2009 SENATE NATURAL RESOURCES

SB 2139

# 2009 SENATE STANDING COMMITTEE MINUTES

Bill/Resolution No. SB 2139

Senate Natural Resources Committee

☐ Check here for Conference Committee

Hearing Date: January 16, 2009

Recorder Job Number: 7119

| Committee Clerk Signature | |
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Minutes:

**Senator Lyson** opened the hearing on SB 2095, relating to geologic storage of carbon dioxide, and SB 2139, relating to the ownership of subsurface pore space. All committee members were present.

**Sandi Tabor**, VP of Administration and Policy Development of the Lignite Energy Council, introduced SB 2095 and SB 2139 (see attached testimony #1).

**John Harju**, Associate Director of the Energy and Environmental Research Center, gave a PowerPoint presentation for SB 2095 (see attachment #2).

**Senator Schneider**, you mentioned that you are currently sequestering about a million tons a year.

**John Harju**, the plan with this project is to sequester on the order of a million tons per year.

**Senator Schneider** can you give us an idea on how that relates to commissions, how much are we talking about?

**John Harju**, in the overall region we have met about six hundred million tons a year from stationary sources. There is an additional three hundred million a year from non stationary vehicles and machinery and so on.

**Senator Hogue**, in section 38-20-17 it states the operator can get a certificate of completion after 10 years of the last injection. Is that a science based deadline? Is that the point when you predict the CO2 to lose its properties?

**John Harju**, any apparent risk associated with these projects tends to dissipate very rapidly at the point of cessation of injection. You are stressing the system while you are injecting, while you are operating. At the cessation of injection everything is more relaxed.

**Senator Hogue** asked for a projection on the capacity for North Dakota to store CO2. Do you anticipate that we will be able to take CO2 that comes from outside the region?

**John Harju**, I do anticipate that we would be able to do so. We have done certain stimulations where just capacities were looked at and by no means have we done an exhaustive analysis of capacity. We have done analysis where all of the available lignite in the state could be burned over a course of the next eight hundred years and we would have more than enough capacity to store the entire incident CO2 and still account additional CO2 from outside the state.

**Senator Triplett**, can you describe the magnitude of the project for the group, in terms of how long have you been working on it and will continue to work on it and the dollar value over time with all the partnerships that you have established?

**John Harju**, Since 2003 we have ended up with over 90 partners and the total dollar value of the project including the funds that have gone into the infrastructure for the small scale demonstration projects we have underway, and the anticipant and the miles of planning stages of the commercial scale projects; we are well in access of a half a billion dollars worth of direct research in this regard.

**Lynn Helms**, Director of the Department of Mineral Resources for the North Dakota Industrial Commission, appeared to walk the committee through the bill and its amendments (see attached testimony #3). This is not in testimony, but we are required to report to the legislative council and the staffs of this fund. The first time is in 2014 and every four years after that. It is a tracking mechanism for the legislature to see if we are over funded, underfunded and find out what the status of this fund is and to get a report from around the world.

**Senator Lyson** asked Lynn to speak on SB 2139 and tell why it is a companion bill.

**Lynn Helms**, SB 2139 defines who owns pore space. You recieved a good idea of what pore space is so you can picture it in your mind. We are now going to do something artificial, not in nature, to that pore space that is going to occupy it for 500-1,000 years. The current law in North Dakota does not address impacting that pore space in a manner like that. This statue through amalgamation brings the owners of the pore space in as part of the "union" agreement, and therefore we need to define who they are.

**Senator Hogue** asked if he could see what a balance sheet of a storage operator would look like. Would they have to have a certain financial work, and is that something you do in a follow up regulation?

**Lynn helms**, what we typically require is bonding by the storage operator. We do not normally look at the operator's balance sheet. What we do is allow the actuaries at the bonding company to do that.

**Senator Schneider** questioned whether the other states mentioned are coming to the same conclusion in 38-20-17 that the state should bare the long term responsibility for these carbon sequestration facilities.

**Lynn Helms,** The governor of Wyoming has indicated that there is no way he wants the state to be responsible. All the other states that have acted have come to the conclusion that it is the only way.

**Senator Hogue**, referring to SB 2139, asked if a surface owner or mineral owner has attempted to sever the pore space from the surface.

**Lynn Helms** replied that no one on the working crew could think of a situation that they knew of, but we felt that it might take place now that the issue has been raised.

**Charles Carvell**, Assistant Attorney general of the N.D. Attorney General's Office, testified in favor for SB 2139 (see attached testimony #5).

**Curtis Jabs**, representing Basin Electric Power Cooperative, testifying in favor of both bills 2095 and 2139.

**Senator Triplett**, on the issue of converting enhanced oil recovery to long term storage, is the process sufficiently similar that you could do that after the fact or would you think that as a utility you should be coordinating with the Department of Mineral Resources up front if you plan to do the conversion at some point so you know that you are doing it in a way that would make it easily convertible?

**John Harju**, there is inherent storage that occurs during the conduct oil enhance recovery project. We believe we will have preselected the ability of the oil and gas reservoir to be a long term container for this objective CO2. In turn the rules and regulations that would allow for that conversion, for the enhance oil recovery to this long term storage project would be simplistic and straight forward.

**Senator Hogue**, does Basin anticipate that this CO2 could be stored in one of these long term storage facilities and then be brought back to the surface and put in a pipeline and be sent to Canada? Is that an economical viable proposition?

**John Harju**, Basin electric intends to market the CO2 to oil companies for enhanced oil recovery and they will hold the title of that. Once the CO2 is in the ground you have to go through the commission to bring it back up.

**Al Christianson**, representative for Great River Energy, we are here to ask for your support, these two bills are very important for our industry.

**Dave Glautt**, Chief of the environmental Health Section for the North Dakota Department of Health, testified in support of SB 2095 (see attached testimony #7).

**Robert Harms**, President of Northern Alliance, we participated in the workgroup and the process was active. I think we had vigorous discussion about the policy choices that are included in the bill. We support both of them.

**David Straley**, North American Coal Corp., we support both of these bills.

**Jeb Oehlke**, representing a business coalition which includes the North Dakota chamber of Commerce as well as local chambers of commerce and their member businesses, (see attached testimony #8).

**Harlan Fuglesten**, representative for the North Dakota Association of Rural Electric Cooperatives, we are in support of this bill. We think it is the way to help ensure a future for coal in North Dakota to meet our energy needs and we urge a do pass.

**Senator Lyson** closed the hearing on SB 2095 and SB 2139.

# 2009 SENATE STANDING COMMITTEE MINUTES

Bill/Resolution No. 2139

Senate Natural Resources Committee

☐ Check here for Conference Committee

Hearing Date: January 23, 2009

Recorder Job Number: 7623

| Committee Clerk Signature | |
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Minutes:

**Senator Lyson** opened the discussion on SB 2139, relating to the ownership of subsurface pore space. One member was absent.

**Senator Hogue** I am against it because I find it unnecessary. I am concerned how the companion bill already provides that nothing in the act will interfere with the right of the mineral owner to develop their mineral interest. This is a standalone amendment which makes a statement that the mineral estate is dominate. Mineral owners have the right to develop their mineral interests over the objection of surface owners. I recommend that we not adopt this amendment.

**Charles Carvell**, Attorney General's Office, the amendment was desired by the oil and gas industry. I don't necessarily disagree with Senator Hogue that our common law already expresses the dominate nature of the mineral estate. Oil and gas industry said well we are getting into new territory referring to pore space and who owns it and what the rights are. We want to make sure that we are not losing any ground and to be sure the status quo stays as it is. They asked that the amendment be attached to the bill and the others who worked on the bill supported it.

**Senator Lyson** asked Senator Hogue if the amendment "cluttered up" the bill.

**Senator Hogue** I wouldn't say it clutters up the bill, but the concern of the industry is addressed within the bill 2095. We make it clear in that bill that we are going to permit the storage of CO2 underground and nothing we do in allowing the operator to store CO2 can interfere with the mineral owner's right.

**Senator Schneider** I could be reading the bill incorrect, but it seems like it would restrict what a mineral owner could do.

**Senator Triplett** the first line is "nothing in this chapter prevents them from doing it as long as they comply with the integrity of the storage..". I don't disagree with Senator Hogue that it is maybe not entirely necessary, but I am having a hard time seeing where it is a problem. The policy statement in 21-39 on page 1 line 6 says that our policy is to provide clarity and land titles among security and stability for economic development. We are making an effort to clarify title property. The main point of the bill is to provide the definition of pore space, but defining pore space relative to other estates doesn't seem like a bad idea. Senator Hogue do you think it is a bad idea or just unnecessary?

**Senator Hogue** I went through it again and I do think it is a bad idea. SB 2095 is limiting the mineral owners in the case where we have created an underground storage facility. It is telling the mineral owner "guess what,  you don't get to drill through this storage facility". To that extent it is actually infringing on the mineral estate. I could see someone making an argument with this, it says "as between the mineral and the pore space the mineral space is dominate". So now the court would have to resolve the two conflicts if the mineral owner is saying I want to go through that underground storage facility, because this section says I'm dominate, you have to yield to me. Section 38-20-13.2 says you cannot drill through a storage facility and interfere with the integrity of the underground storage facility.

**Lynn Helms**, Director of Department of Mineral Resources, we deal with this every day. I am a bit torn on this subject. I understand the oil and gas industry's concern with this. My difficulty is with the way this is stated, as just a complete unrestrained dominance therein rises the conflict that Senator Hogue has addressed. After the court cases in the early '80's' that declared the mineral estate dominate, this body saw fit to enact such things as in 38-11.1 which limited that dominance. It states that you are dominating and you have the right to access your minerals, but there are considerations you have to give the surface owner. It is not just an absolute dominance. This statement is an absolute dominance where as the statement in 2095 is a limited dominance. It says we are not going to prevent you from accessing your minerals if they are underneath or next to one of these facilities. However, that access is going to have to take into consideration the permit that has been granted for the facility and all requirements and restrictions that the Industrial Commission may put upon your well bore. I like the idea of having something in 2139 that establishes that relationship but I think a blunt absolute dominance is not a good idea. I am thinking something more like 38-20-13.2 witch says nothing in here establishes or limits the right of mineral owner to access their minerals by use of the pore space above or next to those minerals.

**Senator Triplett** subsection 2 on 20-95 on page 6, is clearly related to that chapter so we would have to repeat it in title 47 to make it effective?

**Lynn Helms**, exactly, it is one of the things I meant to say. There are other potential uses for pore space besides CO2 storage. So it needs to have this in there to preserve the right s of the mineral owners to go through the pore space. It needs to be insightful and thought out dominance.

**Senator Lyson** I understand that the wording of this is causing problems. I am going to select Senator Hogue, Senator Triplett and Senator Schneider to get together and come up with an amendment that is going to fit this bill. We will rehear it next week.

**Senator Lyson** closes discussion on Sb 2139.

# 2009 SENATE STANDING COMMITTEE MINUTES

Bill/Resolution No. 2139

Senate Natural Resources Committee

☐ Check here for Conference Committee

Hearing Date: January 29, 2009

Recorder Job Number: 8084

| Committee Clerk Signature | |
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Minutes:

**Senator Lyson opened the discussion on SB 2139.**

**Sandi Tabor, Lignite Energy Council,** Senator Hogue had raised a question about the amendment that we had proposed regarding the relationship between the mineral estate and the pore space and surface interest. A subcommittee was formed of Senator Schneider, Senator Triplett and Senator Hogue. John Morrison, ND CO2 Storage work group, proposed some language for an amendment and the committee looked over and agreed that it would be ok. This language defines the relationship and we put it in there so we weren't changing any of the relationships with the mineral estate. In North Dakota the mineral estate has some dominance and we wanted to be sure that we did not do anything that would change the status quo. It also puts an emergency clause on the bill. In order to be sure people didn't go out and try to sever the pore space from the surface estate before this bill was enacted.

**Senator Hogue** commented that Sandi has accurately stated the process. I have looked at the amendment and it has been accurately transcribed.

**Senator Hogue** moves to adopt the amendment.

**Senator Schneider** seconds the amendment.

Voice vote was taken and motion passed.

**Senator Hogue** moves a Do Pass recommendation on 2139 as amended.

**Senator Triplett** seconds the motion.

Roll call was taken, the bill passed with a vote of 7 to 0.

# FISCAL NOTE
**Requested by Legislative Council**
12/23/2008

Bill/Resolution No.: SB 2139

1A. **State fiscal effect:** *Identify the state fiscal effect and the fiscal effect on agency appropriations compared to funding levels and appropriations anticipated under current law.*

| | 2007-2009 Biennium | | 2009-2011 Biennium | | 2011-2013 Biennium | |
|---|---|---|---|---|---|---|
| | General Fund | Other Funds | General Fund | Other Funds | General Fund | Other Funds |
| Revenues | $0 | $0 | $0 | $0 | $0 | $0 |
| Expenditures | $0 | $0 | $0 | $0 | $0 | $0 |
| Appropriations | $0 | $0 | $0 | $0 | $0 | $0 |

1B. **County, city, and school district fiscal effect:** *Identify the fiscal effect on the appropriate political subdivision.*

| 2007-2009 Biennium | | | 2009-2011 Biennium | | | 2011-2013 Biennium | | |
|---|---|---|---|---|---|---|---|---|
| Counties | Cities | School Districts | Counties | Cities | School Districts | Counties | Cities | School Districts |
| $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |

2A. **Bill and fiscal impact summary:** *Provide a brief summary of the measure, including description of the provisions having fiscal impact (limited to 300 characters).*

SB 2139 establishes in law the ownership of subsurface pore space. There is no fiscal impact.

B. **Fiscal impact sections:** *Identify and provide a brief description of the sections of the measure which have fiscal impact. Include any assumptions and comments relevant to the analysis.*

There is no fiscal impact.

3. **State fiscal effect detail:** *For information shown under state fiscal effect in 1A, please:*
   A. **Revenues:** *Explain the revenue amounts. Provide detail, when appropriate, for each revenue type and fund affected and any amounts included in the executive budget.*

   B. **Expenditures:** *Explain the expenditure amounts. Provide detail, when appropriate, for each agency, line item, and fund affected and the number of FTE positions affected.*

   C. **Appropriations:** *Explain the appropriation amounts. Provide detail, when appropriate, for each agency and fund affected. Explain the relationship between the amounts shown for expenditures and appropriations. Indicate whether the appropriation is also included in the executive budget or relates to a continuing appropriation.*

| | | | |
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| **Name:** | Karlene K. Fine | **Agency:** | Industrial Commission |
| **Phone Number:** | 3283722 | **Date Prepared:** | 01/06/2009 |

Date: Jan 29, 2009

Roll Call Vote #: 2139 #1

**2009 SENATE STANDING COMMITTEE ROLL CALL VOTES**
**BILL/RESOLUTION NO.** "Click here to type Bill/Resolution No."

Senate Natural Resources Committee

☐ Check here for Conference Committee

Legislative Council Amendment Number 98163.0101

Action Taken ☒ Do Pass ☐ Do Not Pass ☐ Amended

Motion Made By Sen. Hogue Seconded By Sen. Schneider

| Senators | Yes | No | Senators | Yes | No |
|---|---|---|---|---|---|
| Senator Stanley W. Lyson, Chairman | ✓ | | Senator Jim Pomeroy | ✓ | |
| Senator David Hogue, Vice Chairman | ✓ | | Senator Mac Schneider | ✓ | |
| Senator Robert S. Erbele | ✓ | | Senator Constance Triplett | ✓ | |
| Senator Layton W. Freborg | ✓ | | | | |

Total (Yes) 7 No 0

Absent

Floor Assignment

If the vote is on an amendment, briefly indicate intent:

Voice vote was taken.

Date: Jan 29, 2009

Roll Call Vote #: 2139 #2

**2009 SENATE STANDING COMMITTEE ROLL CALL VOTES**
**BILL/RESOLUTION NO.** "Click here to type Bill/Resolution No."

Senate Natural Resources Committee

☐ Check here for Conference Committee

Legislative Council Amendment Number ____________

Action Taken ☒ Do Pass ☐ Do Not Pass ☒ Amended

Motion Made By Sen. Hogue Seconded By Sen. Triplett

| Senators | Yes | No | Senators | Yes | No |
|---|---|---|---|---|---|
| Senator Stanley W. Lyson, Chairman | ✓ | | Senator Jim Pomeroy | ✓ | |
| | | | | | |
| Senator David Hogue, Vice Chairman | ✓ | | Senator Mac Schneider | ✓ | |
| | | | | | |
| Senator Robert S. Erbele | ✓ | | Senator Constance Triplett | ✓ | |
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| Senator Layton W. Freborg | ✓ | | | | |
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Total (Yes) 7 No Ø

Absent ____________

Floor Assignment Sen. Hogue

If the vote is on an amendment, briefly indicate intent:

**REPORT OF STANDING COMMITTEE**

**SB 2139: Natural Resources Committee (Sen. Lyson, Chairman)** recommends **AMENDMENTS AS FOLLOWS** and when so amended, recommends **DO PASS** (7 YEAS, 0 NAYS, 0 ABSENT AND NOT VOTING). SB 2139 was placed on the Sixth order on the calendar.

Page 1, line 2, remove "and" and after "application" insert "; and to declare an emergency"

Page 1, line 21, replace the first "Act" with "chapter" and replace the second "Act" with "chapter"

Page 1, after line 22, insert:

"**Mineral and pore space estates - Relationship.** In the relationship between a severed mineral owner and a pore space estate, this chapter does not change or alter the common law as of the effective date of this chapter as it relates to the rights belonging to, or the dominance of, the mineral estate.

**SECTION 3. EMERGENCY.** This Act is declared to be an emergency measure."

Renumber accordingly

2009 HOUSE NATURAL RESOURCES

SB 2139

# 2009 HOUSE STANDING COMMITTEE MINUTES

Bill/Resolution No. 2095 / 2139

House Natural Resources Committee

☐ Check here for Conference Committee

Hearing Date: 2-26-09

Recorder Job Number 9778

| Committee Clerk Signature Nancy L. Gerhardt |
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Minutes:

Chairman Porter - We will open the hearing on SB's 2095 & 2139.

Sandi Tabor – Lignite Energy Council – See **Attachment # 1**.

John Harju – Energy & Environmental Research Center – See **Attachment # 2**. CO2 is one of several heat absorbing gases that has a place in the atmosphere and allows our planet to be habitable. Zero CO2 in the atmosphere would make this an inhabitable place. However, if there are excess green house gases in the atmosphere we would essentially have over heating of the planet. If we are to reduce our CO2 emission we need to do several things, including changing the way we use energy, changing the way we generate energy, but also looking at what we call carbon capturing and storage, or sequestration. Carbon capturing and storage or sequestration is captured from a major immersion source. In turn you would compress and transport that CO2 to a storage site, via pipeline. We pump that CO2 underground as a dense fluid. We put that into very deep portions of the sub surface below about 2500 ft. is where the native pressure of the subsurface would keep the CO2 in that super critical state which allows us to efficiently use porosity, and in turn that CO2 would stay in place over geologic time. **Explanation of pictures in Attachment # 2**.

Chairman Porter – Is it only injectable into the rock formation or can it go into the salt water areas if there is free space and then into the reservoir area if there is actual free space. When Mr. Helms was here earlier he talked about pot ash mining and then creating a free space and possibly using that as a sink.

Mr. Harju – The CO2 will tend to displace other fluids that are occupying that space. CO2 does have a tendency to dissolve into salt water as well. CO2 injected would tend to ultimately reside in a handful of places in that subsurface injection zone. It would tend to displace fluid and behave like a buoyant fluid that would tend to rise to the top of the injection zone to find that cap rock or ceiling rock and reside as a free face CO2 at the top of a resevoir. Some of that CO2 would dissolve into water, in a salt water bearing zone. Some would also dissolve into hydrocarbons in that injection zone; some would mineralize, or become part of new rock and mineral itself within the reservoir. I think the simple answer is yes. Continue going over and explaining **Attachment # 2** pictures. Questions

Rep. Hunskor – You use words like leakage, are there concerns about leakage?

Mr. Harju – Yes, we do tend to be contacted. We look for locations where we don't have leakage. That is a primary concern when you are going to conduct a project like this. You need to choose those sites properly, so we know they can confine the fluid we inject.

Rep. Hunskor – If there are concerns do you conduct seminars in the area to educate people regarding that?

Mr. Harju – Yes we do.

Rep. Hofstad – You alluded to sequestering carbon in wetlands, it seems to me not too long ago the emphasis was on wetlands and grasses and changing agricultural practices. Have we changed directions or is that still a viable option?

Mr. Harju – Yes, the wetlands related work that we've done has very much provided additional verification of the ability of those wetlands to act as these places in the near surface environment. To grab CO2 from the atmosphere and incorporate it into that biosphere.

Rep. Pinkerton – When you take stream coming out of combustion, that has to be purified some or else you end up with some real bad PH problems as you inject it? Is that correct?

Mr. Harju – The CO2 itself in the presence of water tends to become ascetic as well. It is less the PH issues and more the volumes. In an emissions source, CO2 tends to be only 10 and 15% of the total volume coming out of a combustion source.

Rep. Pinkerton – What's the other 85% then?

Mr. Harju – The other 85% is actually nitrogen.

Rep. Pinkerton – Can that nitrogen be captured for anhydrous ammonia use?

Mr. Harju – I'm not really qualified to answer that question.

Vice Chairman Damschen – You talked about leakage – what is the threat to the surrounding life if there is a leak?

Mr. Harju – CO2 is something everyone of here is exhaling. In low concentrations CO2 tends to be very normal. However, CO2 in high concentrations can accumulate in low lying places and effectively displace oxygen. In a worst case scenario a significant leak of CO2 in low lying areas could form a blanket and cause oxygen deprivation to a receptor.

Vice Chairman Damschen – Both Rep. Hofstad and I are very deeply invested in a business that converts CO2 into oxygen. I'm wondering if there's any research to enhance that or make it more profitable.

Mr. Harju – We are in collaborative way participating with our friends at ND State University, and in the first phase of the work was create a series of templates, if you will, that would look at what sort of a value of a carbon credit would facilitate consideration of something like no till application to maximize that CO2 uptake and O2 generation. What we found in places like the Red River Valley to cause someone to change the nature of their farming application to a no till type operation.

Vice Chairman Damschen – Has there been any comparisons done as to what the actual growing plant converts into oxygen as compared to what the benefit is to sequestering and the no till farming.

Mr. Harju – When that plant is ultimately consumed we turn that carbon that has been accumulated by that plant back into carbon dioxide.

Chairman Porter – At what point in the research process are we looking at going back into these sinks and retrieving some of the CO2 for other beneficial uses?

Mr. Harju – As we look at one of the two commercial scale demonstration projects we are planning in NE British Columbia, this is one of the long term visions for this location. To inject that CO2 into one of these non hydrogen bearing sinks to provide near term opportunity for this facility to manage their carbon emissions.

Lynn Helms – ND Industrial Commission – See **Attachment # 3**.

Rep. Keiser – On page 4 lines 1 through 3, what is rule 4?

Mr. Helms – Rule 4 of the ND Rules of Civil Procedure, you've got me stumped there.

Charles Carvell – Attorney General's office – Rule 4 governs service of complaints and how we serve those on defendants. Usually it requires personal service. There are some options for service by publication.

Mr. Helms – Continuing testimony – **Attachment # 3**.

Chairman Porter – Inside of that the 40% that would be left out, let's say it reached the bare minimum of 60% to be the unit, the 40%, what happens to the royalty payment for that 40% that wouldn't sign?

Mr. Helms – That 39% and loose change that did not give written consent would still receive a payment based on their pour space portion of the reservoir. They aren't cut out of the royalty payments or storage payments or anything that goes along with that.

Rep. Keiser – Aren't these really different? Extracting oil, getting oil lease out of that is a little bit different than sequestration. Was there any discussion that the % should have been a little bit higher?

Mr. Helms – We did hold that discussion. They are different, not so different that we can quantify any amount the % should change by. In both cases these folks are going to be compensated for what happens in their subsurface. We went back to the history of the oil and gas statute, which started out at 80% then dropped to 70% and finally was dropped to 60%. In that history we found each one of those %'s higher than 60 created some serious impediments to forming units.

Rep. Keiser – On Sec. 8 page 5, line 12 – it sounds good, but what if you're wrong? What if you're wrong, we complete it, and now the state has a liability? The operator is out of business.

Mr. Helms – There are a couple things here under part 12, number 1 is we set those boundaries, but we also have to include a bumper area. Even the bumper area wasn't working. It's my understanding, we can expand this project. There are provisions within the law and within those unit agreements that allow you to identify an expansion area and then using the same % bring them into the unit. You recalculate everyone's participation based on the new area. The folks in the original area have to stay in the same relative relationship to each other. Rep. Keiser – If there is a problem and we have to take care of it, how do we pay?

Mr. Helms – If it occurs during the injection period or the closure period there will be a bond in place. We are going to require a bond to cover these expenses. There will also be an operator of record and they will be financially required to take care of the work. There will also be a couple of fees. Two fees will be collected by the industrial commission. 1) To take care of the expenses of regulating and the ongoing operational fees. 2) Accumulate in a permanent appropriation which would be a fund for taking care if a problem pops up.

Rep. Keiser – What if the bond is inadequate to cover it in phase 1? And in phase 2, what if it is a super spill and the bond don't cover it, what do we do?

Mr. Helms – We will always have the opportunity of going to EPA and working under the super fund to get back. Under super fund you can go back to anybody to try to get money to deal with the problem.

Chairman Porter – As we get this started and the funds in both of these are minimal there's going to be a general fund risk to the state of ND until we reach a level of financial security inside of the two funds.

Mr. Helms – I would agree with that other than you're going to have a viable operator of record who has cash flow at that time. We are going to try during that time period that operator of record exists and we can go after them as a company to fix the problems to accumulate the cash to take care of problems after they are gone.

Chairman Porter – Are you also looking at that bond as another means of insurance against the general fund for that same purpose?

Mr. Helms – Yes we are.

Rep. Pinkerton – Have there ever been any problems with leakage?

Mr. Helms – No there have not.

Rep. Pinkerton – The west Texas wells, are they about the same depth?

Mr. Helms – The west Texas wells run around 3500' to 6000', so they would be very similar to the Broom Creek. Our initial wells will be around 9,000' to 11,000'.

Charles Carvell – ND Attorney General's Office – See **Attachment # 4**. I was approached by Howard Meloy, he is with the ND Land Title Association, and his organization has concerns with lines 18 & 19 on page 1. They think it is a little too broad and needs to be defined a little better. He gave me an amendment and I would like time to review that amendment, talk to our working group and Ms Tabor about it and get back to committee next week.

Curtis Jabs – Basin Electric Power Cooperative – See **Attachment # 5**.

Chairman Porter – What is the time frame on your project?

Mr. Jabs – Currently we hope the project will be operational either December 2012 or the beginning of 2013.

L. David Glatt – ND Dept. of Health – See **Attachment # 6**.

Jeb Ochlke – ND Chamber of Commerce – See **Attachment # 7**.

Ron Ness – ND Petroleum Council – We have been involved with the process and we support the concept and one of our goals was to ensure the provisions you're looking at today don't have any impacts on oil and gas. We are OK with the amendment.

Chairman Porter – Further testimony in support? Is there any opposition to either SB 2095 or 2139? Seeing none we will close the hearings on SB 2095 and 2139.

# 2009 HOUSE STANDING COMMITTEE MINUTES

Bill/Resolution No. 2139

House Natural Resources Committee

☐ Check here for Conference Committee

Hearing Date: 2-26-09

Recorder Job Number: 9816

| Committee Clerk Signature | Nancy L. Gerhardt |
|---|---|

Minutes:

Chairman Porter – Ok we have SB 2139 and there is an amendment.

Rep. DeKrey – I move the Meloy amendment.

Chairman Porter – Rep. DeKrey moves the amendment.

Rep. Hofstad – 2nd.

Chairman Porter – 2nd from Rep. Hofstad. Any discussion on the amendment? All those in favor – unanimous voice vote – opposed – none – we have an amended bill.

Rep. DeKrey – I move Do Pass as Amended.

Rep. Clark – 2nd.

Chairman Porter – We have a motion from Rep. DeKrey and a 2nd from Rep. Clark for a Do Pass As Amended. Is there any discussion? The clerk will call the roll on SB 2139 – Do Pass As Amended.

Yes 11 No 0 Absent 2 Carrier Rep. Pinkerton

98163.0201
Title.0300

Adopted by the Natural Resources Committee
February 26, 2009

YR 2/26/09

PROPOSED AMENDMENTS TO ENGROSSED SENATE BILL NO. 2139

Page 1, line 19, after "void" insert "as to the severance of the pore space from the surface interest"

Renumber accordingly

Date: 2-26-2009
Roll Call Vote #: 

**2009 HOUSE STANDING COMMITTEE ROLL CALL VOTES**
**BILL/RESOLUTION NO.** SB 2139

## House Natural Resources Committee

☐ Check here for Conference Committee

Legislative Council Amendment Number 

Action Taken ☑ ~~Do Pass~~ ☐ Do Not Pass ☑ ~~As~~ Amended

Motion Made By DeKrey Seconded By Clark

| Representatives | Yes | No | Representatives | Yes | No |
|---|---|---|---|---|---|
| Chairman Porter | ✓ | | Rep Hanson | ✓ | |
| Vice Chairman Damschen | ✓ | | Rep Hunskor | ✓ | |
| Rep Clark | ✓ | | Rep Kelsh | | |
| Rep DeKrey | ✓ | | Rep Myxter | ✓ | |
| Rep Drovdal | | | Rep Pinkerton | ✓ | |
| Rep Hofstad | ✓ | | | | |
| Rep Keiser | ✓ | | | | |
| Rep Nottestad | ✓ | | | | |
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Total (Yes) 11 No 0

Absent 2

Floor Assignment Pinkerton

If the vote is on an amendment, briefly indicate intent:

## REPORT OF STANDING COMMITTEE

**SB 2139: Natural Resources Committee (Rep. Porter, Chairman)** recommends **AMENDMENTS AS FOLLOWS** and when so amended, recommends **DO PASS** (11 YEAS, 0 NAYS, 2 ABSENT AND NOT VOTING). SB 2139 was placed on the Sixth order on the calendar.

