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BEFORE THE
MINNESOTA OFFICE OF ADMINISTRATIVE HEARINGS
100 Washington Square, Suite 1700
Minneapolis, Minnesota 55401-2138
FOR THE
MINNESOTA PUBLIC UTILITIES COMMISSION
127 7th Place East, Suite 350
St. Paul, Minnesota 55101-2147

In the Matter of the Petition of Excelsior Energy Inc. and Its Wholly Owned Subsidiary MEP-I, LLC, for Approval of Terms and Conditions for the sale of Power from Its Innovative Energy Project Using Clean Energy Technology under Minn. Stat. § 216B.1694 and a Determination that the Clean Energy Technology Is or Is Likely to Be a Least-Cost Alternative under Minn. Stat. § 216B.1693

PREPARED REBUTTAL TESTIMONY AND EXHIBITS OF EXCELSIOR ENERGY INC. AND MEP-I LLC

EDWARD N. STEADMAN

OCTOBER 10, 2006

EXCELSIOR ENERGY INC.

BEFORE THE MINNESOTA PUBLIC UTILITIES COMMISSION

PREPARED REBUTTAL TESTIMONY AND EXHIBITS OF

EDWARD N. STEADMAN

I. INTRODUCTION AND QUALIFICATIONS

Q Please state your name.

A My name is Edward N. Steadman.

Q By whom are you employed and what is your position?

A I am a Senior Research Advisor at the Energy & Environmental Research Center (EERC) at the University of North Dakota (UND). I am one of the founders of, and currently direct, the Plains CO_2 Reduction (PCOR) Partnership. The EERC has ten Centers of Excellence that were initiated to provide solutions to strategic energy and environmental issues, one of those centers being the Center for Climate Change and CO_2 Sequestration.

Q What is the mission of EERC?

A The EERC is recognized as one of the world's leading developers of cleaner, more efficient energy and environmental technologies to protect and clean our air, water, and soil.

The EERC is a high-tech, nonprofit branch of UND. The EERC operates like a business; conducts research, development, demonstration, and commercialization activities; and is dedicated to moving promising technologies out of the laboratory and into the commercial marketplace.

The EERC is recognized internationally for its expertise in the development, demonstration, and commercialization of advanced energy systems and pollution prevention and cleanup technologies for air, water, and soil. Established as a federal research and development facility in 1951, the EERC has been part of UND since 1983 when it was defederalized by the U.S. Department of Energy's (DOE). Today, the EERC is recognized as one of the world's leading developers of energy and environmental technologies.

The EERC is international in scope, having established working relationships with numerous organizations from all corners of the globe. Since 1987, the EERC has served over 915 clients in 48 countries and all 50 states, involving both individual contracts and multiclient consortia with private industry, federal and state agencies, and academic institutions. In FY06, the EERC had 438 active contracts, of which over 83% were with private sector clients. Contract awards exceeded $45 million in 2006, the fourth consecutive record year.

The EERC practices a philosophy that emphasizes true working partnerships between private industry, government agencies, academic institutions, and the research community. By fostering private sector partnerships from the initiation of a research and development program, the opportunities for technology commercialization are dramatically enhanced. The EERC's mission is to improve the global quality of life by providing leadership in visionary multidisciplinary research and development leading to the demonstration and commercialization of innovative, clean, and efficient energy and environmental technologies. The EERC accomplishes this mission by:

- Being cognizant of the interconnected nature of the environment and energy.

- Being focused, practical, and sensitive to the marketplace.
- Being international in scope.
- Being committed not only to research and development, but also to demonstration and commercialization of innovative technologies.
- Fostering cooperation among industry, government, and the research community.
- Providing opportunities for economic development and job creation.
- Providing fundamental and applied research and training opportunities for highly motivated students and professionals at all levels.

Q What is the Center for Climate Change and CO_2 Sequestration?

A It is one of ten centers of excellence established by the EERC to provide solutions to strategic energy and environmental issues. Other centers of excellence established by EERC include the National Center for Hydrogen Technology, the Center for Renewable Energy, and the Emissions Control Technologies Center.

Q What is the Plains CO_2 Reduction (PCOR) Partnership?

A The PCOR Partnership is a diverse group of public and private-sector stakeholders working together to better understand the technical and economic feasibility of capturing and storing carbon dioxide (CO_2) emissions from stationary sources in the central interior of North America (Figure 1). The PCOR Partnership is one of seven regional partnerships funded by the DOE Regional Carbon Sequestration Partnership Program and a broad range of project sponsors. Consistent with DOE's overall program the PCOR Partnership has had two phases to date: Phase I – a regional characterization phase and Phase II – a field validation phase. Phase I activities were completed in September 2005. On June 9, 2005, the EERC was awarded a contract for the Phase II

Figure 1. PCOR Partnership region.

effort, which began in October 2005. Phase II is a 4-year program focused on demonstration and validation of promising CO_2 sequestration opportunities in our region. The total value of the PCOR Partnership Phase II is currently over $21.5 million, with two-thirds of the funding coming from DOE and the balance contributed by industry and other nonfederal partners.

Q What has been your role and involvement with the PCOR Partnership?

A I wrote the successful proposal by the EERC to DOE in 2003 which resulted in the creation of the PCOR Partnership, I recruited all of its partners, and I currently serve as the Project Manager.

In 2003, the EERC submitted a proposal in response to the DOE request for proposal (RFP) solicitation (DE-PS26-03NT41713) "Regional Carbon Sequestration Partnerships (RCSP) – Phase I." Many EERC technical contributors assisted in the writing of the proposal, including me. The EERC was awarded funding, resulting in the creation of the PCOR Partnership. I currently serve as the Project Manager for the PCOR Partnership. Phase I of the PCOR Partnership consisted of undertaking a comprehensive assessment of the PCOR Partnership's major stationary CO_2 sources and major CO_2 sinks. Because of the EERC's long-standing relationships with the energy industry and other interested parties, we were able to assemble a group of over 40 partners. With the help of these partners, we put together a practical consortium focused on developing a regional vision and strategy for dealing with carbon management issues in our region.

As the lead organization for the PCOR Partnership, it is the EERC's responsibility to:

- Develop a work plan that meets the DOE goal of determining the most suitable technologies, regulations, and infrastructure needs for carbon capture, storage, and sequestration in different areas of the country as well as the goals of the various sponsors (reference: National Energy Technology Laboratory [NETL] Carbon Sequestration Web site: www.netl.doe.gov/techologies/carbon_seq/partnerships/partnerships.html).
- Assemble the best engineers and outside consultants to perform the tasks.
- Involve the sponsors in decision-making activities when appropriate.
- Ensure that the program meets all reporting and financial requirements and deadlines.
- Ensure that all work products and deliverables are of high quality.

Q What is the purpose of DOE's Regional Carbon Sequestration Partnerships?

A There are four aspects to the DOE RCSP: 1) core research and development, 2) infrastructure, 3) integration, and 4) international (Figure 2). On behalf of DOE, NETL manages the seven RCSPs, one of which is the PCOR Partnership. These partnerships engage state agencies, universities, and private companies to create a nationwide network that will help determine the best approaches for capturing and permanently storing greenhouse gases.

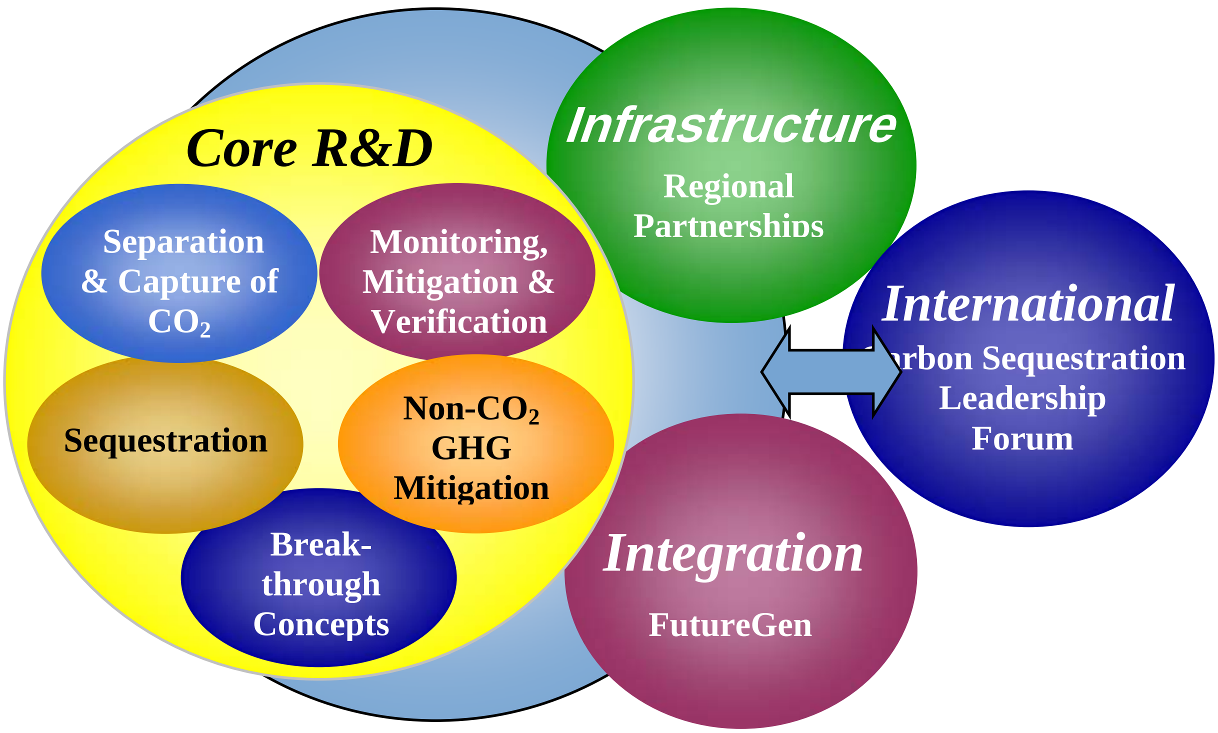

Figure 2. DOE Sequestration Program Organization
Source: www.netl.doe.gov/coalpower/sequestration/index.html

Work accomplished through the seven RCSPs helps determine the most suitable technologies, regulations, and infrastructure needs for carbon capture, storage, and sequestration.

Some of the reasons for establishing the regional partnerships are to:

- Better understand the regional opportunities.
- Match sources and sinks and define the scenarios under which sequestration should be implemented first.
- Test and refine geologic models for CO_2 storage.
- Measure the chemical and physical fate of CO_2 and compare measurement techniques.
- Create best management practices that address site selection, well design, operations, monitoring, and closeout.
- Engage regional stakeholders.

Q Describe PCOR's activities with regard to carbon management?

A Since the fall of 2003, the PCOR Partnership, covering a region of nine states and three Canadian provinces, has grown to nearly 60 public and private sector groups working to lay the groundwork for practical and environmentally sound CO_2 sequestration in the heartland of North America. Exhibit ___ (ENS-1) In addition to characterizing the region's sinks and largest CO_2 point sources, the PCOR Partnership is investigating the applicability and cost of various CO_2 capture technologies, researching applicable regulations, educating the public and regional decision makers on the topics, and implementing the four field validation test to be performed (Figure 3).

The physical and/or chemical CO_2 sequestration sinks currently under evaluation can be categorized, in a general sense, as either "geologic" or "terrestrial." By "geologic," we refer to the use of geologic conditions hundreds if not thousands of feet below the earth's surface (e.g., impermeable rock units and seems, oil fields, and saline water bearing rock units (saline aquifers)) as the physical and/or chemical sequestration trap. By "terrestrial," we refer to the use of near surface flora and/or fauna (e.g., plants within a wetland environment) as the bio-chemical trap. PCOR's 4 pilot scale field validation tests are categorized and named/referred to as follows:

- **Geologic Validation Tests**
  - Beaver Lodge, North Dakota. CO_2 injection site for CO_2 sequestration and enhanced oil recovery (EOR)
  - Zama, Alberta. Acid gas injection site for CO_2 sequestration and EOR
  - Lignite in North Dakota. CO_2 injected into an unminable lignite seam for CO_2 sequestration and possible enhanced coalbed methane (ECBM) production
- **Terrestrial Validation Test**
  - Restoration of wetlands to test monitoring, mitigation, and verification (MMV) and accounting protocols

Q Who are the PCOR partners?

A The PCOR Partnership was developed with a strong commitment to involving present and future stakeholders in CO_2 sequestration. The initial proposal for Phase I included significant participation from industry, governments, and nongovernmental organizations (NGOs). The growing focus on carbon management and other greenhouse gas issues, coupled with the PCOR Partnership's client focus and commitment to provide value to our membership, has allowed the membership to grow to nearly 60 participants in Phase II (shown in Table1).

