Field Validation Test of North Dakota Lignite

The injection of carbon dioxide (CO_2) into unminable coal seams is one option being investigated through the U.S. Department of Energy's Regional Carbon Sequestration Partnership Program to conduct comprehensive evaluations of the opportunities for CO_2 capture and storage in North America. To evaluate this storage option, the Plains CO_2 Reduction (PCOR) Partnership conducted laboratory- and field-based investigations of an unminable lignite coal seam located in Burke County in northwestern North Dakota. The purpose of the study was to assess the feasibility of storing anthropogenic CO_2 in lignite seams while simultaneously producing coalbed methane (CBM). More specifically, the goals of the study were as follows:

- To demonstrate that CO_2 can be safely injected and trapped in lignite by means of adsorption.
- To assess the feasibility of CO_2-enhanced methane production from lignite.
- To evaluate a variety of carbon storage operational conditions to determine their applicability to similar coal seams within the region or beyond.

The selection of the demonstration test site was driven by a number of technical and nontechnical factors. The former included the review of geophysical logs which identified multiple coal seams. Following this reconnaissance effort, water well logs and other available data sets, e.g., gamma ray logs, were examined to identify the water quality, coal characteristics, and baseline geologic settings in these candidate coal seams. The availability of mineral rights was also an important screening factor.

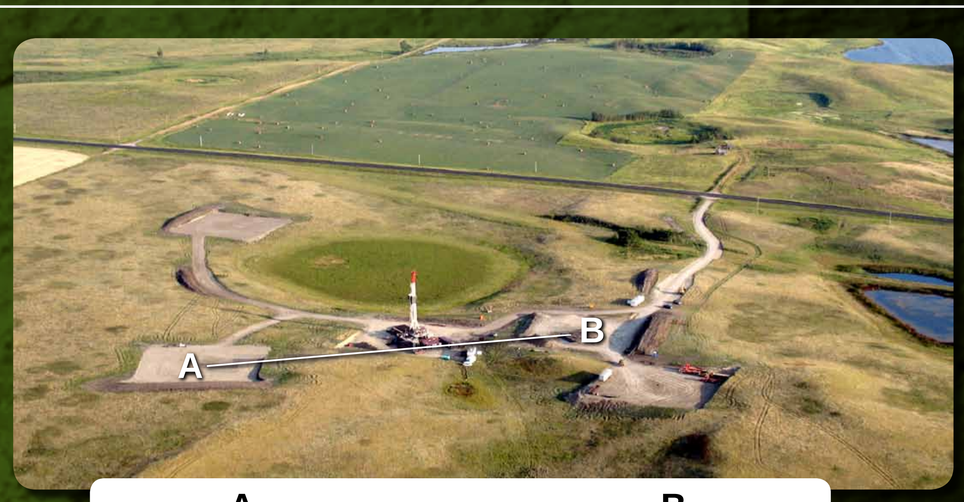
The injection well and the four monitoring wells were drilled as part of a single mobilization. A core was collected during the drilling of the injection well to provide samples for the conduct of selected laboratory tests.

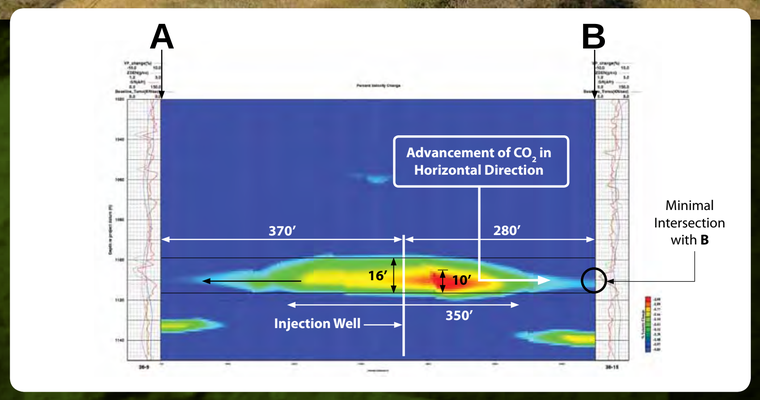
Well development was conducted through a staged application of different stimulation techniques with the intent of avoiding more aggressive techniques that had the potential to negatively influence the injection zone and complicate the interpretation of postinjection monitoring. Techniques employed during the demonstration, in order of application, included swabbing, sonic hammer, nitrogen N-fit test (i.e., minifrac), and acid treatment.