Page 1, line 19, after "void" insert "as to the severance of the pore space from the surface interest"

Renumber accordingly

2009 TESTIMONY

SB 2139

Attachment #1

# Senate Natural Resources Committee
# Testimony on SB 2095 and SB 2139


**Presented by Sandi Tabor**
VP of Administration and Policy Development
Lignite Energy Council


January 16, 2009

Senate Bill 2095 and Senate Bill 2139 are companion bills that establish the key components necessary for the regulation of the underground storage of carbon dioxide and associated greenhouse gases[1]. The bills were drafted by a committee formed in late 2007 called the ND $CO_2$ Storage Workgroup (Workgroup). Members of the Workgroup included representatives from the Attorney General's Office, the Department of Health, the Oil and Gas Division of the ND Industrial Commission, the ND Petroleum Council, the Lignite Energy Council and the Energy and Environmental Research Center (EERC).

Why did we take on this task? Presently, the debate over "how" (not "if") greenhouse gas emissions will be regulated is taking place in the halls of Congress and in the halls of state legislatures across the country. In fact in 2007 Minnesota passed a goal to reduce greenhouse gas emissions by 80% by 2050. The first phase of the Minnesota goal is to reduce emissions by 15% by 2015. With this in mind, the challenge for the lignite industry is to develop a comprehensive plan not only dealing with how to capture $CO_2$, but also considering how captured $CO_2$ can be commercially used or stored.

The lignite industry is one of the North Dakota's major industries. The future of our industry is dependent upon the state and the industry working together as partners to find solutions to the thorny issue of climate change. As such, the interest of the State of North Dakota in geologic storage of $CO_2$ and other greenhouse gases arises because, in addition to conservation, it is among the most immediate and viable strategies available for mitigating the release of $CO_2$ into the atmosphere. The passage of these bills ensures that North Dakota will have in place the critical legal and regulatory infrastructure for the safe and secure storage of $CO_2$.

To facilitate our efforts we took advantage of the work product of a task force formed by the Interstate Oil and Gas Compact Commission (IOGCC). Its membership included representatives from IOGCC member states, **including North Dakota**, international affiliate provinces, state and provincial oil and gas agencies, the U.S. Department of Energy (DOE), DOE-sponsored Regional Carbon Sequestration Partnerships, **including the PCOR partnership**[2], the Association of American State Geologists and independent experts. Funded by DOE and its

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[1] Associated greenhouse gases include methane, nitrous oxide, chlorofluorocarbons and ozone.
[2] The "PCOR Partnership" is the Plains $CO_2$ Reduction Partnership which is a collaborative effort of over 80 US and Canadian stakeholders whose mission is to develop the groundwork for practical and environmentally sound underground storage of $CO_2$. The EERC administers the program.

National Energy Technology Laboratory, the Task Force undertook an examination of the technical, policy and regulatory issues related to the safe and effective long-term storage of $CO_2$ in oil and gas fields, coal seams and deep saline formations. The end result of the task force work was the development of a model statute and a set of model rules to govern the underground storage of $CO_2$.

The Workgroup used the model statute as a starting point for the development of SB 2095. During the course of the Workgroup's deliberations it became clear that a companion bill clarifying the ownership of pore space was also necessary. SB 2139 was drafted to further clarify what we believe is the existing common law in North Dakota --- that the surface owner owns the pore space.

This morning the Workgroup would like to provide you with a brief primer on $CO_2$ storage which will be presented by John Harju from the PCOR Partnership. After John's presentation, Lynn Helms will provide a section by section analysis of SB 2095. Curtis Jabs from Basin Electric Power Cooperative will provide insight as to the practical application of the bills in relation to future $CO_2$ capture projects. Following comments from other interested parties, Charles Carvell will explain SB 2139.

Before we begin the primer, I would like to provide the committee with a couple of technical amendments to SB 2095. The first involves the location of the new chapter in the ND Century Code. The bill will create a new chapter 38-22, not 38-20.

Additionally, on page 4 of the bill, we are recommending that the phrase "mineral lessees" be inserted after "owners" on lines 22 and 23. This change will ensure that subsection 08 of the bill is consistent with subsection 06. The amendments are attached for your consideration and we can discuss them in more detail after Lynn's review of the bill.

In closing, you may have noticed that the bill was introduced at the request of the ND Industrial Commission. In November the Commission voted unanimously to support the bills and have the bills introduced as Industrial Commission bills.

And finally, the Lignite Energy Council urges the Committee to vote a "do pass" recommendation on SB 2095 and SB 2139.

Proposed Amendment to Senate Bill No. 2095

Submitted by Sandi Tabor
January 16, 2009

1. Page 1, line 1, delete "38-20" and insert "38-22"

2. Page1, line 6, delete "38-20" and insert "38-22"

3. Renumber each section as 38-22 rather than 38-20

4. Page 4, line 22, after "owners" insert, "or mineral lessees"

5. Page 4, line 23, after "owners" insert, "or mineral lessees"

Renumber accordingly

ATTachment #2

Pages 1-12 also given to House.

EERC — EERC Technology... Putting Research into Practice

# Introduction to $CO_2$ Sequestration

## The Plains $CO_2$ Reduction (PCOR) Partnership

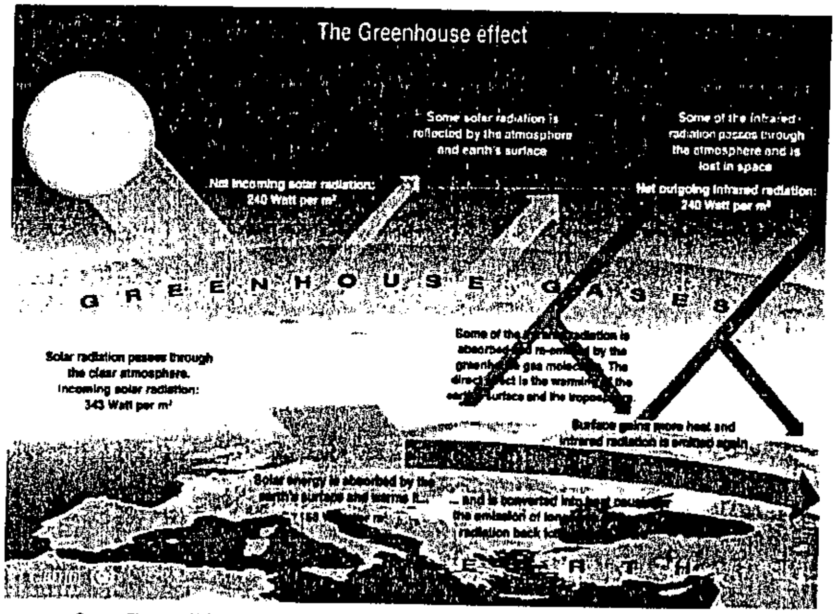
Bismarck, North Dakota
January 16, 2009

John Harju
Energy & Environmental Research Center

PCOR Partnership

NETL

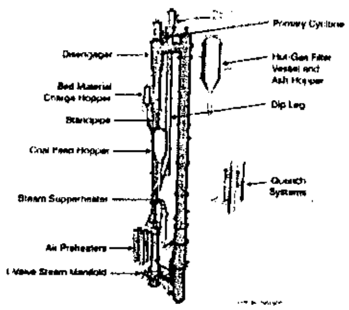
# The Greenhouse Effect

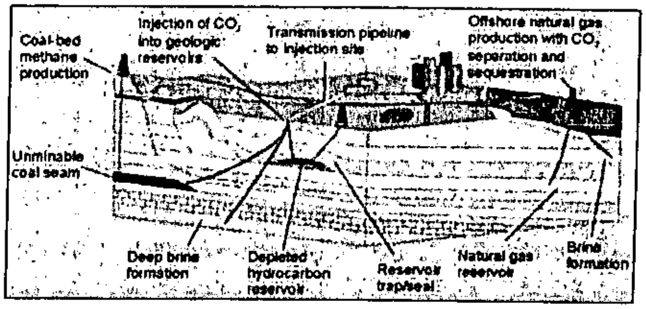


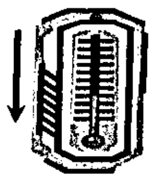

Source: Okanagan University College, Canada; University of Oxford; U.S. Environmental Protection Agency; United Nations Environment Programme (UNEP) and World Meteorological Organization (WMO).

## Methods for Reducing $CO_2$ Emissions

- Renewable energy technologies
- Advanced high-efficiency energy systems
- Improve efficiency on existing systems
- Reduce consumption of energy
- **Sequester greenhouse gas (GHG) emissions, often called carbon capture and storage (CCS)**

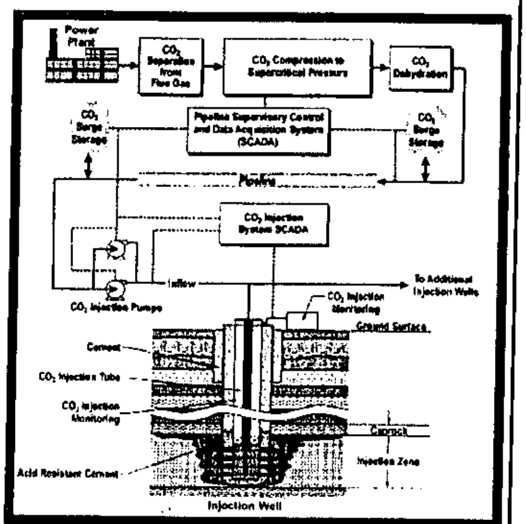


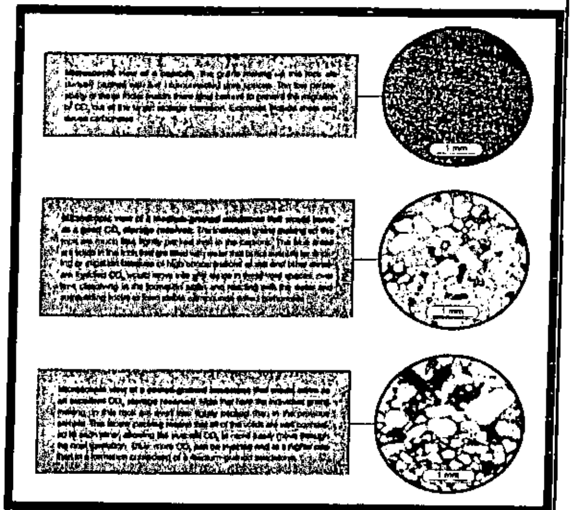
## How Does CCS Work?

- $CO_2$ is captured from major stationary sources
- $CO_2$ is compressed and transported to a suitable storage site.
- $CO_2$ is pumped underground (as a liquid) at great depths into traps in the geologic structure that ensure storage over geologic time.



## What are Geologic Sinks and Seals?

- Geologic sinks are rock layers that have the capacity to store $CO_2$ in their pore spaces.
- Geologic seals are rock layers that don't allow for the $CO_2$ to move through them.
- Since $CO_2$ is buoyant in water, the ideal storage site consists of a sink rock that is overlain by a seal rock layer.




Source: JJ Dooley, et al. "Carbon Dioxide Capture and Geologic Storage," Technology Report from the Second Phase of the Global Energy Strategy Program, April 2006

## What Are the Key Questions for Choosing Good Sites for CCS?

- What is the storage capacity of the target geologic formation (sink) the area of interest?
- What is the fate of the $CO_2$?
- What is the potential for leakage?

Site characterization data provide the basis for a geologic model that can be used to begin answering these questions.

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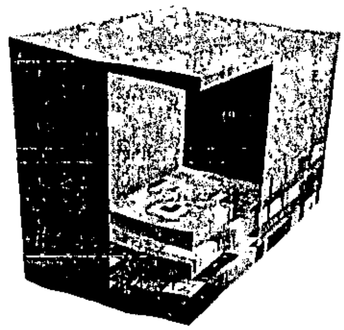
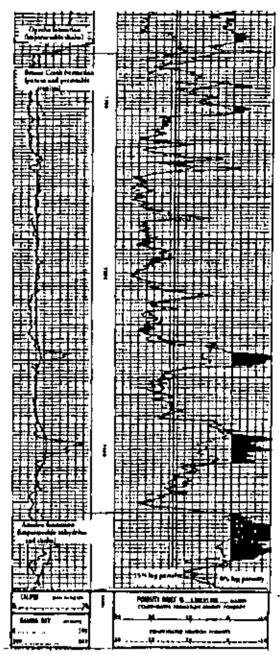
## What Needs to Be Characterized?

- Geology
- Hydrogeology
- Injection zone
- Cap rock and seal



Baseline characterization for demonstration sites should be done at **small, medium, and large scales.**

Figure Courtesy of Saskatchewan Industry & Resources

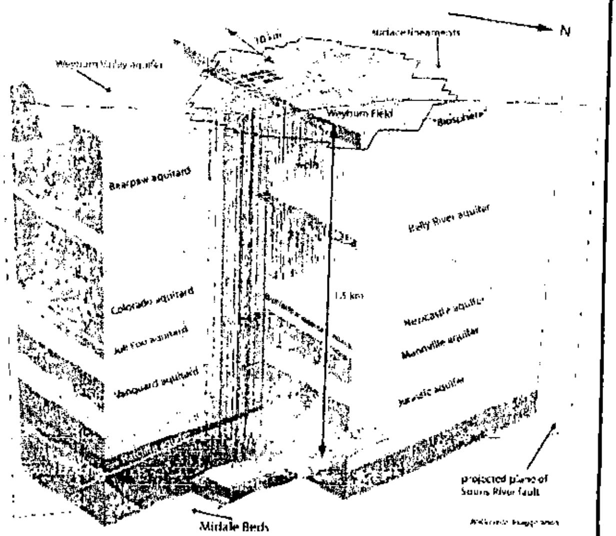


## Well Logs Are Good for Initial Examinations

- Tools lowered down well boreholes generate measurements that allow for estimation of some rock properties.
- Can identify zones of relative porosity:
  - High-porosity zones may be good sinks (injection targets).
  - Low-porosity zones may indicate good seals.

## Characterization Yields Geological Model

- Geological architecture of system
- Properties of system
  - Lithology
  - Hydrogeological characteristics
  - Faults
- Necessary for robust numerical modeling and risk assessment




Figures Courtesy of Saskatchewan Industry & Resources

## Risk Assessment Philosophy

- We work closely with our industry partners to implement cost-effective monitoring, mitigation, and verification (MMV) strategies which both add value to the projects and mitigate potential risks.

Threat Level

| Likelihood \ Impact | Low | Medium | High |
|---|---|---|---|
| High | Medium | High | Critical |
| Medium | Low | Medium | High |
| Low | Low | Low | Medium |

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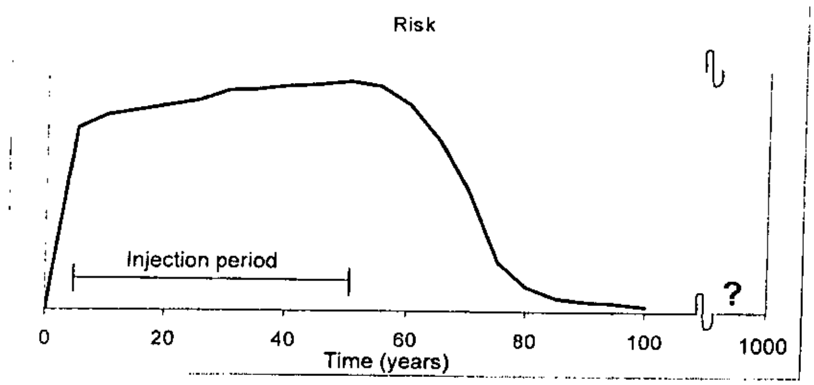
## The risk timeline for leakage is heavily-laden in early times.




Why does it look like this?

- Pressure driver during and post injection
- Most "changes" occur in early phase
- Long-term effects trap larger quantities of $CO_2$
- Seals may be affected over long-term

NETL

## Stacked Sinks

- A recently completed effort focused on multiple target formations in west-central North Dakota.

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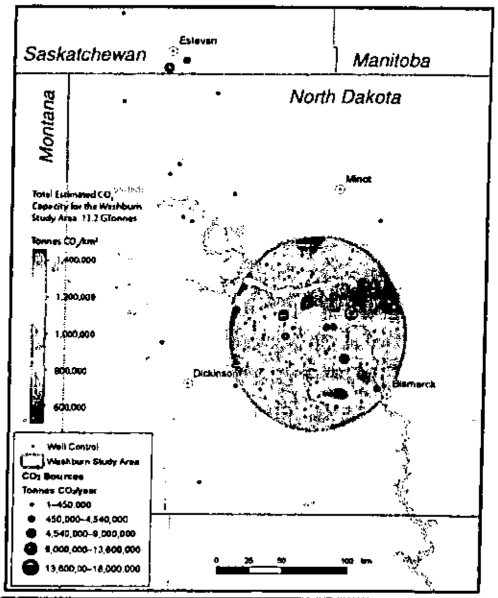
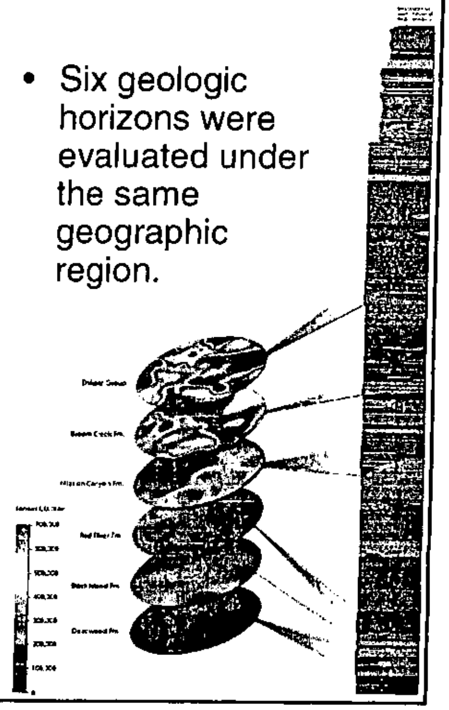
# Stacked Sinks

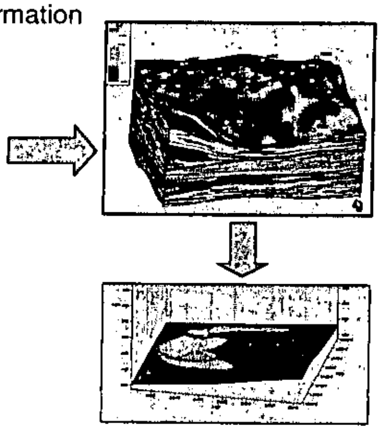



- Six geologic horizons were evaluated under the same geographic region.



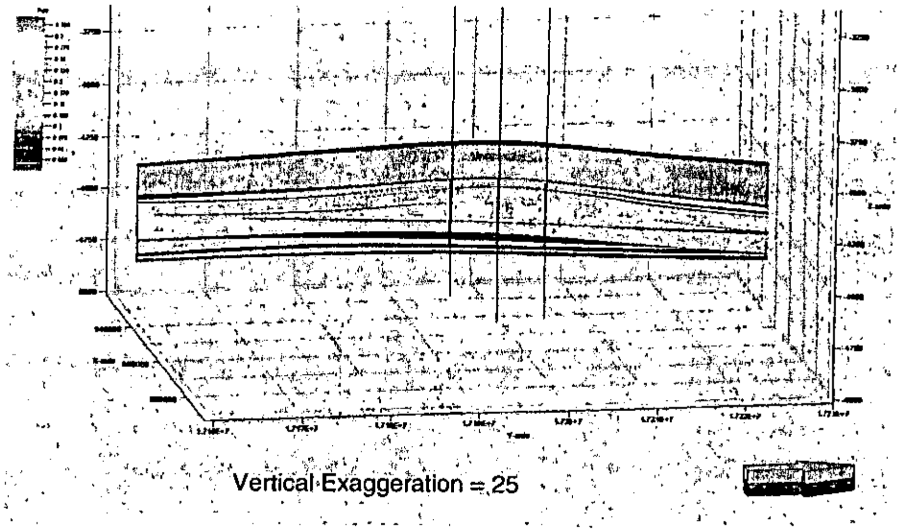
# Brine-Saturated Formation Modeling

Well logs, core analyses, and geophysical data are used to create maps of key formation properties.



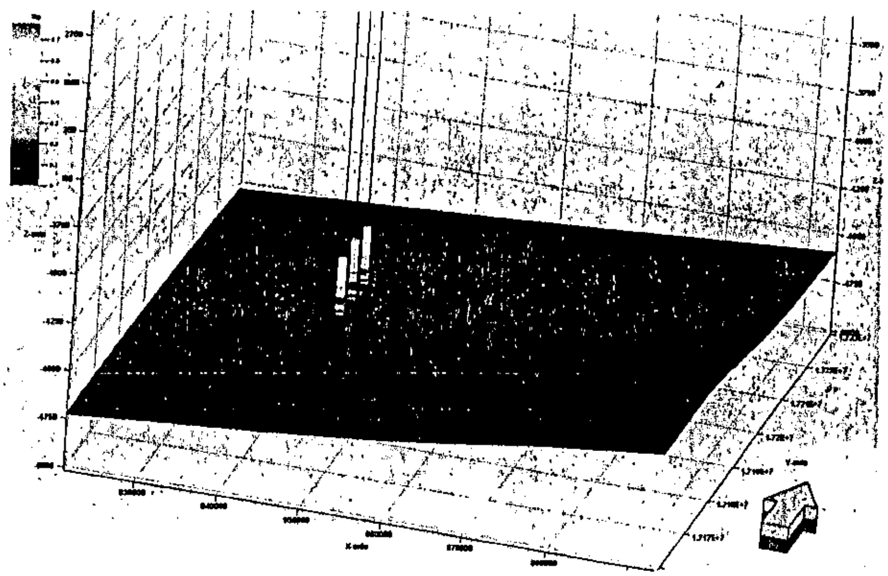
Maps are then used to create a petrophysical model of the sink–seal system.

Injection and plume behavior and fate can then be modeled.

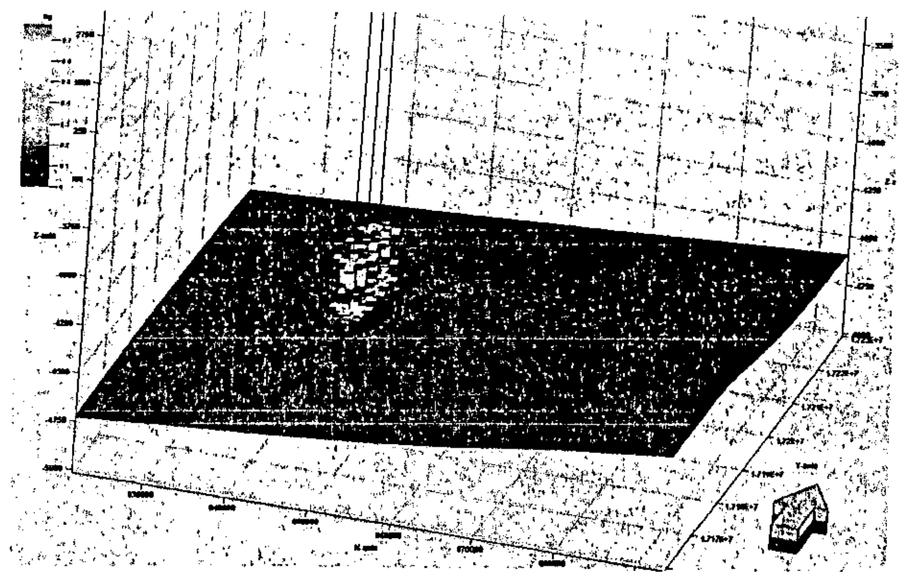



- Four perforated zones (shown in red): the high porosity sands in each well were perforated.
- The tight zones (presumed to be anhydrite stringers) between were not perforated.

