FACT SHEET FOR PARTNERSHIP FIELD VALIDATION TEST

Partnership Name	Plains CO_2 Reduction (PCOR) Partnership – Phase II	
Contacts: DOE/NETL Project Mgr.	Name Organization E-Mail Andrea McNemar, U.S. Department of Energy, andrea.mcnemar@netl.doe.gov	
Principal Investigator	Edward Steadman	
Field Test Information: Field Test Name	Williston Basin EOR Field Test	
Test Location	Northwest McGregor Oil Field, Williams County, North Dakota	
Amount and Source of CO_2	Tons 440 tons	Source Commercial vendor
Field Test Partners (Primary Sponsors)	Eagle Operating, Inc.	
	Schlumberger Carbon Services	
	Praxair	

Summary of Field Test Site and Operations:

The Plains CO_2 Reduction (PCOR) Partnership, working closely with Eagle Operating, Inc. (Eagle), has conducted field and laboratory activities to determine the effects of injecting carbon dioxide (CO_2) into a carbonate formation in the Northwest McGregor oil field in North Dakota (Figure 1). The purpose of the activities is to evaluate the potential dual purpose of CO_2 sequestration and enhanced oil recovery (EOR) in carbonate rocks deeper than 8000 ft. A technical team that includes Eagle, the Energy & Environmental Research Center (EERC), Praxair, and Schlumberger Carbon Services has conducted a variety of activities to 1) determine the baseline geological characteristics of the injection site and surrounding areas, 2) inject CO_2 into the target oil reservoir using a huff ‘n’ puff (HnP) approach, and 3) evaluate the effect that injected CO_2 has on the ability of the oil reservoir to sequester CO_2 and produce incremental oil. Praxair carried out the injection process, while the EERC conducted the baseline geological characterization work. The CO_2 monitoring, verification, and accounting (MVA) activities at the site were jointly designed and implemented by the EERC and Schlumberger Carbon Services.

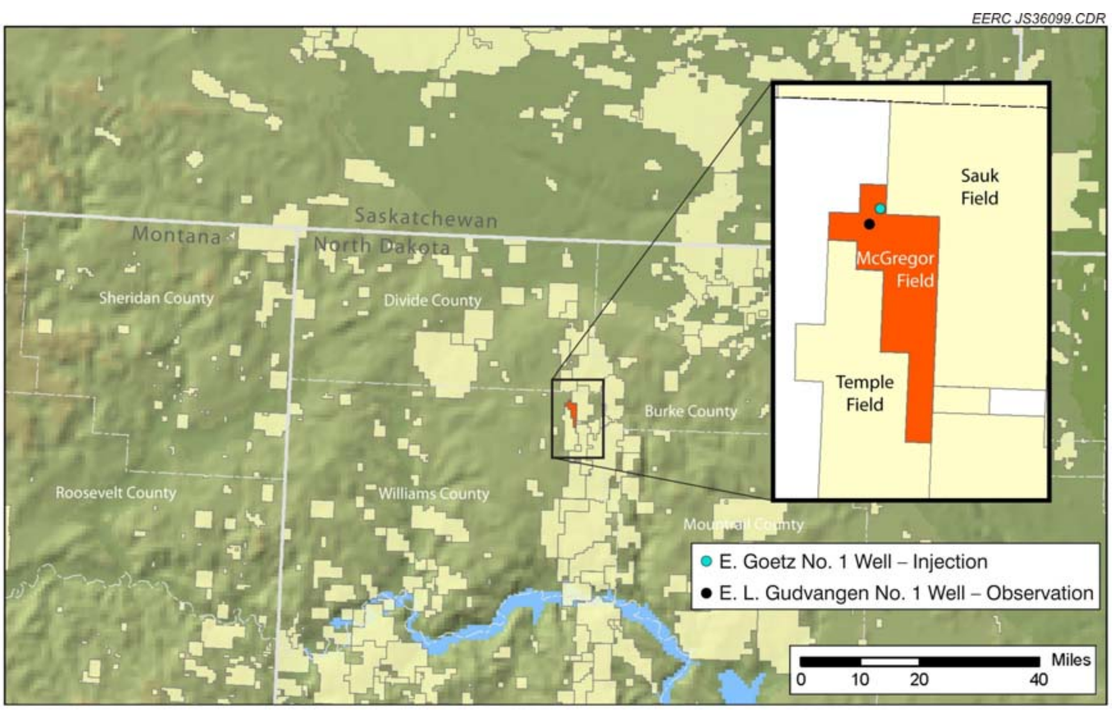


Figure 1. Oil fields of the Williston Basin.