Results of the N-fit tests indicated that the coal formation was significantly underpressurized, with an actual reservoir pressure of about 345 psia versus an expected formation pressure of approximately 470 psia. This underpressurized situation was not anticipated, and as a result, well drilling, completion, and development activities were greatly affected. Additionally, low reservoir pressure can also result in low natural gas content as was noted at this site. The low methane content at the demonstration site effectively negates any potential to implement enhanced CBM (ECBM) production during CO_2 storage at this site.

Approximately 90 tons of CO_2 was injected over a roughly 2-week period into a 10–12-ft-thick coal seam at a depth of approximately 1100 ft. Monitoring, verification, and accounting (MVA) techniques were selected based on the characteristics of the site and a number of techniques were utilized.

After analysis of all gathered data, it was determined that relatively simple downhole measurements of pressure and pH provided effective MVA data at the site. Additionally, a combination of seismic image tomography and Reservoir Saturation Tool (RST) measurements was found to provide significant MVA information. These techniques demonstrated that the CO_2 was contained within the coal seam for the duration of the approximately 3-month monitoring period.



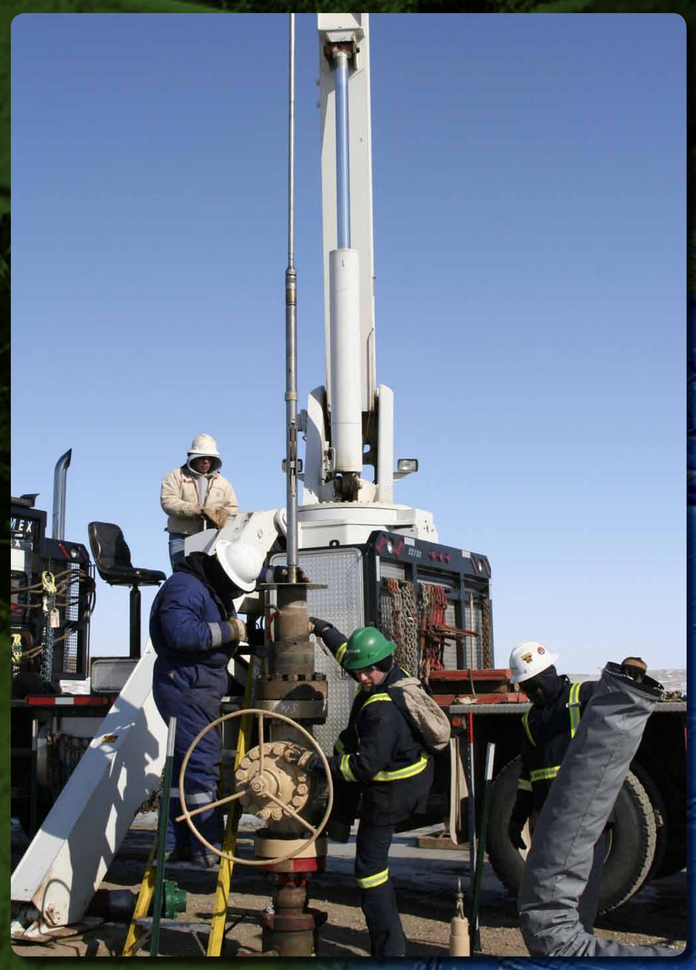


Injection Summary

- Total injection = 90 tons
- Period = 16 days
- A sustainable rate of 1.4 gpm was achieved at below the average permitted injection pressures (720 psig).
- ~ 25% injectivity loss in first 2 days.
- Injection pressure primarily influences injection rate, provided the CO_2 is predominantly in the gas phase.
- Attempt to decrease density and viscosity (630 psia) – too little pressure drive.
- Heating CO_2 at the surface and injecting high-pressure gas provides for a greater injection rate than pumping cold liquid.

MVA Techniques

- **Wells outfitted with downhole and surface data acquisition telemetry**
- **RST used to identify free gas**
- **Microseismic – potentially locate CO_2 during injection**
- **Cross-well seismic – potentially locate CO_2 after injection**
- **Fluorocarbon gas tracer – used to positively identify injected gas**
- **Gas and fluid sampling**



Lignite Site

The PCOR Partnership, one of seven regional partnerships funded by the U.S. Department of Energy's National Energy Technology Laboratory Regional Carbon Sequestration Partnership Program, is managed by the EERC at the University of North Dakota in Grand Forks, North Dakota.