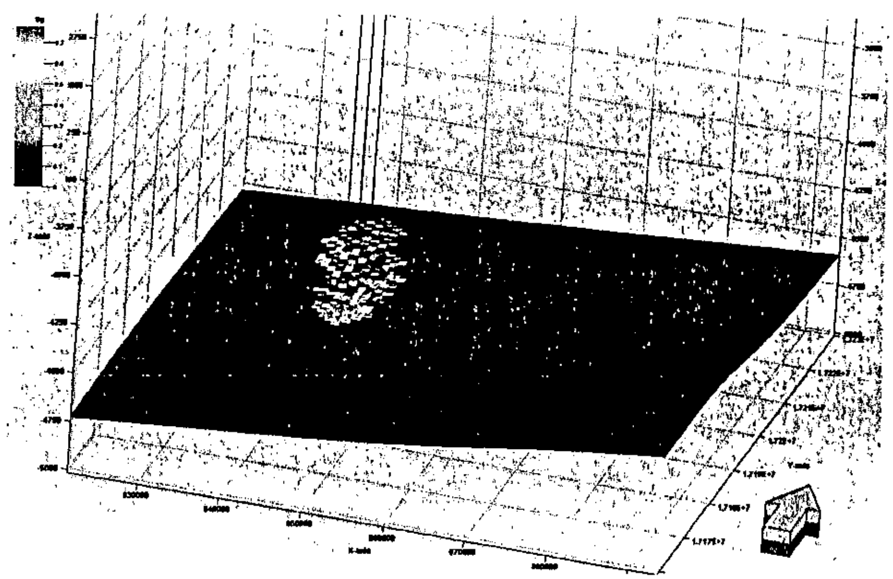
**1 Year**



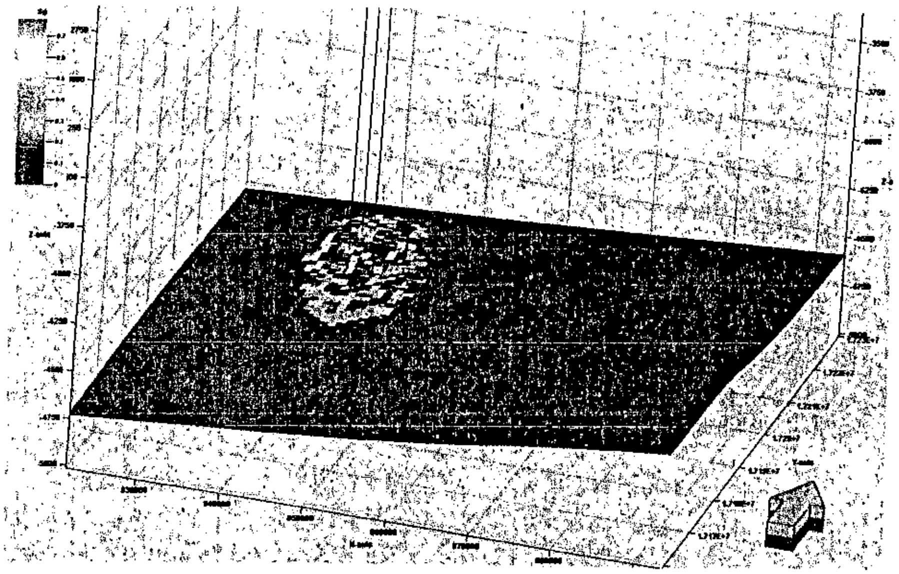
## 10 Years



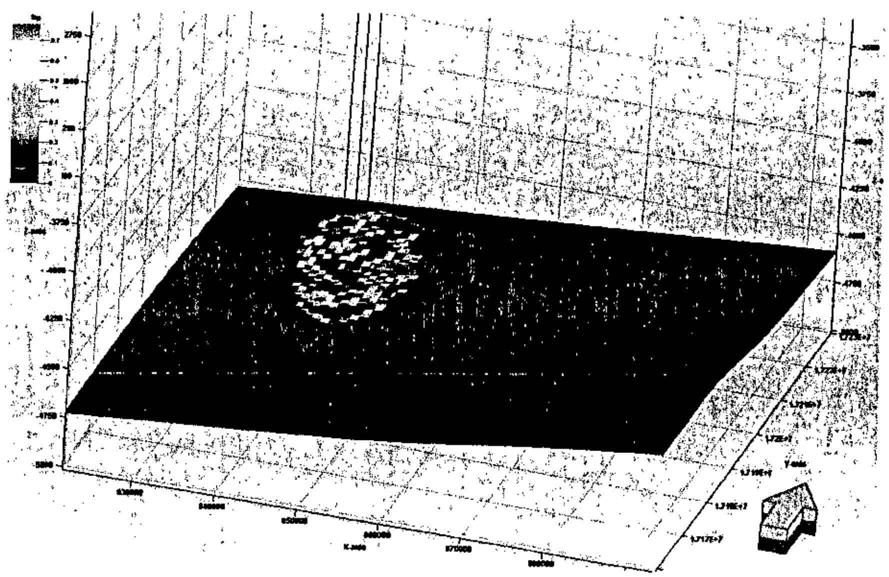
## 25 Years



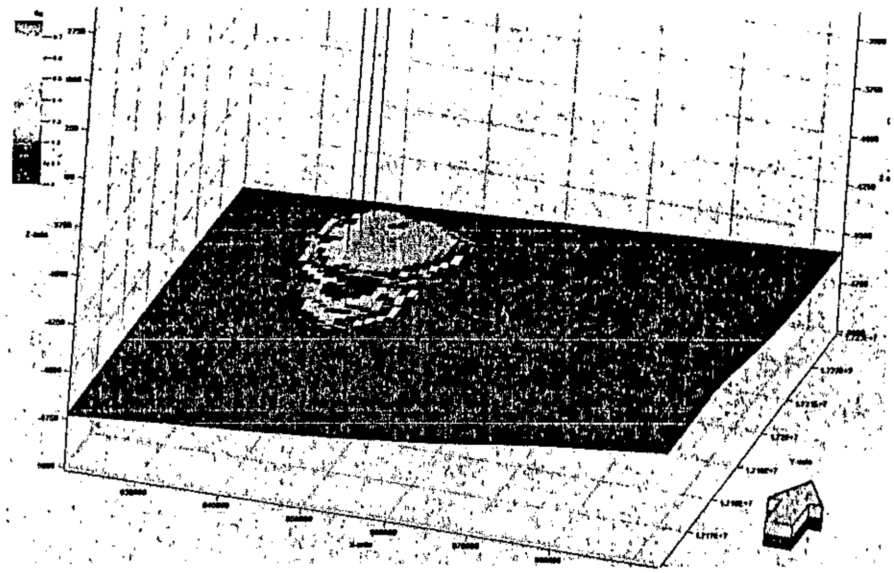
## 50 Years



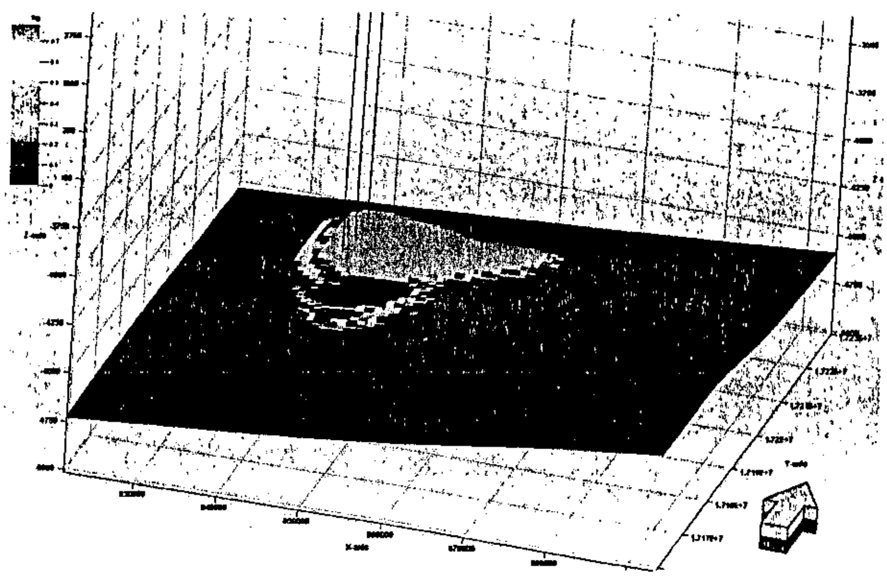
## 100 Years

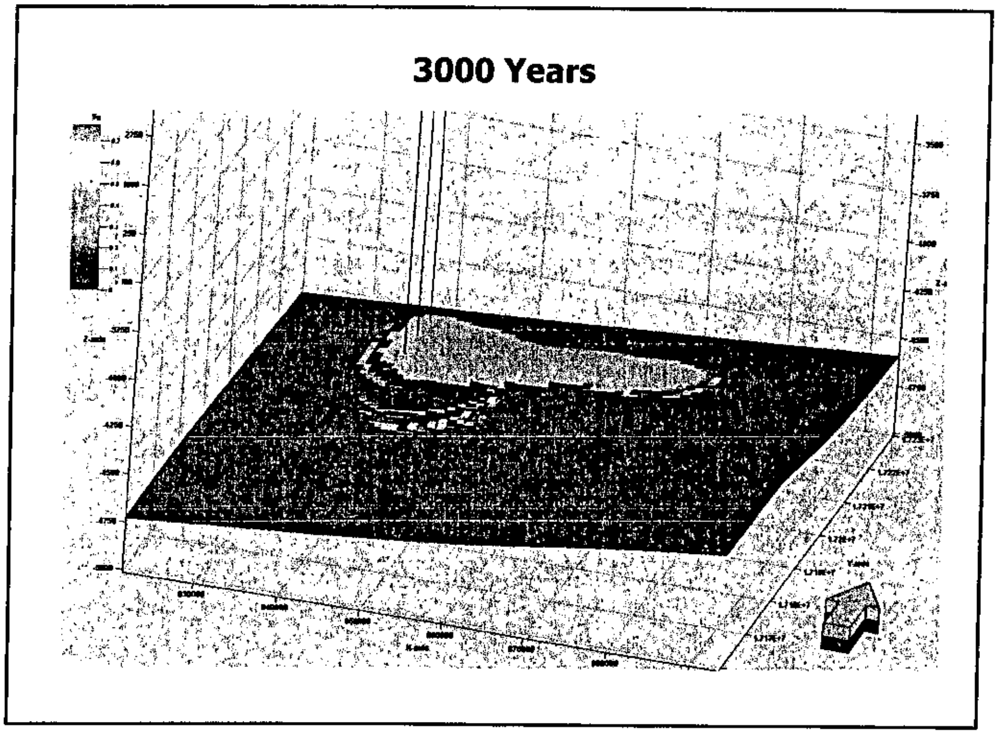


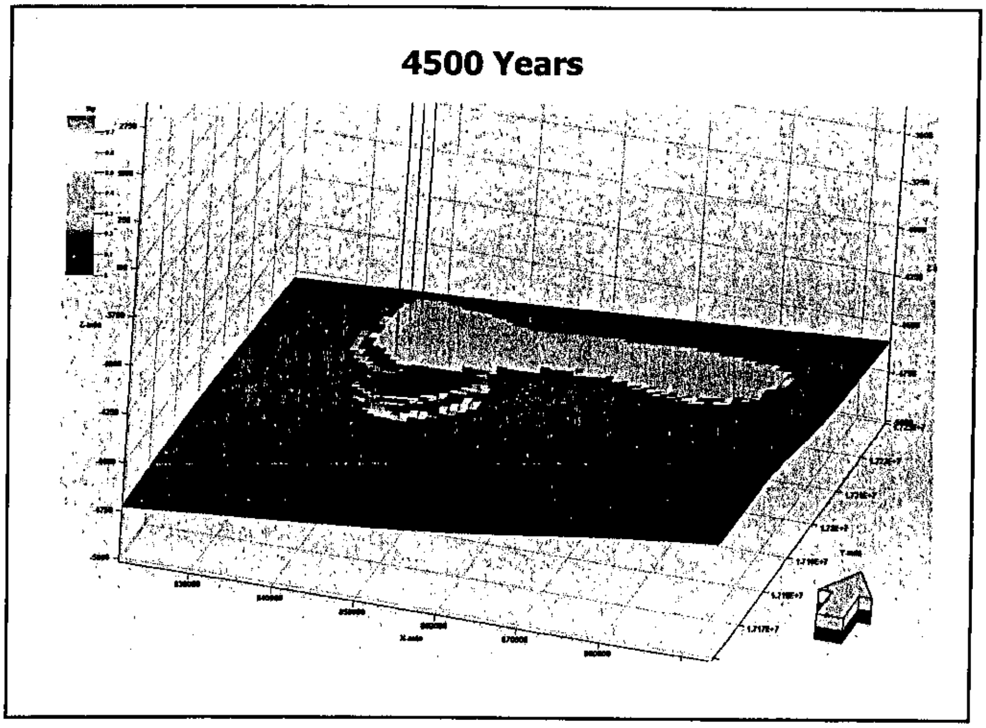
## 500 Years



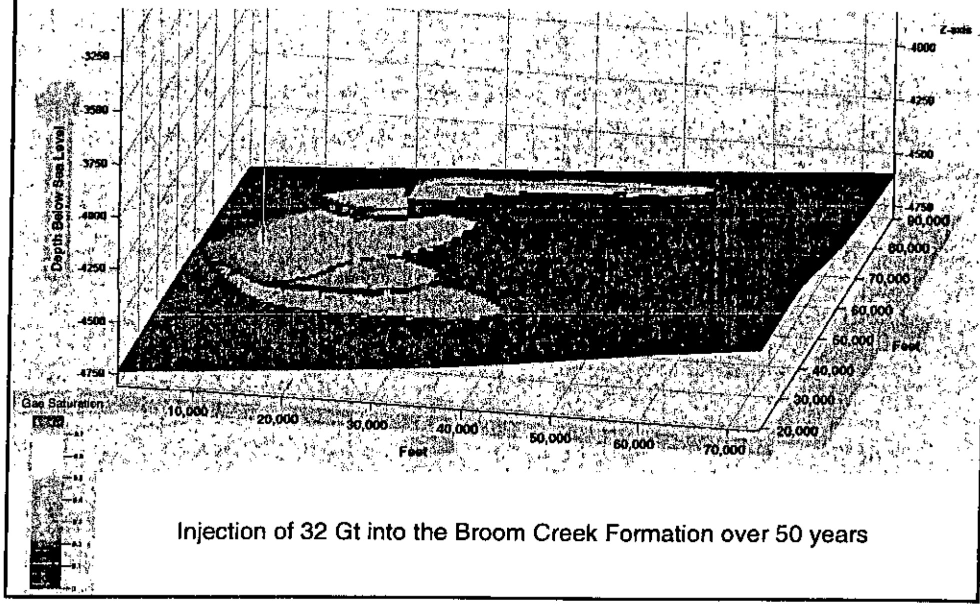
## 1500 Years




3000 Years


4500 Years

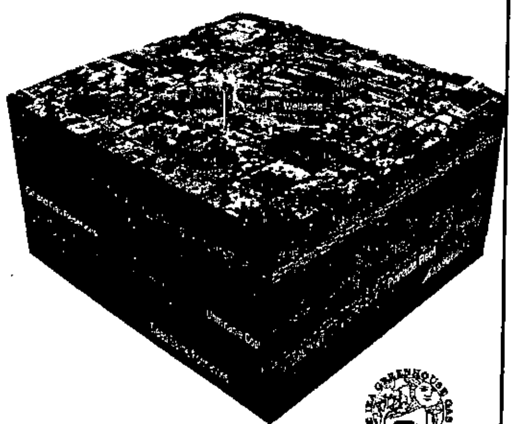
end of injection
T= 50 years (end of injection)




Injection of 32 Gt into the Broom Creek Formation over 50 years

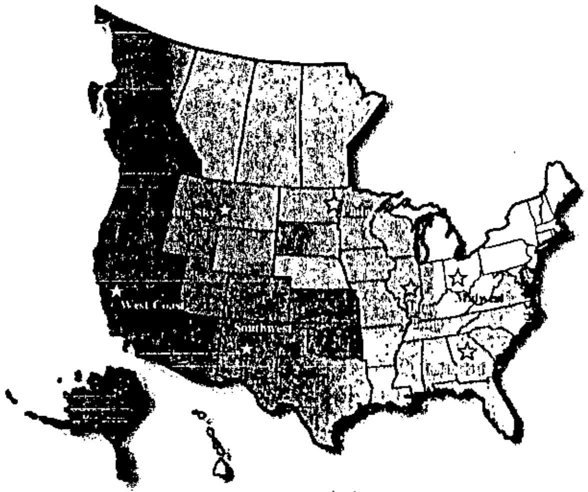
# EERC $CO_2$ CCS Work

- The EERC is one of seven Regional Carbon Sequestration Partnerships that the US DOE and other partners are funding to demonstrate CCS across North America.
- We are finishing four Phase II small-scale demonstrations and developing two Phase III commercial-scale demonstrations.



PCOR Partnership NETL EERC UND University of North Dakota

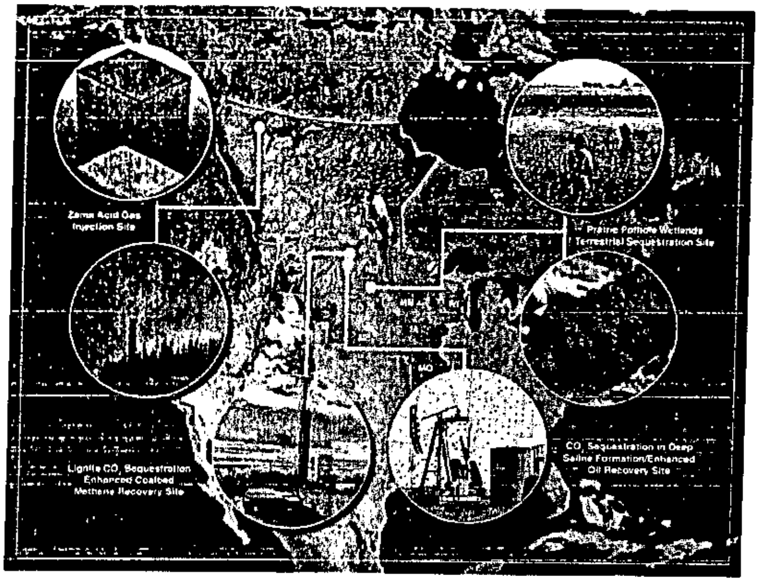
# Regional Carbon Sequestration Partnerships



The PCOR Partnership has brought together the key stakeholders to make geologic $CO_2$ sequestration a viable option for carbon management in our region.

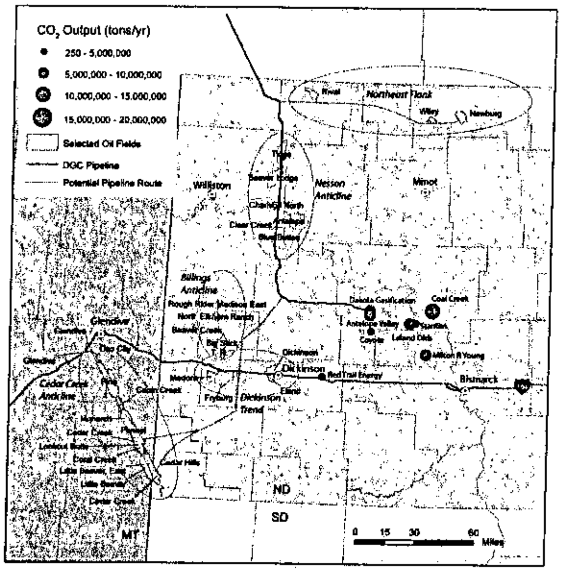
PCOR Partnership 2003–Present

## PCOR Phase II Field Validation Tests




## We Are Planning Two Phase III Efforts

## Williston Basin Candidate Oil Fields




## Williston Basin $CO_2$-Based EOR Potential

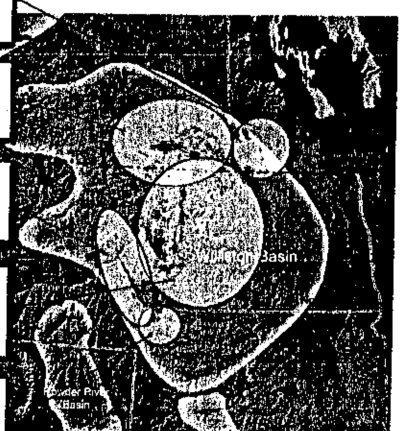
**Selected Manitoba Oil Fields**
- Three fields
- Potential incremental oil = 39 million bbl
- Total $CO_2$ needed for EOR = 319 Bcf

**Selected Saskatchewan Oil Fields**
- 11 fields
- Potential incremental oil = 331 million bbl
- Total $CO_2$ needed for EOR = 2652 Bcf

**Selected Montana Oil Fields**
- Ten fields
- Potential incremental oil = 390 million bbl
- Total $CO_2$ needed for EOR = 3120 Bcf

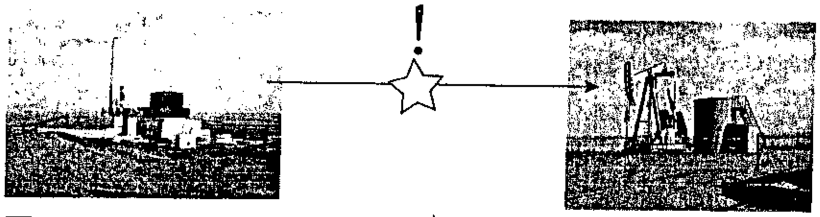
**Selected North Dakota Oil Fields**
- 28 fields
- Potential incremental oil = 262 million bbl
- Total $CO_2$ needed for EOR = 2095 Bcf

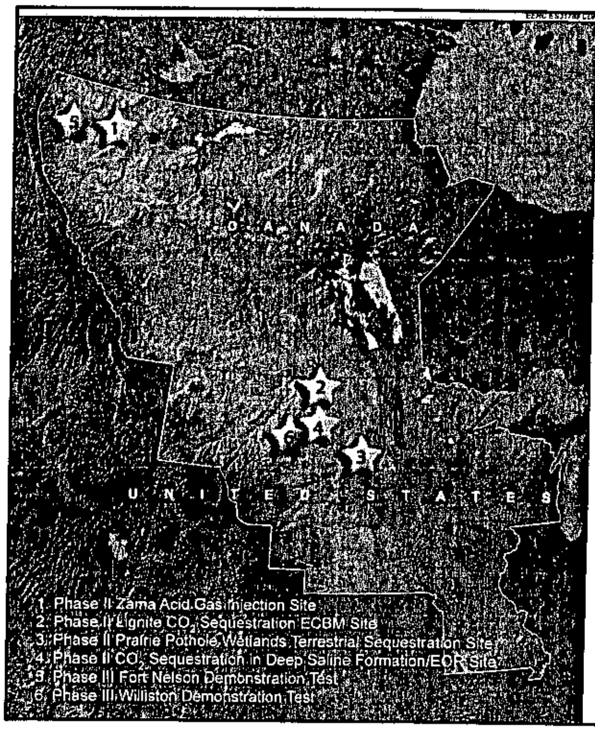
**Buffalo Field, South Dakota**
- Portions of this field are currently undergoing tertiary recovery operations using air injection.
- $CO_2$-based EOR may be technically feasible.



## Williston Basin Phase III – Concept

- Capture approximately 1 Mt/yr of $CO_2$ at an existing coal-fired power plant in central North Dakota.
- Transport via pipeline to Williston Basin oil field.
- Meet or exceed all of the U.S. Department of Energy Phase III objectives.
- Conduct MMV activities to document integrity of storage.
- Ultimately monetize credits.






PCOR Partnership

**For more information on the PCOR Partnership, please contact:**


Ed Steadman
(701) 777-5279
esteadman@undeerc.org

John Harju
(701) 777-5157
jharju@undeerc.org

Attachment #5

**SENATE BILL NO. 2095**

Senate Natural Resources Committee
January 16, 2009

Testimony of Lynn D. Helms, Director
Department of Mineral Resources
North Dakota Industrial Commission

**Summary** – Senate Bill 2095 creates a new chapter in the North Dakota Century Code that establishes the policies and priorities necessary to store carbon dioxide geologically. This chapter is based on the model developed by an Interstate Oil and Gas Compact Commission working group during a 2 year study of the issue. The Interstate Oil and Gas Compact Commission has assisted states in writing model statutes and regulations for the conservation of oil and gas since 1935. North Dakota has been a member since 1953. There are currently 30 member states, 8 affiliated member states, and 9 international member affiliates.

**Section 38-20-01** – is the statement of policy behind the legislation. It describes the environmental, industry, and economic benefits that will ensue as well as the need to promote cooperative management of the various property interests involved.

**Section 38-20-02** – provides the definitions required to properly interpret the new statute.

**Section 38-20-03** – sets out the Industrial Commission's authority to set up, regulate the operation, and oversee the closure of geologic storage sites. The powers described here are very similar to the statutory unitization authority the commission has exercised for more than 40 years.

**Section 38-20-04** - establishes the requirement to obtain a geologic storage permit from the Industrial Commission and to get commission approval to transfer such permit to a new operator.

**Section 38-20-05** - establishes Industrial Commission authority to set permit requirements, charge a permit fee, and recover notice and hearing costs. It also directs the commission to give priority to carbon dioxide produced in North Dakota.

**Section 38-20-06** – set out the storage permit notice and hearing requirements.

**Section 38-20-07** – requires the Industrial Commission to consult the Department of Health before issuing a storage permit.

**Section 38-20-08** – identifies what the Industrial Commission must investigate and find to issue a storage permit. Note part 5 requires that 60% of the pore space ownership has given consent. This is the same percentage now required to unitize and oil and gas reservoir so that a process to increase recovery can be utilized.

**Section 38-20-09** – grants the Industrial Commission the authority to include in a permit or order all of the things necessary to carry out this chapter's objectives and to protect and adjust the rights and obligations of persons affected.

**Section 38-20-10** – gives the Industrial Commission the authority to amalgamate the ownership. This process would be very similar to the one utilized today to unitize an oil and gas reservoir.

**Section 38-20-11** – requires the Industrial Commission to issue a certificate stating the permit has been issued and to file that certificate with the county recorder(s).

**Section 38-20-12** – sets out the requirement for the Industrial Commission to take action to prevent pollution or nuisance, explicitly states the policy that properly stored carbon dioxide is neither a pollutant nor a nuisance, and preserves the full jurisdiction of the department of health.

**Section 38-20-13** – preserves the rights of property not committed to the storage facility and mineral owners under and near it.

**Section 38-20-14** – grants the Industrial Commission the authority to set a per ton of carbon dioxide fee through the administrative rule process for paying the commission's anticipated expenses for regulating storage facilities during their construction, operational, and pre-closure phases or a cooperating agency's actual expenses for the same.

**Section 38-20-15** – grants the Industrial Commission the authority to set a per ton of carbon dioxide fee through the administrative rule process for paying the commission's or a cooperating agency's expenses for regulating the long term monitoring and management of a closed storage facilities.

**Section 38-20-16** – set out the ownership of the carbon dioxide and who is responsible for it prior to project completion.

**Section 38-20-17** – identifies what the Industrial Commission must determine in order to issue a certificate of project completion. Note part 4 requires a minimum time period of ten years after injection ends before the commission can consider this issue. This section also transfers title to the facility and carbon dioxide as well as responsibility to the state at the time the certificate of project completion is issued, but provides for future transfer of these items to the federal government should the federal government decide to assume responsibility for long-term monitoring and management.

**Section 38-20-18** – grants authority to the Industrial Commission to assess civil penalties for violations in the same amount and in a similar process to current oil and gas laws and regulations.

**Section 38-20-19** – exempts oil and gas enhanced oil recovery projects from this chapter and leaves them under chapter 38-08, but allows the Industrial Commission to convert those projects into storage projects under the provisions of this chapter.

**Section 38-20-20** – grants authority for the Industrial Commission to enter into the inter-governmental and inter agency agreements as well as the private contracts that it determines are necessary to carry out the objectives of this chapter.

**Section 38-20-21** – exempts geologic storage facility cooperative agreements from trust, monopoly, and restraint of trade statutes.

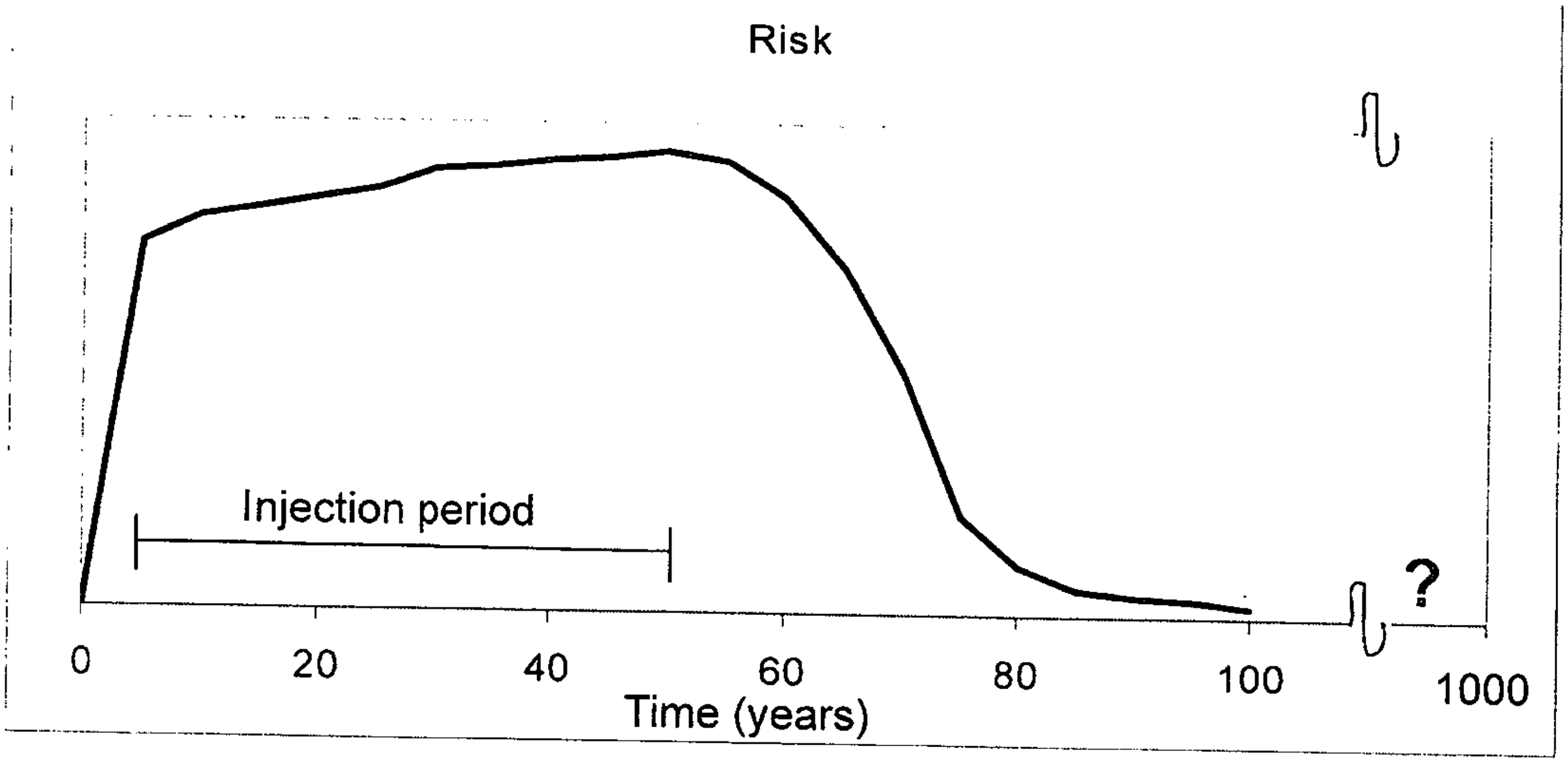
**Section 38-20-22** – grants officials controlling state or political subdivision interests the authority to consent to and participate in geologic storage projects.

**Section 38-20-23** – gives the Industrial Commission the authority to determine how much of the carbon dioxide injected into an enhanced oil or gas recovery project is being stored. This will allow the parties to claim carbon storage credits should the federal government set up such a system. The commission can set a reasonable fee to be deposited into the fund set up in 38-20-14 for making such a determination.

**Section 2** of this bill repeals chapter 38-08-24 which required the industrial commission, department of mineral resources, public service commission, or any other state entity that approved a carbon sequestration or storage project to give priority to an operation located in this state for the expected life of the operation.

Attachment #3

# The risk timeline for leakage is heavily-laden in early times.




Why does it look like this?

- Pressure driver during and post injection
- Most "changes" occur in early phase
- Long-term effects trap larger quantities of $CO_2$
- Seals may be affected over long-term

NETL

2K-2571

# PCOR Partnership Atlas
## 2nd Edition, Revised 2008

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The Plains $CO_2$ Reduction (PCOR) Partnership is a group of public and private stakeholders working together to better understand the technical and economic feasibility of sequestering $CO_2$ emissions from stationary sources in the central interior of North America. The PCOR Partnership is managed by the Energy & Environmental Research Center (EERC) at the University of North Dakota and is one of seven regional partnerships under the U.S. Department of Energy's Regional Carbon Sequestration Partnership Program.

# NOTICE



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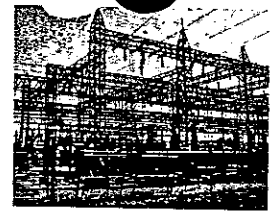
A number of individuals at the Energy & Environmental Research Center provided valuable support for this effort. We are grateful to Earl Battle and Paul Gronhovd for their work in producing many of the graphics used in this document and to Joyce Riske for editing the atlas.



