PROJECT facts

U.S. Department of Energy
Office of Fossil Energy
National Energy Technology Laboratory

Carbon Sequestration

04/2008

# Plains $CO_2$ Reduction (PCOR) Partnership—Deployment Phase

## CONTACTS

**Sean Plasynski**
Sequestration Technology Manager
National Energy Technology Laboratory
626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236
412-386-4867
sean.plasynski@netl.doe.gov

**Darin Damiani**
Project Manager
National EnergyTechnology Laboratory
3610 Collins Ferry Road
PO Box 880
Morgantown, WV 26507
304-285-4398
darin.damiani@netl.doe.gov

**John A. Harju**
Associate Director for Research
Energy & Environmental Research Center
University of North Dakota
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018
701-777-5124
jharju@undeerc.org

## Background

As part of a comprehensive effort to assess options for sustainable energy systems, the U.S. Department of Energy (DOE) has selected seven Regional Partnerships, through its Regional Carbon Sequestration Partnership (RCSP) Program, to determine the best approaches for capturing and permanently storing carbon dioxide ($CO_2$), a greenhouse gas which may contribute to global climate change. The RCSPs are made up of state agencies, universities, private companies, national laboratories, and nonprofit organizations that form the core of a nationwide network helping to establish the most suitable technologies, regulations, and infrastructure needs for carbon sequestration. Altogether, the Partnerships include more than 350 organizations, spanning 41 states, three Indian nations, and four Canadian provinces.

The Regional Partnerships' initiative is being implemented in three phases. The Characterization Phase began in September 2003 with the seven Partnerships working to develop the necessary framework to validate and potentially deploy carbon sequestration technologies. In October 2005, work transitioned to the Validation Phase, a 4-year effort focused on validating promising $CO_2$ sequestration opportunities through a series of field tests in the seven regions. Presently, activities in the Deployment Phase (2007–2017) are proceeding as an extension of the work completed to date and will demonstrate that $CO_2$ capture, transportation, injection, and storage can be achieved safely, permanently, and economically at a large scale. These large-scale tests will promote understanding of injectivity, capacity, and storability of $CO_2$ in the various geologic formations identified by the Partnerships. Results and assessments from these efforts will help in the commercialization efforts for future sequestration demonstrations in North America.

The PCOR Partnership, led by the University of North Dakota's Energy & Environmental Research Center, includes all or part of the states of Iowa, Minnesota, Missouri, Montana, Nebraska, North Dakota, South Dakota, Wisconsin, and Wyoming and the Canadian provinces of Alberta, British Columbia, Manitoba, and Saskatchewan. The PCOR Partnership includes over 80 organizations. The nine states in the PCOR Partnership account for about 12% of total U.S. $CO_2$ emissions from stationary sources. The region offers significant potential for sequestration in limestone, sandstone, and unmineable coal seams, as well as depleted oil and gas reservoirs. Of particular interest is the use of $CO_2$ for enhanced oil recovery (EOR) in tandem with sequestration.

## Project Description

### Project Summary

The PCOR Partnership is planning two $CO_2$ sequestration projects for the Deployment Phase, also known as Phase III (Figure 1). The Williston Basin demonstration will transport a minimum of 450,000 tonnes (500,000 U.S. tons) of $CO_2$ per year from

## CONTACTS (cont.)

**Edward N. Steadman**
Technical Contact
Energy & Environmental Research Center
University of North Dakota
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018
701-777-5279
esteadman@undeerc.org

## PARTNERS

- Advanced Geotechnology, a division of Hycal Energy Research Laboratories, Ltd.
- Air Products and Chemicals, Inc.
- Alberta Department of Energy
- Alberta Energy and Utilities Board
- Alberta Energy Research Institute
- Alberta Geological Survey
- ALLETE
- Ameren Corporation
- American Lignite Energy (ALE)
- Apache Canada Ltd.
- Basin Electric Power Cooperative
- Bechtel Corporation
- Blue Source, LLC
- BNI Coal, Ltd.
- British Columbia Ministry of Energy, Mines, and Petroleum Resources
- Carbozyme, Inc.
- Center for Energy & Economic Development (CEED)
- Chicago Climate Exchange
- Dakota Gasification Company
- Ducks Unlimited Canada
- Ducks Unlimited, Inc.
- Eagle Operating, Inc.
- Eastern Iowa Community College District
- Enbridge Inc.
- Encore Acquisition Company
- Environment Canada
- Excelsior Energy Inc.
- Fischer Oil and Gas, Inc.
- Great Northern Power Development, LP
- Great River Energy
- Hess Corporation

