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The Plains CO_2 Reduction (PCOR) Partnership: Progressing Geologic Storage Through Applied Research

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Abstract

The Energy & Environmental Research Center (EERC) is focused on solving the world's energy and environmental challenges. Through its Center for Climate Change & Carbon Capture and Storage, the EERC is engaged in research activities in direct support of carbon management. One significant carbon management effort led by the EERC is the Plains CO_2 Reduction (PCOR) Partnership.

The PCOR Partnership is one of seven regional partnerships established by the U.S. Department of Energy National Energy Technology Laboratory to assess and develop carbon storage opportunities. The PCOR Partnership, comprising state agencies; coal, oil and gas, and other private companies; electric utilities; universities; and nonprofit organizations, covers an area of over 1.4 million square miles in the central interior of North America and includes all or part of nine states and four Canadian provinces.

The PCOR Partnership region has stable geologic basins that are ideal storage targets for carbon capture and storage (CCS). These basins have been well-characterized because of commercial oil and gas activities and have very significant CO_2 storage capacities. The region's energy industry is evaluating carbon management options including CCS. Many of the region's oil fields could develop carbon dioxide (CO_2)-based enhanced oil recovery (EOR) projects if CO_2 were more readily available. CO_2-based tertiary EOR projects offer a means of developing the expertise and infrastructure required to make geologic CCS a commercial reality.

The PCOR Partnership is teaming with industrial partners to conduct two commercial-scale (greater than 1 million tons a year) CCS demonstrations in its region. One of the large-scale tests will demonstrate CO_2 storage in a saline formation, while the other will be a combined CCS and EOR demonstration. The sources of CO_2 in both demonstrations are natural gas-processing facilities. The commercial-scale demonstration tests are designed to establish the technical and economic efficacy of CCS in the region, and injections are planned to begin between 2012 and 2014 for both projects.

Introduction

The Plains CO_2 Reduction (PCOR) Partnership is one of seven regional partnerships operating under the U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL) Regional Carbon Sequestration Partnership (RCSP) Initiative. The PCOR Partnership is led by the Energy & Environmental Research Center (EERC) at the University of North Dakota in Grand Forks, North Dakota, and includes stakeholders from the public and private sector.

The PCOR Partnership was established in the fall of 2003. Phase I focused on characterizing CO_2 storage opportunities in the region. In the fall of 2005, the PCOR Partnership launched its 4-year Phase II program, which focused on carbon storage field validation projects that were designed to develop the regional technical expertise and experience needed to facilitate future large-scale CCS efforts in the region's subsurface and in terrestrial settings. In the fall of 2007, the PCOR Partnership initiated its 10-year Phase III program, which is focused on implementing two commercial-scale geologic carbon storage demonstration projects in the region. The project sites are located 1) in the Bell Creek oil field in Powder River County in

southeastern Montana and 2) near Spectra Energy's Fort Nelson gas-processing facility, situated near Fort Nelson, British Columbia, Canada (Figure 1).

The PCOR Partnership's objectives for the demonstration projects are as follows: 1) conduct a successful field demonstration to verify that the region's large number of oil fields have the potential to store significant quantities of carbon dioxide (CO_2) in a safe, economical, and environmentally responsible manner and 2) conduct a successful demonstration to verify the technical and economic feasibility of using the region's carbonate saline formations for safe, long-term CO_2 storage. During Phase III, the PCOR Partnership will continue to refine storage resource estimates and evaluate other factors relevant to regional storage goals, including facilitating the development of the infrastructure required to transport CO_2 from sources to the injection sites, facilitating development of the rapidly evolving North American regulatory and permitting framework, developing opportunities for PCOR Partnership partners to capture and store CO_2, establishing a technical framework by which carbon credits can be monetized for CO_2 stored in geologic formations, continuing collaboration with other RCSPs, and providing outreach and education for CO_2 capture and storage stakeholders and the general public.