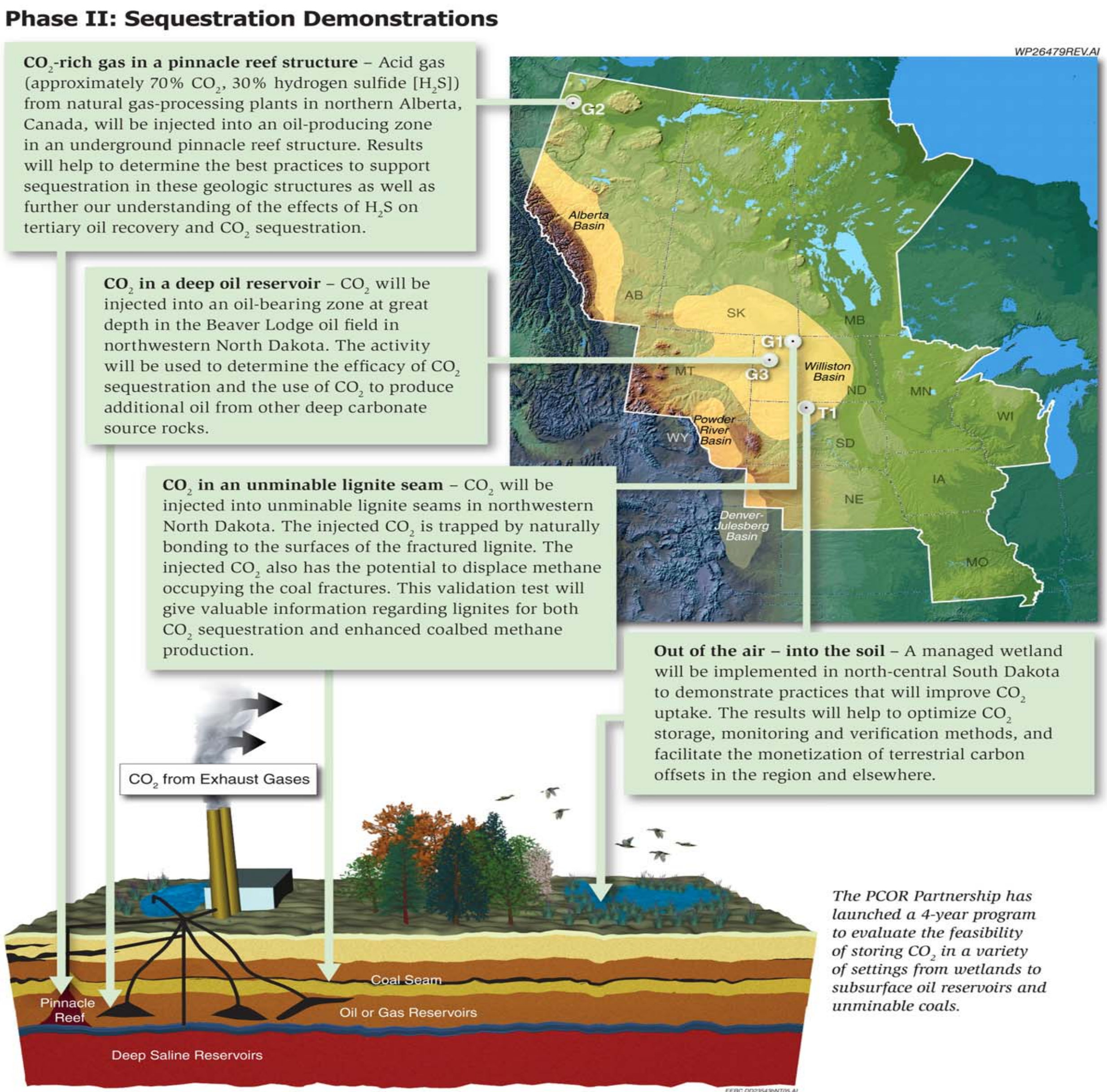

Figure 3. PCOR Partnership Phase II Sequestration Demonstrations.

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Table 1. PCOR Phase II Partners as of 10/9/06
University of North Dakota Energy & Environmental Research Center (EERC)
Advanced Geotechnology Inc.
Air Products and Chemicals
Alberta Department of Energy
Alberta Energy and Utilities Board
Alberta Geological Survey
Amerada Hess Corporation
Apache Canada Ltd.
Basin Electric Power Cooperative
British Columbia Ministry of Energy, Mines and Petroleum Resources
Carbozyme, Inc.
Center for Energy and Economic Development (CEED)
Dakota Gasification Company
Ducks Unlimited Canada
Ducks Unlimited, Inc.
Eagle Operating, Inc.
Eastern Iowa Community College District
Encore Acquisition Company
Environment Canada
Excelsior Energy Inc.
Fischer Oil and Gas, Inc.
Great Northern Power Development, LP
Great River Energy
Interstate Oil and Gas Compact Commission
Iowa Department of Natural Resources – Geological Survey
Lignite Energy Council
MEG Energy Corporation
Minnesota Power
Minnkota Power Cooperative, Inc.
Missouri Department of Natural Resources
Montana–Dakota Utilities Co.
Montana Department of Environmental Quality
National Commission on Energy Policy
Natural Resources Canada
Nexant, Inc.
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
Continued. . .

Table 1. PCOR Phase II Partners as of 10/9/06 (continued)
North Dakota State University
Otter Tail Power Company
Petroleum Technology Transfer Council
Prairie Public Television
Ramgen Power Systems, Inc.
Saskatchewan Industry and Resources
SaskPower
Suncor Energy Inc.
University of Alberta
U.S. Department of Energy
U.S. Geological Survey Northern Prairie Wildlife Research Center
Western Governors' Association
Wisconsin Department of Agriculture, Trade and Consumer Protection
Xcel Energy

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Q For whom are you testifying?

A I am testifying on behalf of MEP-I LLC and Excelsior Energy Incl. (collectively "Excelsior"), the developers of the Mesaba Energy Project (the "Project").

Q Please summarize your qualifications and experience.

A I began working at the EERC (when it was known as the Energy and Mineral Research Center) in 1986 as a Research Associate, conducting research into the chemical and physical mechanisms of coal combustion and the characterization of coal and coal ash.

In 1988, I was named Research Manager of the Fuels and Materials Science area, where I was responsible for inorganic analytical methods. In 1994, I was appointed Associate Director for Research, a position in which he developed and administered environmental programs involving water management and contamination cleanup and built industry–government–academic teams to carry out research, development, demonstration, and commercialization of environmental products and technologies.

In 2003, I became a Senior Research Advisor, a position in which I direct a multidisciplinary team of researchers for the PCOR Partnership, a carbon sequestration program in which detailed inventories of CO_2 sources, geologic and terrestrial sinks, and sequestration infrastructure have been made; CO_2 capture and separation technologies have been identified; MMV technologies and permitting requirements are being investigated; and the most promising opportunities for carbon sequestration in nine states and three Canadian provinces are being defined. Current activities include conducting four CO_2 field validation tests. Sponsor participation in the program has increased to nearly 60 members including energy exploration companies, utilities, regulatory agencies, research and development firms, broadcast media, government agencies, and environmental groups. Other responsibilities as Senior Research Advisor include development, marketing, management, and dissemination of market-oriented research; development of programs focused on the environmental and health effects of power and natural resource production, contaminant cleanup, water management, and analytical techniques; publication and presentation of results; client interactions; and advising EERC staff.

My resume is attached as Exhibit ___ (ENS-2).

Q What is the purpose of your testimony?

A I will provide information on carbon management issues requested by members of the Minnesota Public Utilities Commission in proceedings on July 27, 2006, and I will comment on the testimony of parties on carbon management filed September 5, 2006.

II.
CARBON MANAGEMENT INFORMATION REQUESTED BY THE COMMISSION

Q Have you reviewed the transcript of the July 27, 2006, Hearing before the Minnesota Public Utilities Commission in this proceeding?

A Yes.

Q In particular have you identified the information requested by the Commissioners in that transcript regarding carbon management?

A. Yes, I have identified the following questions or requests for information from the Minnesota Commissioners on the subject of carbon management:

1. Commissioner Reha made the following statement (at Tr. 10-12):

"A tougher one is the issue of the carbon capture and sequestration, which I am very much interested in from the environmental level. And that is why, with respect to your permit requests and the scoping of the environmental document, I would like to see that addressed. But I do not know whether the costs of carbon capture, storage, and sequestration—it is quite speculative at this particular point because there is so many different technologies out there that are available for carbon capture; and your proposal, your petition does not require that now. You talk about the potential for retrofit in the future, but—but you do not talk about right—you know, that this is not your proposal right now.

So I do not know how far we need to go with respect—in my opinion—I do not know; I can not speak for anybody else—we need to go into the costs of something that speculative that may occur in the future with all the various different types of technologies that are out there for carbon capture that are still being developed and perfected. And there are all sorts of tests and pilot programs and so forth for capture and storage and sequestration, cost of those, that equipment, that seems, when I think about that, to try to quantify those costs that are kind of speculative at this point whether that makes sense in this power purchase agreement docket."

2. Commissioner Johnson made the following statement (Tr. at 20):

"And IGC and capture of carbon I think is really, really important and the option of having a clean plant and the people of Minnesota be able to buy that. Even if it is going to cost more money, they would have the option to protect the environment. An my question is are you building in the right spot? I mean, I do not know and I know there is studies going on where you're going to store this stuff. And from what I have been reading, pumping it over 300 miles is a no-no."

3. Commissioner Nicolai made the following statement (Tr. at 55):

"We also have to make findings on the project's potential to contribute to a transition to a hydrogen as a fuel resource and an emissions—and the emissions reductions achieved compared to other solid fuel baseloads so that if they have got claims—say you have got—we've got the potential to capture carbon; therefore, you've got to give us credit for that, well, then we need information about is it really feasible."

4. Chair Koppendrayer made the following statement (Tr. at 63):

"I think Commissioner Nickolai spelled out quite clearly the interpretation of the statute; and if it is not satisfied, if we are not satisfied with what you come back with, we are going to start over. And I do not think anybody wants to do that. So the more complete the record is, the better we are."

Q How have you organized your testimony in response to the requests of the Minnesota Commissioners?

A My testimony will address the following subjects in response to the Commission's July 27, 2006, request for more information on carbon management:

(1) An explanation of the work of the PCOR Partnership on carbon management.

(2) The processes employed by the PCOR Partnership to identify carbon sequestration opportunities and sources of CO_2 within the region and the current results of those efforts.

(3) The PCOR Partnership's vision for a carbon-constrained economy.

(4) An explanation of the work the PCOR Partnership is doing in partnership with Excelsior Energy to develop carbon sequestration plans for the integrated gasification combined cycle (IGCC) plants Excelsior is planning in northern Minnesota.

A. PCOR'S WORK ON CARBON MANAGEMENT

Q Describe PCOR's work on carbon management.

A The PCOR Partnership's work is planned in three phases consistent with the organization of the DOE program, which provides partial funding for the regional partnership program. The first phase began in 2003 with the initial application from the EERC, which resulted in the formation of the PCOR Partnership, and was completed in September 2005. The purpose of Phase I was to assess and prioritize opportunities for carbon sequestration in the region through a comprehensive assessment of the region's carbon sources and sinks. The purpose of Phase II, which began in October 2005, is a 4-year effort to develop regional field validation testing for carbon sequestration. Phase III will involve development of a commercial-scale demonstration project in the region. Applications for Phase III demonstration projects were originally scheduled for 2008 but may be advanced to late 2007 by DOE.

In addition, the PCOR Partnership region is currently home to a major value-added sequestration demonstration project that involves injection of CO_2 from a Dakota Gasification Company (DGC) synfuels plant in Beulah, North Dakota, via pipeline (200 miles) to the Weyburn oil field in southern Saskatchewan, Canada, to enhance oil production and store the CO_2. Information on that project is set forth in Exhibit ___ (ENS-3).

Q Describe PCOR's Phase I activities.

A Phase I activities were completed in September 2005. The purpose of Phase I was to assess and prioritize the opportunities for carbon sequestration in the region and to help resolve technical, regulatory, and environmental barriers to the most promising sequestration opportunities.

Phase I developed many work products, including 23 technical topical reports, six fact sheets, public and private Web sites, Press release/newspaper articles, a documentary for public television, the PCOR Partnership Atlas, and the PCOR Partnership Decision Support System (DSS), a Web-based geographic information system (GIS) program that houses the regional characterization data in an interactive, user-friendly format designed to facilitate the assessment of sequestration opportunities. As the project manager, I have overseen all aspects of the project including developing the work plan and assembling the research team to oversee product/deliverable preparation, recruiting partners, and performing administrative duties.

The PCOR Partnership developed the following products in Phase I:

1) A comprehensive regional assessment of CO_2 sources and sinks (assessed more than 1000 sources and evaluated all major geologic sink potentials in the five major basins located in the region [Alberta, Williston, Powder River, Denver–Julesberg, and Forest City Basins (*see* Exhibit___(ENS—4]).

2) A DSS in the form of a GIS-based database providing a tool to evaluate CO_2 sequestration opportunities within the region.

3) Identification, ranking, and action plans for promising sequestration demonstration projects.

4) Key GIS products for CO_2 sources and sinks, infrastructure, and regulatory issues.