Basin Electric Power Cooperative's Antelope Valley Station (an existing conventional coal-fired power plant in central North Dakota) and inject the $CO_2$ into an oil reservoir located in western North Dakota or eastern Montana. This large-scale test will demonstrate the simultaneous achievement of two objectives—EOR and sequestration of $CO_2$.


*Figure 1. Location of Phase III sites in the PCOR Partnership region.*

The Fort Nelson project will utilize over 1 million tons of $CO_2$ per year captured from one of the largest gas-processing plants in North America. The $CO_2$ will be compressed and transported in a supercritical state via pipeline to the target injection location. While a specific brine formation and injection location have not yet been chosen, it is anticipated that the target zone will be a Devonian-age carbonate rock formation located in relatively close proximity to the gas plant (<5 miles).

### Injection Site Description

The specific host site for the injection wells needed for the Williston Basin demonstration will be determined during the first year of the Deployment Phase. Discussions with likely partners indicate that at least 40 unitized oil fields in western North Dakota and eastern Montana are likely suitable for $CO_2$-based EOR operations. The specific host site for the injection wells for the Fort Nelson test has not yet been determined but will be located in northeastern British Columbia.

### Description of Geology

The Williston Basin is a relatively large, roughly circular, intracratonic basin with a thick sedimentary cover in excess of 16,000 feet. It underlies several hundred thousand square miles of parts of North Dakota, South Dakota, Montana, and the Canadian provinces of Manitoba and Saskatchewan. The Williston Basin is considered to be tectonically stable. The stratigraphy of the area is well studied, especially in those intervals that are oil producers. The geometry of the Williston Basin is fairly symmetrical, with gently dipping slopes. Thus, in the absence of a structural and/or hydrodynamic trapping mechanism, the migration of a low-gravity fluid like $CO_2$ will be expected to occur updip along the stratigraphic trap, toward the flanks of the basin (Figure 2). However, accumulation of hydrocarbons in the hundreds of oil fields scattered throughout the basin provides evidence of the presence of structural and/or hydrodynamic trapping mechanisms in the area in addition to the prevailing stratigraphic traps.

The oil fields that will most likely be considered for the demonstration are located in four areas of the Williston Basin: the Cedar Creek Anticline, the Billings Anticline, the Nesson Anticline, and the Northeast Flank. While general information on the structural geology, lithostratigraphy, hydrostratigraphy, and petroleum geology of the Williston Basin is readily available, additional characterization data for specific candidate sinks will be necessary before their utilization as $CO_2$ storage sites. The thickest, most comprehensive seal for most of the oil fields under consideration will be provided by the Mississippian-age Charles Formation, which is dominated by