CO_2 Sources. The PCOR Partnership Program has identified, quantified, and categorized over 900 stationary sources in the region that have an annual output of greater than 15,000 tons of CO_2 (Figure 2). These stationary sources have a combined annual CO_2 output of over 600 million tons (1). The annual CO_2 output from stationary sources ranges from 10 to 18 million tons for the larger coal-fired electric generation facilities to under 100,000 tons for industrial and agricultural processing facilities that make up the greatest number of the sources in the region. In some cases, the distribution of the sources with the largest CO_2 output is coincident with the availability of significant CO_2 storage opportunities. Many of the smaller sources are concentrated around more heavily industrialized metropolitan regions such as southeastern Minnesota, southeastern Wisconsin, and eastern Missouri, often in areas with limited CO_2 storage opportunities.

Geologic Sinks: Depositional Basins. The sedimentary basins in the PCOR Partnership region have significant potential as geologic sinks for storing CO_2 (Figure 3). Geologic sinks that may be suitable for long-term storage of CO_2 include both active and depleted petroleum reservoirs, deep saline formations, and coal seams, all of which are common in these basins. While general information on the structural geology, rock types, hydrology, and petroleum geology of these basins is available, additional characterization data for specific geologic sinks are often necessary. Rocks that have been explored or developed for hydrocarbon recovery have been geologically characterized to a great extent, while nonhydrocarbon-bearing zones (such as saline formations) will require significantly more geologic investigation prior to implementation of large-scale storage.

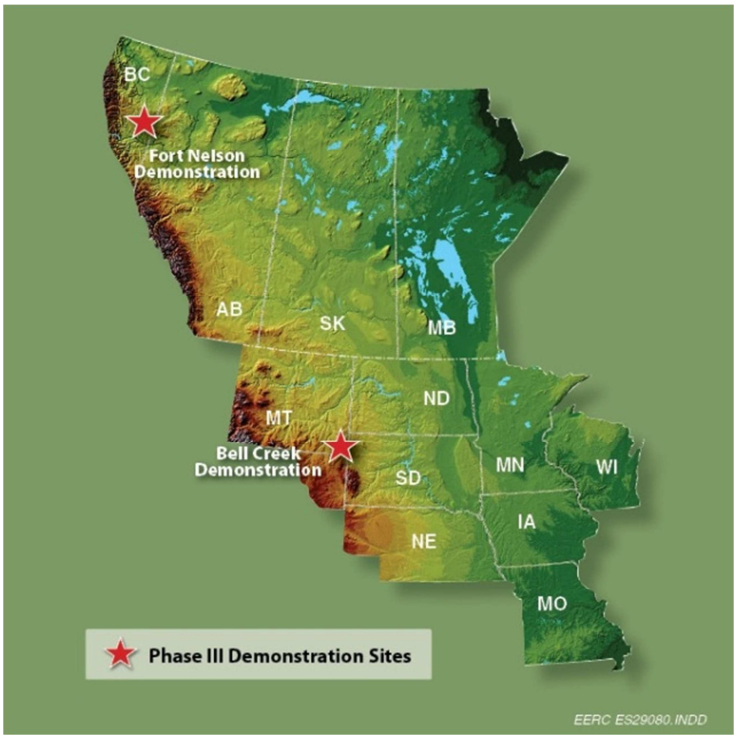

Figure 1. PCOR Partnership Phase III demonstration sites.