5) Recommendations for monitoring and verification systems.

More information on the Phase I products is set forth in Exhibit___(ENS-5).

Q Describe PCOR's Phase II activities.

A The overall goal of Phase II is to validate technologies and identify locations in the region that can support full-scale geologic and terrestrial sequestration opportunities. Specific tasks will include developing field validation projects; evaluating the feasibility of commercial, full-scale selected carbon sequestration technologies; and assessing sink capacity permanence, economics, risk, public acceptance, and societal and monetary cobenefits. Field trials are planned for one terrestrial and two or more geologic sequestration trials as follows: injection of acid gas into a depleted oil reservoir in Alberta, Canada, for acid gas disposal, EOR, and carbon sequestration; injection of CO_2 into a deep carbonate oil reservoir in North Dakota for EOR and carbon sequestration; injection of CO_2 into a lignite coal seam for enhanced methane production and carbon sequestration; and restoration of Prairie Pothole wetlands for carbon sequestration. A written description of Phase II is attached as Exhibit __ (ENS-6).

The success and vision of Phase I were used to develop a successful proposal for Phase II, which continues the regional characterization but focuses on four field validation tests (see Figure 3) to demonstrate the efficiency of CO_2 sequestration in the region. In the fall of 2005, the PCOR Partnership embarked on a 4-year, multi-million-dollar field verification program designed to enhance the local expertise, experience, and working relationships needed to develop practical and environmentally sound sequestration operations in the region. The region, in turn, will benefit from the "lessons learned" in more than two dozen sequestration demonstrations that will be conducted in the other six DOE partnership regions across North America as well as from the sequestration projects under way in other parts of the world. The knowledge garnered from these demonstrations will help identify and implement projects to realize the best opportunities for monetized CO_2 offset projects in the region, including value-added CO_2 enhanced oil and gas recovery projects and terrestrial CO_2 sequestration projects.

B. CARBON SEQUESTRATION OPPORTUNITIES AND SOURCES IN THE REGION

Q Describe the investigation process PCOR has used to identify carbon sequestration opportunities within the region.

A There are essentially four sequestration opportunities which we search for in the region: 1) sequestration in oil fields to achieve EOR; 2) sequestration in other stable geologic formations with an ability to trap CO_2, such as saline formations; 3) sequestration into unminable coal seams; and 4) sequestration in terrestrial systems that exploits the natural process whereby CO_2 will be used/converted biologically into a nongaseous state (e.g., absorbed into plants through photosynthesis). All of these sequestration opportunities are commonly referred to as "carbon sinks."

As a general rule, we prioritize the sequestration opportunities based on permanence, cost, and capacity. As an example of both permanence and cost prioritization, carbon sequestration in underperforming or depleted oil fields has economic value to the owners of the oil fields, and that value will reduce the cost of the sequestration infrastructure in that type of carbon sink. Further, these reservoirs have very competent seals, making them positive choices for permanent storage. Thus it is a priority to identify EOR opportunities in the region because market forces will help enable their development as a result of infrastructure cost subsidization from the market value of CO_2 as a mechanism to enhance oil production.

As an example of capacity prioritization, there are differences in the storage capacities of the three types of geologic sequestration opportunities resulting from their geological characteristics. The storage capacity of an oil field will be variable based on the size, depth, and geologic characteristics of the field. Fortunately, the PCOR Partnership region is comparatively rich in oil fields and saline formations, which underlie most of the state of North Dakota, for example. Although some of the saline formations have a very large storage capacity, until carbon management regulations require sequestration and storage by producers of carbon dioxide, there will be little market subsidization of infrastructure development for those saline structural carbon sinks, compared to the case currently with EOR carbon sinks.

The PCOR Partnership has developed a DSS with its partners to identify and prioritize the inventory of carbon sinks in the region based on cost and capacity. A description of that system is contained in Exhibit ____ (ENS-7).

Data Collection and Organization

One of the goals of the PCOR Partnership project is to match regional CO_2 sources with sequestration options objectively. To accomplish this goal, data have been gathered regarding more than 1000 CO_2 sources and geologic sinks contained in the PCOR Partnership region; terrestrial sinks, including modified farming practices and wetlands; CO_2 capture and separation technologies, including those currently in use as well as those still under development; transportation options; and deployment issues, including permitting, measurement, monitoring, and verification.

These data have been input into a series of Excel™ spreadsheets. One spreadsheet contains the data for the entire PCOR Partnership region, while the other spreadsheets contain the information specific to a particular state or Canadian province.

Data Screening and Matching

The CO_2 sources can be screened according to their physical properties, including:

- Quantity of CO_2 produced.
- Percentage of CO_2 in the exit stream.
- Presence of sulfur dioxide (SO_2), nitrogen oxides (NO_x), or other compounds.

The CO_2 sources are screened to identify those that match a desired set of physical property criteria. One example of a set of physical property criteria is all sources emitting streams containing at least 20% CO_2 but without SO_2 and having a minimum CO_2 output of 500,000 tons/yr. The CO_2 sources meeting those criteria are then filtered to sort them into source types (such as electricity generation, ethanol production, or metals processing) to group sources that produce gas streams of similar composition.

Similarly, geologic sinks are screened based on their physical properties. Physical properties that are taken into account include volume available for sequestration (including porosity and permeability) and CO_2 leak potential.

Scenario and Strategy Development

The PCOR Partnership DSS, developed for PCOR partners, is then accessed to locate the individual CO_2 sources. Sources of a similar type that are located in relatively close proximity to each other are consolidated into a single source. A buffer of a desired distance is drawn around the center of the consolidated sources, and viable geologic sinks located within that buffer are identified. The type of sequestration that could be performed in those sinks (*e.g.*, EOR, deep-well injection) is determined from the data in the DSS. If the physical properties of the CO_2 stream do not meet the sink sequestration requirements (for example, CO_2 stream purity), then the match is rejected. For each match of geologic sink and consolidated CO_2 source, called a scenario, the type(s) of technologies that might be used to separate and capture the CO_2 are noted.

It is anticipated that when the entire data set is filtered, many scenarios will be identified at locations around the PCOR Partnership region, some of which will be similar in type (e.g., a consolidation of coal-fired power plants from which the CO_2 will be sequestered during EOR). These similar scenario types are called sequestration strategies. During initial protocol checks, this method of identifying CO_2 sequestration opportunities was found to quickly identify promising scenarios for further investigation.

Selecting and Ranking Scenarios and Strategies

Transportation options and deployment issues such as permitting and methods of measuring, monitoring, and verifying sequestration will be defined for the most promising scenarios and/or strategies. Preliminary economic evaluations will be performed on those strategies that appear to hold the most promise for successful sequestration. While not designed to calculate actual costs for sequestering a given volume of CO_2, the economics will provide a relative cost ranking for the strategies. Those strategies offering the best opportunity to demonstrate cost-effective, successful CO_2 sequestration will be proposed for investigation during the Phase II activities.

Q How does PCOR currently prioritize the sequestration opportunities in its region?

A *Basis for selecting and characterizing opportunities*.

We used an objective method to match CO_2 point sources with geologic sinks. This is summarized in Figure 4. A series of computer spreadsheets were generated using data from the PCOR Partnership DSS and other sources. The spreadsheets contain CO_2 source emission data, geologic sink types and capacities, CO_2 capture and separation technologies (both those currently in use as well as those still under development), and the

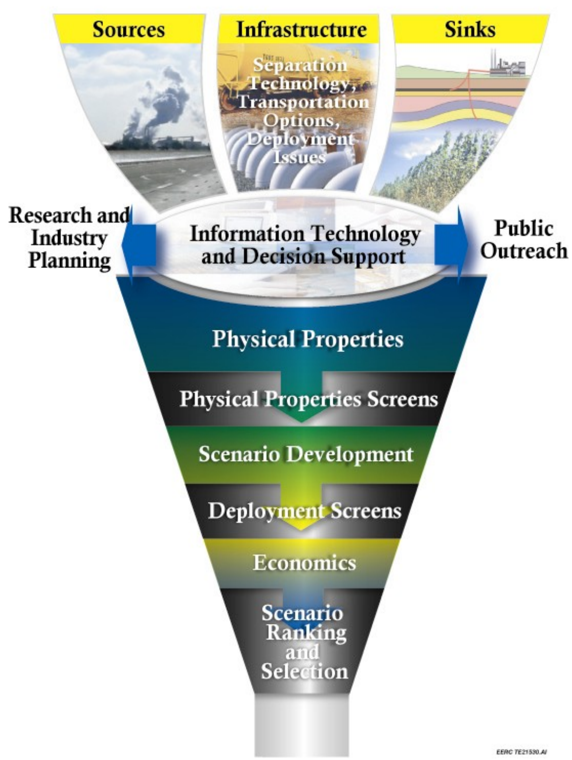

Figure 4. Schematic of the PCOR Partnership CO_2 source–geologic sink matching protocol.

source types to which they could be applied, transportation options, and deployment issues (including permitting and MMV). The largest CO_2 sources were screened according to their source type (e.g., electrical utility, ethanol production, metals processing) and location to group proximal sources that produce similar exit gas streams. These source subgroups were sorted by quantity of CO_2 produced, the percentage of the exit stream comprising CO_2, and the presence of SO_2 and/or NO_x or other compounds to better define the CO_2 streams' compositions and potential ease of capture. The GIS component of the DSS was then used to locate appropriate geologic sinks that are proximal to the groups of point sources (Figure 5).

Figure 5. Data from the PCOR Partnership DSS are used to develop scenarios that pair specific sinks and sources in our region. An economic analysis will be performed on selected scenarios to develop general strategies that have the greatest chance for success in our region.

Basis for prioritizing opportunities.

Priority was given to sequestration opportunities in which sale of value-added products could be used to offset sequestration costs, commercially available capture technology could be applied, and transportation infrastructure existed or could be constructed at a reasonable cost.

Decision Support System and the role it serves.

The PCOR Partnership DSS is an extensive, interactive, Web-based GIS database. The DSS is used to determine the character and spatial relationships of sources, sinks, and infrastructure. The DSS has also been used to identify the location of areas that may present challenges with regard to deployment, such as national wildlife refuges, national parks, national forests, and grasslands. The DSS is the central repository for the characterization information, information that is generated by the field validation projects, MMV activities, regulatory compliance activities, and capture and transport studies. An interactive regional atlas has been, and will continue to be, developed through the DSS.

The role played by the partners in this process.

When required, PCOR partners provided additional information about specific sequestration opportunities, such as EOR or pipeline information.

Q Describe the carbon sequestration opportunities PCOR has identified in the region.

A. Potential for geological carbon sequestration via enhanced oil recovery (EOR) and saline aquifers.

The PCOR Partnership area is underlain by multiple saline formations and is home to oil and gas production (Figure 6) in five states and three provinces. Saline formations within the Mississippian Madison Group, Lower Cretaceous Aquifer System (Figures 7 and 8), were evaluated to estimate their potential CO_2 storage capacities. Estimates for these systems indicate the potential to sequester CO_2 on a large scale. Tables 2–4 quantify the sequestration capacities in the evaluated geological sinks.

1. <u>Enhanced Oil Recovery (EOR) Carbon Sinks</u>

Q Describe the extent to which there are ongoing EOR operations within the PCOR region and the potential oil reserves that are recoverable using EOR.

A The PCOR Partnership region as a whole is home to several ongoing commercial-scale CO_2–EOR operations. Two CO_2–EOR operations are currently being conducted in the Williston Basin, which is the oil-producing sedimentary basin closest to the proposed Excelsior plant site(s). The sites of these two EOR operations are in the Weyburn and Midale oil fields of southeastern Saskatchewan. A total of over 100 million cubic feet of CO_2 is delivered everyday to these two oil fields from the DGC Great Plains Synfuels Plant in Beulah, North Dakota.

Potential for terrestrial carbon sequestration through wetlands management.

See Figure 3.

Wetlands CO_2 sequestration capacities for the entire PCOR Partnership region total 55 million tons/yr. Phase II of the PCOR Partnership includes a wetlands field validation test that will quantify the practical economic and environmental potential for wetlands sequestration in the PCOR Partnership region.