Research Objectives:

One of the primary goals of the PCOR Partnership Phase II Williston Basin Field Validation Test was to evaluate the effectiveness of CO_2 for EOR and sequestration in oil fields at depths greater than 8000 ft. To achieve that goal, a CO_2 HnP test was conducted on a well that is currently producing oil from an interval of the Mississippian-age Madison Group at a depth of approximately 8050 ft in the Northwest McGregor oil field in Williams County, North Dakota. As an initial pilot-scale HnP test, 440 tons of CO_2 was injected into a single well, allowed to "soak" for 2 weeks, and then produced again. The PCOR Partnership purchased CO_2 from Praxair, who transported it via train and truck to the selected oil field and conducted the injection into the target reservoir. The literature indicates that HnP operations can be an economically and technically efficient means of evaluating the response of a reservoir to CO_2, with respect to both EOR and CO_2 storage. Unique elements of the Madison Group within the Northwest McGregor oil field with respect to the application of a CO_2 HnP operation, as compared to other HnP operations in the literature, include the following:

- At a depth of 8052 ft, it would be among the deepest.
- Pressure (3000 psig) and temperature (200°F) would be among the highest.
- Most HnPs in the literature are in clastic reservoirs. The Northwest McGregor field is a carbonate reservoir.

The activities at the Northwest McGregor oil field provides for the testing of two specialized downhole geophysical logging techniques under high-pressure and -temperature conditions in a carbonate reservoir. The specialized logging tools are Schlumberger's Reservoir Saturation Tool (RST) and Vertical Seismic Profile (VSP) tool. The relatively low injection volume provides an opportunity to test the lower limits of these tools to detect CO_2 in a carbonate reservoir.

Summary of Modeling and MVA Efforts (use the table provided for MVA):

MVA equipment was installed and operations conducted to monitor pressure, temperature, pH, and resistivity as well as changes in bulk fluid density and volume within the reservoir. Monitoring of CO_2 via tracers was conducted. A current production well, located approximately 500 m from the injection well and producing from the same formation, served as an observation well, allowing for fluid sampling to evaluate potential CO_2 migration within the target formation.

Measurement Technique	Measurement Parameters	Application
Introduced Tracers	Travel time Partitioning of CO_2 into brine or oil Identification sources of CO_2	Tracing movement of CO_2 in the storage formation Quantifying solubility trapping Tracing leakage
Fluid Composition	CO_2, HCO_3, CO_3^{2-} Major ions Trace elements Salinity Hydrocarbon composition	Quantifying solubility and mineral trapping Quantifying CO_2–water–oil–rock interactions Detecting leakage
Subsurface Pressure	Formation pressure Annulus pressure	Control of formation pressure below fracture gradient Wellbore and injection tubing condition Leakage out of the storage formation
Well Logs	Cement bond logs CO_2 saturation Vertical seismic profile	Determine effects on wellbore integrity Tracking migration of CO_2 Reservoir characterization and tracking migration of CO_2.

Accomplishments to Date:

In June 2009, 440 tons of CO_2 were injected into a single well in a Madison Formation reservoir in the Northwest McGregor oil field. The dynamic response of the injection zone was evaluated for changes over the course of the project using RST and VSP logging tools, reservoir fluid sampling and analysis, and the monitoring of pressure in the injection well and another nearby producing oil well that provided limited service as an observation well. Using a petrophysical model of the Northwest McGregor oil field, preinjection predictions regarding the nature of CO_2 in the target reservoir during and after injection were compared to actual postinjection reservoir conditions as monitored over the duration of the study period. The preinjection modeling predictions and calculations were found to be in close alignment with the field observations. The results of the mass balance evaluation and downhole logging demonstrated that the fate of injected CO_2 within the target reservoir was as predicted, i.e., the injected CO_2 was calculated to have remained within the reservoir. Productivity of the oil well was observed to have significantly increased as compared to its preinjection productivity, which demonstrates the effectiveness of the injected CO_2 for enhancing oil recovery from the reservoir. Overall, the results of the field demonstration indicate that 1) CO_2-based HnP operations are a technically viable option for improved oil recovery in deep carbonate oil reservoirs and 2) deep carbonate oil reservoirs are reasonable targets for large-scale CO_2 storage, even those with relatively low primary permeability such as had been reported at the Northwest McGregor field.