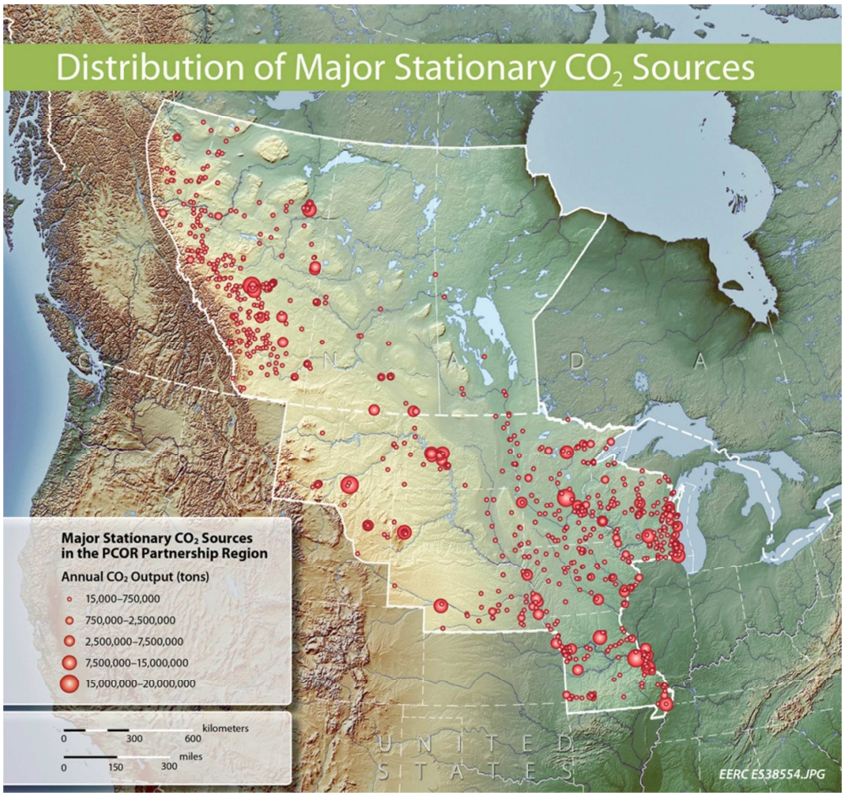

Figure 2. Major Stationary CO_2 sources in the PCOR Partnership Region (2).

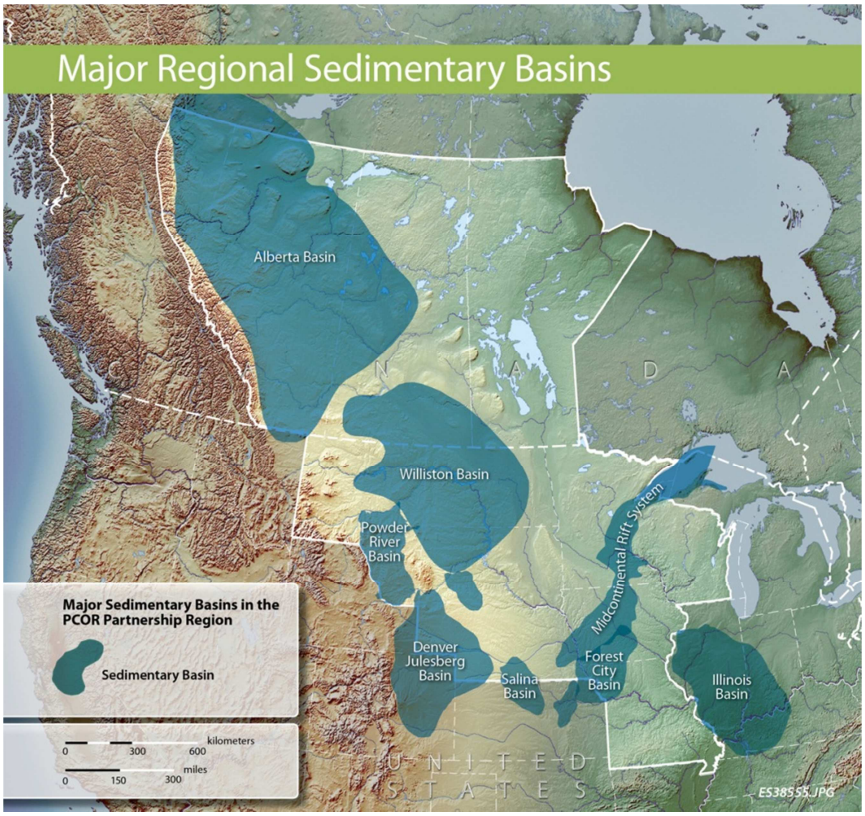

Figure 3. Major Depositional Basins in the PCOR Partnership Region (2).