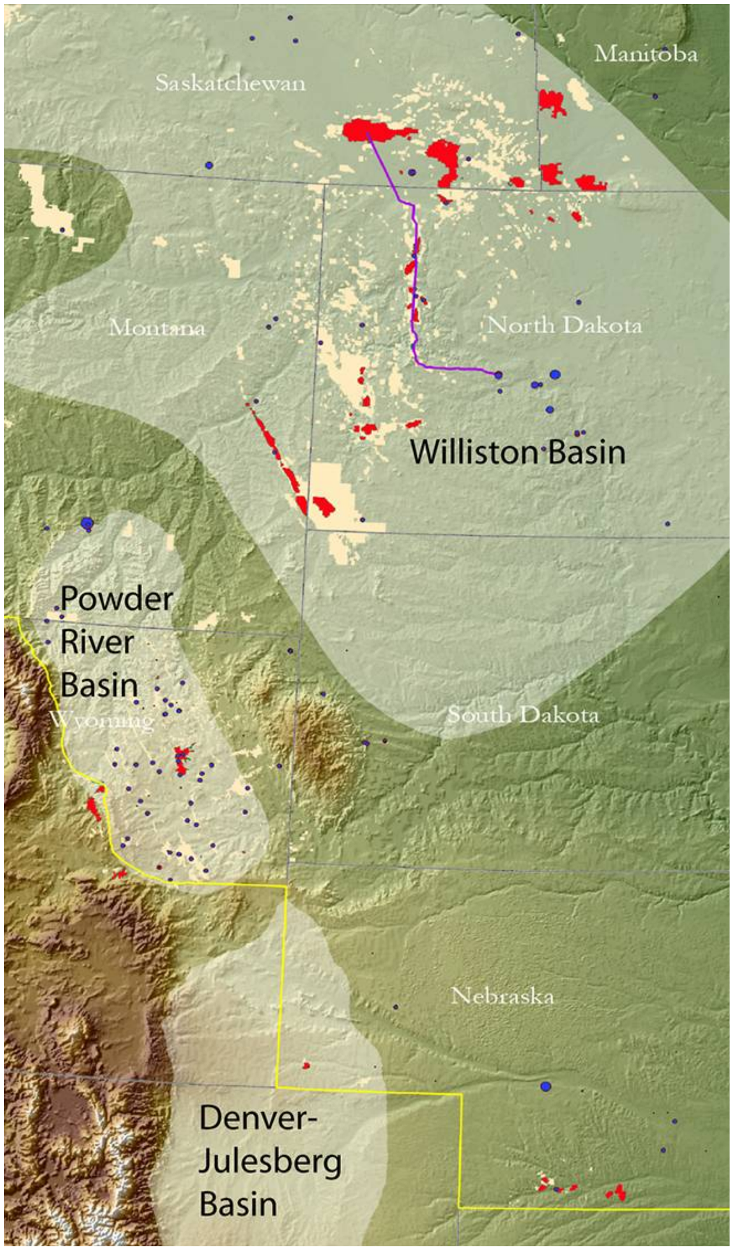

Figure 6. Evaluated oil pools. EOR opportunities are shown in red, and CO_2 sources are shown in blue.

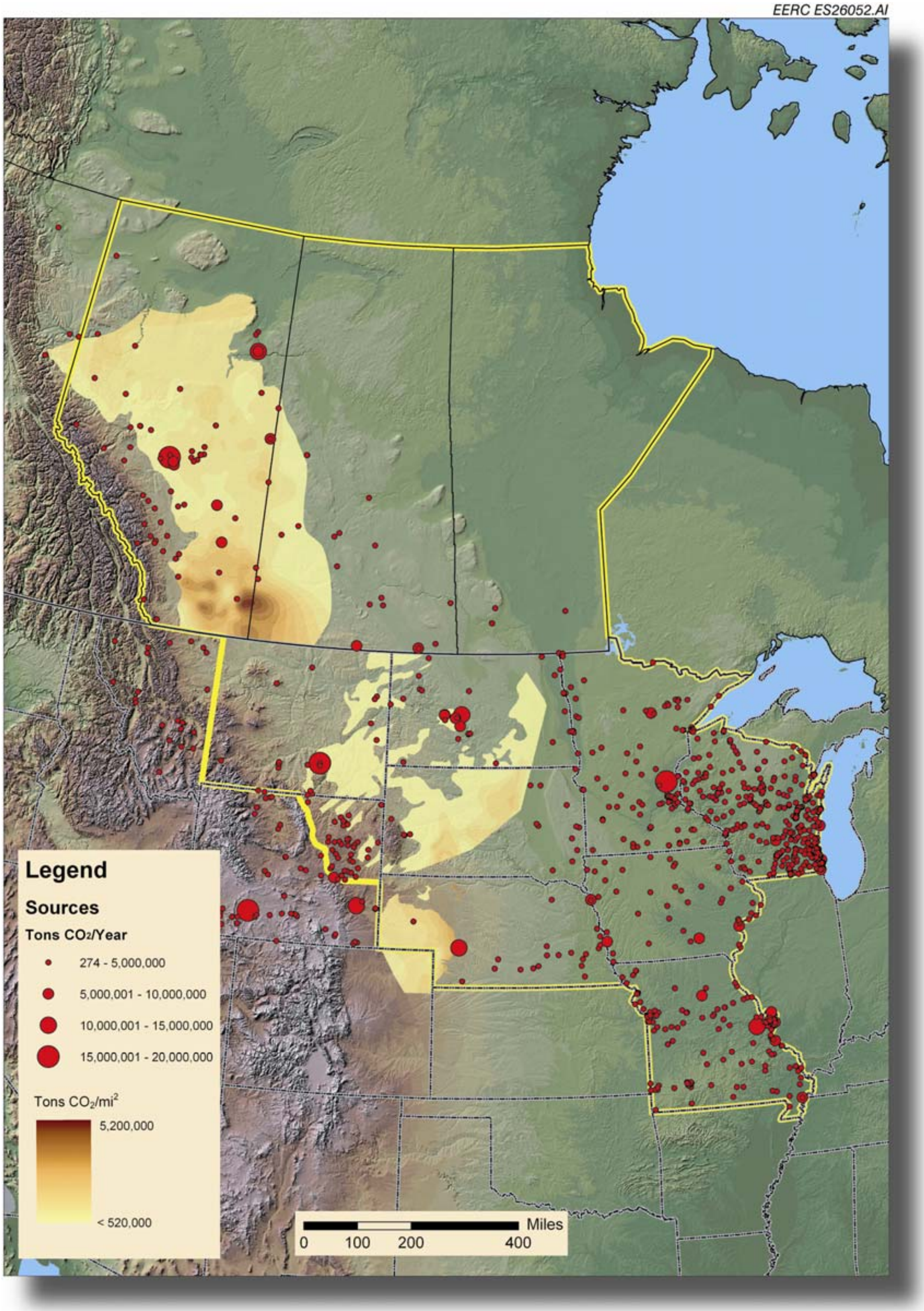

Figure 7. Lower Cretaceous Aquifer System evaluated in the Alberta, Williston, Denver–Julesberg, and Powder River Basins. Red dots indicate large point sources in the region.

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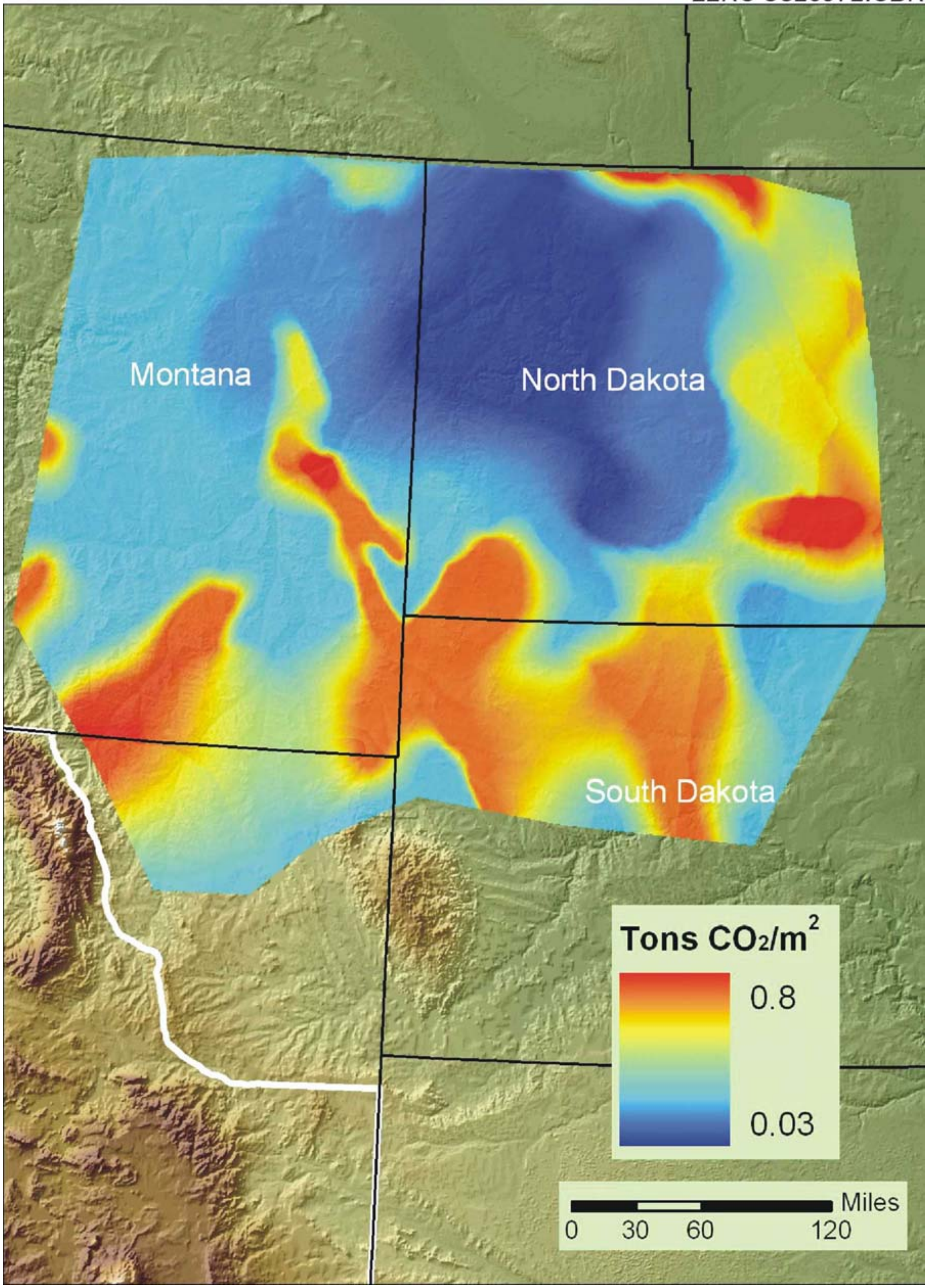


Figure 8. Mississippian Madison System evaluated in the Williston Basin.

Table 2. CO_2 Sequestration Evaluation of Selected Oil Fields in the PCOR Partnership Region. This approximates about 1 year of CO_2 emissions from large point sources in the region.

Basin	Cumulative Incremental Recovery from CO_2 EOR in Selected Units (million stb)	CO_2 Sequestration Potential Through EOR in Selected Units (million tones)
Williston	1023	450
Powder River	381	170
Denver–Julesberg	25	11

Table 3. Volumetric Totals in Oil Pools Evaluated in the PCOR Partnership Region. This total is representative of 16 years of large point source CO_2 emissions in the region.

Basin	Number of Pools Evaluated	Potential Storage Capacity in Evaluated Fields
Williston	845	> 8 billion tones
Powder River	225	> 0.9 billion tonnes
Denver-Julesberg	21	> 12 million tonnes

Table 4. Summary of Sequestration Capacity in Evaluated Aquifer Systems.

Aquifer System Evaluated	Basin	Estimated CO_2 Capacity (Billion tons)
Lower Cretaceous System		
Newcastle Fm.	Williston and Powder River	42
Viking Fm.	Alberta	100
Maha Fm.	Denver–Julesberg	19
Mississippian System		
Madison Fm.	Williston and Powder River	60

Commercial CO_2–EOR projects are also being conducted in three oil fields in Alberta and two oil fields in Wyoming. It is worth noting that numerous CO_2-based EOR projects are in various stages of planning throughout the PCOR Partnership region.

The application of CO_2-based EOR operations to oil fields in the PCOR Partnership region, especially the Williston Basin, is receiving a great deal of attention for the following reasons:

- In the Williston Basin alone there is the potential to recover over 1 billion barrels of oil that may not otherwise be recoverable. If all of the oil-producing states and provinces in the PCOR Partnership region are considered, there are over 3 billion barrels of incremental oil that could be produced using CO_2 EOR techniques in the PCOR Partnership region.

- Over 800 oil pools located throughout the Williston Basin have characteristics that indicate that they may be suitable candidates for the application of CO_2-based EOR.

Q Describe how the CO_2 operates to enhance oil recovery in an EOR operation.

A ***Miscible/Immiscible Processes***.

At atmospheric conditions, CO_2 exists in a gaseous state. In order to be used for injection into an oil reservoir for tertiary oil recovery, the CO_2 must be under sufficient temperature and pressure to achieve a supercritical state. In a supercritical state, CO_2 becomes more like a liquid and less like a gas. This change is beneficial to most EOR schemes because when CO_2 comes into contact with reservoir oil, mixing of the two fluids into a single phase is generally expected. This mixing of the two fluids is a ***miscible*** process. The CO_2 stream used for a miscible flood generally must have a purity of at least 95%.

By contrast, substances are said to be ***immiscible*** if they cannot be mixed together. An analogy to this exists at reservoir conditions where oil and water coexist as separate fluids. CO_2 streams that are less than 95% pure will generally result in an immiscible flood.