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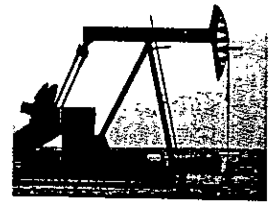
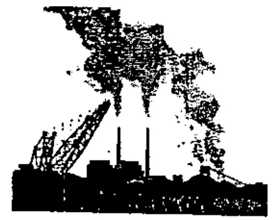
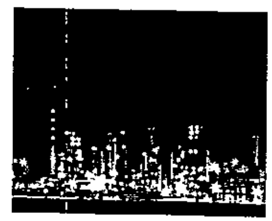
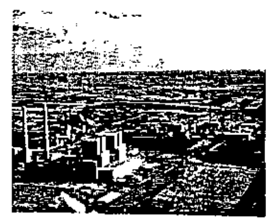








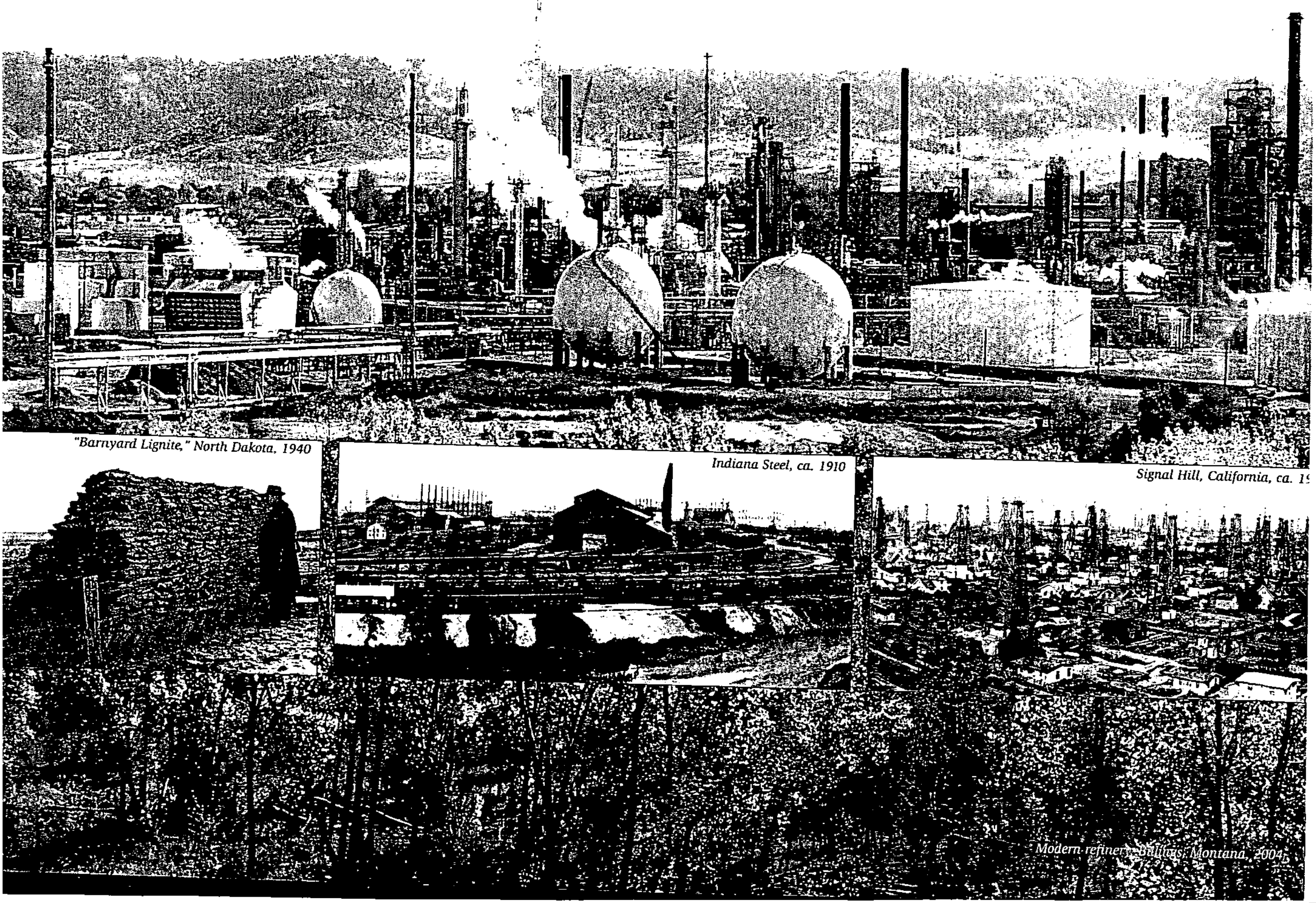
# Introduction

Global climate change is considered to be one of the most pressing environmental concerns of our time. This is due in part to the potential magnitude of the changes it could cause and also to the immense economic, technological, and lifestyle changes that may be necessary in order to respond to it. Although uncertainty still clouds the science of climate change, there is strong indication that we may have to significantly reduce anthropogenic greenhouse gas (GHG) emissions. Carbon sequestration offers a promising set of technologies through which carbon dioxide ($CO_2$) and potentially other GHGs can be stored for long periods of time in sinks represented by biologic materials, geologic formations and, possibly, other places such as oceans. Within central North America, the Plains $CO_2$ Reduction (PCOR) Partnership is investigating sequestration technologies in order to provide a safe, effective, and efficient means of managing the carbon dioxide emissions across the center of the continent.

The regional characterization activities conducted under the initial effort of the PCOR Partnership confirmed that while there are numerous large stationary $CO_2$ sources, the region also has a variety of sinks that represent a tremendous capacity for $CO_2$ sequestration. The varying sources reflect the geographic and socioeconomic diversity of the region. In the upper Mississippi River Valley and along the shores of the Great Lakes Michigan and Superior, large coal-fired electrical generators power the manufacturing plants and breweries of St. Louis, Minneapolis, and Milwaukee. To the west, the prairies and badlands of the north-central United States and central Canada are home to coal-fired power plants, natural gas processing plants, ethanol plants, and refineries that further fuel the industrial and domestic needs of cities throughout North America.

The PCOR Partnership region is rich in agricultural lands, forests, and wetlands that hold tremendous potential for terrestrial sequestration. The Prairie Pothole Region, which stretches from northwestern Iowa, across the Dakotas, and into Saskatchewan and Alberta, holds promise as an area that can be transformed into a significant terrestrial $CO_2$ sink. Deep beneath the surface of the region lay geologic formations that hold tremendous potential to store $CO_2$. Oil fields well suited for sequestering $CO_2$ can be found in roughly half the region, while formations of limestone, sandstone, and coal suitable for $CO_2$ storage exist in basins that, in some cases, extend over thousands of square miles. In many cases, large sources in the region are proximally located to large-capacity sinks, and in some cases, key infrastructure is already in place.

This atlas provides an introduction into the concept of global climate change and a regional profile of $CO_2$ sources and potential sinks across nearly 1.4 million square miles of the PCOR Partnership region of central North America.



"Barnyard Lignite," North Dakota, 1940

Indiana Steel, ca. 1910

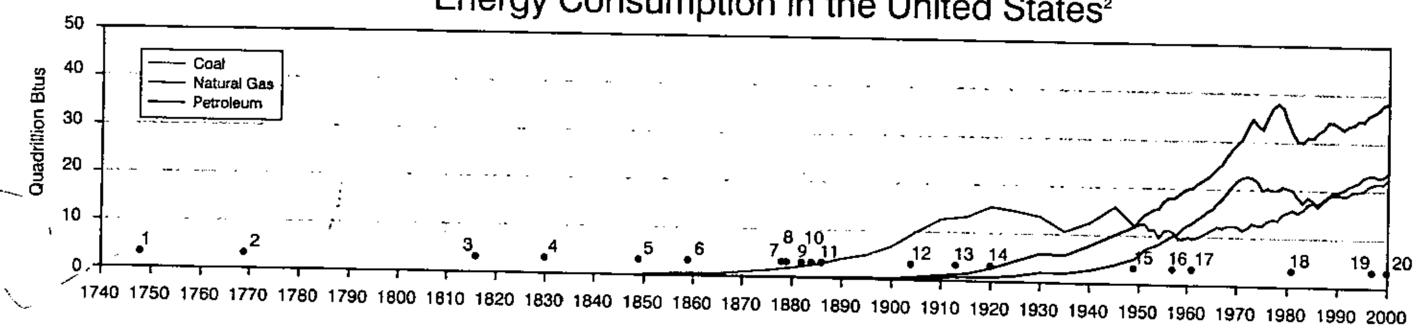
Signal Hill, California, ca. 1

Modern refinery, Billings, Montana, 2004

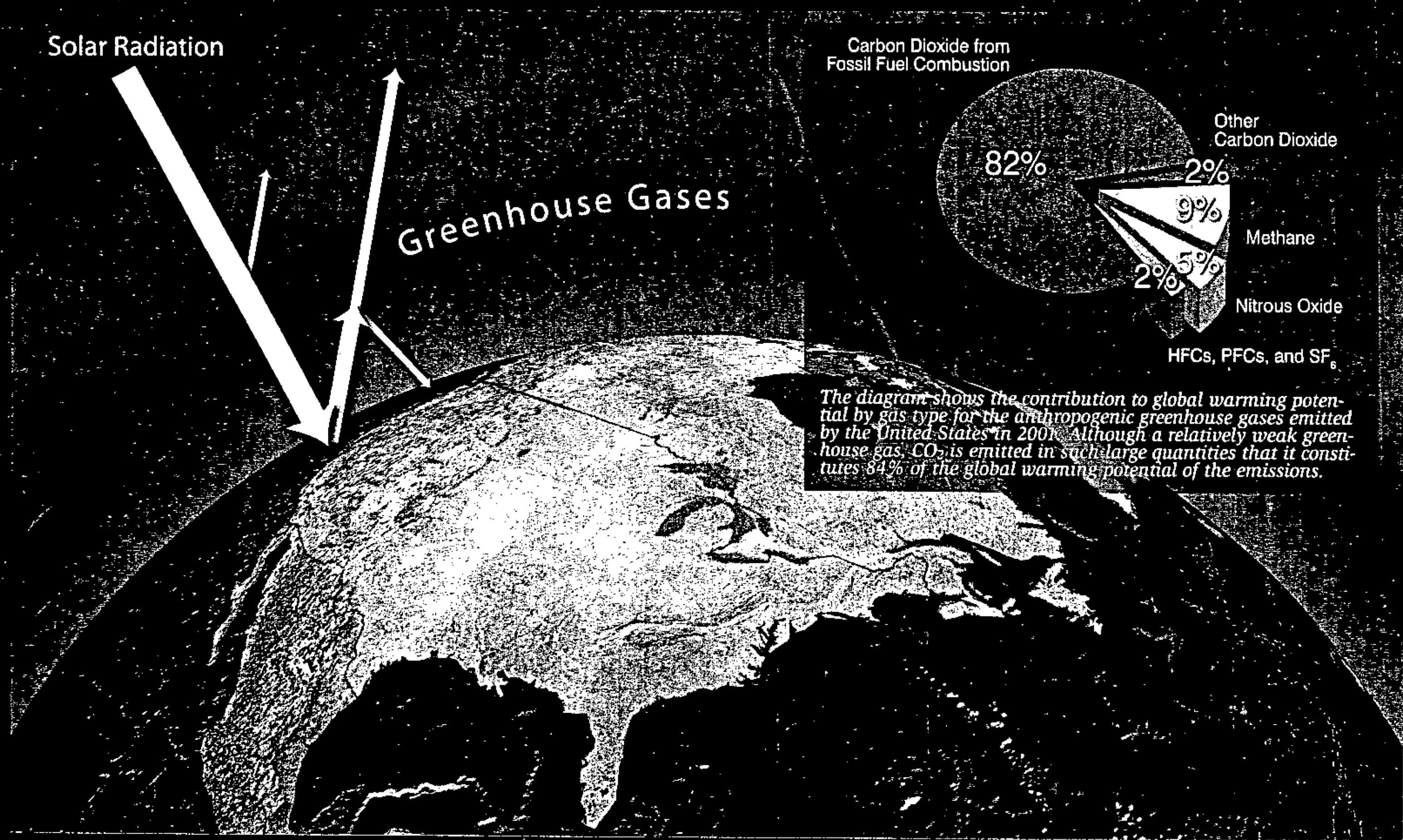
# A Change Is in the Air

Just 200 years ago, before the onset of the Industrial Revolution, we had modest needs for energy and most of the energy we used came from what we now know as renewable sources. We used horses for transportation, burned animal dung and wood for heat, and used vegetable or animal oils in lamps for light. Water supplied much of the needed power to grind grain and for the limited manufacturing of the time. But as the Industrial Revolution moved forward, largely on the shoulders of the steam engine, better energy sources were needed to fuel factories and transportation and provide energy to generate electricity. Energy-rich fossil fuels, including coal, oil, and natural gas worked well for these needs. Fossil fuel use has continued to increase dramatically in the industrialized world in the last 150 years.[1]

## Energy Consumption in the United States[2]




1. First commercial U.S. coal production begins near Richmond, Virginia[3]
2. James Watt patents modifications to steam engine[3]
3. Baltimore, Maryland, becomes first city to light streets with gas from coal[3]
4. First steamship to cross Atlantic[3]
5. Distillation of kerosene replaces whale oil[4]
6. First oil well in United States[4]
7. Edison invents electric lighting[5]
8. First commercial electric power station opens in San Francisco[5]
9. First practical coal-fired electric generating station goes into operation to supply household lights in New York.[5]
10. Steam turbine invented[5]
11. Gasoline-powered internal combustion engine developed[3]
12. Svante Arrhenius is first to investigate the effect that doubling atmospheric carbon dioxide would have on global climate.[6]
13. Electric refrigerator invented[5]
14. 9 million autos in the United States[5]
15. U.S. population at 149.2 million[7]
16. First commercial nuclear power plant[5]
17. 61.6 million autos registered in the United States[8]
18. Beginning of the modern global warming debate[6]
19. 129.7 million autos registered in the United States[8] and an estimated 600 million motor vehicles in the world[9]
20. U.S. population at 281.4 million[7]


Solar Radiation
Greenhouse Gases
Carbon Dioxide from Fossil Fuel Combustion
82%
Other Carbon Dioxide
2%
9%
Methane
5%
2%
Nitrous Oxide
HFCs, PFCs, and $SF_6$
The diagram shows the contribution to global warming potential by gas type for the anthropogenic greenhouse gases emitted by the United States in 2001. Although a relatively weak greenhouse gas, $CO_2$ is emitted in such large quantities that it constitutes 84% of the global warming potential of the emissions.

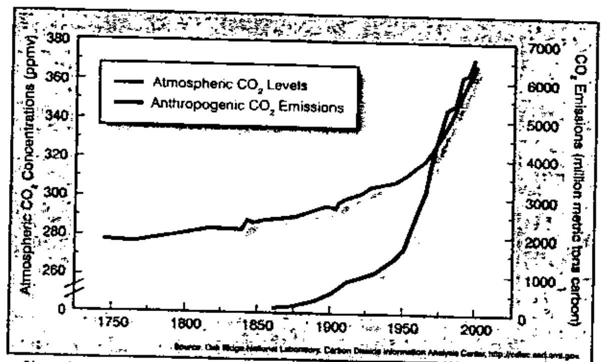
# Greenhouse Effect

Energy from the sun drives the earth's weather and climate and heats the earth's surface; in turn, the earth radiates energy back into space. Certain atmospheric gases (water vapor, carbon dioxide, and other gases) trap some of the outgoing energy, retaining heat somewhat like the glass panels of a greenhouse.

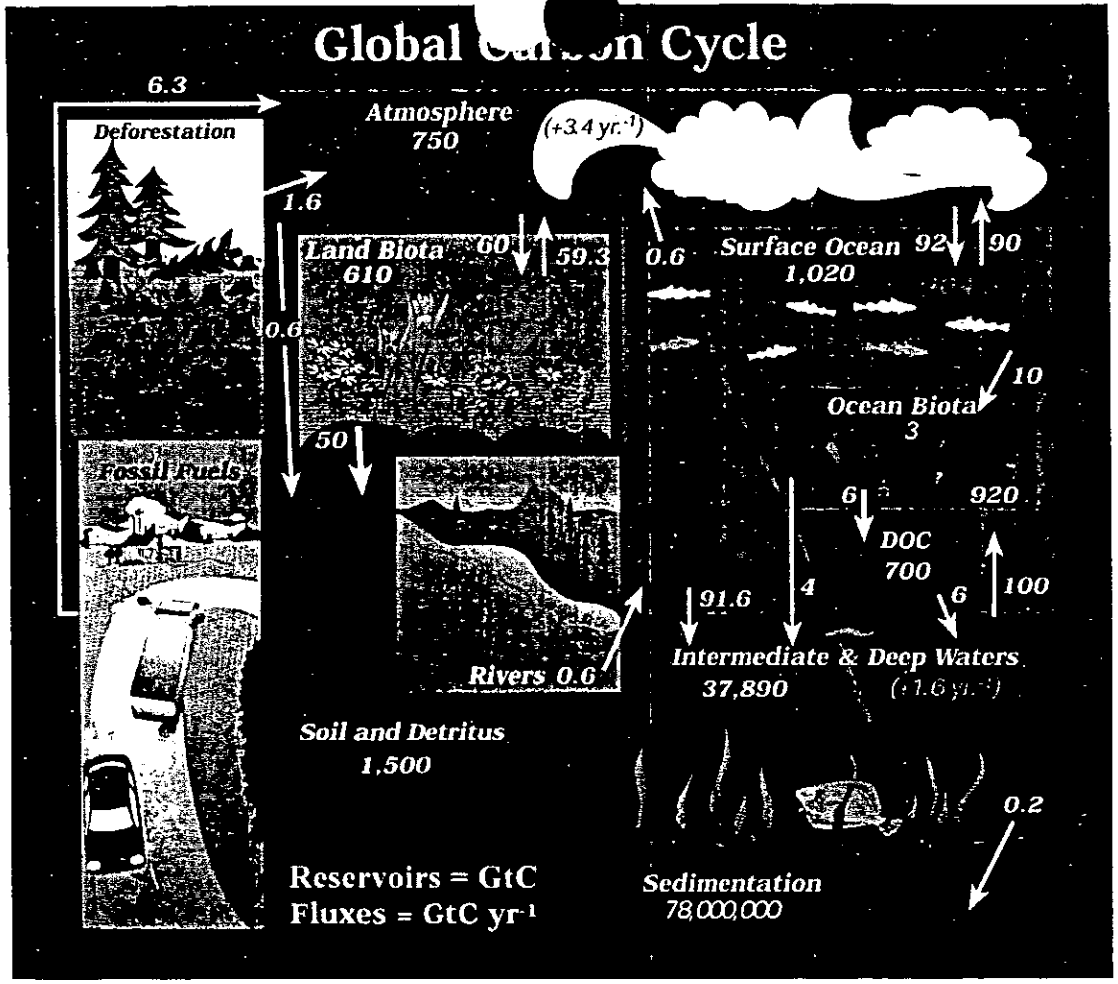
Without this natural "greenhouse effect," global temperatures would be considerably lower than they are now, and life as it is known would not be possible. However, problems may arise when the atmospheric concentration of GHGs increases.[10]

Nearly 100 years ago, Swedish scientist and Nobel Prize winner Svante Arrhenius postulated that anthropogenic increases in atmospheric $CO_2$ as the result of fossil fuel combustion would have a profound effect on the heat budget of the earth. In 1904, Arrhenius became concerned with rapid increases in anthropogenic carbon emissions and recognized that "the slight percentage of carbonic acid in the atmosphere may, by the advances of industry, be changed to a noticeable degree in the course of a few centuries."[11]

Human (anthropogenic) activity, including the use of fossil fuel, generates a significant volume of GHGs like $CO_2$. Since the beginning of the Industrial Revolution, atmospheric concentrations of carbon dioxide have increased nearly 30%, methane concentrations have more than doubled, and nitrous oxide concentrations have risen by about 15%.[10] These increases have enhanced the heat-trapping capability of the earth's atmosphere. There is concern that the anthropogenic GHGs entering the atmosphere are causing increased warming and that this warming will affect climate on a global scale.




*Since the beginning of large-scale industrialization about 150 years ago, the level of $CO_2$ in the atmosphere has increased by about 30%.*




*The cycle of carbon movement between the biosphere, atmosphere, hydrosphere, and geosphere is a complex and important global cycle. In the atmosphere, carbon occurs primarily as carbon dioxide. Across the landscape, carbon occurs mainly in living organisms and decaying organic matter in soils.*

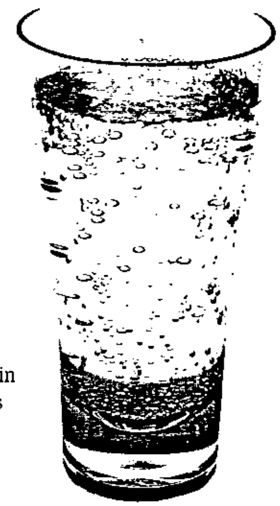
*Carbon is continuously circulated between reservoirs in the ocean, land, and atmosphere, where it occurs primarily as carbon dioxide. On land, carbon occurs primarily in living biota and decaying organic matter. In the ocean, the main form of carbon is dissolved carbon dioxide and small creatures, such as plankton. The largest reservoir is the deep ocean, which contains close to 40,000 GtC, compared to around 2000 GtC on land, 750 GtC in the atmosphere, and 1000 GtC in the upper ocean. Although natural transfers of carbon dioxide are approximately 20 times greater than those due to human activity, they are in near balance, with the magnitude of carbon sources closely matching those of the sinks.*

# What Is $CO_2$?

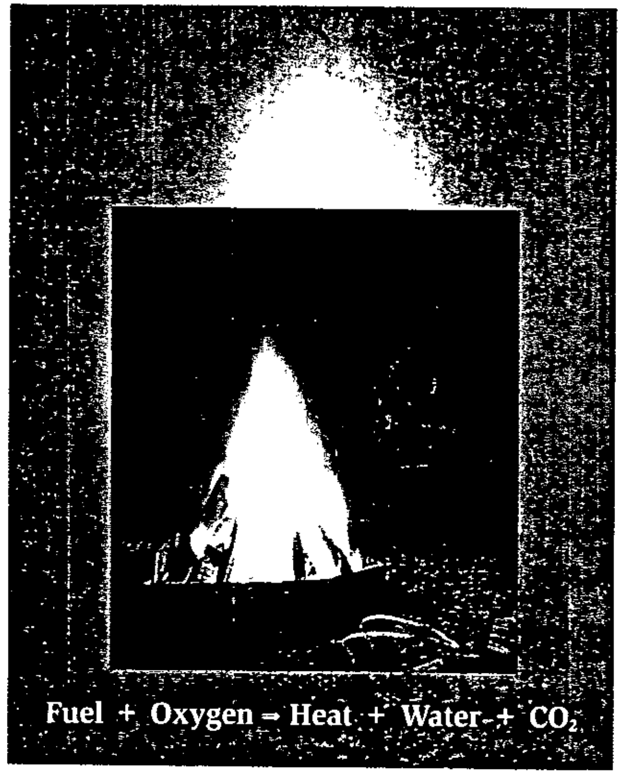
Carbon dioxide (chemical formula $CO_2$) is a colorless, naturally occurring gas composed of one atom of carbon and two atoms of oxygen. At temperatures below -78°C (-109°F), $CO_2$ condenses into a white solid called dry ice. When warmed, dry ice vaporizes directly from a solid to $CO_2$ gas in a process called sublimation. With enough added pressure, liquid carbon dioxide can be formed.

We use $CO_2$ to make the bubbles in soft drinks, and $CO_2$ (as dry ice) is used to keep things cold. Carbon dioxide is also used in fire extinguishers ($CO_2$ displaces the oxygen the fire needs to burn).

Presently, the earth's atmosphere is composed of about 0.04% $CO_2$. This small amount plays an important role in maintaining the natural greenhouse effect that makes Earth hospitable to life. Carbon dioxide is essential to plant life and is a key part of the global carbon cycle. An important component of this cycle takes place when plants take in $CO_2$ and break it down into carbon and oxygen through the process of photosynthesis. The carbon is stored in the plant and the oxygen is released to the atmosphere. When the plant dies or it is burned, much of the carbon recombines with oxygen to again form $CO_2$.

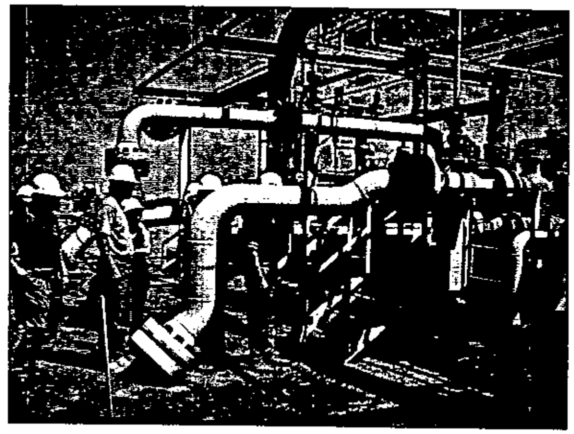


Carbon dioxide formed through human action is referred to as anthropogenic $CO_2$. Examples of activities that result in the production of anthropogenic $CO_2$ include plowing land, which exposes the carbon in the soil to the oxygen in the air; heating limestone to make lime for cement, which releases carbon in the limestone that combines with oxygen in the air; and burning fossil fuels for energy which combines the carbon in the fuel with oxygen. This anthropogenic $CO_2$ adds additional carbon to the global carbon cycle.



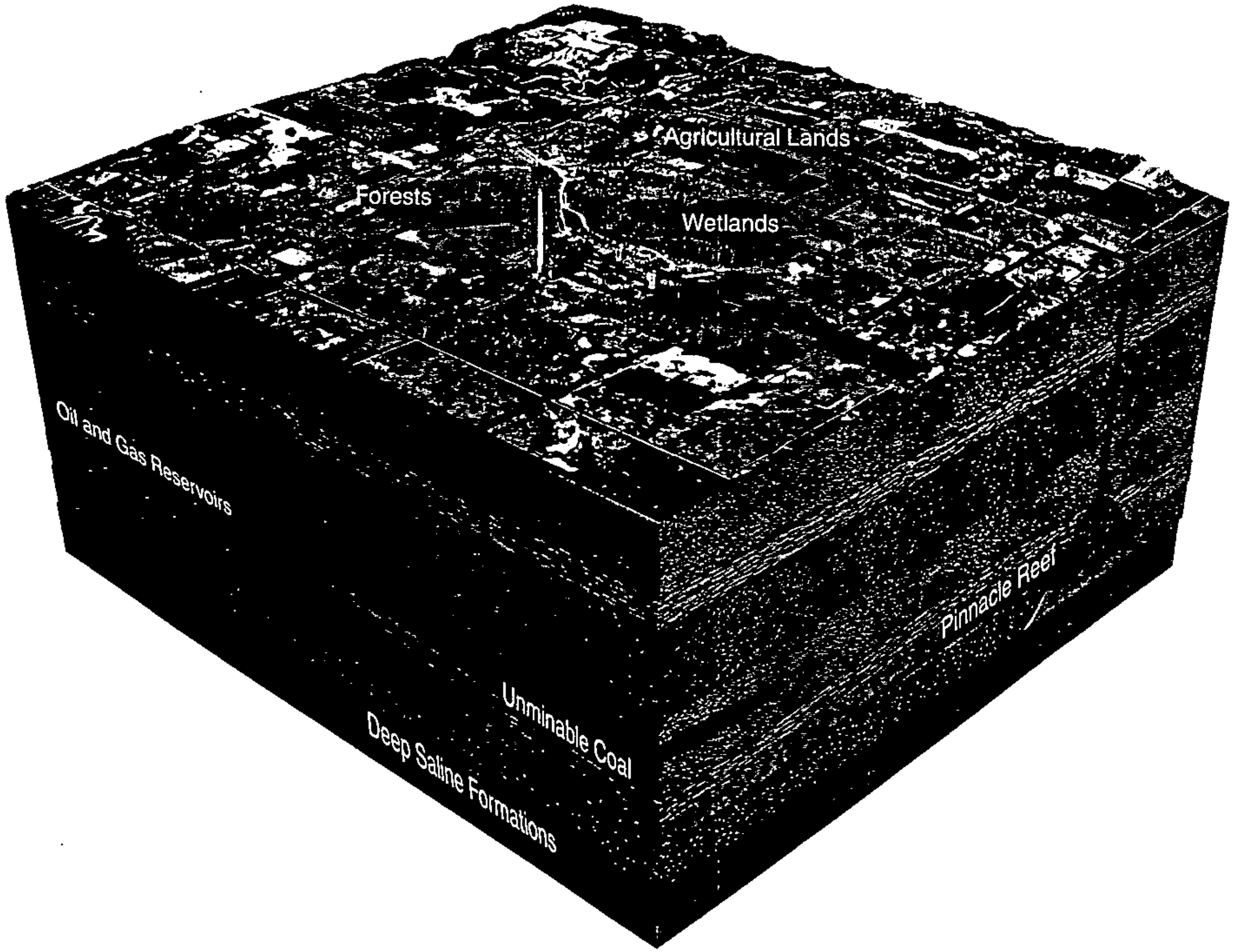
# Carbon Management

To stabilize the levels of $CO_2$ in the environment, there needs to be a reduction in the amount of $CO_2$ that is released by human activity. Reducing anthropogenic $CO_2$ emissions with the goal of stabilizing the level of $CO_2$ in the atmosphere is called carbon management. Carbon management is a complex issue because most of the anthropogenic $CO_2$ comes from the use of fossil fuels for energy, and maintaining our energy flow is critical to our economy and our quality of life. Carbon dioxide emissions can be reduced by energy conservation, the use of more efficient fossil fuel energy systems, increased use of renewable and nuclear energy, and carbon sequestration.



Carbon sequestration, also known as carbon capture and storage, is the capture and storage of $CO_2$ and other GHGs that would otherwise be emitted to the atmosphere and potentially contribute to global climate change. The GHGs can be captured at the point of emission, or they can be removed from the air. Captured gases can be used; stored in underground reservoirs or, possibly, the deep oceans; absorbed by trees, grasses, soils, and algae; or converted to rocklike mineral carbonates or other products. Carbon sequestration holds the potential to substantialy reduce GHG emissions.

There are two types of sequestration: *direct* and *indirect*. Direct, or geologic, sequestration involves capturing $CO_2$ at a source before it can be emitted to the atmosphere. The most efficient concept would use specialized processes to capture $CO_2$ at large stationary sources like factories or power plants and then inject the $CO_2$ into secure storage zones deep underground (geologic sequestration) or into the deep ocean. Indirect, or terrestrial, sequestration removes $CO_2$ from the atmosphere. Indirect sequestration employs land management practices that boost the ability of natural $CO_2$ sinks, like plants and soils, to remove carbon as $CO_2$ from the atmosphere, regardless of its source. Opportunities for indirect sequestration can be found in forests, grasslands, wetlands, and croplands.