Demonstration Projects. A programmatic RCSP Phase III goal is the implementation of large-scale field testing involving at least 1 million metric tons of CO_2 per project. Each of the RCSP's large-volume injection tests is designed to demonstrate that the CO_2 storage sites have the potential to store regional CO_2 emissions safely, permanently, and economically (Figure 4). The PCOR Partnership is working toward the establishment of two demonstration sites:

1) The Bell Creek Integrated CO_2 EOR and Storage Project will be conducted in the Bell Creek oil field in Powder River County, southeastern Montana, United States, and will provide insight regarding the impact of CO_2 flood tertiary recovery on oil production and successful CO_2 storage within a sandstone reservoir in the Cretaceous Muddy Formation.

2) The Fort Nelson CCS Feasibility Project is exploring the potential of permanently storing up to 2 million tons of sour CO_2 (mixture of CO_2 and hydrogen sulfide [H_2S]) a year in a saline formation. The CO_2 will be captured from one of the largest gas-processing plants in North America. The sour CO_2 will be compressed and transported approximately 9 miles via pipeline to the target injection location. The target zone is the Devonian-age Elk Point carbonate rock (limestone and dolomite) formation located in relatively close proximity to the gas plant at a depth of >7200 feet.

Bell Creek Integrated CO_2 EOR and Storage Project. Denbury Resources Inc. (Denbury), a leader in CO_2 enhanced oil recovery (EOR) operations, is implementing a commercial CO_2 EOR project that will add 20-plus years and 35 million barrels to the life of the Bell Creek oil field in southeastern Montana. A 232 miles long pipeline, will deliver CO_2 from the Lost Cabin natural gas-processing facility in central Wyoming to the Bell Creek oil field. CO_2 injection for EOR is scheduled to start after the pipeline is completed in December 2012. Denbury has teamed with the PCOR Partnership to characterize and model CO_2 behavior in the subsurface as a basis for designing a comprehensive monitoring plan for the CO_2 storage and EOR operation. Detailed site characterization, modeling, and monitoring of the CO_2 EOR and storage operations will allow site operators to account for the CO_2 utilized in oil production and to verify that the CO_2 remains in place once EOR operations are complete. The integrated approach at the Bell Creek oil field helps meet the commonsense safety expectations of local landowners and communities. Further, by storing human-generated CO_2 at the Bell Creek oil field, Denbury benefits the environment by decreasing the carbon footprint of its regional oil field operation. The results of the Bell Creek project will help future projects effectively implement a proven CO_2 monitoring, verification, and accounting (MVA) system as part of a comprehensive approach to subsurface CO_2 management and operations.

Figure 4. Geologic column depicting depth of oil and gas reservoirs and deep saline formations (2).

Fort Nelson CCS Feasibility Project. Spectra Energy, one of North America's premier natural gas infrastructure companies, and the PCOR Partnership are leading a collaborative venture that plans to fully demonstrate the concept of CCS to manage the CO_2 emissions of natural gas-processing facilities. In this proposed demonstration, up to 2 million tons a year of sour CO_2 (mixture of CO_2 and H_2S) would be injected into a saline formation deep underground. The behavior of the sour CO_2 in the subsurface would then be closely monitored to ensure the safe and effective operation of regional geologic storage. The proposed demonstration project has the potential to store 20 million tons of CO_2, which would otherwise enter the atmosphere over a period of just 10 years.