A double dose of CO_2 is not released once the oil is recovered and consumed (i.e., oil does not soak up CO_2 and when it is burned, the dissolved CO_2 and the carbon originally present in the oil are released as CO_2.)

As oil is produced and brought to the surface, it must be treated prior to going to market. This is generally done on-site at a processing facility. At this facility, the oil is stripped of associated gases and impurities that are not desirable for transport and refining. These gases include hydrocarbons, hydrogen sulfide, nitrogen, and carbon dioxide. If an oil field is being flooded by carbon dioxide, it can be present in higher quantities than the natural conditions. Because CO_2 has value as a miscible agent, it is separated from the other gases prior to the refining process and recycled for reinjection into the oil field. Recycled CO_2 will be combined with newly purchased CO_2 as flooding continues. The CO_2 contacts the oil column and helps push the oil toward the producing unit.

Although EOR does produce additional fossil fuels that will ultimately result in CO_2 emissions when used, EOR using anthropogenic CO_2 is still a net positive with respect to the environment. This is because the CO_2 used would have been vented to the atmosphere if it had not been employed for EOR. Further, the EOR process can extend the life of existing oil fields by decades, reducing the need for drilling and production in new fields. Since the infrastructure (roads, pipelines, processing facilities, wells, etc.) for oil and gas production and processing is already in place in the EOR fields, extending the life of existing oil fields makes a great deal of environmental and economic sense. The CO_2 used either stays in the geologic formations or is recycled back into the EOR process. The oil or gas produced is no higher in CO_2 concentration than that which is produced by other methods.

Q Describe the extent to which EOR operations are occurring in the PCOR region and the potential oil reserves that are recoverable.

A The PCOR Partnership has evaluated over 6000 oil fields in its region in the Williston, Powder River, Denver–Julesberg, and Alberta Basins. Based on this analysis the PCOR Partnership estimates that application of EOR would yield a sequestration capacity of 1 billion tons of CO_2 and yield an incremental oil production increase of over 3 billion barrels of oil for the 160 fields it has evaluated. The PCOR Partnership estimates the total sequestration capacity utilizing EOR in the region to be in excess of 10 billion tons. *See* Exhibit___(ENS-8)

The PCOR Partnership has also studied the sequestration capacity of coal fields and the incremental methane production capacity from sequestration. The storage capacity in the region's coal fields is estimated to exceed 8 billion tons, and the potential incremental methane production potential is greater than 17 trillion cubic feet from ECBM in these coal seams. See Exhibit__ (ENS-9)

In the Williston Basin, the PCOR Partnership has estimated the incremental oil potential from EOR sequestration to be 1.02 billion barrels (stb), worth approximately $60 billion in today's dollars. For North Dakota, the estimate is 262 million barrels, worth about $15 billion in today's dollars ($59.50/stb 8/8/06).

Oil and gas regulatory agencies in the United States use a process commonly referred to as "unitization" to organize oil fields into units for the purpose of secondary and tertiary recovery operations. The technical reports of successful unit applications generally provide data on the geology of the reservoir, including lithological descriptions and maps showing the structure of the reservoir formation and its productive intervals, interval thickness, and porosity and permeability. Some geologic reports include key supplemental information such as core descriptions and analyses, geophysical data, and geochemical data. Engineering reports provide in-depth discussions of reservoir properties, fluid properties, reservoir performance and pressure history, oil-in-place calculations, reserves, unitization parameters, pressure maintenance, and economic evaluation of the proposed unitization plan.

Analysis to date has indicated that the oil and gas fields in the Williston Basin region contain approximately 1100 fields that could be utilized during CO_2 sequestration, especially as part of EOR activities. These fields can be served by numerous CO_2 sources that may or may not be a part of yet-to-be-developed regional pipeline and aggregation facility infrastructure.

Q Describe the optimal characteristics of the sources of CO_2 needed to supply an EOR sequestration project.

A From the point of view of an EOR operation, the optimal characteristic of a source facility is its ability to provide large volumes of high-purity CO_2 (at least 95% CO_2) in a supercritical state as a relatively uninterrupted stream.

The costs of pipeline and compressor station construction, operation, and maintenance are a major portion of the capital and operational costs of a CO_2 flood EOR scheme. It is axiomatic that longer pipelines will induce greater costs of construction, operation, and maintenance. Therefore, it follows that large volumes of oil will have to be produced in order to offset the costs of longer pipelines. To produce large volumes of oil, CO_2 flood EOR operations will have to be conducted in either a single large oil field or in multiple oil fields that are in close proximity to each other. Significant volumes of CO_2 will have to be supplied to the target oil field or fields in order to produce large volumes of oil.

The CO_2 flood EOR project currently being conducted at the Weyburn field in Saskatchewan is an example of this relationship in action. According to PCOR Partnership calculations, the Weyburn oil field has the potential to incrementally produce an estimated 65 million barrels of oil through the injection of CO_2. To economically produce that amount of oil over a span of 20 years, the Weyburn EOR project will require a stream of approximately 71 million cubic feet (mmcf) of CO_2 per day. Only a very large source of CO_2 will be able to provide Weyburn with the CO_2 necessary to make this operation economical. In this case, the Weyburn EOR project is using anthropogenic CO_2 produced by the DGC plant delivered via a pipeline that is over 200 miles long.

Q Has PCOR studied the quantities of CO_2 needed for EOR operations in the region?

A An evaluation of literature suggests that anywhere from 6 thousand cubic feet (mcf) to 16 mcf of CO_2 may be required for each incremental barrel of oil produced. The actual value varies from reservoir to reservoir, depending on a variety of geological and operational characteristics.

Q Over what lengths of time will EOR operations last?

A It has been reported that the CO_2-based EOR projects that are currently being conducted in the PCOR Partnership region have been developed with plans to operate for a minimum of 20 years. It is worth noting that some oil fields in west Texas have been conducting CO_2 flood EOR operations for over 30 years.

Q What sources of CO_2 are currently in use in EOR operations within the PCOR region?

A ***Natural gas recovery operations.***

In the late 1980s, CO_2 EOR began in Wyoming at the Lost Soldier and Wertz oil fields. CO_2 is supplied from the Big Piney–LaBarge area and sent via pipeline to the fields. In 2003, Anadarko began plans to bring CO_2 to the Salt Creek field (Wyoming), which is expected to increase production by approximately 25,000 barrels per day and sequester nearly 30 million tons over 20 years. Anadarko has also purchased marketing rights for CO_2 produced at the LaBarge gas plant and intends to sell the product to producers interested in initiating CO_2 floods at depleted oil fields.

Dakota gasification facility in Beulah, ND.

The CO_2 that is produced by the Dakota Gasification facility in Beulah, North Dakota, currently is being utilized for EOR in two oil fields in Saskatchewan. The CO_2 is transported via pipeline from the plant and delivered to the Weyburn and Midale fields in a supercritical state. Approximately 120 mmcf per day of CO_2 are being utilized in these fields, and incremental production has grown by approximately 20%.

Q Does an IGCC power plant represent a source for CO_2?

A An IGCC plant has some inherent advantages over the retrofit of standard coal combustion power plants. The plant can be designed to accept CO_2 capture technologies from the start, and the CO_2 concentration in the flue gas is higher than for a standard coal-fired power facility. These characteristics facilitate the capture of CO_2 relative to the retrofit of standard coal combustion power plants.

Q How will PCOR apply the experience gained from EOR projects to other sequestration options?

A Development of EOR carbon sinks is an expedient method of research and development for carbon sinks in other geological formations. There is minimal need for new exploration with EOR because the sites are fully characterized. Practical experience, derived from EOR processes, will guide the design and establishment of injection in saline formations. For example, experience with injection of CO_2 in EOR programs will verify MMV techniques, provide experience with developing leakage assessments, establish legal requirements and regulatory requirements for the operation of geological sequestration projects, and provide benchmark cost assessments.

Because the oil and gas fields have already undergone extensive geologic characterization, these costs can be eliminated from the costs of sequestration. Saline formations, and other noneconomic strata would have to undergo significant geologic characterization before they could be considered for sequestration. By choosing EOR opportunities first, we are better able to develop the infrastructure and MMV technologies that will be applied to non-EOR sequestration opportunities in the future. It just makes sense to exploit the EOR opportunities first to help defray the costs of pioneering work on CO_2 sequestration. Without more mature carbon markets, the economic drivers for sequestration are not present for non-EOR scenarios.

With further research and demonstration projects, the cost of CO_2 sequestration will be better defined.

It takes time to research and characterize a geological system with respect to its potential as a carbon sink. Typically, qualification of a site requires a thorough understanding of the site-specific geology and testing involving the installation of injection and monitoring wells. The EOR projects provide the opportunity to refine geological assessment and testing mechanisms and methods which can be applied to the evaluation of other geologic formations and conditions such as saline structures. The PCOR Partnership is able to utilize existing geological data and wells developed by oil companies in evaluating the suitability of oil fields for EOR projects. In addition, licensing and access to the geological structure for installation of an EOR system is facilitated by the unitized ownership of most oil fields and the economic benefit the EOR system provides in terms of enhanced oil production.

It will take time for carbon markets to develop and mature. Until then, there will be little economic motivation for injecting CO_2 into saline or terrestrial sequestration formations, so long as EOR sequestration potential exists. Thus the PCOR Partnership believes the first sinks to be utilized will be those employing EOR systems.

2. <u>Geologic Carbon Sinks (Saline or Brine Formations)</u>

Q What is the long range potential of saline formation carbon sinks?

A Saline formations are the best long-range choice for carbon sinks because they provide the needed capacity and are more widely accessible to sources.

In the PCOR Partnership region the primary large-capacity sequestration sites are located in its vast geologic sedimentary basins. These basins cover 440,828 square miles, or 32% of the surface area of the region. These basins contain multiple opportunities for sequestration including value-added sequestration through EOR in oil fields and coal seams and sequestration in large, stable saline (or brine) formations.

Regional capacity is significant

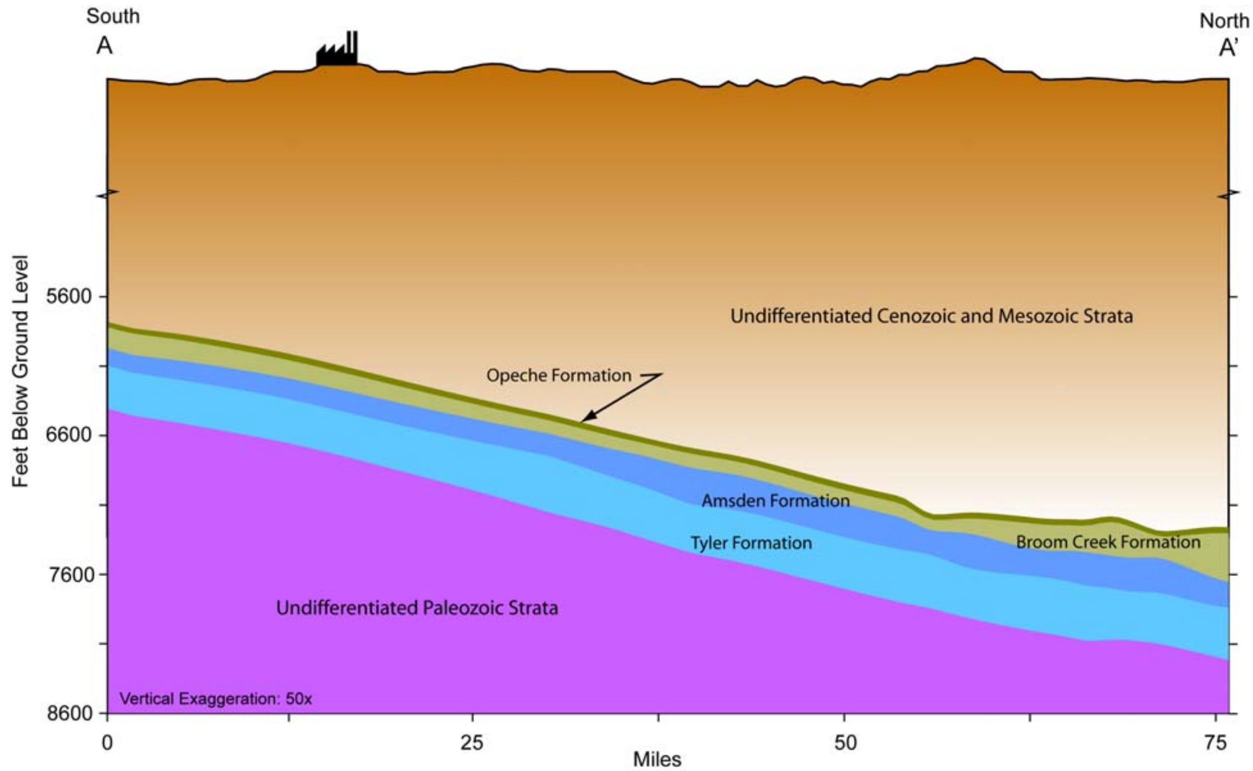
Three studies focused on saline formations in the PCOR Partnership region have been completed to date. Results of these studies indicate the potential to sequester over 200 billion tons of anthropogenic CO_2. *See* Figure 7. Approximately 500 million tons of CO_2 was produced in the year 2000 in the PCOR Partnership region. If all of this CO_2 were captured and sequestered, this would represent approximately 400 years of emissions.