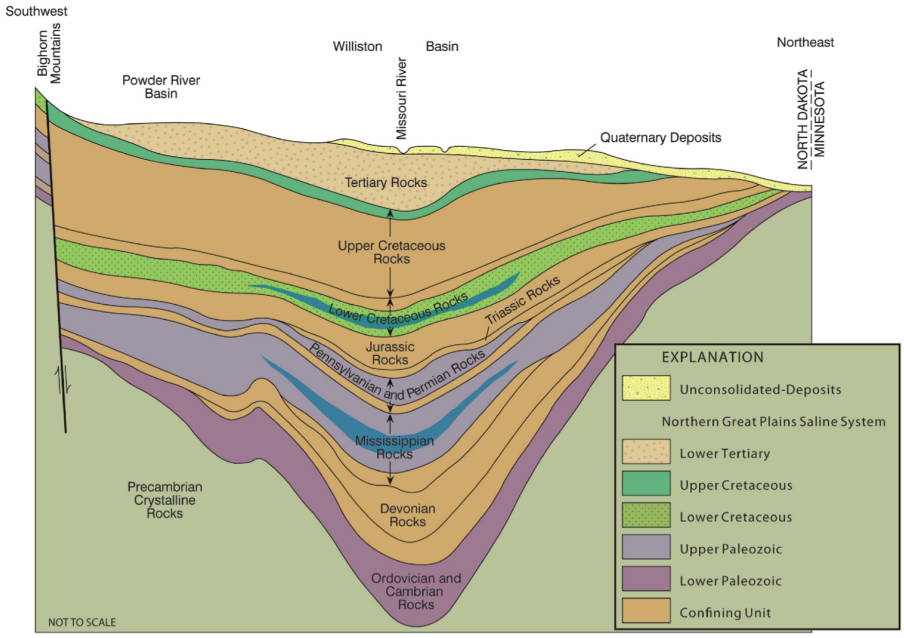


*Figure 2. Generalized cross section of the Williston Basin*

thick evaporites (anhydrite and halite) characterized by extremely low permeability and high geomechanical strength. No seismically active faults are present in North Dakota. No historically known earthquakes have occurred in the vicinity of any of the oil fields being considered.

While a specific saline formation and injection location have not yet been chosen for the Fort Nelson demonstration, it is anticipated that the target zone will be a carbonate rock formation located in relatively close proximity to the Fort Nelson gas plant. The thickest and most comprehensive seal for the carbonate rock formations under consideration will be provided by the massive and extensive shales of the Fort Simpson Formation, which is characterized by low permeability and high geomechanical strength. This cap provides a very competent seal for underlying brine-saturated formations. The cumulative average thickness of the Fort Simpson Formation is approximately 500 meters, and in some areas the thickness can be in excess of 1000 meters. The Fort Simpson Formation is laterally extensive, underlying thousands of square miles. Secondary seals also exist above the Fort Simpson Formation, the most competent and massive being the Banff Formation, which is predominantly shale and not less than 100 feet thick in the Fort Nelson area.

## Source of $CO_2$

For the Williston Basin demonstration, $CO_2$ will be obtained from Basin Electric Power Cooperative's Antelope Valley Station, a lignite-fired facility in central North Dakota. The power plant will be retrofitted with a system that can capture $CO_2$ from the flue gas. The $CO_2$ will be compressed and transported to a selected injection site by pipeline as a supercritical fluid. The Fort Nelson demonstration will utilize $CO_2$ from the Spectra Energy Fort Nelson natural gas-processing plant in northwestern British Columbia. The $CO_2$ will be captured using an existing amine-based acid gas removal system, dried, compressed, and transported by pipeline as a supercritical fluid to a nearby injection site. Its composition will be approximately 85% $CO_2$ and 15% hydrogen sulfide.

## Injection Operations

For the Williston Basin demonstration, the injection strategy will be developed in cooperation with the commercial EOR partner. Since the oil fields being considered have undergone secondary recovery, injection strategies have already been established

## PARTNERS (cont.)

- Interstate Oil and Gas Compact Commission
- Iowa Department of Natural Resources—Geological Survey
- Kiewit Mining Group Inc.
- Lignite Energy Council
- Manitoba Hydro
- MEG Energy Corporation
- Melzer Consulting
- Minnesota Geological Survey-University of Minnesota
- Minnesota Pollution Control Agency
- Minnesota Power
- Minnkota Power Cooperative, Inc.
- Missouri Department of Natural Resources
- Missouri River Energy Services
- Montana–Dakota Utilities Co.
- Montana Department of Environmental Quality
- Montana Public Service Commission
- Murex Petroleum Corporation
- National Commission on Energy Policy
- Natural Resources Canada
- Nexant, Inc.
- North American Coal Corporation
- North Dakota Department of Commerce Division of Community Services
- North Dakota Department of Health
- North Dakota Geological Survey
- North Dakota Industrial Commission Department of Mineral Resources, Oil and Gas Division
- North Dakota Industrial Commission Lignite Research, Development and Marketing Program
- North Dakota Industrial Commission Oil and Gas Research Council
- North Dakota Natural Resources Trust
- North Dakota Petroleum Council
- North Dakota State University
- Otter Tail Power Company
- Petroleum Technology Research Centre

## PARTNERS (cont.)

Petroleum Technology Transfer Council

Prairie Public Broadcasting

Pratt & Whitney Rocketdyne, Inc.

