CO₂ Sequestration Test in a Deep, Unminable Lignite Seam

From 2005 to 2009, the Plains CO₂ Reduction (PCOR) Partnership implemented a field-based validation test to determine the feasibility of storing CO₂ from human activities in unminable lignite seams as a way of addressing climate change concerns. At the same time, the test was designed to determine the feasibility and economics of stimulating the production of natural gas trapped in low-rank coals like lignite. The Lignite Field Validation Test was one of the four CO₂ storage validation field projects performed during Phase 2 (2005 to 2009) of the ongoing PCOR Partnership Program.

Key Results

The Lignite Field Validation Test injected CO₂ into a deep, unminable lignite seam. The test was successful at demonstrating that gaseous CO₂ could be injected and stored safely under real-world conditions. The postinjection monitoring techniques demonstrated that the CO₂ was contained within the injection zone coal seam for the duration of the approximately 3-month monitoring period. Because of the unusually low natural gas (methane) content of the coal at the project locality, the test was less successful in conclusively demonstrating the recovery of methane resulting from CO₂ injection.

These findings opened the door for the execution of other similar CO₂ injection tests at a larger scale and of longer duration. The experience would also be valuable in the design of future tests in coal seams, including those intended to gauge the potential of methane recovery.

Results suggest that unminable lignite seams can permanently store CO₂.
Site Selection
Lignite coal is found in the PCOR Partnership region in the area comprising western North Dakota, eastern Montana, and southwestern Saskatchewan. For this project, the screening criteria included locally continuous lignite seams with a minimum thickness of 10 feet, a depth below the maximum economic limit for mining, and mineral rights owners amenable to validation test activity. Several locations under state ownership met these criteria. Candidate sites were then assessed using geophysical logs from the North Dakota Industrial Commission (NDIC) Oil and Gas Division. Geologic character and groundwater occurrence and quality were assessed using water well logs and other available data sets (e.g., gamma ray logs). A 160-acre area northwest of Minot (Burke County, northwestern North Dakota) was eventually selected for the test, and local government officials and landowners were contacted. Because of the potential for economic development, the project was positively received.

Drilling and Well Installation
In August 2007, five wells were drilled in a modified five-spot configuration within a 160-acre spacing unit. These were designated as Wells 36-9, 36-10, 36-15, 36-15C (injector well), and 36-16. The table below is a summary of the sampling and logging activities, and the figure above shows the well pattern. Immediately after drilling, the wells were completed with standard casing. All wells were cased and cemented from top to bottom to protect shallow USDWs. The injection and monitoring wells were then perforated at the level of the injection zone, a 10-foot-thick lignite coal seam at a depth of approximately 1100 feet.

Drilling, coring, logging, and well completion activities prepared the site for the 16-day CO2 injection test.

Well Development and Preinjection Monitoring
Once the wells were completed, they underwent a series of development activities intended to facilitate the flow of CO2 into the coal seam from the injection well as well as the return flow of methane (if present) from the coal. Monitoring activities focused on analyzing fluids and gases taken from the wells. In the field, fluid samples were analyzed for sodium, calcium, magnesium, iron, potassium, chloride, carbonate, bicarbonate, and sulfate; gas samples underwent composition analysis.

In addition, portable field instruments were employed in the wells to detect pressure changes, fluctuations in water elevations, and the presence of in situ gases (methane and CO2). All wells were equipped with surface and downhole sensors to measure temperature, pressure, conductivity, and pH. The downhole sensors were deployed inside the casing at the top of the perforated interval. Sensor data collection schedules varied from well to well to correspond with well development activities.

Prior to injection, reservoir saturation tool (RST) logs were run in all wells, and crosswell seismic surveys were conducted between Wells 36-9 and 36-15 and Wells 36-16 and 36-10. This provided the baseline information to compare to subsequent seismic runs focused on the detection of CO2.

CO2 Injection
Food-grade CO2 (99.9% pure) was shipped from Wyoming to a rail depot just north of the injection location and then trucked to the injection site. Approximately 90 tons of CO2 was injected into a 10–12-foot-thick coal seam during a 16-day period in March 2009. During the injection, the movement of CO2 in the lignite seam was tracked using temperature and pressure sensors located in the wells. Higher pressure and lower temperature indicated the presence of CO2.

Postinjection Monitoring
Postinjection monitoring occurred for a 90-day period following injection. Monitoring included temperature, pressure, and pH data collected by the in-well sensors as well as 1) direct measurements, which provided information directly related to the fluid pathways at the shape of space occupied by fluids, and 2) indirect measurements, which provided data regarding certain parameters that characterized the fluid movement at discrete points of the formation. Methods included RST well log analysis for measurement of gas saturation near the wellbore; analysis of multiple lines/episodes of time-lapse crosswell seismic tomography for the measurement of translational differences of sound waves created by CO2 injection; gas sampling at wellheads as a basis for field measurements of methane, CO2, and oxygen concentrations and laboratory analysis from gas chromatography; microseismic measurements, including both geophones and tiltmeters; and laboratory analyses of fluid samples from wells to evaluate any inflections in pH or carbonate concentrations.

Well Closure and Site Reclamation
In September 2011, approximately 30 months’ 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 throughout 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.

The site reclamation was deemed successful after two summers, with vegetation well established and suitable for grazing.
Why Inject CO₂ into Coal Seams?

Many coal seams are too deep, too wet, or too thin to mine for fuel. In addition, many coal seams have the ability to trap natural gas (also known as coalbed methane [CBM]). Some types of seams, especially low-rank seams (i.e., lignite, subbituminous coal) have the ability to naturally attract and hold CO₂ molecules.

The northern Great Plains region of the United States and Canada contains extensive lignite and subbituminous coal deposits that contain natural gas and can store CO₂. Injecting CO₂ captured at power plants or ethanol facilities into these seams for permanent storage could reduce our carbon footprint. Using the injected CO₂ to dislodge the methane gas naturally trapped in coal seams could help increase our supply of clean-burning, low-carbon natural gas.

How Does CO₂ 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 CO₂, 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 m]) or too thin to be economically mined may prove to be viable sites for CO₂ storage. Carbon storage in unminable coal seams relies on the adsorption of CO₂ 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 CO₂.

In addition to being potential storage zones for CO₂, many coal beds contain commercial quantities of adsorbed natural gas (methane). CBM recovery can be achieved by injecting CO₂, which preferentially adsorbs onto the fracture surfaces of the coal, displacing the methane. Depending on the coal rank, up to 13 molecules of CO₂ can be adsorbed for every 29 molecules of methane displaced. This enhanced CBM procedure could create revenue to offset the costs associated with the injection and storage of CO₂ in coal beds.

The Plains CO₂ Reduction (PCOR) Partnership is a group of public and private sector stakeholders working together to better understand the technical and economic feasibility of storing CO₂ 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:

Charles D. Gorecki, Senior Research Manager, (701) 777-5355; cgorecki@undeerc.org
Edward N. Steadman, Deputy Associate Director for Research, (701) 777-5279; esteadman@undeerc.org
John A. Harju, Associate Director for Research, (701) 777-5157; jharju@undeerc.org

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