Of the three studies completed, the most relevant is possibly the study to site a 275-MW IGCC power plant that vents virtually no emissions to the atmosphere. The EERC focused on a saline formation in the southwest corner of North Dakota to receive the CO_2 produced from the plant. Injection rates used in the study were 1 million metric tons per year of CO_2 and a maximum of 50 million metric tons over the life of the plant, estimated to be approximately 30 years.

This study indicated that the chosen formation, the Minnelusa Broom Creek, would accept these emissions with little difficulty. Figures 9–11 show the generalized cross section, the location studied and the extent of the underlying Broom Creek Formation, and the projected/estimated CO_2 plume extent after 4 and 50 years of CO_2 injection. After 30 years of continuous injection, it is estimated that the CO_2 will occupy a radius around the plant of approximately 2 miles. While the plume will not be perfectly circular, as the illustration shows, the scientific calculations indicate that there is more than enough capacity to accept the proposed mass of CO_2.

Location is central for more sources.

The PCOR Partnership region makes up one of the largest continuous locations in the United States where large-scale CO_2 sequestration can be applied. The region comprises multiple sedimentary basins covering over 400,000 surface miles. This is significant when looked at volumetrically. Furthermore, the region is rich in coal, oil, natural gas, and farm crops which will be utilized to provide feedstock for tomorrow's power plants and energy requirements.



<u>Figure 9</u>. Generalized cross-sectional view of the relative stratigraphic location and depth of the Broom Creek and the primary seal formation, Opeche Formation.

<u>Figure 10</u>. Map showing the regional extent of the Broom Creek Formation.

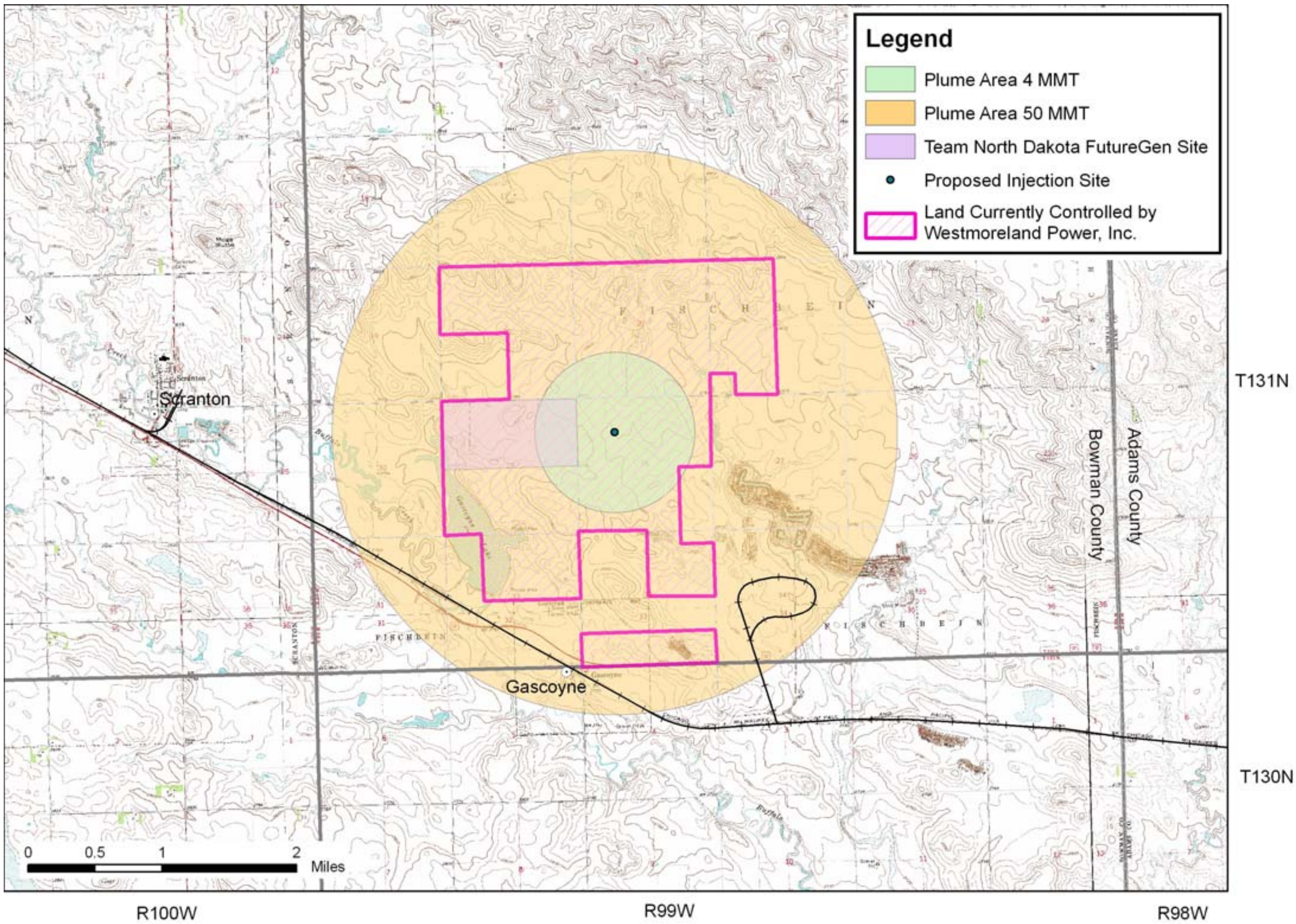


Figure 11. Map showing the extent of the 4-MMT and 50-MMT plume.

Motivation for use of saline formations is not mature.

It is highly likely that sources in the future will be collocated with suitable CO_2 storage sinks. While oil fields will likely be the first targets to accept CO_2, saline formations will likely have a significant role as a result of their volumetric capacity. The current economy is allowing for more oil to be produced utilizing CO_2. Future markets are still uncertain; however, it is likely that CO_2 will become a commodity to be traded on a global market. As geologic sequestration becomes more prevalent, it is likely that many oil reservoirs will reach their volumetric capacity to store CO_2. As EOR opportunities become scarce, saline formations will be turned to as the next sequestration target. In the interim, a robust carbon credit-trading market will likely be established and provide a mechanism by which CO_2 can be bought and sold on open markets.

As with oil field operations, CO_2 to be sequestered in a saline formation will have to be delivered to the end user. The likely mechanism will be by pipeline. It is expected that the infrastructure utilized in the oil industry for CO_2 flooding during EOR will be used to sequester CO_2 in saline formations. By using existing pipes, the cost to move product will effectively be lessened. Saline formations can also be utilized for overflow conditions where an oil field cannot handle an entire stream. In this case, if there is an interruption in delivery and systems are in place, CO_2 could be drawn from a CO_2 storage reservoir (saline formation), cleaned of impurities, and injected into an oil reservoir for enhanced production.

3. <u>Pipeline Issues</u>

Q Does the cost of pipeline construction to carry CO_2 to a carbon sink make the use of EOR sites and saline formations infeasible economically in PCOR's region?

A No. Current evidence from existing CO_2 pipelines shows that they can be economically feasible and operate successfully for years. A good example is that of the Dakota Gasification Plant in Beulah, North Dakota. This EOR system is successfully taking the CO_2 produced at the DGC plant and carrying it by pipeline 200 miles north to the Weyburn oil fields in southern Saskatchewan, Canada.

Pipeline costs make up a significant fraction of the total estimated CO_2 sequestration cost. However, if the value of products of the activity (such as oil or coalbed methane) is sufficiently high, companies interested in producing these materials may contribute a significant fraction of the cost of the pipeline in order to take advantage of the

EOR or ECBM opportunity. This scenario is probably only likely in the time frame when the sequestration sites are still capable of producing such products.

In a carbon-managed world, the economics of pipeline transportation will reflect the value of CO_2 in terms of not only value-added products, but carbon credits. If widespread sequestration were performed, pipeline costs could be shared by many different producers, thereby minimizing the cost to any one producer.

Q Does a CO_2 pipeline differ from a natural gas pipeline?

A Natural gas, water, or oil pipelines cannot be converted to transport CO_2 because CO_2 is typically transported at supercritical pressures (greater than 1200 psi), and other types of pipelines are usually rated at lower pressures and are, therefore, unsuitable for CO_2 service. Because CO_2 is not corrosive by itself, special materials of construction, coatings, or anticorrosion agents are not required unless the gas stream contains H_2S or water.

Although not poisonous, CO_2 is heavier than air and can cause suffocation if sufficiently concentrated. For that reason, pipeline monitoring and maintenance is crucial. The Dakota Gasification plant continually monitors the pressures within the pipeline; a drop in pressure would indicate a leak. In addition, a small amount of a mercaptan has been added to the CO_2 to provide an odor (much like the mercaptan added to natural gas) that serves as a warning/signal to any persons in the vicinity of a leak. Dakota Gasification performs the following scheduled maintenance to ensure the integrity of the pipeline:

- Aerial patrols are performed 26 times per year.
- A population density survey is performed once a year.
- A right-of-way inspection is conducted twice a year.
- Valves are maintained and inspected twice a year.
- The emergency systems are checked once a year.
- Rectifier maintenance is performed twice a year.

- A cathodic protection survey is performed once a year.
- An electronic tool is used to inspect the pipeline interior every 5 years.

(Reference: www.dakotagas.com/SafetyHealth/Pipeline_Information.html)

Q What are the costs of construction of a CO_2 pipeline?

A Estimates of pipeline costs include:

$25,000/in.–mile (in 2002 dollars) Ref: Melzer, L.S. *The Permian Basin CO_2 Sequestration Model and Ridgeway Petroleum's St. Johns Project*. Presented at the Annual Convention of the Southwest Section of the American Association of Petroleum Geologists, Ruidoso, NM, June 2002.

$24,089/in.–km (which equals $38,767/in.–mile; in 2005 dollars) Ref: *Building Capacity for CO_2 Capture and Storage in the APEC Region. A Training Manual for Policy Makers and Practitioners.* "Module 4–CO_2 Compression and Transportation to Storage Reservoir" by Sam Wong, March 2005.

$43,700/in.–mile (in 2003 dollars) Ref: Natural Gas Transmission Pipeline Construction Cost, R.W. Beck, Inc., Oil & Gas Bulletin, 2003.

$21,160/in.–mile for a 12-in.-diameter CO_2 pipeline (in 1994 dollars) Ref: Kovscek, A.R. "Screening Criterial for CO_2 Storage in Oil Reservoirs," Petroleum Science and Technology 20(7&8), pp. 841–866, 2002.

At the PCOR Partnership Annual Meeting EOR Workshop held in Calgary, Alberta, on September 13, 2006, speaker Steven Melzer noted that the rule of thumb is $30,000/in.–mile. During the CO_2 capture and transportation workshop held at the same meeting on September 15, 2006, an attendee noted that his/her company uses a rule of thumb of $60,000/in.–mile.

According to the Kovscek reference, the CO_2 pipeline from the Dakota Gasification plant in Beulah, North Dakota, to the Weyburn field in Saskatchewan costs roughly $122 million to build. It is 204 miles in length and varies in diameter (some is 12-in.- and some is 15-in.-diameter pipe). Assuming a 12-in. diameter (the worst-case scenario on a cost per in.–mile basis), the cost was $49,837/in.–mile.

Pipeline costs could be shared by nearby CO_2 sources producing similar-quality CO_2 streams, or the pipeline costs could be shared between the CO_2 producer and the CO_2 users (assuming sequestration for EOR or ECBM production).

4. <u>Terrestrial Carbon Sinks</u>

Q Please explain the situations to which terrestrial sequestration options can be applied.

A *__Important terrestrial sequestration options exist, but do not have the capacity for sequestering large amounts of carbon.__*

Terrestrial sequestration is not meant to be a "stand-alone" solution. It is to be used in conjunction with geologic sequestration. This is because terrestrial sequestration exploits natural buildup of carbon in plant soils and sediments. This natural buildup eventually reaches a new equilibrium at which time no additional carbon will be stored.

Examples of available capacity.

We estimated that the Canadian Prairie Pothole Region (PPR) had 2.7 million acres of potentially restorable wetlands (i.e., cropland wetlands), and in the United States, National Wetland Inventory and Nature Resources Institute-derived estimates of restorable wetlands ranged from 3.4 million to 9.5 million acres, respectively (Table 5). When combined, the area of potentially restorable wetlands in the PPR ranges from 6.1 million to 12.2 million acres (Table 5). Based on this range, restoration of cropland wetlands in the PPR has the potential to sequester 60.4 million to 122.6 million tons of soil organic carbon (Table 5) or, in terms of CO_2 equivalents, 221.3 million to 448.7 million tons. More information on wetland carbon sinks in the glaciated North American prairie is provided in Exhibit __ (ENS-10)

Recent work for the PCOR Partnership by the U.S. Geological Survey (USGS) and Ducks Unlimited Canada scientists demonstrated that restoration of previously farmed wetlands results in the rapid replenishment of soil organic carbon (SOC) lost to cultivation at an average rate of 1.34 tons/acre per yr.