Ramgen Power Systems, Inc.

RPS Energy

Saskatchewan Industry and Resources

SaskPower

Schlumberger

Shell Canada Energy

Spectra Energy

Strategic West Energy Ltd.

Suncor Energy Inc.

Tesoro Refinery (Mandan)

University of Alberta

University of Regina

University of North Dakota Energy & Environmental Research Center

U.S. Department of Energy

U.S. Geological Survey Northern Prairie Wildlife Research Center

Western Governors' Association

Westmoreland Coal Company

Wisconsin Department of Agriculture, Trade, and Consumer Protection

Xcel Energy

## COST

**Total Project Value**
$135,586,059

**DOE/Non-DOE Share**
$67,000,000/$68,586,059

## CUSTOMER SERVICE

**1-800-553-7681**

## WEBSITE

**www.netl.doe.gov**

at demonstration sites that should facilitate a more rapid engineering and permitting process for $CO_2$ injection. For the Fort Nelson demonstration, Spectra Energy will install significant infrastructure to transport the supercritical $CO_2$ to the injection site, including construction of acid gas compressors, a dehydration system, a pipeline for the acid gas stream, and an acid gas pump. The specific host site for the injection wells needed for the Fort Nelson demonstration has not yet been determined, but will likely be located within 5 miles of the chosen gas-processing plant. The target injection formation will be at a depth of between 6,500 and 7,500 feet. Formations in this depth range will be at the temperature and pressure that ensure the injected $CO_2$ remains in a supercritical state.

### Simulation and Monitoring of $CO_2$

An emphasis on cost-effectiveness and integration with routine oil field activities is the driving philosophical basis for developing the monitoring, mitigation, and verification (MMV) plan that will be implemented as part of the Deployment Phase. MMV techniques used will include the following: pressure monitoring, fluid sampling (oil, gas, water), pressure and geochemical monitoring of overlying formations, downhole geophysical monitors (passive microseismic and/or tiltmeters), surface $CO_2$ measurements, ion chemistry and isotopes of sampled fluids, and tracer (e.g., perfluorocarbons) monitoring.

## Goals and Objectives

The PCOR Partnership's overall goal is to validate the information and technology developed under the Characterization and Validation Phases relative to research and field activities, public outreach efforts, and regional characterization. Specific objectives include the following:

- Conduct a successful Williston Basin demonstration to verify and validate the concept of utilizing the region's large number of oil fields for large-scale injection of anthropogenic $CO_2$, resulting in incremental oil production.
- Conduct a successful Fort Nelson demonstration to verify and validate the concept of utilizing the region's carbonate saline formations for large-scale injection of anthropogenic $CO_2$.
- Gather characterization data that will verify the ability of the target formations to meet the goal of storing 50% of the region's point source $CO_2$ emissions for the next 100 years.
- Advance the regulatory and permitting framework.
- Provide a demonstration bed for developing technologies related to $CO_2$ sequestration.
- Develop a method to monetize carbon credits for $CO_2$ sequestered in geologic formations.
- Meet or exceed the expectations of the members of the PCOR Partnership by developing project(s) that are commercially successful.

## Benefits to the Region

The PCOR Partnership region, which covers over 1.4 million square miles, emits approximately 500 million tonnes (550 million U.S. tons) of $CO_2$ yearly from large stationary sources in the region. Over the course of 100 years, it is assumed that approximately 50 to 55 billion tonnes (55 to 60 billion U.S. tons) of $CO_2$ will be generated by large stationary sources. The results of regional sink characterization activities conducted under the Characterization and Validation Phases indicate that oil fields and saline formations in the region have the capacity to store nearly 28 billion tonnes (31 billion U.S. tons) and 455 billion tonnes (500 billion U.S. tons) of $CO_2$, respectively, which is greater than 50% of the anticipated regional emissions over the next 100 years, assuming a static emission profile.