Anthropogenic $CO_2$ can be captured and sent to storage before it enters the atmosphere (direct sequestration), or land management practices can be used to enhance carbon uptake after it enters the atmosphere (indirect sequestration).

# Geologic Sequestration

Geologic sequestration involves the capture of anthropogenic $CO_2$ before it is released to the atmosphere and then injection into deep underground geologic formations. These formations, or $CO_2$ sinks, exist in a variety of configurations in sedimentary basins and include unminable coal beds, oil and gas reservoirs, and deep geologic layers that contain salty water (brine formations).

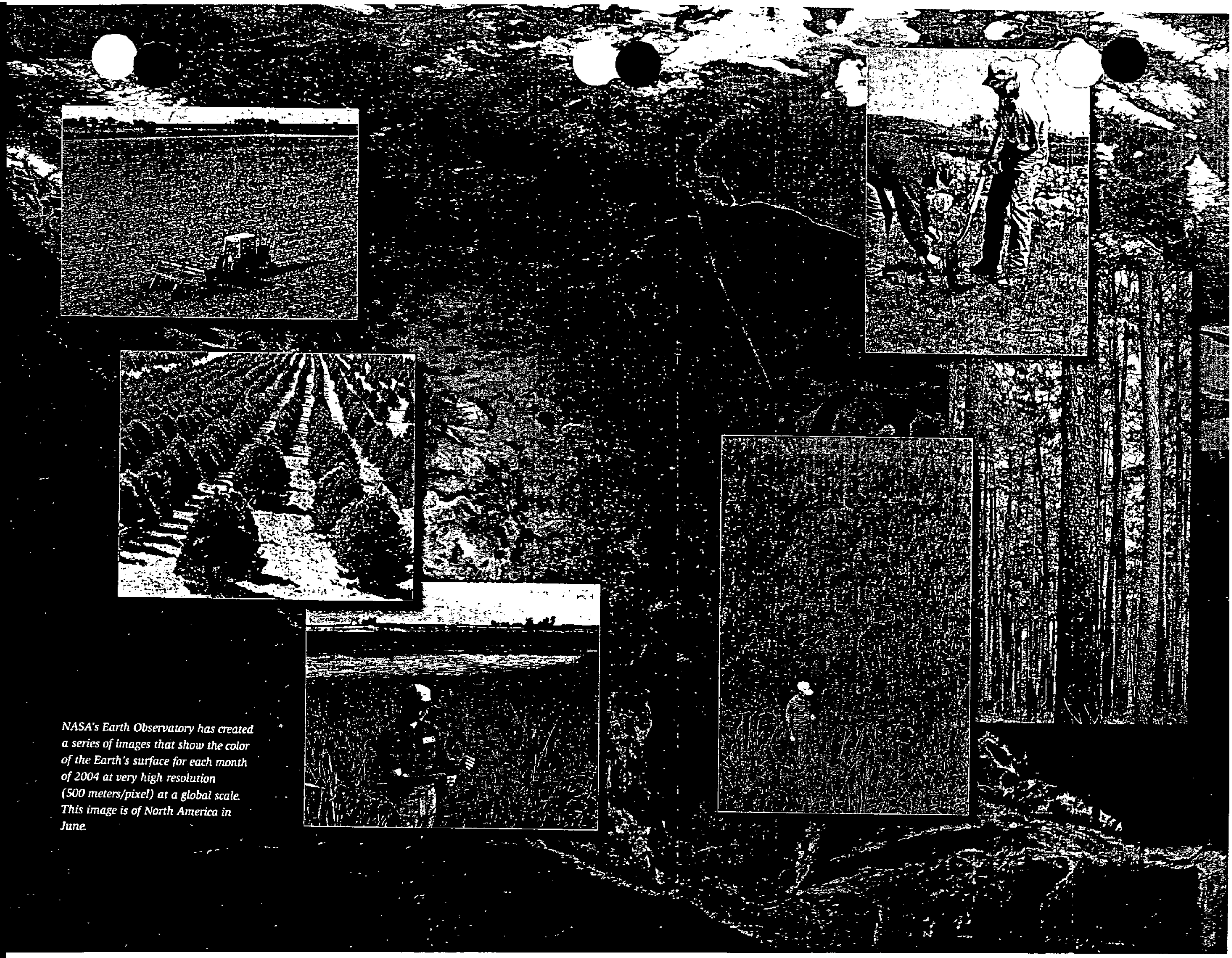
To be considered for sequestration, geologic sinks must have the characteristics that can hold the $CO_2$ in place for a long period of time (for example, a seal above a permeable zone of rock similar to the situation that would trap and store oil or natural gas), be isolated geologically from underground sources of drinking water, and be in a stable area (that is, an area not prone to earthquake activity). Successful geologic sequestration requires that the $CO_2$ stay in place and not pose a danger to human health and the environment.

Pure $CO_2$ has been stored as a gas in natural underground deposits for millions of years, and since the 1970s, oil field operators in west Texas have safely pumped millions of tons of $CO_2$ underground into oil-producing formations to increase production.

Under high-temperature and high-pressure conditions, such as those encountered in deep geologic formations (greater than 2600 feet), $CO_2$ will exist in a dense phase that is referred to as "supercritical." When injected into a geologic formation, a portion of the supercritical $CO_2$ may be dissolved in any fluids, such as water or oil, that are present in the formation, while another portion will be available to react with rock minerals. When $CO_2$ dissolves in oil, it acts as a solvent, reducing oil viscosity and increasing its mobility. The sequestration of $CO_2$ in a supercritical form is beneficial for two reasons: 1) the supercritical state maximizes the number of $CO_2$ molecules that can be injected into a given volume and 2) if injected into an oil reservoir, supercritical $CO_2$ can increase oil production, which, in turn, can be used to pay for the capture and transportation of the $CO_2$ from the original source.

As with many disciplines and technologies, a precise and descriptive vocabulary is needed to adequately describe and discuss the sequestration of $CO_2$ in geologic formations. In the petroleum industry, a rock layer that contains fluid or gas is referred to as a ***reservoir***. A rock layer that oil or gas cannot flow through is referred to as a ***trap*** or a ***cap***. In hydrogeology, a rock layer that contains water is referred to as an ***aquifer***. A rock layer that contains water with dissolved solids (salt) concentrations higher than drinking water standards is commonly known as a ***saline aquifer*** or a ***brine formation***. A rock layer that water cannot flow through is referred to as an ***aquitard*** or a ***confining bed***.

Carbon dioxide can be geologically sequestered in sedimentary basins by the following mechanisms: 1) stratigraphic and structural trapping in depleted oil and gas reservoirs, 2) solubility trapping in reservoir oil and formation waters, 3) adsorption trapping in unminable coal seams, 4) cavern trapping in salt structures, and 5) mineral immobilization.



*NASA's Earth Observatory has created a series of images that show the color of the Earth's surface for each month of 2004 at very high resolution (500 meters/pixel) at a global scale. This image is of North America in June.*

# Terrestrial Sequestration

Terrestrial sequestration occurs at the Earth's surface through management practices that increase the amount of the carbon stored in roots and vegetable matter in the soil. It is important to remember that terrestrial sequestration does not store $CO_2$ as a gas but stores the carbon portion of the $CO_2$. If the soil is disturbed and the soil carbon comes in contact with oxygen in the air, the exposed soil carbon can combine with $O_2$ to form $CO_2$ gas and reenter the atmosphere, reducing the amount of carbon in storage.

Promising land and water management practices that lead to terrestrial sequestration of carbon include conservation tillage, reducing soil erosion, and minimizing soil disturbance; using buffer strips along waterways; enrolling land in conservation programs; restoring and better managing wetlands; eliminating summer fallow; using perennial grasses and winter cover crops; and fostering an increase in forests. Typically land management practices that store carbon have other benefits to the ecosystem including biodiversity, water filtration, increased soil health and fertility, and many others.

Soil can only take in and store a limited amount of carbon. On average, after a 50- to 100-year time frame, the soils will have reached equilibrium and not accept any more carbon. Once this "steady state" has been reached, the carbon will remain sequestered in the soil as long as the land is undisturbed and conservation land management practices are continued.

Terrestrial sequestration is important because it can be implemented immediately and can begin to reduce atmospheric $CO_2$ levels in the next few years. Using terrestrial sequestration now means we can get started on reducing $CO_2$ levels in the atmosphere while we adopt other carbon control measures.

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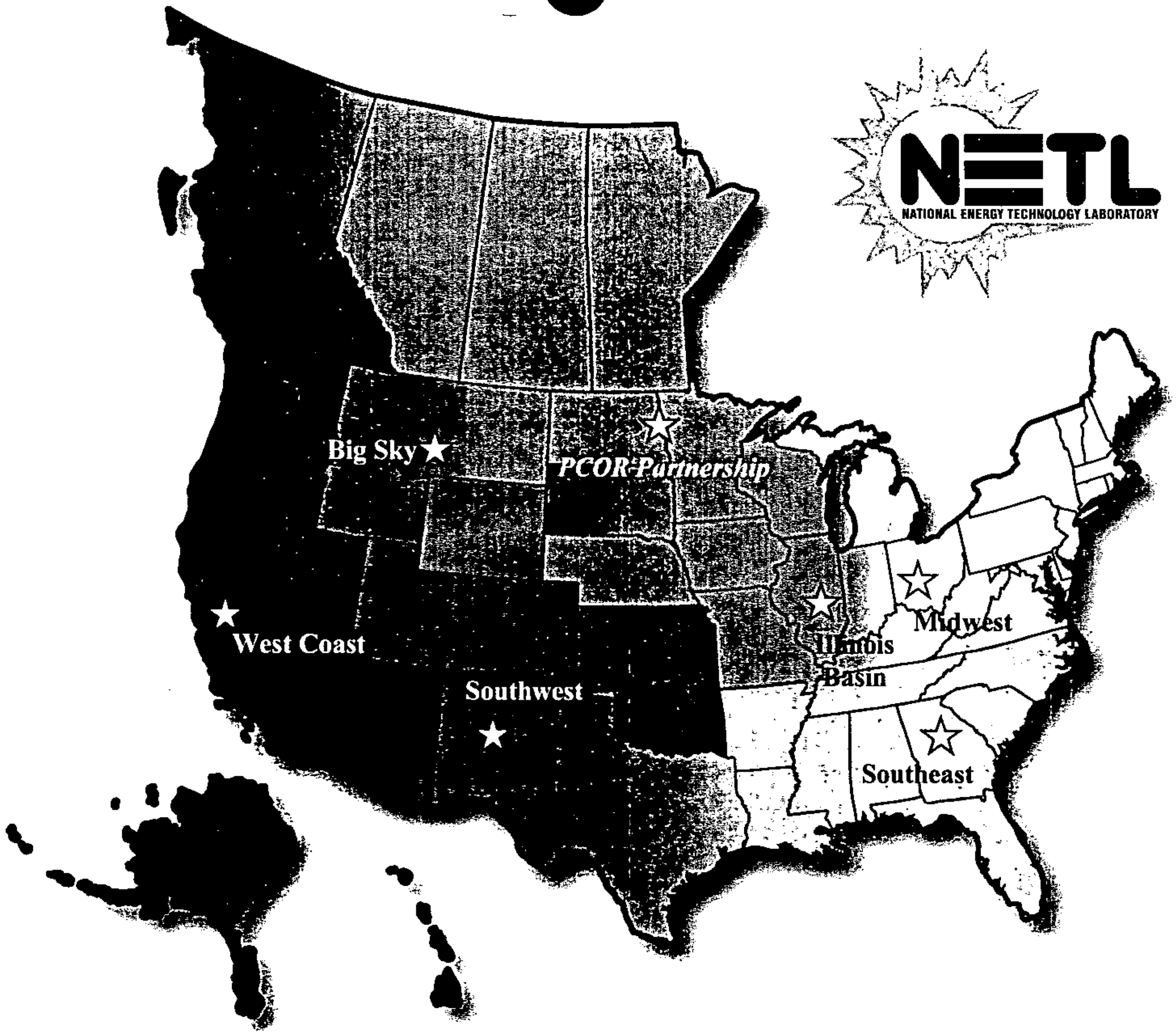


# DOE's Carbon Sequestration Regional Partnerships

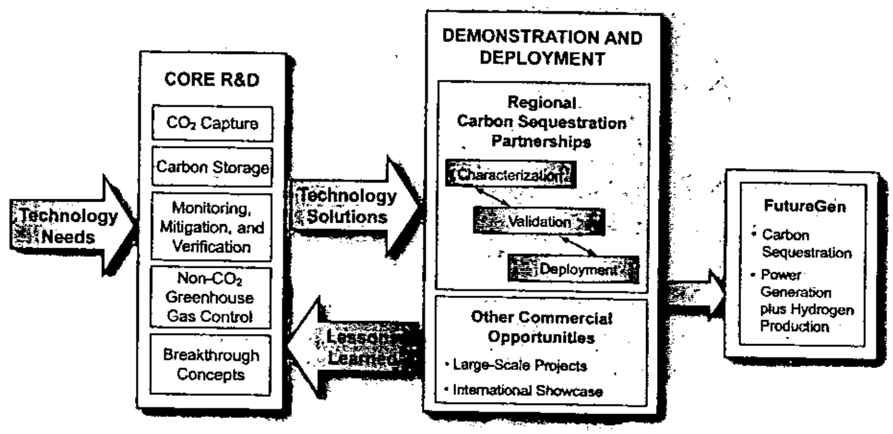
If the decision is made that carbon sequestration must be implemented in the United States on a broad scale and in a relatively short time frame (meaning over the next 10–20 years), it will take a concerted effort of federal and state agencies working in cooperation with technology developers, regulators, and others to put into place both the economic framework and the necessary infrastructure to achieve meaningful carbon reductions.

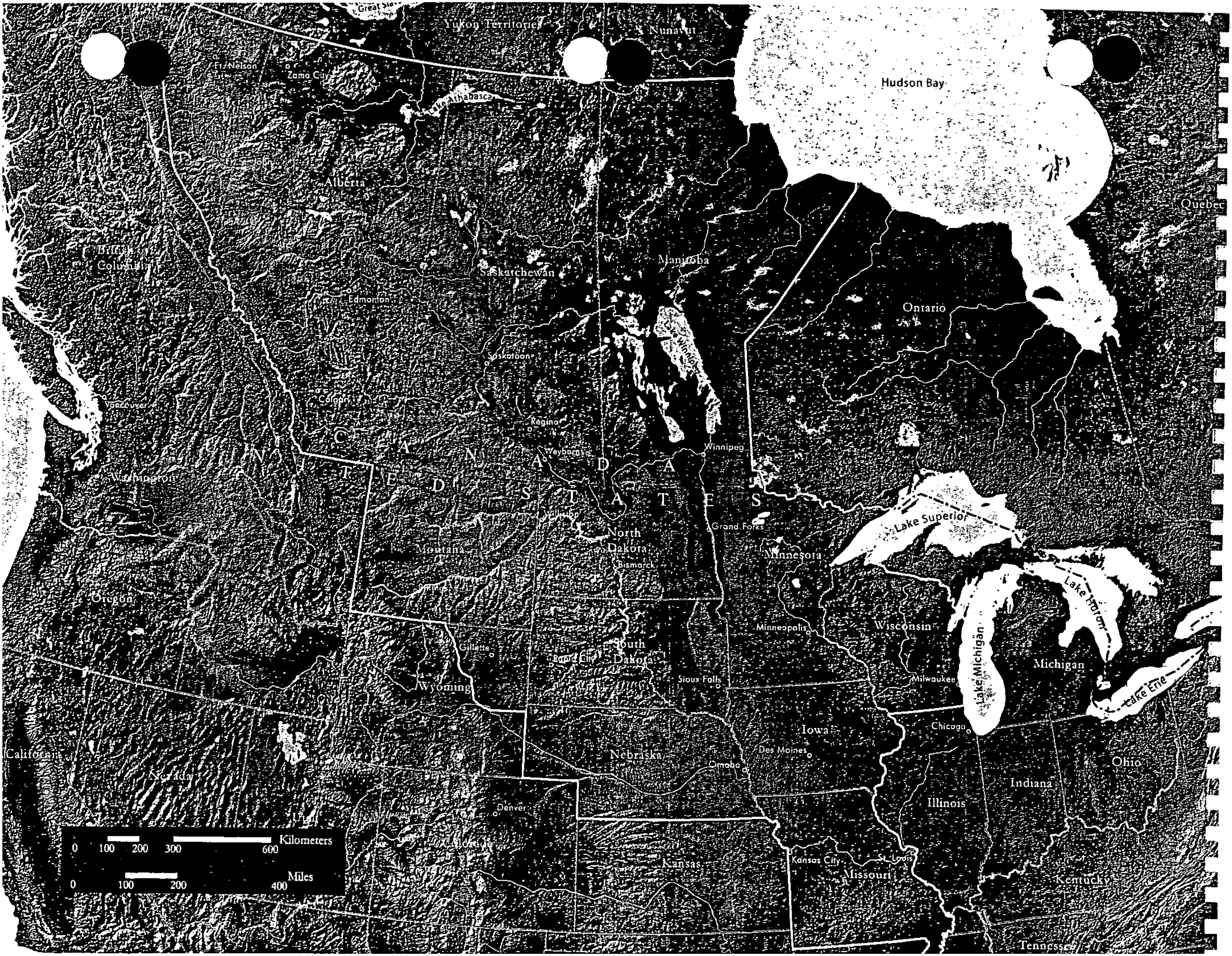
To ensure that America is fully prepared to implement this climate change mitigation option, then-Secretary of Energy Spencer Abraham on November 21, 2002, announced plans to create a national network of public–private sector partnerships that would determine the most suitable technologies, regulations, and infrastructure needs for carbon capture, storage, and sequestration in different areas of the country. The Secretary called the partnership initiative "the centerpiece of our sequestration program." The partnerships are a key part of President Bush's Global Climate Change Initiative.

On August 16, 2003, following a competitive evaluation, Energy Secretary Spencer Abraham named seven teams, called Regional Carbon Sequestration Partnerships, to evaluate and promote the carbon sequestration technologies and infrastructure best suited to their unique regions. The original partnerships included leaders from more than 140 organizations spanning 33 states, three American Indian nations, and two Canadian provinces. By February 2007, the partnerships had expanded to include 350 organizations spanning 41 states, three American Indian nations, and four Canadian provinces.[12]

Today, the seven U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL) partnerships are developing the framework needed to validate and potentially deploy carbon sequestration technologies. They are evaluating numerous sequestration approaches that have emerged in the last few years to determine which are best suited for specific regions of the country. They are also identifying possible regulations and the necessary infrastructure requirements should our society determine that sequestration be deployed on a wide scale in the future.

U.S. DOE Carbon Sequestration Technology Development

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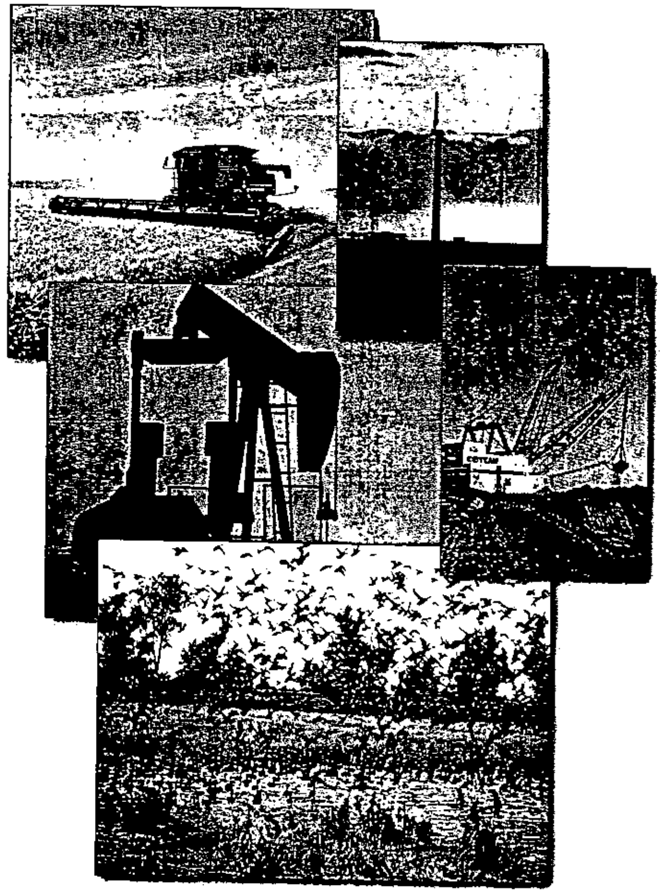
Yukon Territories
Nunavut
Quebec
Ft. Nelson
Zama City
Lake Athabasca
Alberta
British Columbia
Saskatchewan
Manitoba
Ontario
Edmonton
Saskatoon
Calgary
Vancouver
Regina
Weyburn
Winnipeg
CANADA
UNITED STATES
Washington
Oregon
Montana
North Dakota
Bismarck
Grand Forks
Minnesota
Lake Superior
Lake Huron
Lake Michigan
Lake Erie
Minneapolis
Wisconsin
Michigan
Milwaukee
Gillette
South Dakota
Rapid City
Sioux Falls
Wyoming
Iowa
Des Moines
Chicago
California
Nebraska
Omaha
Ohio
Indiana
Illinois
Denver
Kansas
Kansas City
St. Louis
Missouri
Kentucky
Tennessee
0 100 200 300 600 Kilometers
0 100 200 400 Miles

# The PCOR Partnership

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 $CO_2$ emissions from stationary sources of $CO_2$ in the central interior of North America. The PCOR Partnership is managed by the Energy & Environmental Research Center (EERC) at the University of North Dakota and is one of seven regional partnerships funded by DOE's Regional Carbon Sequestration Partnership Program and a broad array of project sponsors.

The PCOR Partnership has assessed and prioritized the opportunities for sequestration in the region and identified and worked to resolve the technical, regulatory, and environmental barriers to the most promising sequestration opportunities. At the same time, the PCOR Partnership has informed policy makers and the public regarding $CO_2$ sources, sequestration strategies, and sequestration opportunities.

- Based on available data, the states and provinces within the PCOR Partnership region contributed roughly 13% of the total $CO_2$ emissions from stationary sources in the United States and Canada.[13]
- Enhanced oil recovery (EOR), depleted oil and gas zones, deep saline reservoirs, and unminable coals in the PCOR Partnership region represent opportunities for direct (geologic) sequestration projects.
- The PCOR Partnership region is currently home to the Weyburn direct sequestration EOR demonstration project. There are four additional $CO_2$ sequestration field validation test sites in the PCOR Partnership region.
- Croplands, wetlands, rangelands, and forests in the PCOR Partnership region represent opportunities for indirect (terrestrial) sequestration projects.
- The PCOR Partnership region is currently home to several indirect sequestration research projects involving wetlands, cultivated land, prairie, and forest.



# Current PCOR Partnership Partners

NETL
EERC, UND University of North Dakota, Grand Forks
ABENGOA BIOENERGY
ADVANCED GEOTECHNOLOGY
AIR PRODUCTS
Alberta Energy
EUB
AGS Alberta Geological Survey

ALLETE
Ameren
ACCCE American Coalition for Clean Coal Electricity
American Lignite Energy
Apache Canada Ltd.
Basin Electric Power Cooperative
Blue Source
BNI COAL
British Columbia Ministry of Energy and Mines
Carbozyme Inc.
Dakota Gasification Company

Ducks Unlimited Canada
Ducks Unlimited
Eagle Operating Inc.
EICCD
Enbridge
Encore Acquisition Company
Environment Canada
Excelsior Energy
Fischer Oil and Gas, Inc.
Great Northern
Great River Energy

HESS
HUNTSMAN
Interstate Oil and Gas Compact Commission
DNR
Lignite Energy Council
Manitoba
Marathon
MEG Energy Corp
Melzer CO2nsulting
Minnesota Geological Survey
Minnesota Power

Minnkota Power Cooperative, Inc.
Missouri Department of Natural Resources
Missouri River Energy Services
Montana-Dakota Utilities Co.
Montana Department of Environmental Quality
National Commission on Energy Policy
Natural Resources Canada
Nexant

North American Coal Corporation
North Dakota Department of Commerce
North Dakota Department of Health
North Dakota Geological Survey
North Dakota Oil and Gas Division
Industrial Commission of North Dakota Lignite Research, Development and Marketing Program
Industrial Commission of North Dakota Oil and Gas Research Council
North Dakota Natural Resources Trust
North Dakota Petroleum Council
NDSU North Dakota State University

Otter Tail Power Company
PTRC
Prairie Public
Pratt & Whitney, A United Technologies Company
RAMGEN
RPS Energy
Saskatchewan Industry and Resources
SaskPower
Schlumberger

Shell Canada Limited
Spectra Energy
Strategic West Energy Ltd.
Suncor Energy
TGS
University of Alberta
USGS
Western Governors' Association
Westmoreland Coal Company
Wisconsin Department of Agriculture, Trade & Consumer Protection
Xcel Energy

6/08

# Current PCOR Partnership Partners

Since October 2005, the PCOR Partnership has brought together more than 75 public and private sector stakeholders that have expertise in power generation, energy exploration and production, geology, engineering, the environment, agriculture, forestry, and economics. Our partners are the backbone of the PCOR Partnership and provide data, guidance, and practical experience with direct and indirect sequestration, including value-added projects.

Current PCOR Partnership Partners:

- U.S. Department of Energy National Energy Technology Laboratory
- University of North Dakota Energy & Environmental Research Center
- Abengoa Bioenergy New Technologies
- Advanced Geotechnology, a division of Hycal Energy Research Laboratories, Ltd.
- Air Products and Chemicals
- Alberta Department of Energy
- Alberta Energy and Utilities Board
- Alberta Geological Survey
- ALLETE
- Ameren Corporation
- American Coalition for Clean Coal Electricity
- American Lignite Energy (ALE)
- Apache Canada Ltd.
- Basin Electric Power Cooperative
- Blue Source, LLC
- BNI Coal, Ltd.
- British Columbia Ministry of Energy, Mines and Petroleum Resources
- Carbozyme, Inc.
- Dakota Gasification Company
- Ducks Unlimited Canada
- Ducks Unlimited, Inc.
- Eagle Operating, Inc.
- Eastern Iowa Community College District
- Enbridge Inc.
- Encore Acquisition Company
- Environment Canada
- Excelsior Energy Inc.
- Fischer Oil and Gas, Inc.
- Great Northern Power Development, LP
- Great River Energy
- Hess Corporation
- Huntsman Corporation
- Interstate Oil and Gas Compact Commission
- Iowa Department of Natural Resources – Geological Survey
- Lignite Energy Council
- Manitoba Geological Survey
- Marathon Oil Company
- MEG Energy Corporation
- Melzer Consulting
- Minnesota Geological Survey – University of Minnesota
- Minnesota Power
- Minnkota Power Cooperative, Inc.
- Missouri Department of Natural Resources
- Missouri River Energy Services
- Montana–Dakota Utilities Co.
- Montana Department of Environmental Quality
- National Commission on Energy Policy
- Natural Resources Canada
- Nexant, Inc.
- North American Coal Corporation
- North Dakota Department of Commerce Division of Community Services
- North Dakota Department of Health
- North Dakota Geological Survey
- North Dakota Industrial Commission Department of Mineral Resources, Oil and Gas Division
- North Dakota Industrial Commission Lignite Research, Development and Marketing Program
- North Dakota Industrial Commission Oil and Gas Research Council
- North Dakota Natural Resources Trust
- North Dakota Petroleum Council
- North Dakota State University
- Otter Tail Power Company
- Petroleum Technology Transfer Council
- Prairie Public Broadcasting
- Pratt & Whitney Rocketdyne, Inc.
- Ramgen Power Systems, Inc.
- RPS Energy Canada Ltd. – APA Petroleum Engineering Inc.
- Saskatchewan Industry and Resources
- SaskPower
- Schlumberger
- Shell Canada Energy
- Spectra Energy
- Strategic West Energy Ltd.
- Suncor Energy Inc.
- TGS Geological Products and Services
- University of Alberta
- U.S. Geological Survey Northern Prairie Wildlife Research Center
- Western Governors' Association
- Westmoreland Coal Company
- Wisconsin Department of Agriculture, Trade and Consumer Protection
- Xcel Energy

Coal
Gasification Facility

Coal-Fired
Power Plant

Refinery

Ethanol Plant

Agricultural
Processing
Plant

Gas Processing
Plant

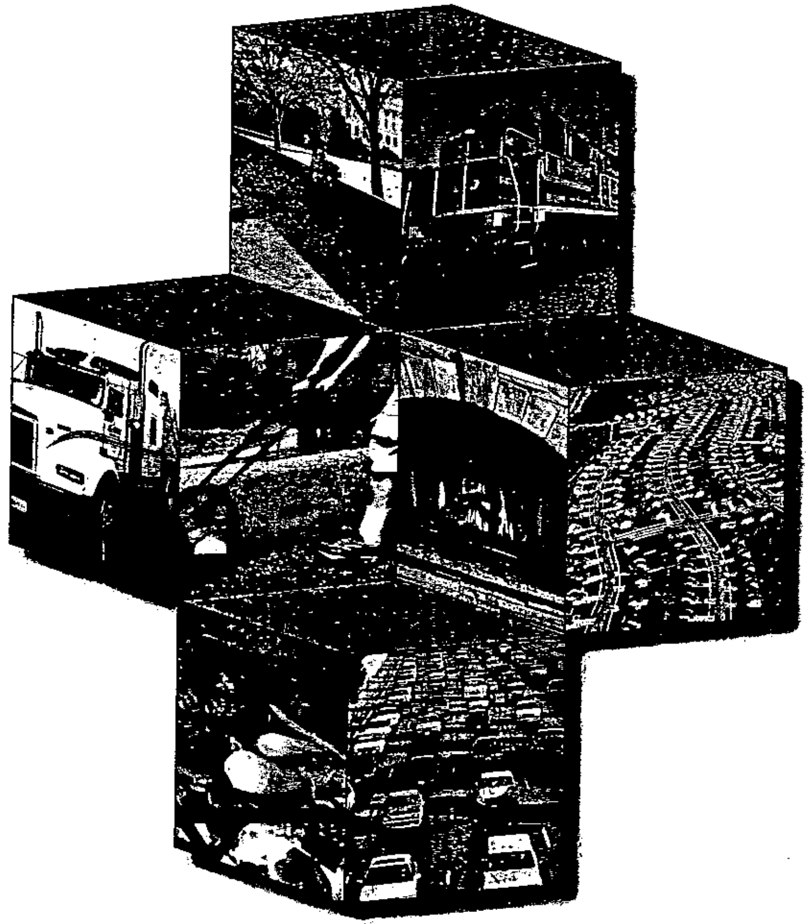
Cement Kiln

# Anthropogenic $CO_2$ Sources

In 2004, the world produced approximately 30 billion tons of $CO_2$ from human activity (anthropogenic $CO_2$).[14] Anthropogenic $CO_2$ is contributed to the atmosphere primarily through the use of fossil fuels in transportation, electrical generation, heating and cooling, and industrial activities. Additional anthropogenic $CO_2$ is also generated through agriculture.