Table 5. Estimate of Potential Carbon Storage in Wetlands in the PPR of North America.

	Area of Potentially Restorable Wetlands, mi^2	Potential Soil Organic Carbon Storage (SE)[a], million short tons	Potential Atmospheric Carbon (SE)[a], CO_2-C storage, million short tons
United States	5260[b] to 14,800[c]	17.3 (3.2) to 79.4 (15.4)	63.1 (11.7) to 290.5 (56.5)
Canada	4250[d]	43.2 (10.6)	158.2 (38.8)
Total	9500 to 19,100	60.4 (11.1) to 122.6 (18.7)	221.3 (40.5) to 448.7 (68.6)

a Standard error of the mean.
b Area of potentially restorable wetlands (i.e., wetland in cropland) estimated using the NWI database.
c Area of potentially restorable wetlands estimated using the NRI database (U.S. Department of Agriculture, 2000).
d Area of potentially restorable wetlands estimated using Ducks Unlimited Canada Wetland Inventory (Ducks Unlimited Canada, 1986).

Terrestrial sequestration options do not need to be at the source, but are more difficult to quantify.

This is the goal of the current field validation tests, to add ease in quantification.

C. EERC's VISION OF a CARBON-CONSTRAINED ECONOMY

Q What is EERC's vision of a future carbon-constrained economy?

A With our partners, the EERC has developed a vision of the role that CO_2 sequestration may play in a carbon-managed future. The partnership will continue to assess and prioritize the opportunities for sequestration in the region and will identify and work to resolve the technical, regulatory, and environmental barriers to the most promising sequestration opportunities. At the same time, the partnership will work to inform policy makers and the public about CO_2 sources, sequestration strategies, and sequestration opportunities.

The PCOR Partnership vision (Figure 12) for our region includes a major network of CO_2 pipelines that connect major sources and sinks. We anticipate that the initial legs of this pipeline system will be developed for EOR projects and that they will be used for

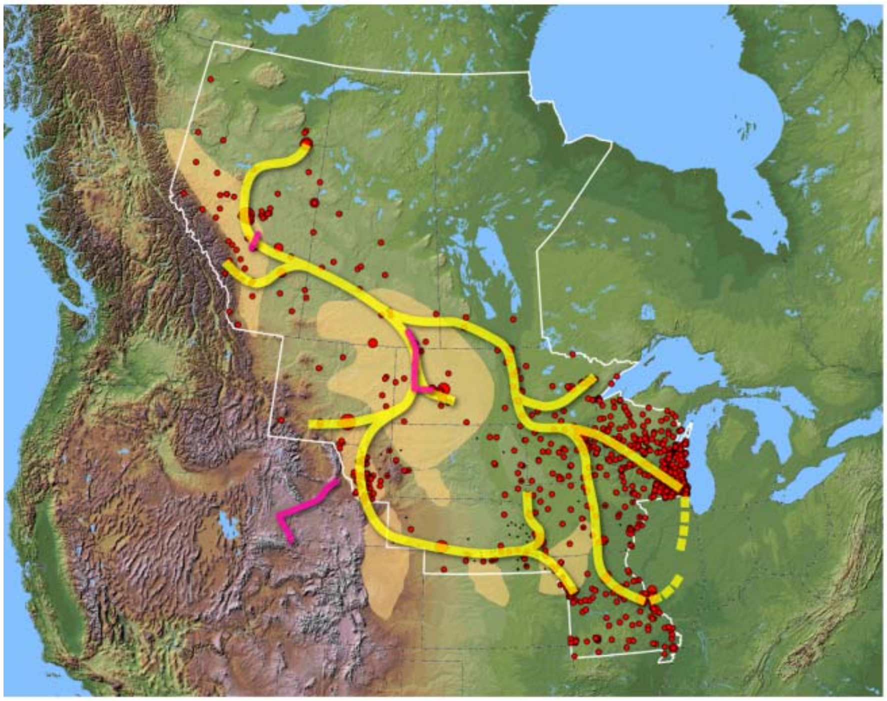


Figure 12. PCOR Partnership vision of future pipeline network linking major stationary CO_2 sources with the region's best geologic sinks.

saline formation injection after the EOR opportunities have been depleted. In our vision, the CO_2 sources that are first adopters will benefit from the revenues produced through the commercial sale of CO_2. Once carbon markets fully develop, the economics of carbon credit trading will control the development of sequestration opportunities.

Power plants will play a large role in the region's carbon-constrained future. As the source of roughly 54% of the CO_2 from stationary sources in the region (41% of all CO_2 emitted in the region), CO_2 captured from these large emitters is likely to be used in the region's oil fields for EOR activities. Facilities that are capture-ready or can be relatively easily retrofitted for CO_2 capture will be able to take advantage of the expected market for their CO_2.

All industrial sectors of the economy are required to account for and offset their carbon releases.

In a future carbon-managed economy, carbon offsets will be offered. Carbon releases from stationary sources will be monitored and evaluated. The sources with the ability to reduce their emissions (either through process changes that eliminate the production of CO_2 or through CO_2 capture, transportation, and sequestration) will likely do so and will trade or sell their carbon offsets to sources for which reducing or eliminating emissions is not economically feasible.

Q What is EERC's vision of the role of base load power plants in the future carbon constrained economy?

A All industrial point sources will be involved in the carbon offset market, either by selling/trading their offsets or purchasing offsets from other sources. Point sources that are likely to find it easier or less expensive to capture their CO_2 because of concentration and/or CO_2 stream purity are ethanol production facilities, natural gas production facilities, gasification plants at which petroleum coke is fed, and methane reformers. Cement kilns and landfill gas collection facilities will probably also find ways to economically capture CO_2 from their offgases. Traditional pulverized-coal-fired power plants and other coal-fired facilities will likely be the purchasers of offsets, at least in the relatively near term.

Q Does EERC have a view about the role of IGCC technology in the future carbon constrained economy?

A IGCC plants produce syngas containing roughly 30 wt% CO_2 (18 to 19 vol% CO_2). This can be compared to the CO_2 concentration in the gas streams from other processes: ethanol plants produce a 99% pure CO_2 stream, cement kilns produce offgas containing about 33 to 35 wt% CO_2, and the flue gas from coal-fired power plants is in the range of 12 to 16 wt% CO_2, depending upon the coal feed characteristics.

Investments in CO_2 sequestration infrastructure will likely become more prevalent as carbon markets mature and prices for carbon offsets stabilize. Markets will ultimately dictate the types of projects that are economical, but geologic sequestration projects and the offsets they produce will likely become a significant part of those markets. IGCC is an option that should be explored in the transition to a carbon-managed economy because of its CO_2 stream concentration.

As a matter of policy the EERC does not endorse one technology over another. That said, it is clear to the EERC that the IGCC technology has advantages which can positively impact the cost of carbon capture and sequestration not enjoyed by conventional coal-fired base load power generation technologies. Thus the EERC's vision is that IGCC may well be a feasible method of getting started with carbon capture and sequestration from base load power plants.

Q Does EERC have a vision for the region regarding the linking of power plant CO_2 sources and geological sinks?

A It is possible to draw a reasonable pipeline route through the PCOR Partnership region that links many of the major stationary sources with the region's best geologic sinks. This is shown in Figure 12.

This approach is not unreasonable. It has been done previously in the Permian Basin, as shown in Figure 13.

Q How long will it take and what must happen for carbon markets to develop and drive sources of CO_2 to build pipeline to capture the long-term value of carbon sequestration units?

A Although existing carbon markets in Europe have seen significant trading volumes for less than a year, they do provide some insight into the likely structure and behavior of

FIG. 1 - CO_2 SOURCES AND PRIMARY PIPELINES FOR THE PERMIAN BASIN

<u>Figure 13</u>. CO_2 sources and primary pipelines for the Permian Basin.

carbon markets in the United States as carbon management becomes more important. Prices on the European market reached very high levels earlier this year as the Kyoto Protocol went into force. Prices spiked at over €30 per ton of carbon and then dropped precipitously as it became apparent that companies were better able to reduce overall CO_2 emissions through the adoption of increased energy efficiency strategies. The prices have stabilized and started to climb of late.

The Chicago Climate Exchange is a voluntary trading platform that has established some precedents for trading carbon credits in the United States Prices have been climbing in anticipation of increased focus on the potential to regulate carbon emissions and environmental stewardship concerns.

The most relevant example of a commercial-scale project that uses anthropogenic CO_2 for EOR and sequestration is the Weyburn project. EnCana's CO_2 EOR project has been under way since 2000 at its Weyburn unit. Located in the southeast corner of the province of Saskatchewan in western Canada, the Weyburn unit is a 70-square-mile oil field discovered in 1954. The Weyburn Field is part of the large Williston sedimentary basin, which straddles Canada and the United States (Figure 14).

In September 2000, EnCana initiated the first phase of a CO_2 EOR scheme in 18 inverted 9-spot patterns. The flood is to be expanded in phases to a total of 75 patterns over the next 15 years. The CO_2 is approximately 95% pure, and the initial injection rate is 5500 tons/day (equivalent to 95 mmscfd). A total of approximately 22 million tons of CO_2 is expected to be injected into the reservoir over the project life. The CO_2 is a purchased by-product from the DGC's synthetic fuel plant in Beulah, North Dakota, and is transported through a 204-mi pipeline to Weyburn, Saskatchewan, Canada. The pipeline, compressors, and other infrastructure were all made a reality based on the economics of the EOR aspect of the project. There are many other potential EOR projects.

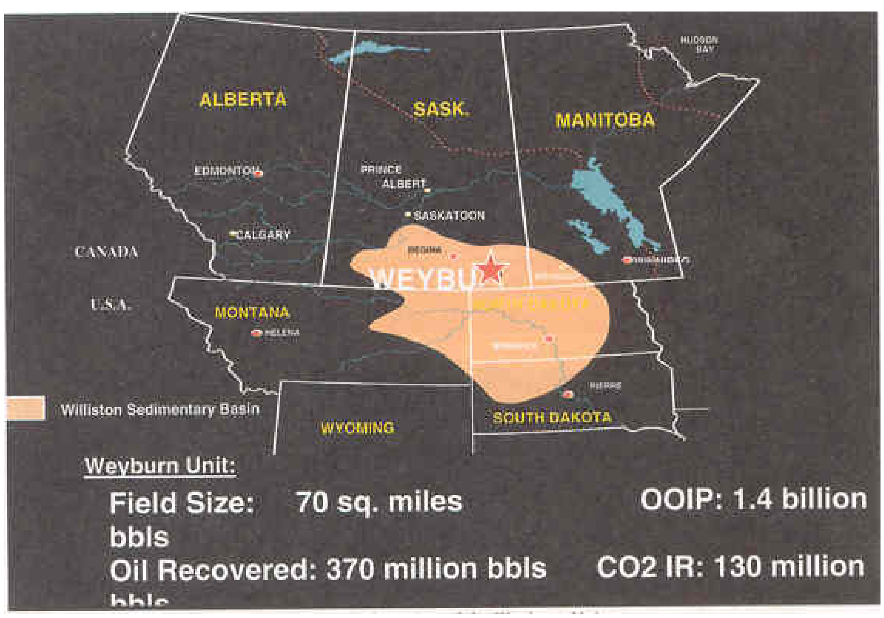


Figure 14. Location of the Weyburn Unit.

Q What are PCOR and EERC doing to further this vision of a future carbon constrained economy?

A *Working to match sources and sinks*.

The CO_2 emissions from the various regional stationary sources are periodically reviewed to ascertain that they are up to date. Any major new sources that come online will be added to the database. Matches made with geologic sinks are reviewed when new information is found. If necessary, better sinks are matched to sources for which the data have been updated.

EERC has worked with North Dakota governmental decision-makers to provide for expedited pipeline-siting processes.

The PCOR Partnership has worked with partners to facilitate the development of draft legislation that would expedite the siting of pipelines to transport energy-related commodities including CO_2.

Creating CO_2 management plan options for Excelsior Energy Inc.

A carbon management plan is being developed for Excelsior Energy Inc.'s Mesaba IGCC plant. This will include recommendations for CO_2 geologic sequestration and waste management options that minimize or eliminate the release of greenhouse gases into the atmosphere. Also included in the plan will be local opportunities for terrestrial carbon sequestration. This plan is significant in that it is being performed prior to plant construction.

Other things EERC has done.