Spectra Energy is currently conducting a feasibility study to evaluate a proposed project that would pipe the sour CO_2 stream approximately 9 miles (15 km) from Spectra Energy's Fort Nelson gas-processing facility, located near Fort Nelson, British Columbia, Canada, to a nearby site where it would be injected over 7200 feet underground for permanent storage in a deep brine saturated formation (saline formation). The sour CO_2 stream (approximately 95% CO_2 and 5% H_2S) would first need to be compressed to a supercritical state. This means that the CO_2-rich gas would be pressurized to meet the conditions it would likely encounter in the underground injection zone. Supercritical sour CO_2 has a density like a liquid but still behaves like a gas. The supercritical fluid would then be injected into the carbonate rocks (limestone and dolomite) of a rock formation in the Elk Point Group, where some of the sour CO_2 is predicted to dissolve into the highly saline water that fills the pores of the rock, while some would most likely precipitate as new carbonate minerals. Some of the sour CO_2 would remain in the pores of the carbonate rocks, and the naturally high-pressure and high-temperature conditions would help maintain that sour CO_2 in the supercritical state. The proposed injection zone is capped by 1800-foot (550-meter)-thick Fort Simpson and Muskwa shale, which is expected to function as an impermeable seal. Characterization studies of the geology of the region show there are potentially many suitable sites for CO_2 storage there.

Specific goals of the PCOR Partnership at this site include the following:

- Development of cost-effective risk management; simulation; and MVA strategies for large-scale CO_2 storage in deep brine saturated formations.
- Testing and refinement of reservoir modeling intended to predict and estimate CO_2 injectivity (the potential for placing CO_2 into the reservoir), areal extent and mobility of the supercritical CO_2 plume in the reservoir, and improved methodologies to ensure that site characterization and MVA results better support risk management objectives and modeling efforts.
- Development of testing strategies to predict the effects of CO_2 on the integrity of overlying sealing formations, including the testing and modeling of key geomechanical and geochemical parameters.

Additional Activities. The PCOR Partnership is currently collaborating with Alberta Innovates – Technology Futures (AITF) on a binational project to characterize and assess the CO_2 storage capacity of the Basal Cambrian System occurring in large parts of both the United States and Canada. This system underlies many of the area's large point sources of CO_2 and represents a regionally significant target for CCS in an area that has not previously been systematically evaluated with respect to CO_2 storage resource. The EERC will work closely with key partners in the United States, including the Geological Surveys of North Dakota, South Dakota, and Montana, Princeton University, and Lawrence Berkeley National Laboratory, to evaluate the American portion of the Basal Cambrian System. AITF is leading a multiprovince team to conduct a similar evaluation for the Canadian portion of this system.

The PCOR Partnership continues to interface regularly with relevant regional regulatory agencies as well as with federal regulatory agencies in the United States and Canada to understand the regulatory framework for project implementation. In addition, the EERC facilitates activities that allow the gathering and exchange of information from pertinent entities, including the Interstate Oil and Gas Compact Commission, that have a voice in project regulation. For the past 3 years, the EERC has coordinated a regulatory meeting for open discussion amongst the PCOR Partnership region's regulatory key personnel in an effort to provide updates on the current status and evolving nature of regulations that affect CO_2 capture, compression, transport, and injection for storage and for EOR operations for all of the jurisdictions in the region. It is hoped that this will lead regulatory strategies to be better coordinated and, ultimately, that such coordination will enhance opportunities for CO_2 storage and EOR in our region.

Conclusion

The PCOR Partnership is applying the lessons learned in its characterization and validation phases toward the successful implementation of two commercial-scale demonstration projects in its region. The region is populated by a large number of sedimentary basins lying under significant sources of CO_2. The EERC has partnered with strong industrial entities to evaluate the efficacy of injecting a million tons of CO_2 per year safely, economically, and responsibly into diverse depositional formations for the utilization and storage of CO_2. The PCOR Partnership is conducting baseline characterization, modeling,

risk assessment, and simulation activities toward development of effective MVA plans for both demonstration sites. In addition, the PCOR Partnership is continuing to refine storage resource estimates and evaluate other factors relevant to regional storage goals, including infrastructure, regulatory framework, and outreach and education.

Acknowledgment

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Reference List

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