Together the United States and Canada generate about a quarter of the world's anthropogenic $CO_2$. The United States produces about 6.5 billion tons (22%) of the global total, and Canada adds another 0.7 billion tons (over 2%).[14] About 40% of Canada's anthropogenic $CO_2$ and 9% of the anthropogenic $CO_2$ generated in the United States are generated in the PCOR Partnership region.

The PCOR Partnership is focused mainly on finding practical ways to manage $CO_2$ from major stationary sources related to electricity generation; energy exploration and production activities; agricultural processing; fuel, chemicals, and ethanol production; and various manufacturing and industrial activities. These major stationary sources account for about 58% of anthropogenic $CO_2$ in the region. The PCOR Partnership is also working to implement terrestrial sequestration options that can capture and store $CO_2$ from the atmosphere.

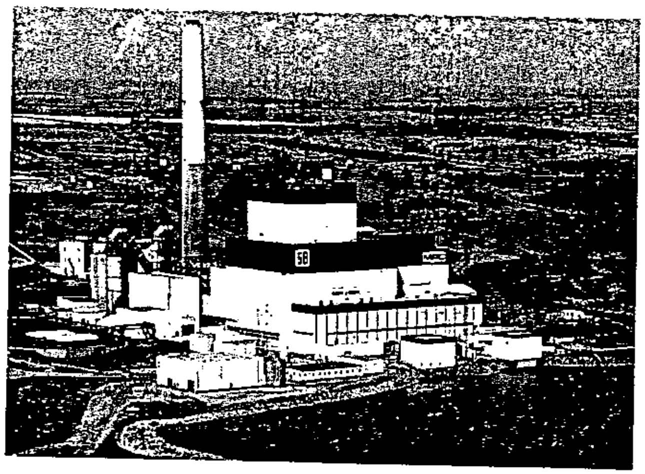


Major Stationary $CO_2$ Sources in the PCOR Partnership Region
Annual $CO_2$ Output (tons)
25–500,000
500,000–5,000,000
5,000,000–10,000,000
10,000,000–15,000,000
15,000,000–20,000,000
0 100 200 300 600 Kilometers
0 100 200 400 Miles

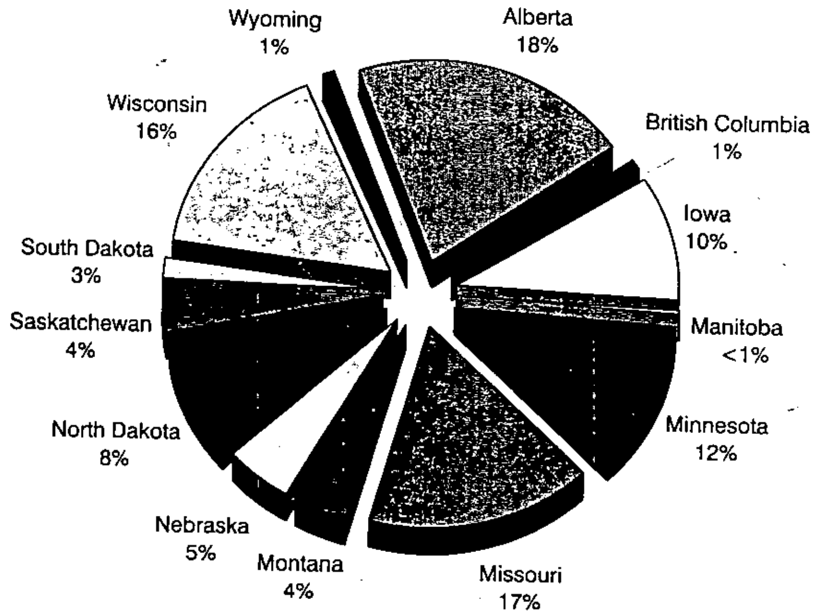
# $CO_2$ Sources

The PCOR Partnership project has identified, quantified, and categorized 1545 stationary $CO_2$ sources in the region. These stationary sources have a combined annual $CO_2$ output of nearly 576 million tons or 9.9 trillion cubic feet. And, although not a target source of $CO_2$ for direct sequestration, the transportation sector in the U.S. portion of the PCOR Partnership region contributes nearly 188 million additional tons of $CO_2$ to the atmosphere every year.[13]

The annual output from the various stationary sources ranges from 10 million to 18 million tons for the larger coal-fired electric generation facilities, to under 5000 tons for industrial and agricultural processing facilities. In some cases, the distribution of the sources with the largest $CO_2$ output is coincident with the availability of fossil fuel resources, namely, coal, natural gas, and oil. This relationship is significant with respect to geologic sequestration opportunities. Many of the smaller sources are concentrated around more heavily industrialized metropolitan regions such as southeastern Minnesota, southeastern Wisconsin, and eastern Missouri.



**Distribution of Annual $CO_2$ Output from Major Stationary Sources in the PCOR Partnership Region**




Classification of Major Stationary $CO_2$ Sources in the PCOR Partnership Region
$CO_2$ Source Types
Ag-Related Processing
Electrical Utility
Industrial
Petroleum and Natural Gas
0 100 200 300 600 Kilometers
0 100 200 400 Miles

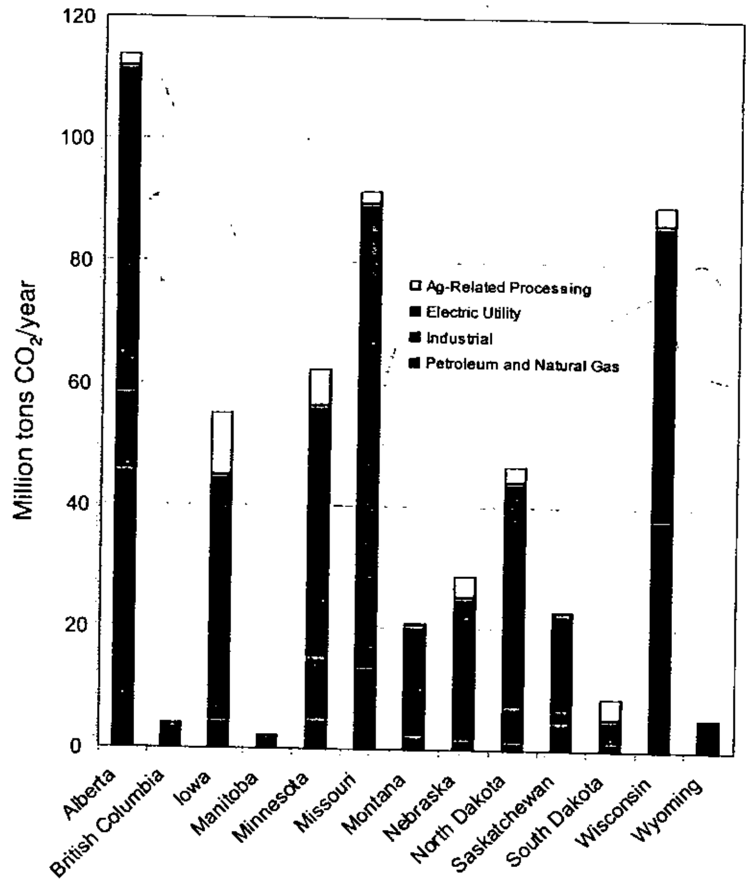
# $CO_2$ Source Types

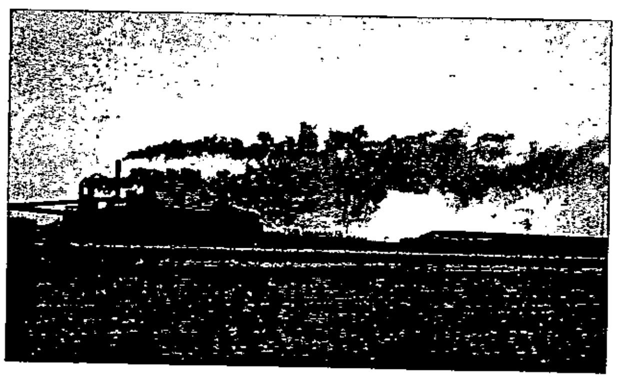
The geographic and socioeconomic diversity of the PCOR Partnership region is reflected in the diversity of the carbon dioxide sources found there. $CO_2$ is emitted from electricity generation; energy exploration and production activities; agricultural processing; fuel, chemicals, and ethanol production; and various manufacturing and industrial activities. The majority of the region's emissions come from just a few source types. About two-thirds of the $CO_2$ is emitted during electricity generation. Additional significant emissions come from industrial sources, petroleum refining and natural gas processing, ethanol production, and agricultural processing.

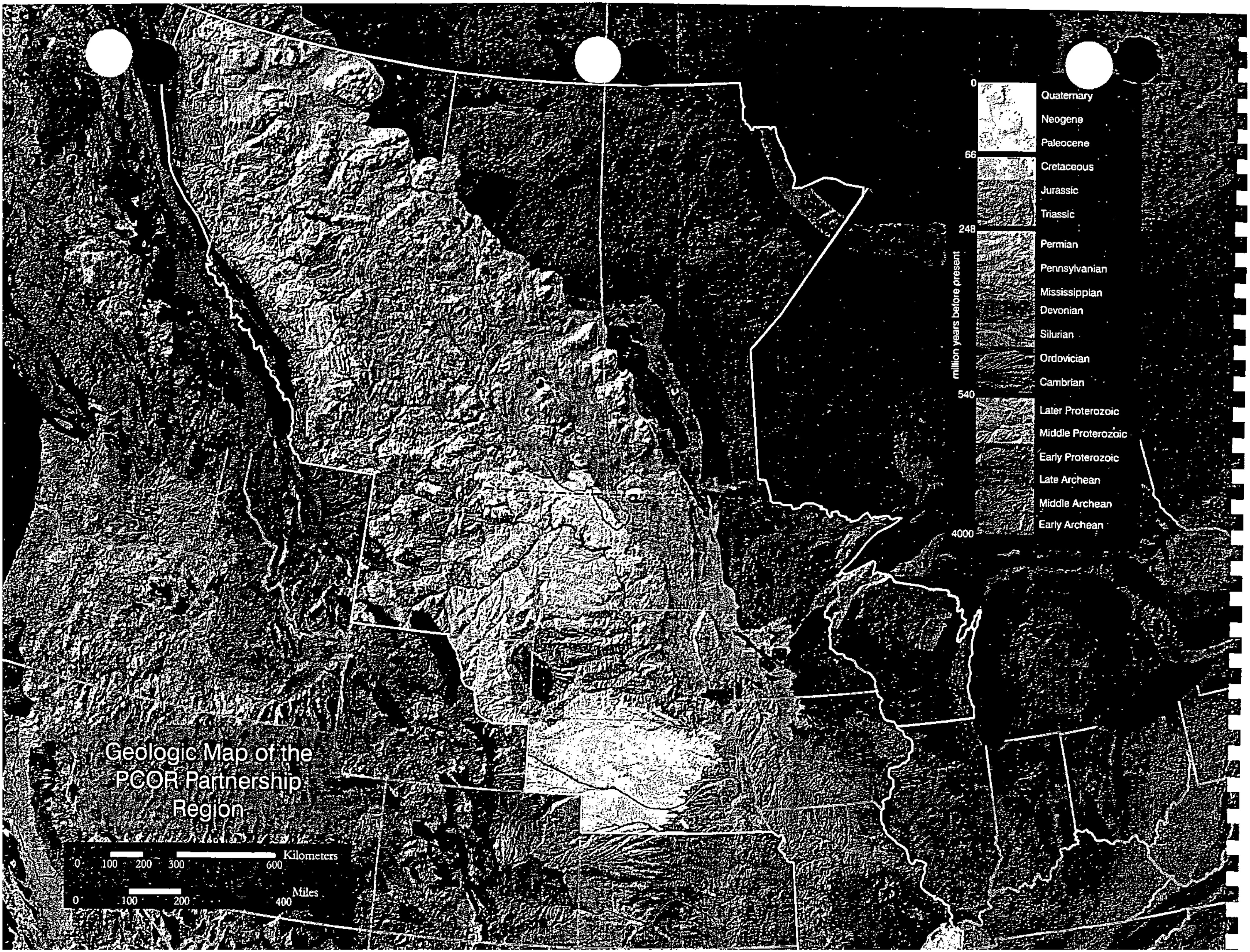
The emission profile (i.e., the percentage of $CO_2$ emissions from various source types) for the Canadian portion of the PCOR Partnership is virtually identical to that of Canada as a whole. When compared to the total U.S. $CO_2$ emissions, the states in the PCOR Partnership region emit relatively more $CO_2$ from electric utilities and less from industries and transportation.[13]

While the $CO_2$ emissions from the individual PCOR Partnership point sources are no different from similar sources located around North America, the wide range of source types within the PCOR Partnership region offers the opportunity to evaluate the capture, separation, and sequestration of $CO_2$ in many different scenarios.

**Annual $CO_2$ Output by Major Source Categories for the States and Provinces in the PCOR Partnership Region**





Geologic Map of the
PCOR Partnership
Region
0
Quaternary
Neogene
Paleocene
66
Cretaceous
Jurassic
Triassic
248
Permian
Pennsylvanian
Mississippian
Devonian
Silurian
Ordovician
Cambrian
540
Later Proterozoic
Middle Proterozoic
Early Proterozoic
Late Archean
Middle Archean
Early Archean
4000
million years before present
0 100 200 300 600 Kilometers
0 100 200 400 Miles

# Geologic Framework

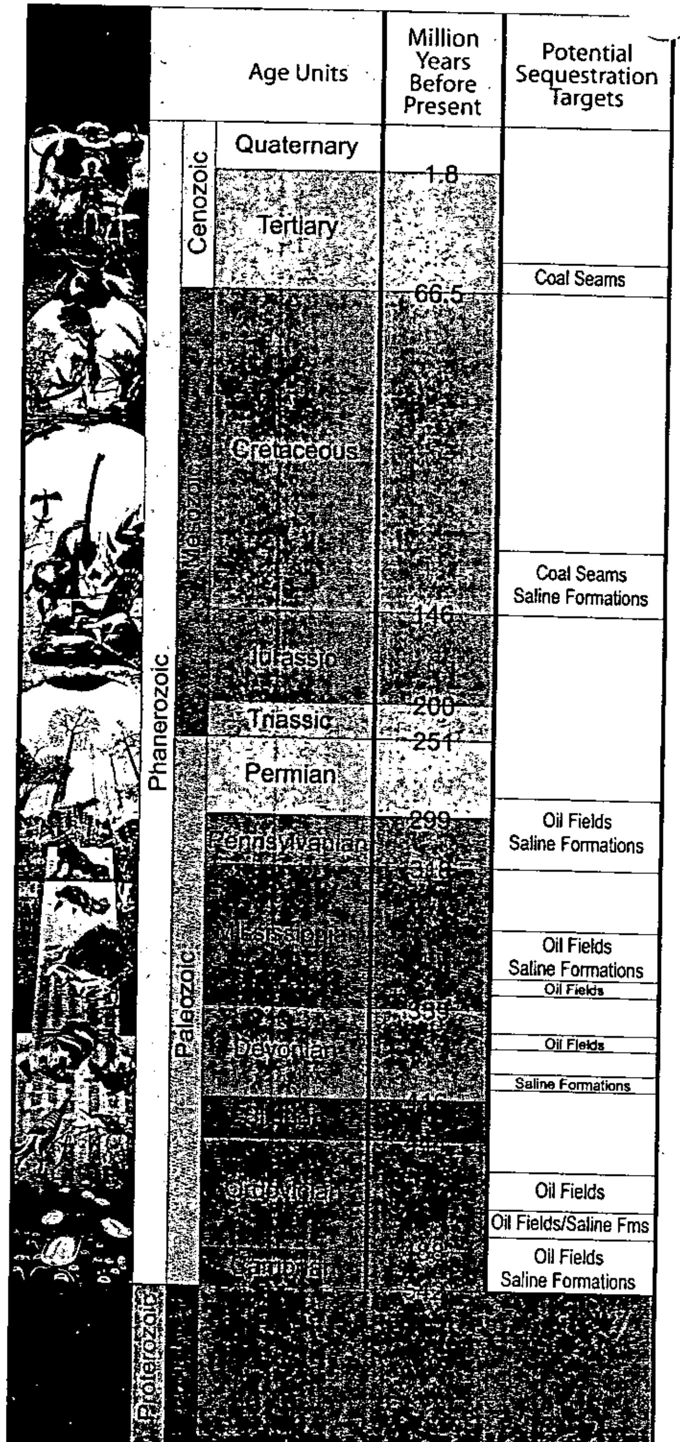
The same geologic framework that makes a large percentage of the PCOR Partnership region a significant producer of fossil fuels also creates prime opportunities for $CO_2$ sequestration. The western two-thirds of the region is underlain by great thicknesses of sedimentary rocks that span the entire stratigraphic record. The remainder of the region is underlain by Precambrian igneous and metamorphic rocks of the Canadian Shield.

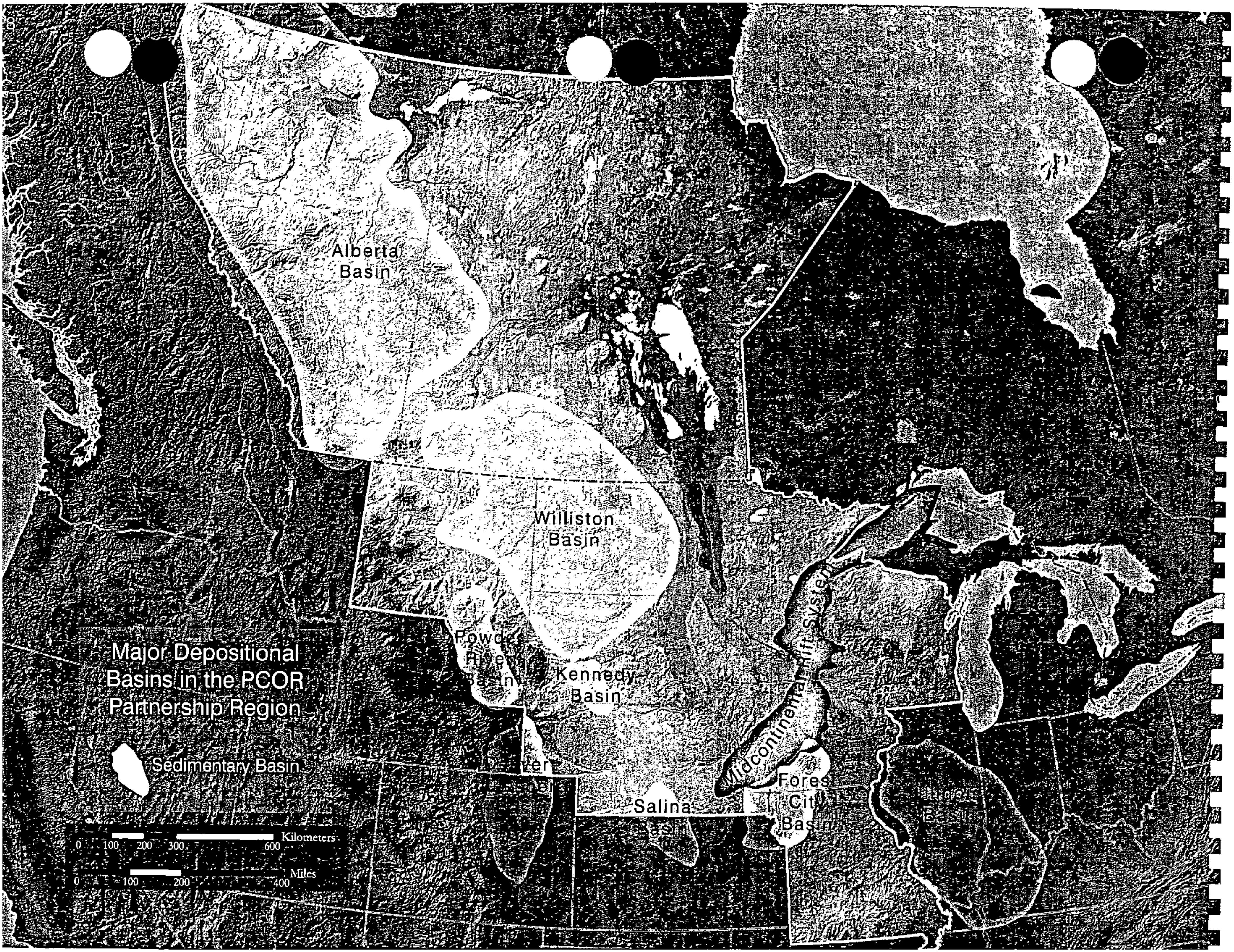
The most extensive sequence of rocks in central North America is represented by the Cretaceous-aged marine sediments that were deposited in the former western interior seaway. This ancient sea extended from the Gulf of Mexico, across the center of North America, to the Arctic Ocean. The deeper portions of these strata and the underlying paleozoic-aged sediments offer tremendous capacity for sequestration.

As the sea retreated from the continent, deltaic and marginal marine environments were established. The remains of these ecosystems are evident in the vast subbituminous coal and lignite reserves of Alberta, Wyoming, Montana, and North Dakota. The unminable portions of these deposits also provide opportunities for $CO_2$ sequestration.

In the millions of years since the seaway retreated, the central portion of the North American continent has been relatively stable. This tectonic stability is of prime importance with respect to safe and secure $CO_2$ sequestration in deep geologic formations.

*Former extent of the Cretaceous-aged western interior seaway.*




Major Depositional
Basins in the PCOR
Partnership Region
Sedimentary Basin
Alberta Basin
Williston Basin
Powder River Basin
Kennedy Basin
Salina Basin
Forest City Basin
Midcontinental Rift System
0 100 200 300 600 Kilometers
0 100 200 400 Miles

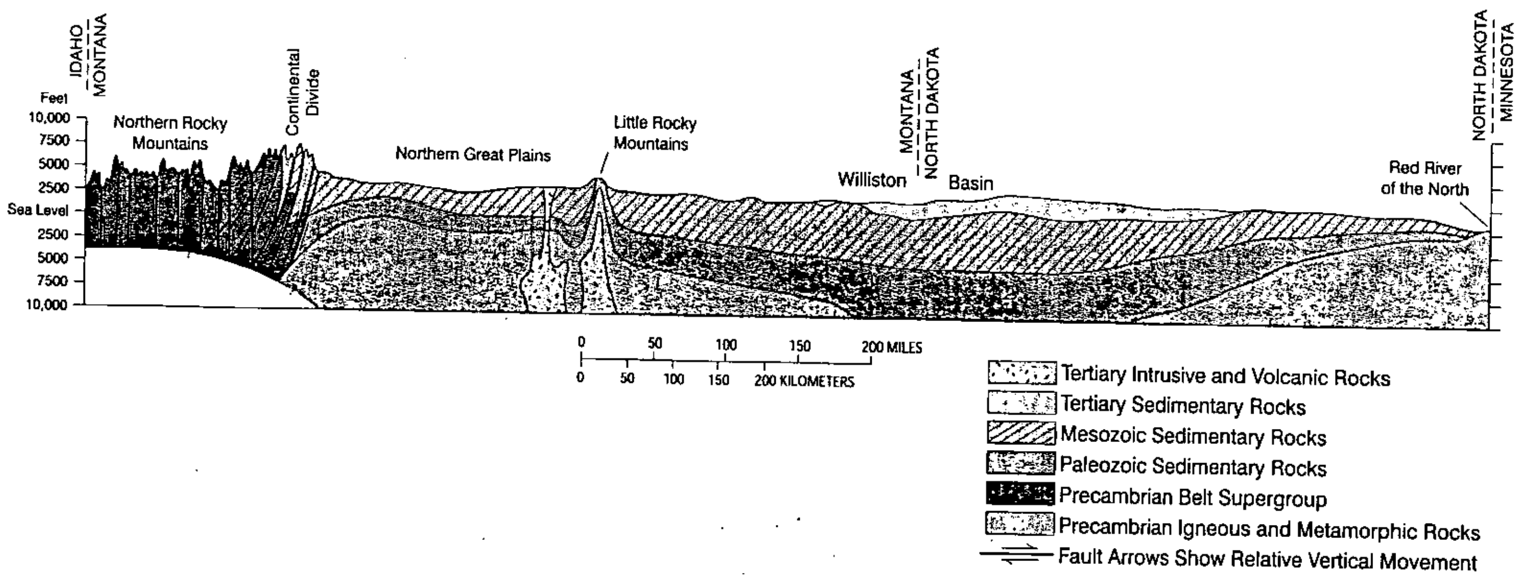
# Sedimentary Basins

Several relatively large and deep basins are found in the PCOR Partnership region, each with a sedimentary cover thousands of feet thick. The basins in the PCOR Partnership region have significant potential as geologic sinks for sequestering $CO_2$. Geologic sinks that may be suitable for long-term sequestration of $CO_2$ include both active and depleted petroleum reservoirs, deep saline formations, and coal seams, all of which are common in these basins.

While general information on the structural geology, lithostratigraphy, hydrostratigraphy, and petroleum geology of these basins is available, additional characterization data for specific geologic sinks will be necessary. Rocks that have been explored or developed for hydrocarbon recovery have been geologically characterized to a great extent, while non-hydrocarbon-bearing zones (such as saline formations) will require significantly more geologic investigation prior to large-scale sequestration.

**Midcontinental Rift System**

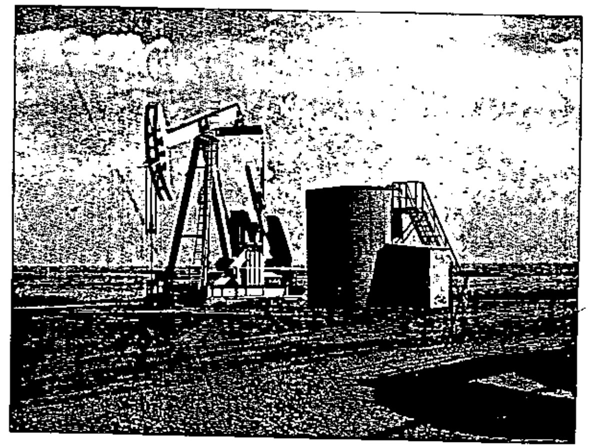
The PCOR Partnership region includes other areas besides the major petroleum-producing basins that are underlain by thick sequences of sedimentary rock. One of the largest and most notable of these areas is the Midcontinental Rift System, which stretches from eastern Nebraska across central Iowa and south-central Minnesota to the western portion of Lake Superior. The sedimentary rocks of Midcontinental Rift System may be viable locations for $CO_2$ sequestration. Because oil and gas have never been discovered in the Midcontinental Rift System, very few deep wells have been drilled in the area; therefore, little is known about the characteristics of these rocks. Continued regional characterization activities being conducted under Phase II of the PCOR Partnership will result in a better understanding of the potential for the sedimentary rocks of the Midcontinental Rift System to sequester large volumes of $CO_2$.



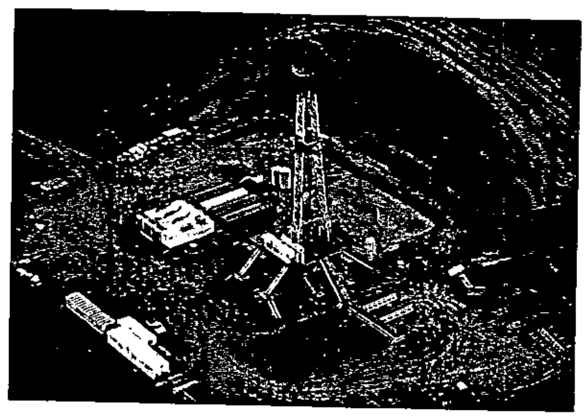

Alberta Basin
Williston Basin
Powder River Basin
Kennedy Basin
Salina
Forest City Basin
Midcontinent Rift System
Distribution of Oil Fields in the PCOR Partnership Region
Oil Field
Sedimentary Basin
0 100 200 300 600 Kilometers
0 100 200 400 Miles

# Oil and Gas Fields

The geology of carbon dioxide sequestration is analogous to the geology of petroleum exploration; the search for oil is the search for sequestered hydrocarbons. Oil fields have many characteristics that make them excellent target locations to store $CO_2$. Therefore, the geologic conditions that are conducive to hydrocarbon sequestration are also the conditions that are conducive to $CO_2$ sequestration. The three requirements for sequestering hydrocarbons are a hydrocarbon source, a suitable reservoir, and an impermeable trap. These requirements are the same as for sequestering $CO_2$, except that the source is artificial and the reservoir is referred to as a sink.

