil. Although the feasibility of recovering methane displaced by injected CO_2 could not be demonstrated at this site, the laboratory sorption tests on the seam portion of the core indicated that injected CO_2 would displace adsorbed methane under the seam pressure. The poorly developed cleats and fractures expressed as low permeability were likely a major factor in the inability to perform pump testing and the low injection rates. Given project results, the technical feasibility of CO_2 storage and coalbed methane recovery in the region's unminable lignites still requires the development and verification of practical injection strategies and monitoring protocols. Future projects should consider:

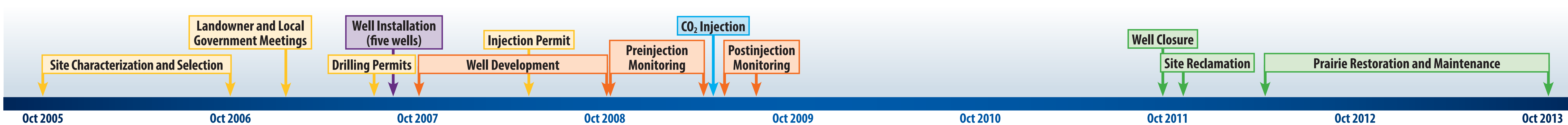
- Characterizing a pilot hole to determine local conditions, including lignite formation pressure.
- Using air mist to optimize communication between the borehole and the seam.
- Strategies that enhance secondary permeability.

Well Closure and Site Reclamation

In September 2011, approximately 2½ years postinjection, the five project wells were plugged by squeezing cement into the perforations at the bottom of the well to seal off the formation and pouring cement plugs at appropriate depths within the well and at the surface.

Earthmoving equipment then returned the land to its original contour, a small seeding drill planted grass seed, and areas were fenced to exclude livestock. The area was inspected through 2013 to ensure vegetation was reestablished and weeds were controlled. The procedure followed the rules administered by the North Dakota Department of Mineral Resources and the State Land Department.

Reclamation of the site began with earthmoving to reestablish the surface contour. Site reclamation was deemed successful after two summers, with vegetation well-established and suitable for grazing.

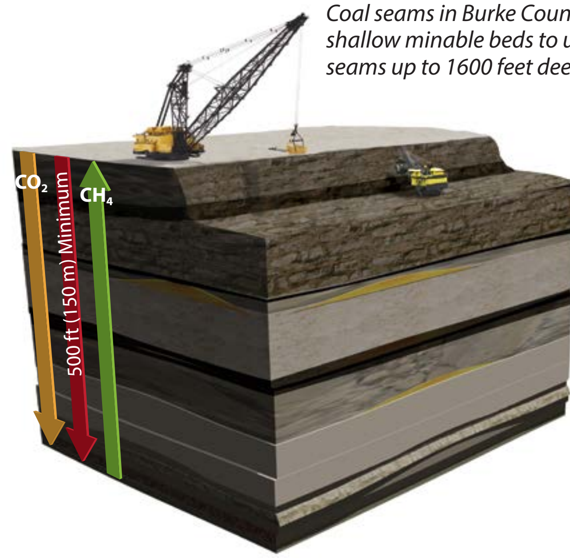


Why Inject CO_2 into Coal Seams?