The PCOR Partnership is committed to developing environmentally sound and practical approaches to carbon management for our partners. We are continuing to characterize the region with respect to sequestration opportunities and are keeping our membership informed with respect to the regulatory and political backdrop for carbon management activities. Our outreach activities seek to better inform our partners and the general public with respect to carbon management. The PCOR Partnership has assessed and prioritized the opportunities for sequestration in the region and helped to resolve the technical, regulatory, and environmental barriers to the most promising sequestration opportunities. At the same time, it has informed policy makers and the public regarding CO_2 sources, sequestration strategies, and sequestration opportunities. The following products have been completed:

- A comprehensive regional assessment of CO_2 sources and sinks.
- The development of the PCOR Partnership DSS, a GIS-based database providing our sponsors with a tool to evaluate CO_2 sequestration opportunities in the PCOR Partnership region.
- Identification, ranking, and action plans for promising sequestration demonstration projects.
- Key GIS products for CO_2 sources and sinks, infrastructure, and regulatory issues.
- Recommendations for monitoring and verification systems.

Further, the PCOR Partnership has worked with partners to facilitate the development of draft legislation that would expedite the siting of pipelines to transport energy-related commodities including CO_2.

The EERC has an extensive outreach program to provide the general public, regional decision makers, and industry executives with the information needed to understand the issues surrounding CO_2 sequestration. Materials include a regional atlas that has also been distributed to teachers for use in their classrooms, a video called "Nature in the Balance – CO_2 Sequestration" that has been aired on Prairie Public Television that is a primer for CO_2 sequestration, various fact sheets about different sequestration topics, articles in regional newspapers, and a public Web site including links to the more than 20 topical reports that were produced by the PCOR Partnership during the Phase I effort.

Public focus groups have provided feedback on the effectiveness of various aspects of the outreach materials.

During Phase II, the PCOR Partnership team is facilitating the field validation of CO_2 sequestration at four sites:

- Sequestration of a mixture of approximately 30% H_2S and 70% CO_2 in Zama, Alberta, for EOR.
- Deep sequestration of CO_2 in the Beaver Lodge oil field in western North Dakota for EOR.
- Sequestration in an unminable North Dakota lignite seam for ECBM recovery.
- Quantification of the amount of carbon that can be sequestered terrestrially in the wetlands.

D. EXCELSIOR ENERGY'S CO_2 MANAGEMENT PLAN

Q What will be addressed in the CO_2 management plan for Excelsior Energy?

A The EERC is conducting the following activities for Excelsior Energy Inc.:

- Development of a CO_2 Management Plan.
- Assessment of CO_2 sequestration opportunities.
  - Indirect sequestration of CO_2 into terrestrial sinks – The EERC will conduct reconnaissance-level evaluation of the carbon sequestration potential of regional terrestrial features, including forests, wetlands, and peat bogs in northern Minnesota.
  - Direct sequestration of CO_2 into geological sinks – The EERC will evaluate geologic formations and features that may be suitable for the storage of CO_2 generated by the Excelsior plant. These include, but are not necessarily limited to, oil and gas fields in the eastern margin of the Williston Basin, sedimentary rocks of the Mid-Continent Rift, mafic rocks of the Duluth Complex, and abandoned underground iron mines.
- Screening and matching of sink–source pairs specific to Excelsior operations. Sequestration opportunities identified during the assessment will be ranked according to engineering, economic, and public acceptance considerations.

The options that will most likely be available to Excelsior Energy Inc. for different time frames will be described and action plans developed to the extent possible when the management plan is prepared.

The action plans will likely include estimates of the CO_2 generated by the Mesaba plant as well as nearby sources, matching of these source(s) to the most proximal sinks with appropriate capacity, and an estimate of the likelihood that value-added products could be produced from the sequestration of Excelsior's CO_2. If the CO_2 from other sources can be combined with the Mesaba CO_2, estimates will be made as to pipeline route and possible division of costs between the sources and potential users of the CO_2.

Ultimate goal is to provide Excelsior EOR and saline formation sequestration options.

The Carbon Management Plan will include the results of a detailed examination of oil fields in the PCOR Partnership region that may be suitable candidates for CO_2 flood EOR activities. Because of their relatively close proximity compared to other basins, oil fields of the Williston Basin will be the primary focus of these efforts. A list of specific oil fields that may be suitable will be compiled and key characteristics of each field, including CO_2 storage capacity, potential incremental oil recovery, and major operating companies, will be provided. Any unique engineering, infrastructure, or regulatory requirements that may be associated with the fields will be described and evaluated with respect to potential impact to an EOR project.

The Carbon Management Plan will also include the results of evaluations of several saline formations in the region. At a minimum, the CO_2 storage capacity and other key characteristics of three saline aquifer formations in the Williston Basin will be evaluated in the context of Excelsior's planned IGCC facilities. Any unique engineering, infrastructure, or regulatory requirements that may be associated with the saline aquifer systems will be described and evaluated with respect to potential impact to Excelsior carbon management operations.

Q What deliverables are planned regarding Excelsior's CO_2 management options and costs for its Minnesota power plants?

A ***Best practices manual for IGCC units laying out steps required to prepare for carbon-constrained future.***

We will prepare a Best Practices Manual for carbon management at IGCC facilities.

White paper discussing the conceptual elements identified in the preceding question.

We will prepare a white paper discussing the conceptual elements identified in the Carbon Management Plan.

Specific match of Excelsior sources to carbon sinks under each of the regulatory solution sets (i.e., expedient, moderate, and deliberate timetables).

The technical and economic information compiled on sources, infrastructure, and sinks will be used to develop recommendations regarding matches of Excelsior sources with types of carbon sinks under various regulatory conditions within the region.

Base maps showing potential pipeline routes and infrastructure requirements (i.e., pumping stations, distribution laterals, etc.) that would serve to deliver CO_2 produced by the Mesaba Energy Project to EOR/saline formation sequestration sites; and graphical displays of potential options for linking other facilities to the distribution laterals.

Please refer to Figure 14.

Cost analysis attending each regulatory solution set and the appropriate regulatory mechanism that would support the timetable established.

We will be providing cost analyses, as appropriate, for the various options that are identified.

Phase III proposal to DOE for deploying carbon capture technology via IGCC Mesaba Energy Project.

It is possible that we would team with Excelsior Energy Inc. to develop a Phase III proposal.

Q What is the timetable for delivering Excelsior's management plan?

A The white paper will be completed in December 2006. The Best Practices Manual for IGCC units will be completed in November 2007. All other analyses will be completed by the end of December 2007.

Q Can this timetable be expedited?

A Proper planning is required to design the demonstration of a carbon sequestration system and to qualify for demonstration project funds from DOE. The funding required will be awarded on DOE's time line. Excelsior is doing everything it can to obtain an expedited demonstration action plan and to obtain funding. We will help them reach the demonstration stage as soon as possible, because Excelsior's project, and what will be learned from it, is an important step in fulfilling the vision of the PCOR Partnership and the EERC for the future carbon-constrained economy in the region.

III.
COMMENTS ON CARBON MANAGEMENT TESTIMONY FILED SEPTEMBER 5, 2006

Q Have you also reviewed the testimony of Xcel witness Roger A. Clarke regarding carbon management issues?

A Yes.

Q Do you have a comment on Mr. Clarke's conclusion: "In addition, while IGCC technology's ability to support carbon sequestration is clear, there are a number of

infrastructure, regulatory, financial and liability issues that must be addressed before this approach is viable in Minnesota." (Clarke Direct Testimony at 20)?

A Yes. While the issues identified by Mr. Clarke do exist, there are a number of ongoing EOR projects which have overcome many of the issues and provide a road map for the development of systems in the future. The PCOR Partnership, and others within RCSP, have made much progress in developing strategies and solutions for the implementation of carbon sequestration in the region. In my opinion, carbon sequestration from base load power plants in Minnesota is feasible and will be implemented in the future.

Q Further, have you reviewed the direct testimony of the Environmental Intervenors witness, J. Drake Hamilton?

A Yes.

Q Do you have a comment on his testimony?

A Yes, and in particular to that portion of his testimony at p. 8, ll, 17–20 which states:

"To my knowledge no one has assessed whether carbon capture and sequestration is feasible from this particular site. However, based on statements from those studying carbon sequestration it appears unlikely that carbon sequestration would ever be a viable option for the Mesaba Project."

Q What is that comment?

A First, with regard to the first sentence quoted above, the PCOR Partnership is currently assessing the feasibility of specific carbon sequestration options for the Mesaba project and plans to assist Excelsior in applying for demonstration grant funds from DOE for the Mesaba Project. Second, I find the second sentence quoted above presumptive. Based on my work within the PCOR Partnership, the fact that there are existing EOR carbon sequestration systems that have been successfully operating for many years delivering CO_2 hundreds of miles from source to sink, the fact that there are a number of sinks suitable to receive and sequester CO_2 from the Mesaba Project which are within technically distances feasible for pipeline transport of CO_2, and the fact that IGCC technology may offer relatively efficient carbon capture retrofitting, it is my opinion that carbon sequestration may be a viable and feasible option for the Mesaba Project. Rendering a valid technical opinion on the feasibility of employing carbon sequestration for the Mesaba Project is not possible prior to the completion of our assessment.

Q. Have you reviewed the direct testimony of Minnesota Power witness Michael G. Cashin regarding carbon capture and sequestration?

A. Yes.

Q. Do you have a comment on his testimony?

A. Yes. On page 5, lines 16–18, Mr. Cashin testifies: "But an IGCC plant in northeastern Minnesota has no realistic opportunity for carbon capture and storage." On page 9, lines 9–11, Mr. Cashin testifies: "The focus on environmental benefits in this proceeding must be on the Mesaba Project's inability to provide carbon capture and sequestration in Minnesota."

My comment is that carbon capture and sequestration from an IGCC plant in Northeastern Minnesota may be feasible and realistic even though the geology of Minnesota does not offer optional carbon sinks. CO_2 pipelines to carry CO_2 from Minnesota sources, such as IGCC power plants, to carbon sinks in North Dakota or Canada are technically feasible using technology currently in use.

Q Have you reviewed the direct testimony of mncoalgasplant.com witness Ronald R. Rich regarding carbon management issues?

A Yes and I have these comments regarding Mr. Rich's comments on whether carbon capture and sequestration from large power plants is feasible and his comments on the plan for carbon sequestration the PCOR Partnership is developing for Excelsior at p. 5–6 of his testimony.

First, I disagree that there is no prior experience to draw upon for carbon sequestration from a power plant "of this configuration." It is unclear what Mr. Rich meant by "of this configuration." If he was referring to IGCC technology in a power plant, he is technically correct. However, his statement fails to take into consideration that the carbon sequestration system which has been utilized at the DGC synthetic fuel plant facility in Beulah, North Dakota, since 1999 is a system employed on a large coal gasification technology somewhat similar to the IGCC technology to be utilized by Mesaba. The CO_2 will be removed from Mesaba's syngas production prior to combustion of the gas for energy just as the CO_2 is removed from the Beulah plant before the syngas is converted to other fuels.

Second, with regard to the plan the PCOR Partnership is developing, it is incorrect to state that it has a wetlands or terrestrial sequestration focus. Terrestrial sequestration is one of two types of CO_2 that the PCOR Partnership is demonstrating. Second, Mr. Rich's statement that "Higher capacity, more viable sequestration locations with sufficient potential capacity exceed 1000 miles from the West Range plant site" is incorrect. There is more than enough geologic capacity for the CO_2 produced by the Mesaba plants in North Dakota alone.

IV. CONCLUSION

Q Please summarize your testimony.

A
- At this time, it appears that it may be feasible for Excelsior Energy Inc.'s Mesaba Energy Project to capture CO_2 and transport it via pipeline to geologic sinks with the capacity to store all of the CO_2 emissions during the plant's lifetime.
- The lack of CO_2 source streams in the region may make EOR an attractive option for the Mesaba CO_2 in the near term.
- The transition to a carbon-managed world may provide Excelsior Energy Inc. with other opportunities in the form of carbon credits that it can sell.
- In a carbon-managed situation, pipeline distance may become less important since CO_2 sequestration will likely be required. This is likely to result in the construction of a pipeline network in which the CO_2 produced by many sources is transported to an area containing many sinks. The pipeline cost to each user could, therefore, be minimized.
- Because Excelsior Energy Inc. is preparing a carbon management plan prior to plant construction, it may be possible for them to take advantage of the near-term opportunities presented by EOR that might not be possible otherwise.

Base load power plants supplying fungible carbon sequestration units to a future carbon marketplace are essential to a future carbon-constrained economy. IGCC technology is compatible with a carbon-constrained economy and offers technological advantages for the capture of carbon over other coal-fired technologies for base load plants. Delay in constructing Excelsior's IGCC plant may delay progress toward carbon sequestration in the region because of the important contribution to implementation of the system Excelsior is making. The locations of the Mesaba Project IGCC power plants in northern Minnesota do not necessarily disqualify the sites from becoming sources in an effective and efficient carbon sequestration system for the region using EOR and geological sinks located hundreds of miles from the sites. Excelsior's plants may be well positioned as early participants in the new carbon-constrained economy and, as early market entrants, may be able to find carbon sequestration options that will provide some level of economic return.

Q Does this conclude your testimony?

A Yes, it does.