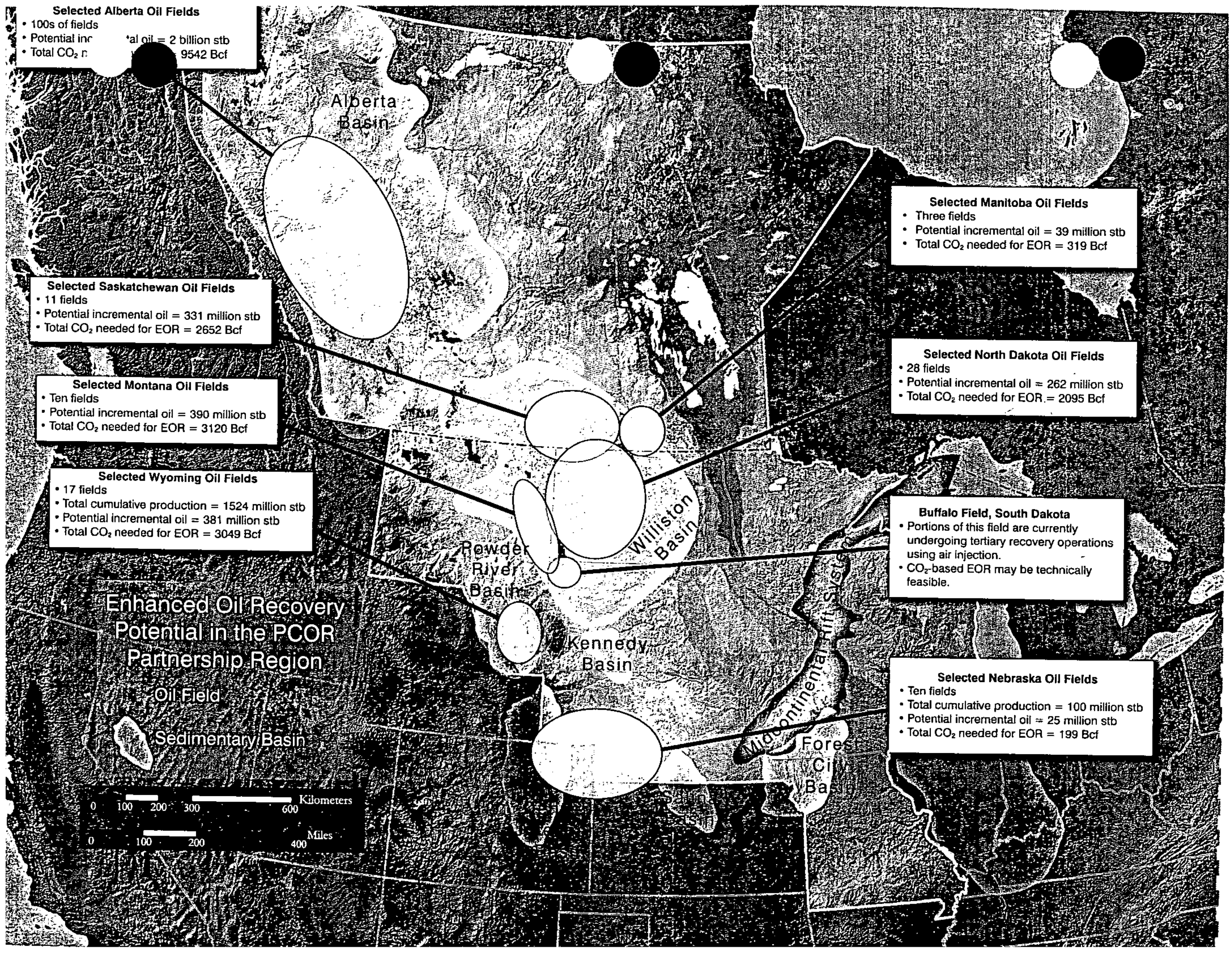


A single oil field can have multiple zones of accumulation that are commonly referred to as pools, although specific legal definitions of fields, pools, and reservoirs vary for each state or province. Once injected into an oil field, $CO_2$ may be sequestered in a pool through dissolution into the formation fluids (oil and/or water), as a buoyant supercritical-phase $CO_2$ plume at the top of the reservoir (depending on the location of the injection zone within the reservoir), and/or mineralized through geochemical reactions between the $CO_2$, formation waters, and formation rock matrix.



Oil is drawn from the many oil fields in the PCOR Partnership region from depths ranging from 2500 to 4000 feet for the shallower pools and up to 12,000 to 16,000 feet for the deepest pools.

Although oil was discovered in this region in the late 1800s, significant development and exploration did not begin until the late 1940s and early 1950s. The body of knowledge gained in the past 60 years of exploration and production of hydrocarbons in this region is a significant step toward understanding the mechanisms for secure sequestration of significant amounts of $CO_2$.



Selected Alberta Oil Fields
• 100s of fields
• Potential inc   al oil = 2 billion stb
• Total CO2 n   9542 Bcf
Alberta Basin
Selected Saskatchewan Oil Fields
• 11 fields
• Potential incremental oil = 331 million stb
• Total CO2 needed for EOR = 2652 Bcf
Selected Montana Oil Fields
• Ten fields
• Potential incremental oil = 390 million stb
• Total CO2 needed for EOR = 3120 Bcf
Selected Wyoming Oil Fields
• 17 fields
• Total cumulative production = 1524 million stb
• Potential incremental oil = 381 million stb
• Total CO2 needed for EOR = 3049 Bcf
Selected Manitoba Oil Fields
• Three fields
• Potential incremental oil = 39 million stb
• Total CO2 needed for EOR = 319 Bcf
Selected North Dakota Oil Fields
• 28 fields
• Potential incremental oil = 262 million stb
• Total CO2 needed for EOR = 2095 Bcf
Buffalo Field, South Dakota
• Portions of this field are currently undergoing tertiary recovery operations using air injection.
• CO2-based EOR may be technically feasible.
Selected Nebraska Oil Fields
• Ten fields
• Total cumulative production = 100 million stb
• Potential incremental oil = 25 million stb
• Total CO2 needed for EOR = 199 Bcf
Williston Basin
Powder River Basin
Kennedy Basin
Midcontinental Rift System
Enhanced Oil Recovery Potential in the PCOR Partnership Region
Oil Field
Sedimentary Basin
0 100 200 300 600 Kilometers
0 100 200 400 Miles

# Enhanced Oil Recovery

Most oil is extracted from the ground in three distinct phases: primary, secondary, and tertiary (or enhanced) recovery. Natural pressures within the reservoir drive oil into the well during primary recovery, and pumps bring the oil to the surface. Primary recovery typically produces roughly 12%–15% of a reservoir's original oil. An additional 15%–20% of the original oil can be extracted through secondary recovery processes which involve injecting water to displace the oil.[15]

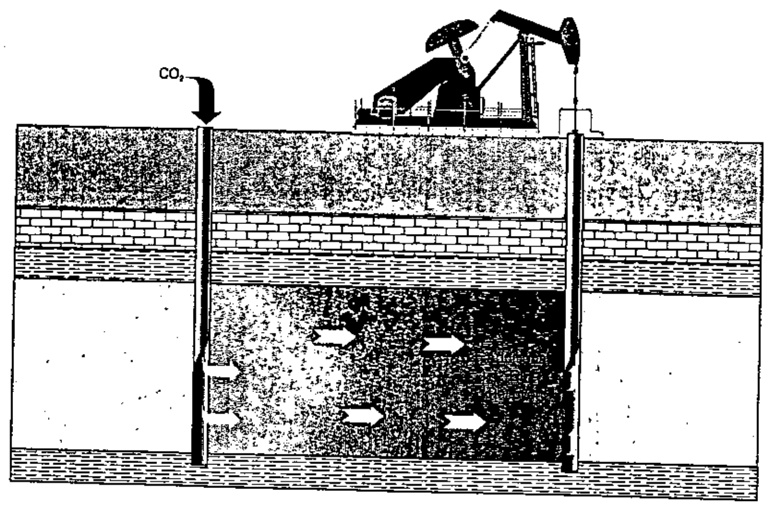
Conventional primary and secondary recovery operations often leave two-thirds of the oil in the reservoir. In the United States, EOR methods have the potential to recover much of that remaining oil, which is estimated to be 200 billion barrels.[15] However, oil recovery is challenging because the remaining oil is often located in regions of the reservoir that are difficult to access, and the oil is held in the pores by capillary pressure.

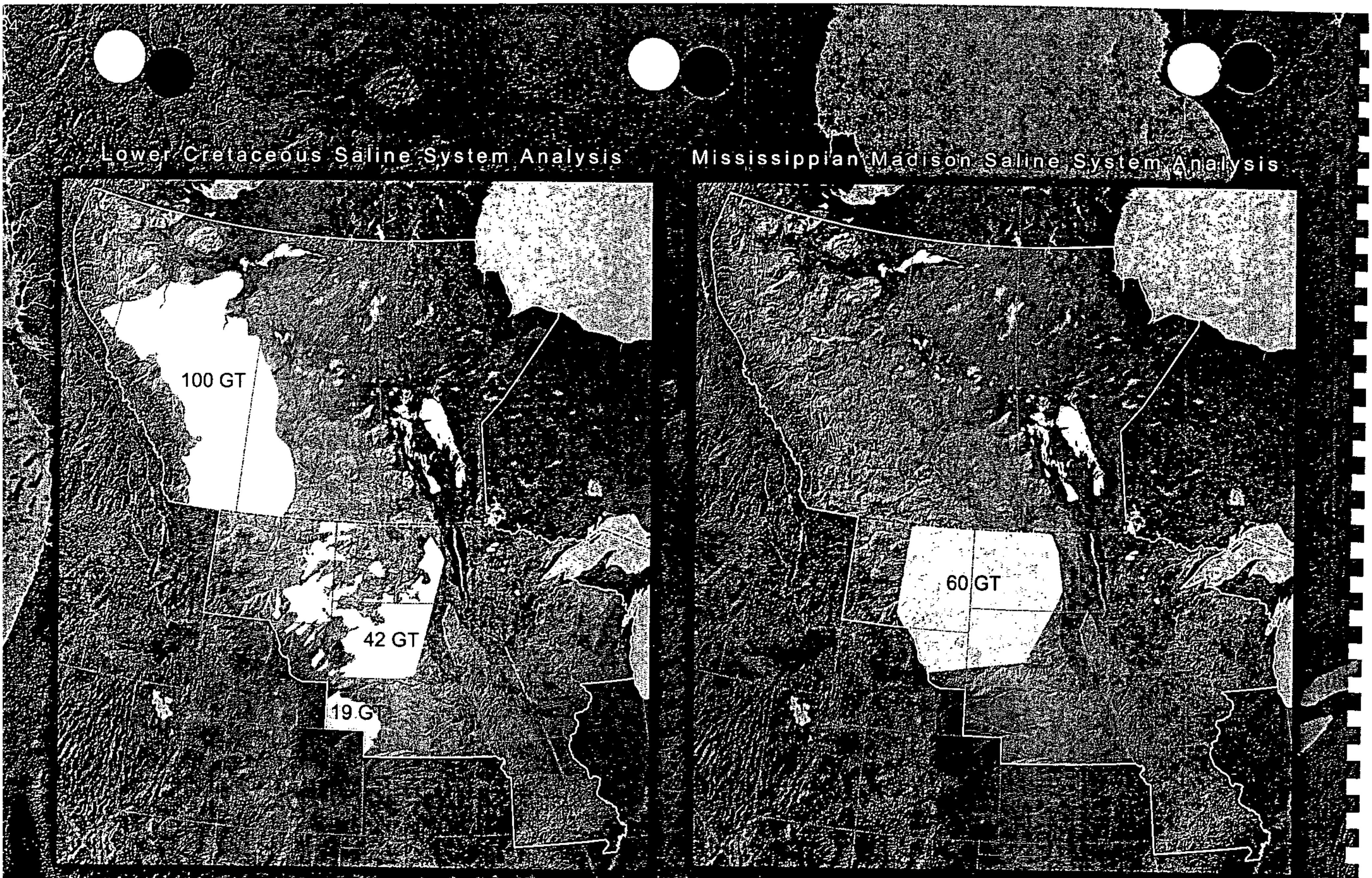
Reconnaissance-level $CO_2$ sequestration capacities were estimated for selected oil fields in the Williston, Powder River, Denver–Julesberg, and Alberta Basins. Two calculation methods were used, depending on the nature of the available reservoir characterization data for each field. The estimates were developed using reservoir characterization data that were obtained from the petroleum regulatory agencies and/or geological surveys from the oil-producing states and provinces of the PCOR Partnership region. Results of the estimates for the evaluated fields (using a volumetric method) in the four basins indicate a storage capacity of over 3.4 billion tons of $CO_2$.

Aside from non-market-based incentives, $CO_2$ sequestration in many geologic sinks is not generally economically viable under current market conditions. However, EOR miscible flooding is a proven, economically viable technology for $CO_2$ sequestration that can provide a bridge to future non-EOR-based geologic sequestration. For example, a portion of the revenue generated by $CO_2$ EOR activities can pay for the infrastructure necessary for future geologic sequestration in brine formations. It is expected that major oil fields subjected to this type of recovery process would retain a significant portion of the injected $CO_2$ (including the amount recycled during production) as a long-term storage solution.

**Storage and Incremental Recovery Through EOR in Selected Fields**

| Basin | Cumulative Incremental Recovery (million stb) | $CO_2$ Sequestration Potential (Bcf) | $CO_2$ Sequestration Potential (million tons) |
|---|---|---|---|
| **Williston** | 1023 | 8186 | 502 |
| **Powder River** | 381 | 3049 | 187 |
| **Denver–Julesberg** | 25 | 199 | 12 |
| **Alberta** | 6000 | 4856 | 2773 |





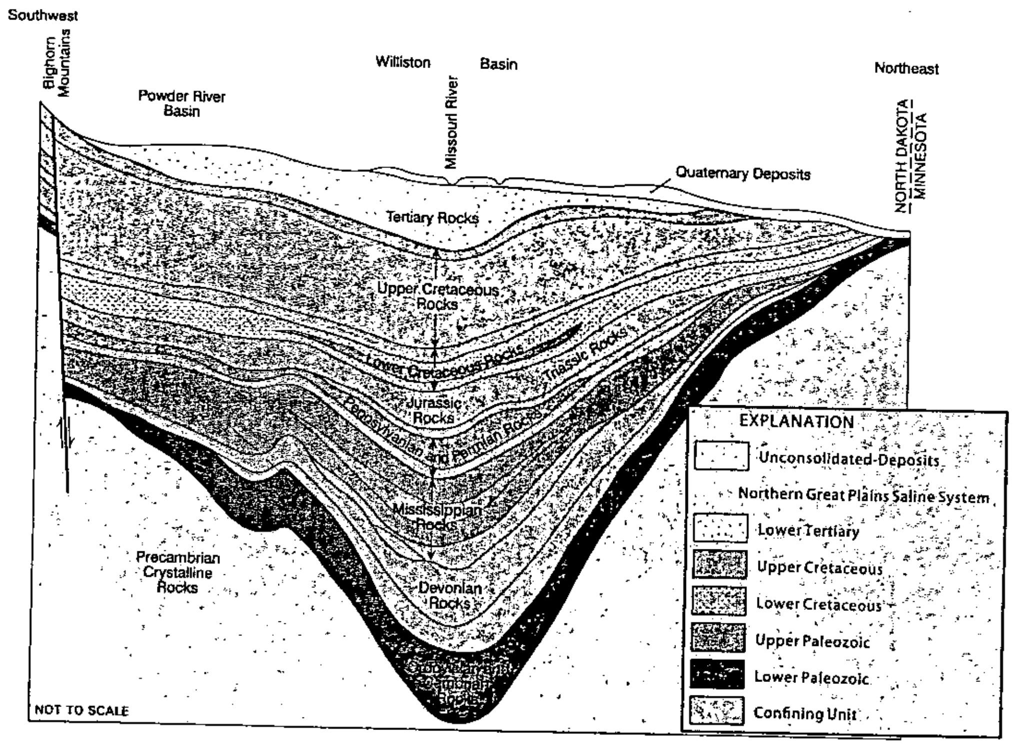

Distribution of selected saline systems evaluated in the PCOR Partnership region.

# Saline Formations

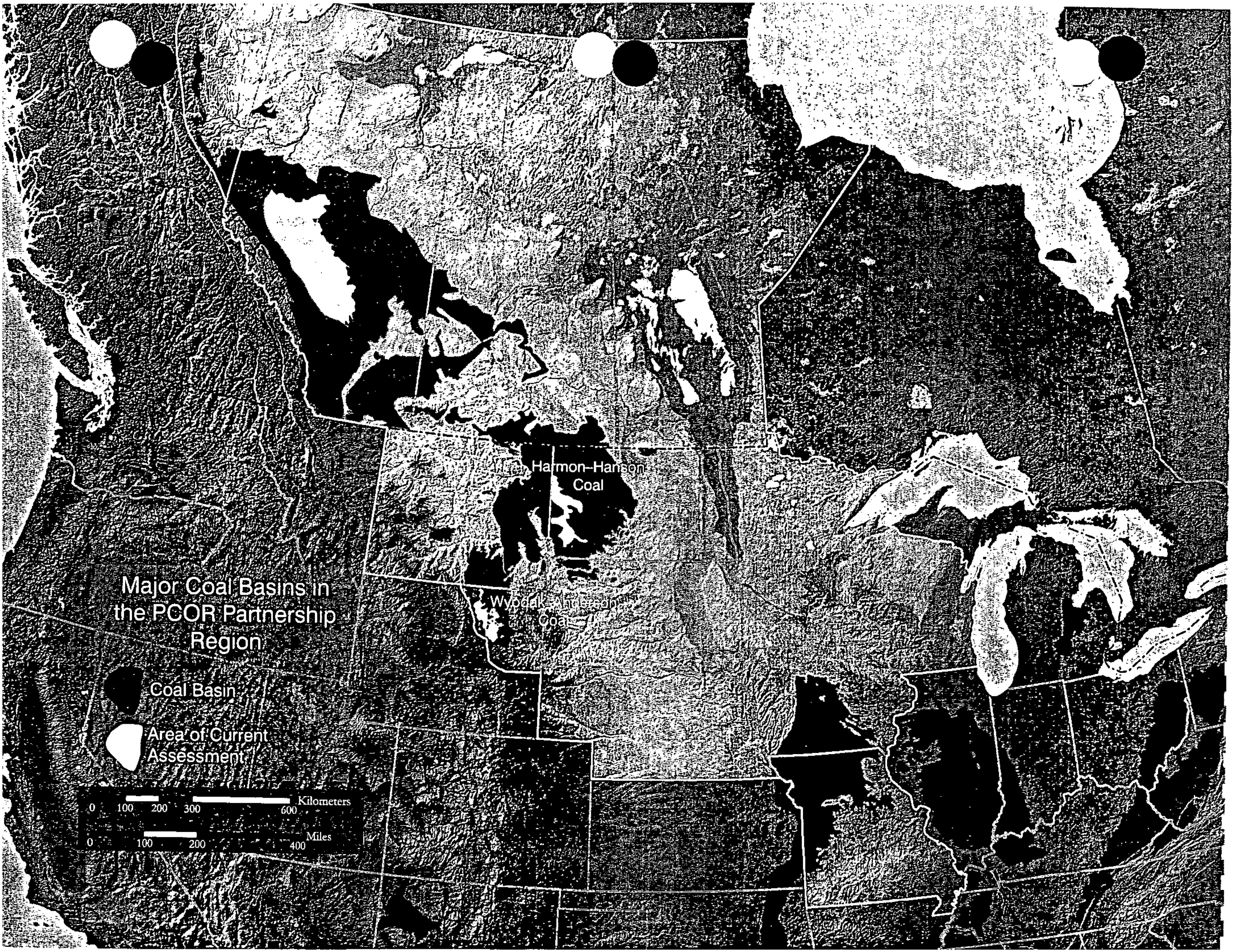
Saline formations within the PCOR Partnership region have the potential to store vast quantities of anthropogenic carbon dioxide. Two saline systems, the Mississippian Madison and the Lower Cretaceous, have been evaluated for their regional continuity, hydrodynamic characteristics, fluid properties, and ultimate storage capacities using published data.

The lateral extent of these formations, the current understanding of their storage potential gained through injection well performance, and the geographic proximity to major $CO_2$ sources suggest they may be suitable sinks for future storage needs. For example, reconnaissance-level calculations on the Mississippian System in the Williston Basin and Powder River Basin suggest the potential to store upwards of 60 billion tons of $CO_2$ over the evaluated region, while the Cretaceous System has the potential to store over 160 billion tons.[16,17]

| Formation | Basin | Estimated $CO_2$ Capacity (billion tons) |
|---|---|---|
| | *Lower Cretaceous System* | |
| Newcastle Formation | Williston and Powder River | 42 |
| Viking Formation | Alberta | 100 |
| Maha Formation | Denver–Julesberg | 19 |
| | *Mississippian System* | |
| Madison Formation | Williston and Powder River | 60 |




*Cross section of the Williston Basin showing major saline formations.*


Major Coal Basins in the PCOR Partnership Region
Coal Basin
Area of Current Assessment
0 100 200 300 600 Kilometers
0 100 200 400 Miles
Harmon–Hanson Coal
Wyodak–Anderson Coal

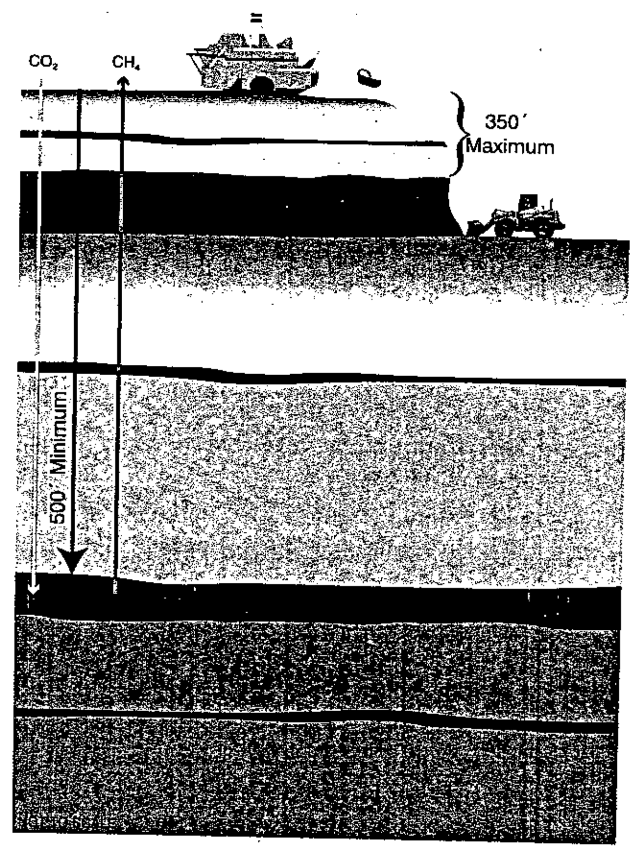
# Sequestration in Coal

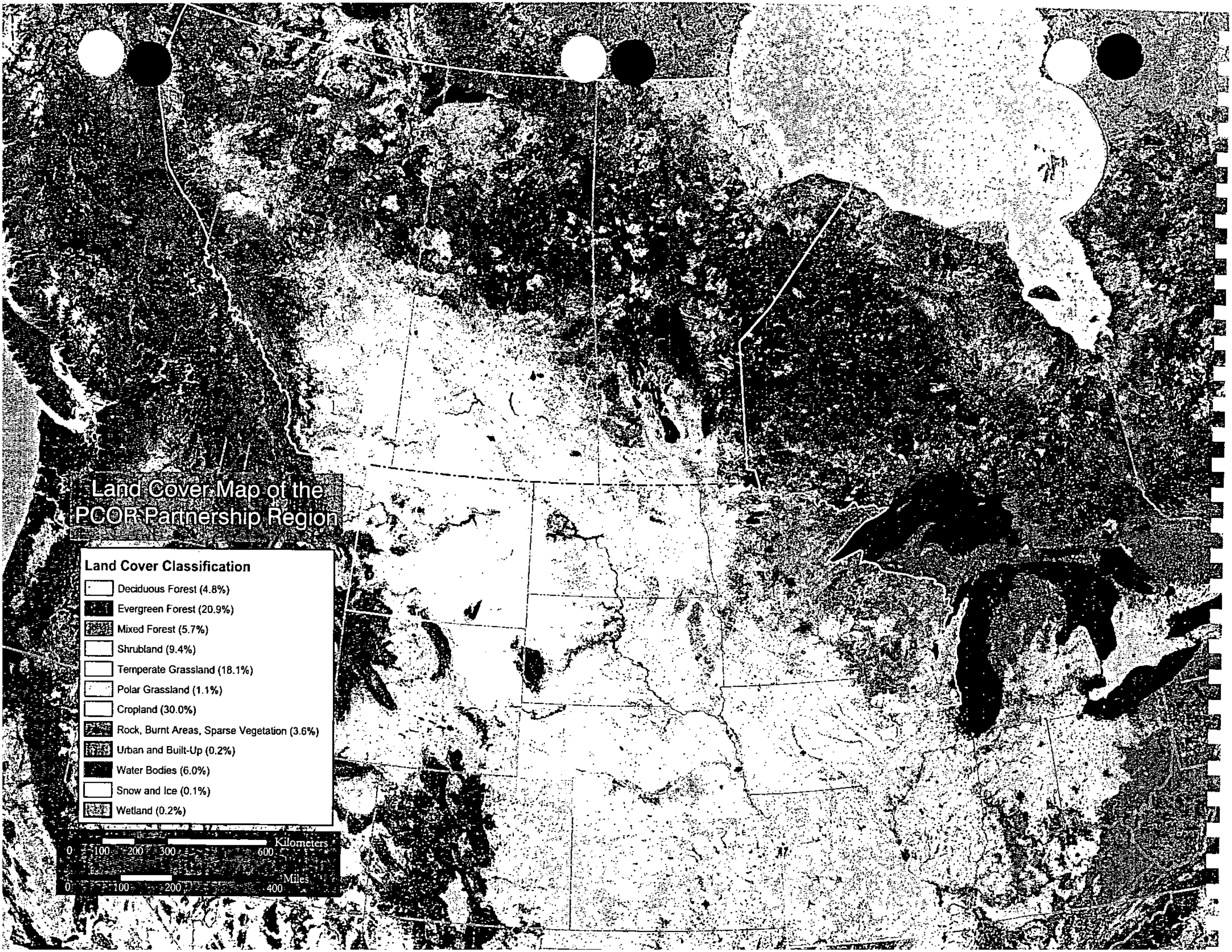
Many coal seams throughout central North America are too deep or too thin to be mined economically. However, many of these coals have varying amounts of methane adsorbed onto pore surfaces, and wells can be drilled into the coal beds to recover this "coalbed methane" (CBM). In fact, CBM is the fastest growing source of natural gas in the United States and accounted for 7.2% of domestic production in 2003.[18]

As with oil reservoirs, the initial CBM recovery methods, dewatering and depressurization, can leave methane in the coal seam. Additional CBM recovery can be achieved by sweeping the coal bed with $CO_2$, which preferentially adsorbs onto the surface of the coal, displacing the methane. For the coals in the PCOR Partnership region, it is possible that up to thirteen molecules of carbon dioxide can be adsorbed for each molecule of methane released, thereby providing an excellent storage sink for $CO_2$.[19] Just as with depleting oil reservoirs, unminable coal beds may be a good opportunity for $CO_2$ storage.