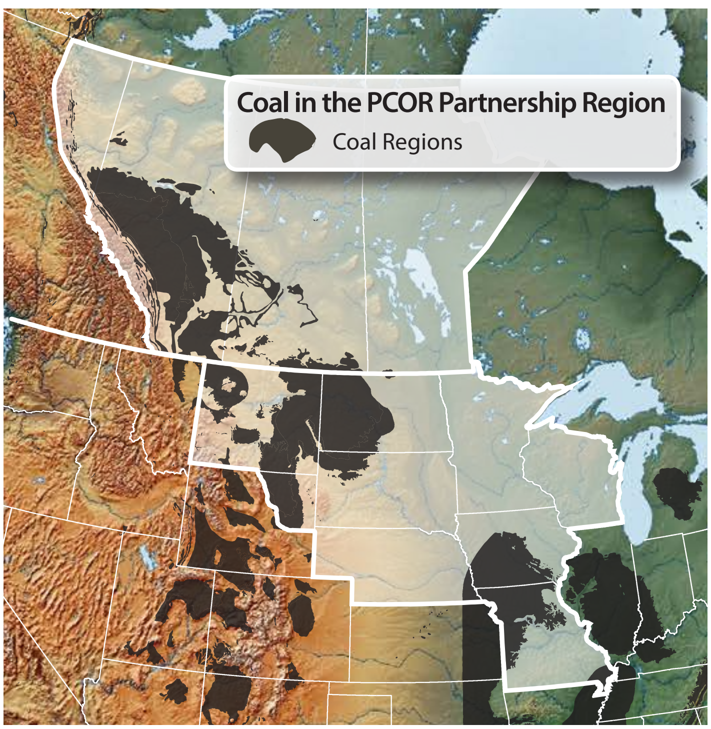
Many coal seams are too deep, too wet, or too thin to mine. In addition, many coal seams have the ability to trap natural gas (also known as CBM). Some types of seams, especially low-rank seams (i.e., lignite, subbituminous coal), have the ability to naturally attract and hold onto CO_2 molecules.

The northern Great Plains region of the United States and Canada contains extensive lignite and subbituminous coal deposits. For the North Dakota portion of the Williston Basin, the CO_2 sequestration potential in unminable lignite coals (depth in excess of 500 feet [150 meters]) is estimated as 599 million short tons (54.3 × 1010 kilograms).[1] Injecting CO_2 captured at power plants or ethanol facilities into these seams for permanent storage could reduce our carbon footprint. Injecting CO_2 could also dislodge the methane gas naturally trapped in many unminable coal seams, which could help increase our supply of clean-burning, low-carbon natural gas.

Coal seams in Burke County range from shallow minable beds to unminable seams up to 1600 feet deep.



The PCOR Partnership region is rich in coal resources and has the potential to store over 8 billion tons of CO_2 in deep, unminable seams.



How Does CO_2 Attach Itself to Coal?

Because of their fractured nature, coal seams have a relatively large internal surface area, and these surfaces have the capacity to accumulate large amounts of gases. Some gases, such as CO_2, have a higher affinity for the coal surfaces than others, such as nitrogen. As a result, coal seams that are too deep (generally >500 feet [150 meters]) or too thin to be economically mined may prove to be viable sites for CO_2 storage. Carbon storage in unminable coal seams relies on the adsorption of CO_2 on the coal fracture surfaces and the permeability of the coal bed. The more microstructures there are in the coal, the more surface area it has to accumulate CO_2.

In addition to being potential storage zones for CO_2, many coal beds contain commercial quantities of adsorbed natural gas (methane). CBM recovery can be achieved by injecting CO_2, which preferentially adsorbs onto the fracture surfaces of the coal, displacing the methane. Depending on the coal rank, up to 13 molecules of CO_2 can be adsorbed for every 29 molecules of methane displaced. This enhanced CBM recovery procedure could generate revenue to offset the costs associated with the injection and storage of CO_2 in coal beds.

References

[1] Nelson, C.R., Steadman, E.S., and Harju, J.A., 2005, Geologic CO_2 sequestration potential of lignite coal in the U.S. portion of the Williston Basin: www.undeerc org/PCOR/NewsAndPubs/pdf/GeologicCO2WillistonBasin.pdf (accessed September 2015).

For more information, please access the CO_2 Sequestration Validation Test in a Deep, Unminable Lignite Seam in Western North Dakota Regional Technology Implementation Plan on the PCOR Partnership Web site.

The Plains CO_2 Reduction (PCOR) Partnership is a group of public and private sector stakeholders working together to better understand the technical and economic feasibility of storing CO_2 emissions from stationary sources in the central interior of North America. The PCOR Partnership is led by the Energy & Environmental Research Center (EERC) at the University of North Dakota and is one of seven regional partnerships under the U.S. Department of Energy's National Energy Technology Laboratory Regional Carbon Sequestration Partnership Initiative. To learn more, contact:

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Visit the PCOR Partnership Web site at www.undeerc.org/PCOR. New members are welcome.

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