Summarize Target Sink Storage Opportunities and Benefits to the Region:

The sedimentary basins of the PCOR Partnership region typically include widespread, thick sequences of carbonate rocks, many of which contain oil reservoirs. Regional characterization activities indicated that Williston Basin oil fields may have over 500 million tons of CO_2 storage capacity associated with potential EOR operations. Oil is produced from at least a dozen rock formations at depths ranging from less than 3000 ft on the northeast margin of the Williston Basin to greater than 14,000 ft near the basin center. While the CO_2-based EOR operations at the Weyburn and Midale fields in Saskatchewan, Canada, are good examples of economically and technically successful injection of CO_2 for simultaneous EOR and sequestration, the depths of injection and, therefore, reservoir conditions in those fields are relatively shallow (ca. 4600 ft) and not necessarily representative of many large Williston Basin oil fields. Many of these carbonate-based oil reservoirs are located at depths greater than 8000 ft. The results from the deep Williston Basin test will be compared to those generated by research activities at other shallower carbonate reservoirs in the region, including the Zama test in Alberta, Canada, and the International Energy Agency project at Weyburn, Canada. Results will provide insight regarding the nature and magnitude of technical challenges associated with CO_2 injection under the pressure (3000 psi) and temperature (200°F) conditions found at depths greater than 8000 ft. Sampling protocols developed for this activity will be applicable to other high-pressure/temperature reservoir environments.

Cost:

Total Field Project Cost: $4,261,382

DOE Share:	$1,989,721	47%
Non-DOE Share:	$2,271,661	53%

Field Project Key Dates:

Baseline Completed: December 31, 2008

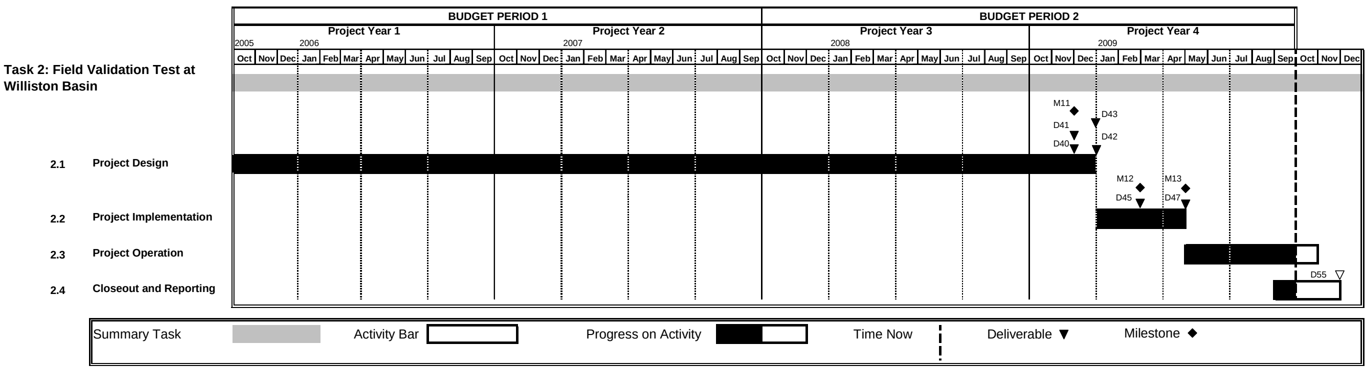
Drilling Operations Begin: Not applicable. An existing well was used.

Injection Operations Begin: June 16, 2009

MVA Events: VSP and RST logging before (May 2009) and after injection (October 2009). Collection and analysis of fluid samples and pressure data periodically between July 5 and October 30, 2009.

Field Test Schedule and Milestones (Gantt Chart):

- Regulatory Permitting Action Plan completed November 2008.
- National Environmental Policy Act compliance document completed November 2008.
- Experimental design package completed December 2008.
- Site Health and Safety Plan completed December 2008.
- Outreach Action Plan completed February 2009.
- Sampling protocols due April 2009.
- Installation of MVA equipment during the first quarter of Year 4.
- Injection initiated during the third quarter of Year 4 and conducted for 2 days.
- Final collection of field data due November 2009.
- Regional Technology Implementation Plan due November 2009.



Key for Deliverables ▼
D40 Williston Basin Field Validation Test Site – Regulatory Permitting Action Plan
D41 Williston Basin Field Validation Test Site – NEPA Compliance Document
D42 Williston Basin Field Validation Test Site – Experimental Design Package
D43 Williston Basin Field Validation Test Site – Site Health & Safety Plan
D45 Williston Basin Field Validation Test Site – Outreach Action Plan
D47 Williston Basin Field Validation Test Site – Sampling Protocols
D55 Williston Basin Field Validation Test Site – Regional Technology Implementation Plan

Key for Milestones ◆
M11 Williston Basin Field Validation Test Site – NEPA Compliance Document Completed
M12 Williston Basin Field Validation Test Site – Outreach Action Plan Completed
M13 Williston Basin Field Validation Test Site – Sampling Protocol Completed

Additional Information