Three major coal horizons in the PCOR Partnership region have been characterized with respect to $CO_2$ sequestration: the Wyodak–Anderson bed in the Powder River Basin, the Harmon–Hanson interval in the Williston Basin, and the Ardley coal zone in the Alberta Basin. The total maximum $CO_2$ sequestration potential for all three coal horizons is approximately 8 billion tons.[20–22]

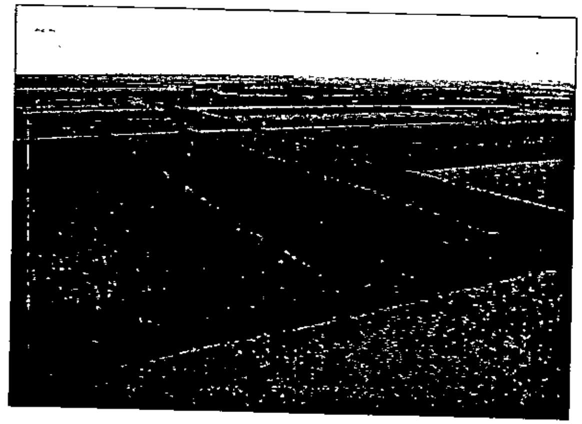
In northeastern Wyoming, the $CO_2$ sequestration potential for the areas where the coal overburden thickness is > 1000 feet is 6.8 billion tons. The coal resources that underlie these deep areas could sequester all of the current annual $CO_2$ emissions from nearby power plants for about the next 150 years.[22]



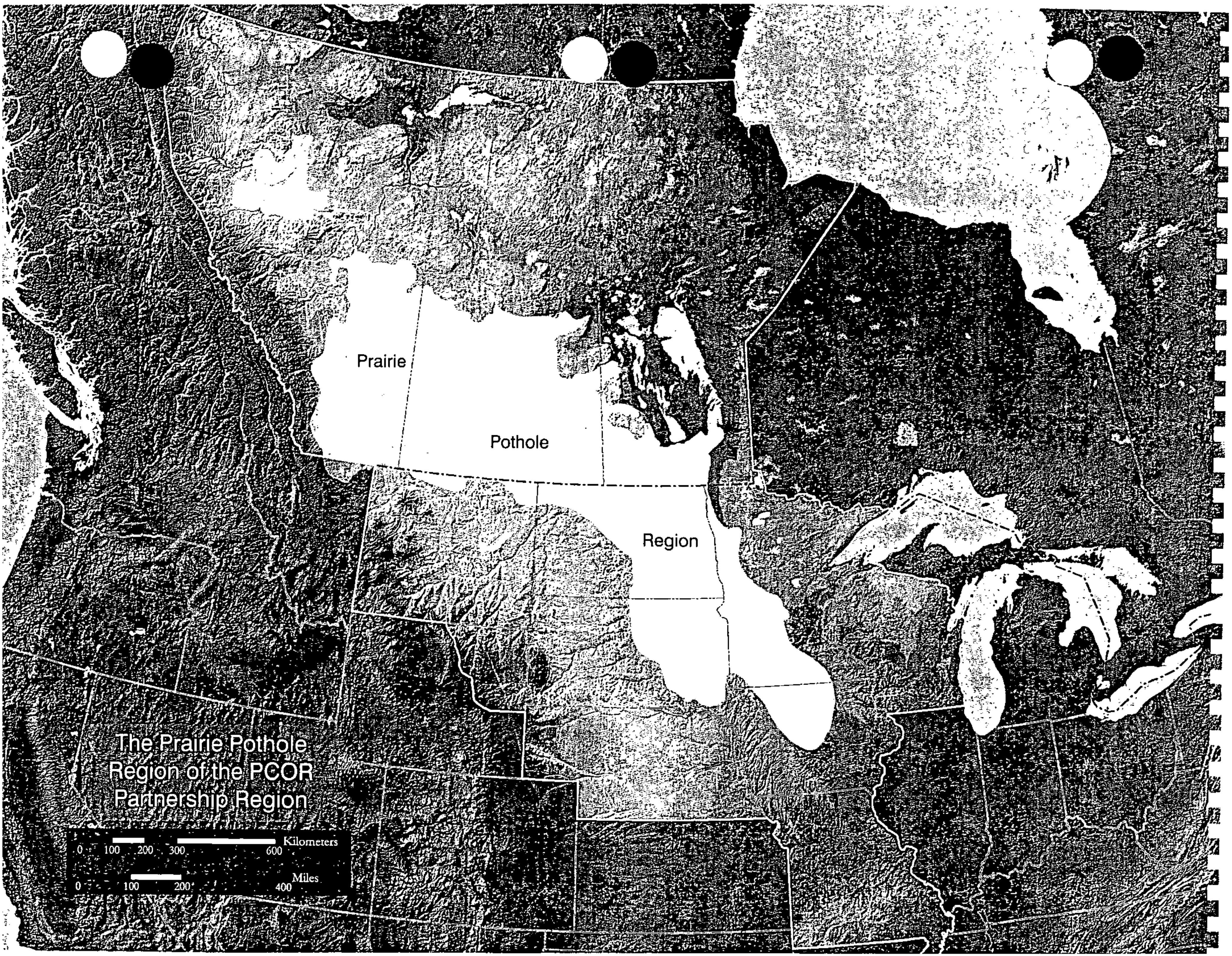

Land Cover Map of the
PCOR Partnership Region
Land Cover Classification
Deciduous Forest (4.8%)
Evergreen Forest (20.9%)
Mixed Forest (5.7%)
Shrubland (9.4%)
Temperate Grassland (18.1%)
Polar Grassland (1.1%)
Cropland (30.0%)
Rock, Burnt Areas, Sparse Vegetation (3.6%)
Urban and Built-Up (0.2%)
Water Bodies (6.0%)
Snow and Ice (0.1%)
Wetland (0.2%)
0 100 200 300 600 Kilometers
0 100 200 400 Miles

# Terrestrial Sequestration

In contrast to geologic sequestration deep within the earth, the concept of terrestrial sequestration focuses on a more passive mechanism of $CO_2$ storage in vegetation and soils within a few feet of the earth's surface. From the Central Lowlands forests and cropland in the southeastern portion of the region, through the expansive grasslands and croplands of the northern Great Plains, to the northern boreal forests of Canada, the PCOR Partnership region has a rich agrarian history founded on fertile soils. However, as central North America developed into the pattern of land use seen today, much of the original soil carbon was lost to the atmosphere. In this setting, the most promising potential to sequester carbon would be to convert marginal agricultural lands and degraded lands to grasslands, wetlands, and forests when favorable conditions exist.[23]



Terrestrial sequestration methods that enhance carbon buildup in biomass and soils include adopting conservation tillage, reducing soil erosion, and minimizing soil disturbance; using buffer strips along waterways; enrolling land in conservation programs; restoring and better managing wetlands; eliminating summer fallow, using perennial grasses and winter cover crops; and fostering an increase in forests.[23,24] Managing soils for increased carbon uptake will pull $CO_2$ from the atmosphere for a 50–100-year time frame, after which the soils will have reached a new equilibrium, i.e., a point at which the total amount of carbon in the soil does not change over time.[25] Once a steady state has been reached, the carbon will remain sequestered until the land management practices change or some other event occurs. The manipulation of soils and biomass for carbon sequestration has the advantage that it can be implemented immediately without the need for new technologies.



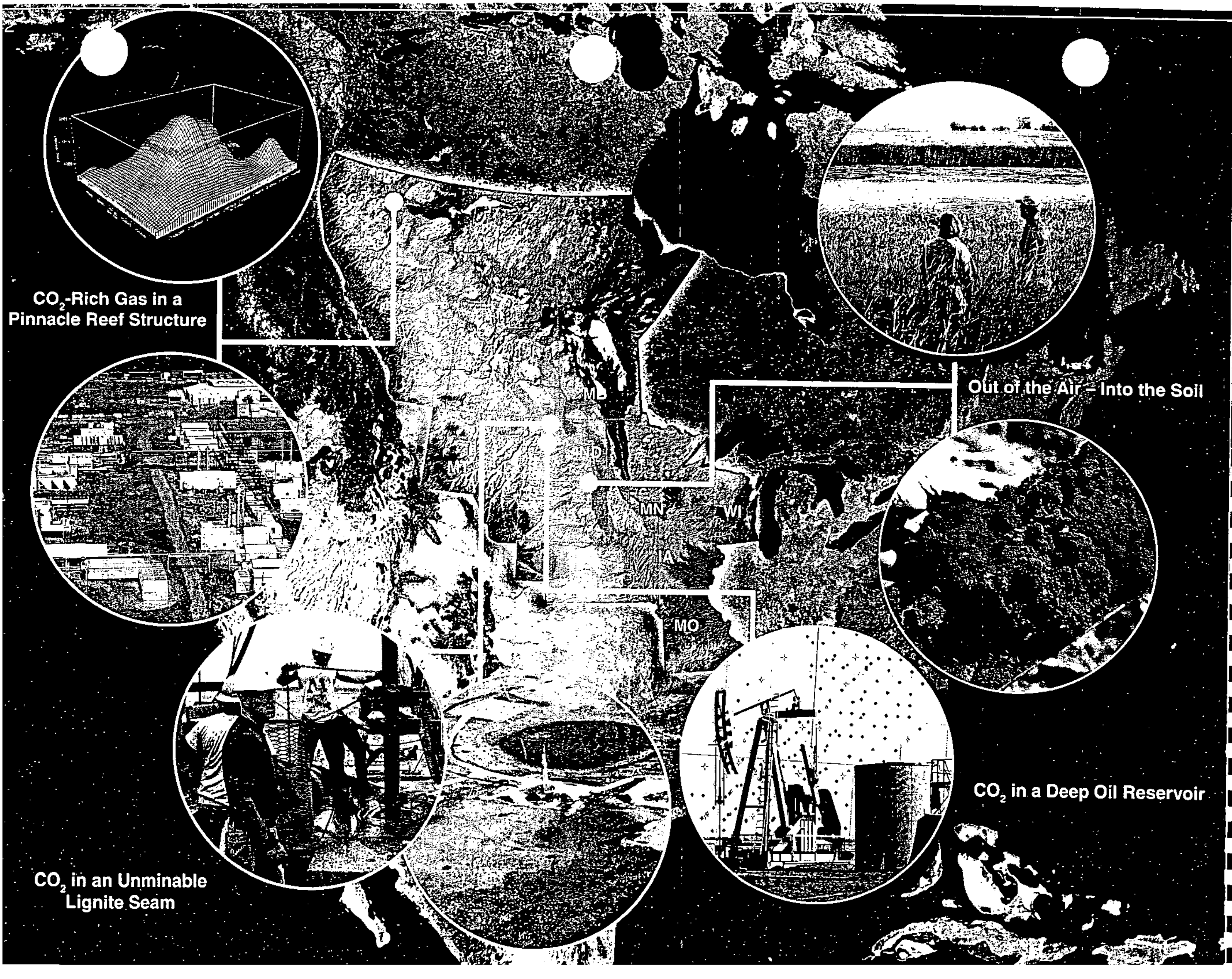
Prairie
Pothole
Region
The Prairie Pothole
Region of the PCOR
Partnership Region
0 100 200 300 600 Kilometers
0 100 200 400 Miles

# Prairie Pothole Region

The PCOR Partnership region includes the Prairie Pothole Region, a major biogeographical region that encompasses approximately 347,000 $mi^2$ (222.4 million acres) and includes portions of Iowa, Minnesota, Montana, North Dakota, and South Dakota in the United States and Alberta, Saskatchewan, and Manitoba in Canada.[26] Formed by glacial events, this region historically was dominated by grasslands interspersed with shallow palustrine wetlands. Prior to European settlement, this region may have supported more than 48 million acres of wetlands, making it the largest wetland complex in North America.[27] However, fertile soils in this region resulted in the extensive loss of native wetlands as cultivated agriculture became the dominant land use. Because of oxidation of organic matter by cultivation, agriculture has depleted significant amounts of soil organic carbon (SOC) in wetlands.

The prairie potholes are an important element of the prairie ecosystem. This region accounts for up to 70% of the wild duck production in North America[27] and provides important breeding and migratory grounds for many types of wildlife. In addition to wildlife benefits, the prairie potholes provide many other ecological benefits, such as reduced erosion, improved water quality, flood and storm buffering, and recreational opportunities.

Recent work by Ducks Unlimited, Inc., and U.S. Geological Survey scientists for the PCOR Partnership demonstrated that restoration of previously farmed wetlands results in the rapid replenishment of SOC lost to cultivation at an average rate of 1.1 tons $acre^{-1}$ $yr^{-1}$.[28] The finding that restored prairie wetlands are important carbon sinks provides a unique and previously overlooked opportunity to store atmospheric carbon in the PCOR Partnership region.



$CO_2$-Rich Gas in a Pinnacle Reef Structure
Out of the Air – Into the Soil
BC
ND
MN
WI
IA
MO
$CO_2$ in a Deep Oil Reservoir
$CO_2$ in an Unminable Lignite Seam

# Field Validation Test Sites

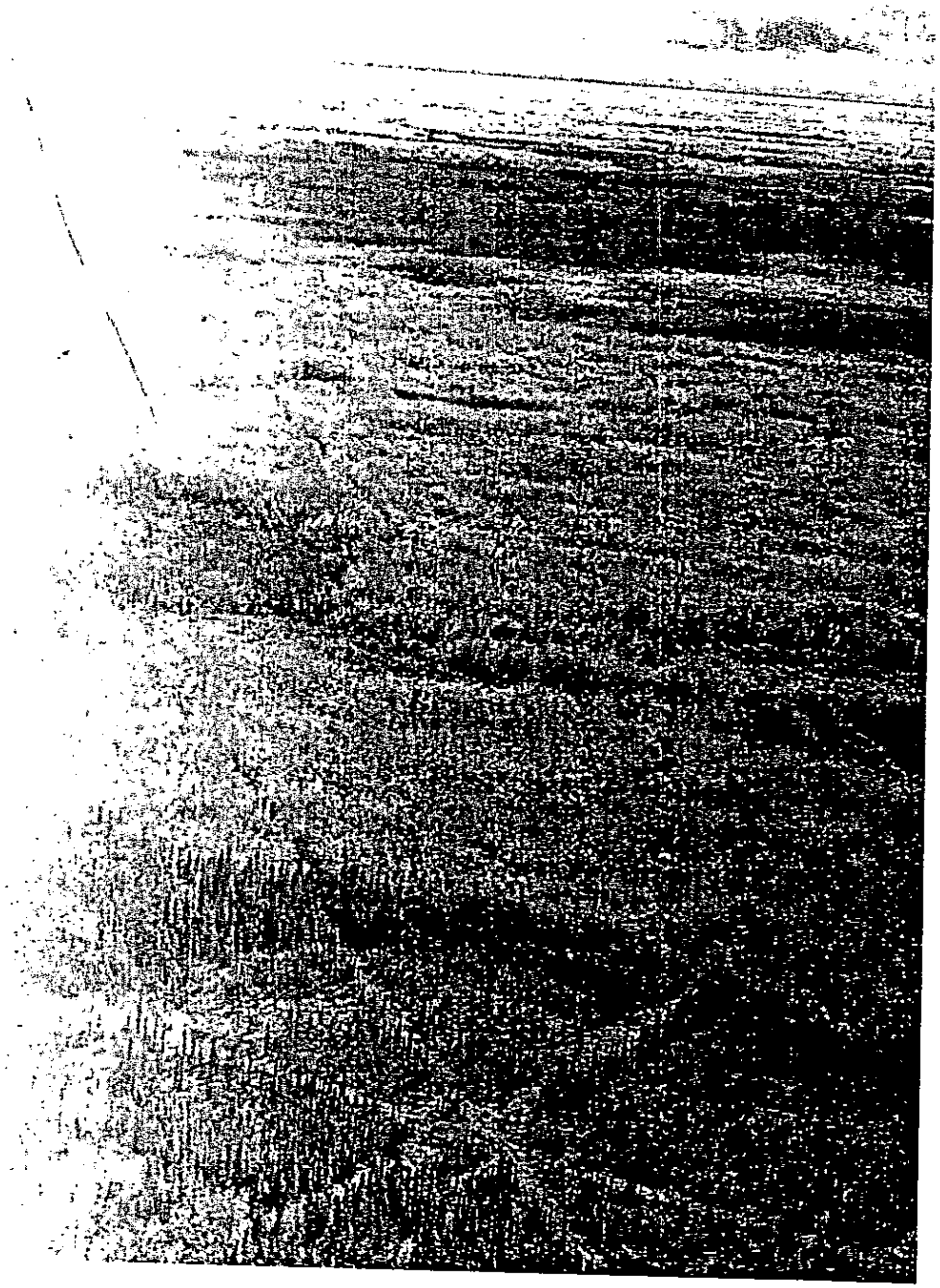
Through the fall of 2009, the PCOR Partnership will be developing and conducting four $CO_2$ sequestration field validation tests: three that will store carbon dioxide as a gas in the deep subsurface and one that will store carbon in the near-surface soils and sediments of wetlands and grasslands. These field projects are designed to develop the expertise, real-world experience, and business models needed to implement major, full-scale, long-term $CO_2$ sequestration projects in the region.

**$CO_2$-rich gas in a pinnacle reef structure** – Acid gas (approximately 70% $CO_2$, 30% hydrogen sulfide [$H_2S$]) from a natural gas processing plant in northern Alberta, Canada, is being injected into an oil-producing zone in an underground pinnacle reef structure. A pinnacle reef is an isolated domed geologic formation suitable for trapping hydrocarbons and $CO_2$. Results will help to determine the best practices to support sequestration in these unique geologic structures as well as further our understanding of the effects of $H_2S$ on tertiary oil recovery and $CO_2$ sequestration.

**$CO_2$ in a deep oil reservoir** – $CO_2$ will be injected into an oil-bearing zone at great depth in the Williston Basin in northwestern North Dakota. The activity will be used to determine the efficacy of $CO_2$ sequestration and the use of $CO_2$ to produce additional oil from deep carbonate source rocks.

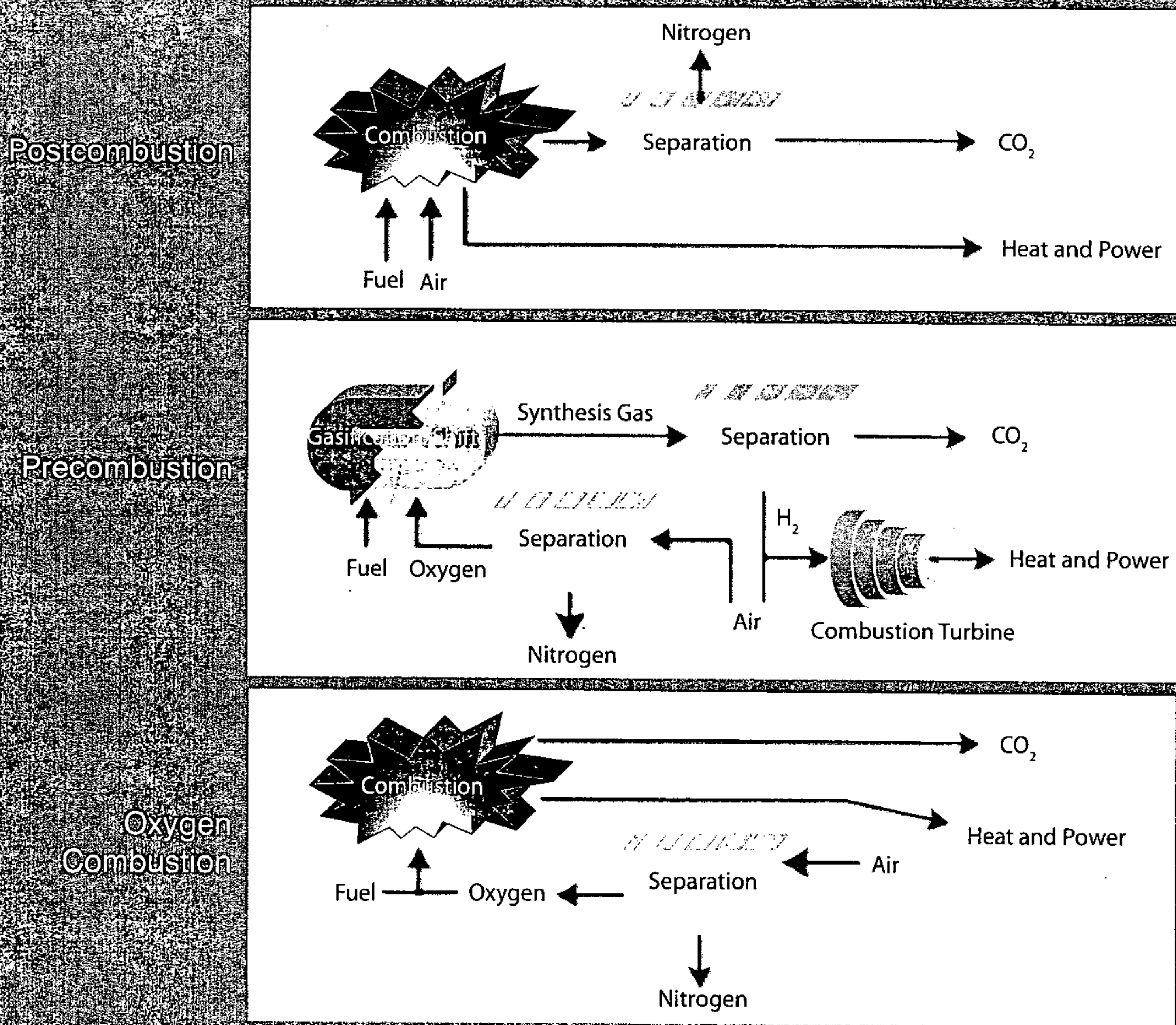
**$CO_2$ in an unminable lignite seam** – $CO_2$ will be injected into unminable lignite seams in northwestern North Dakota. The injected $CO_2$ will be trapped by naturally bonding to the surfaces of the fractured lignite. The injected $CO_2$ also has the potential to displace methane occupying the coal fractures. This validation test will provide valuable information regarding lignites for both $CO_2$ sequestration and enhanced coalbed methane production.

**Out of the air – into the soil** – A managed wetland will be implemented in north-central South Dakota to demonstrate practices that will improve $CO_2$ uptake. The results will help to optimize $CO_2$ storage, monitoring, and verification methods and facilitate the monetization of terrestrial carbon offsets in the region and elsewhere.



PCOR Partnership

# ...sil Fuel Conversion P... ...ms and $CO_2$ Captu...



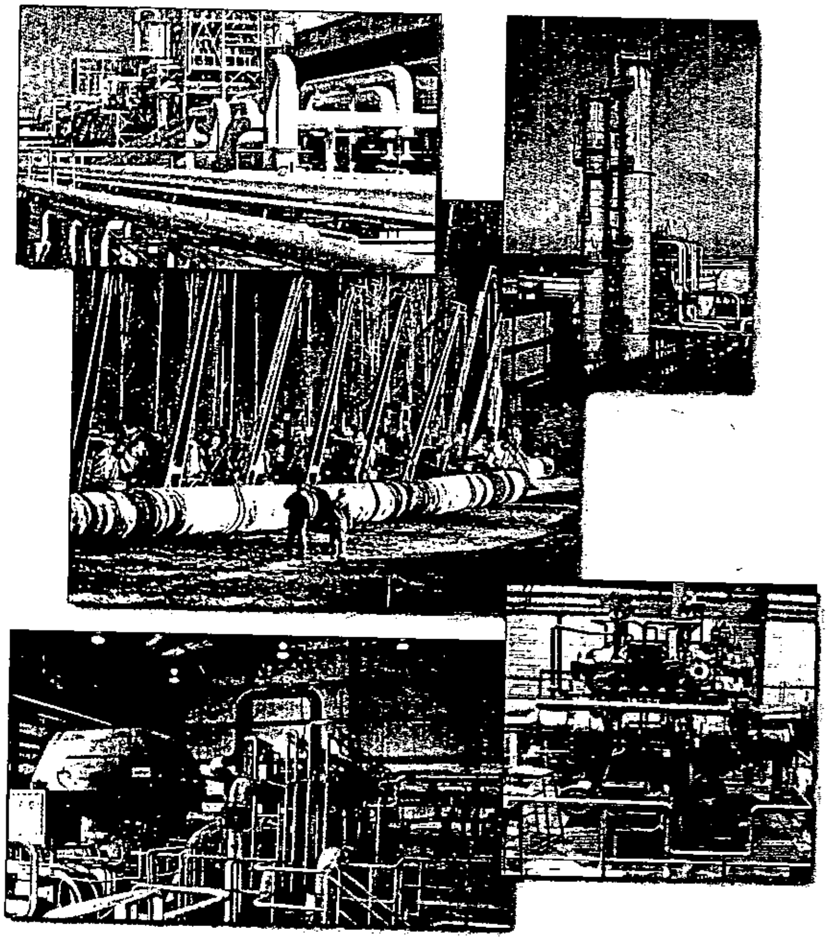
# Carbon Capture and Separation

Before $CO_2$ can be geologically sequestered, it must be captured and separated from other gases, compressed, and transported to the geologic sink. Capture and separation of $CO_2$ are performed as a part of many industrial processes, from $H_2$ production to ammonia synthesis.[29] However, existing capture technologies are not yet optimized for application on a typical power plant exhaust stream. Power plants typically burn coal or natural gas in the presence of air. This approach produces an exhaust gas that contains large amounts of nitrogen that must be separated from the $CO_2$ prior to sequestration. Because the concentrations of $CO_2$ in typical power plant flue gas are so low (ranging from 3% by volume for some natural gas-fired plants[29] to 15% by volume for some coal-fired plants[30]), any capture process must be sized to handle the large quantity of exhaust gas. The large scale of equipment and quantities of chemicals required makes the capture process relatively expensive. In fact, the cost of capturing the $CO_2$ can represent three-fourths of the total cost of a capture–storage–transportation–geologic sequestration system.[29]

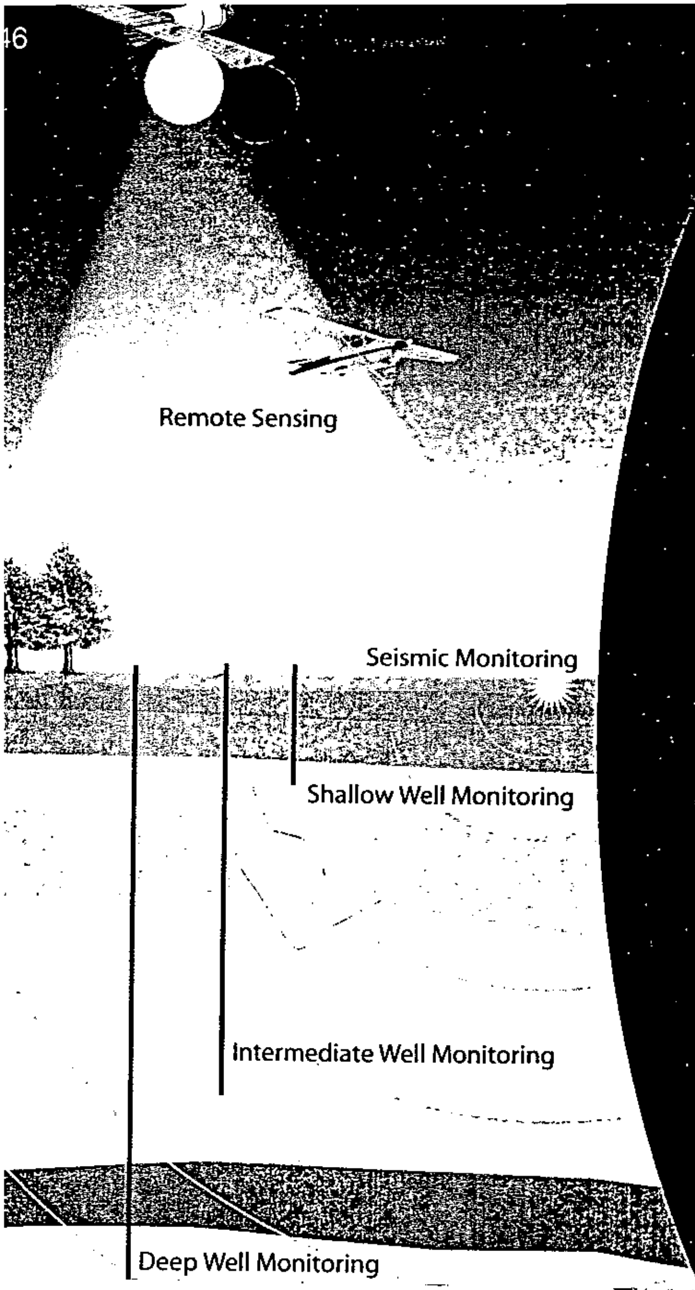
Research is being performed to develop new $CO_2$ capture processes and improve the economics of existing ones. Capture of $CO_2$ can be performed at three points in the power production process: before combustion, during combustion, and after combustion. The precombustion technologies consist of capture of $CO_2$ in conjunction with gasification or reforming, while capture during combustion is only possible when the combustion takes place in nearly pure oxygen rather than air. The majority of capture technologies focus on separating the $CO_2$ from the exhaust gas stream after combustion.

Five different approaches can be taken in postcombustion capture: absorption (both chemical and physical), adsorption, membrane separation, cryogenic cooling, and others such as chemical looping and $CO_2$ hydrate formation. The most common commercial technology available is amine scrubbing, a chemical absorption technology. Two of the more common commercial physical absorption processes are the Rectisol® and Selexol™ processes.

After the $CO_2$ is captured, it must be compressed for either storage prior to truck transport or directly put into a pipeline to the sequestration site. $CO_2$ must be compressed to about 1200 to 1500 psi for transport in a pipeline. Compression is energy-intensive, so improved methods of compression are also being developed.



*Top left and center: In the future, a more extensive $CO_2$ pipeline network will probably be constructed. Top right: Selextol™ towers at a recent integrated gasification combined-cycle start-up. Bottom: $CO_2$ compressors at the Dakota Gasification Company's synfuels plant in central North Dakota each move about 55 million cubic feet of $CO_2$ a day at a discharge pressure of 2700 psi.*




**Selected Technologies Used to Ensure the Safe and Secure Storage of $CO_2$**

## Terrestrial

Plant Matter Measurement
- Multispectral 3-dimensional aerial digital imagery
- Satellite imagery
- Light detection and ranging (LIDAR)

Soil Carbon Measurement
- Laser-induced breakdown spectroscopy (LIBS)
- Inelastic neutron scattering soil carbon

## Geologic

$CO_2$ Fate and Transport Models
- Reservoir models (target formation to vadose)
- Geochemical models
- Geomechanical models
- $CO_2$ equation of state at reservoir conditions

Plume Tracking
- Surface to borehole seismic monitoring
- Microseismic monitoring
- Cross-well tomography
- Reservoir pressure monitoring
- Observation wells/fluid sampling

$CO_2$ Leak Detection
- Vadose zone soil/water sampling
- Air samples/gas chromospectrometry
- Infrared-based $CO_2$ in air detectors
- Vegetation growth rates
- $CO_2$ tracers, natural and introduced
- Subsurface monitoring wells

Mitigation

# Regulatory and Safety Aspects of Carbon Capture and Storage

Currently, no U.S. federal regulations address $CO_2$ emissions. However, regulations do address the transportation of $CO_2$, the injection of $CO_2$ for enhanced resource recovery purposes, and worker safety issues. Also, various state and federal regulations could affect a $CO_2$ sequestration project. Most of these regulations would have bearing on the siting of a potential $CO_2$ source (e.g., power plant), pipeline routing, and injection of the $CO_2$. Further, numerous federal, state, and regional regulatory and/or legislative actions are being contemplated that would address various aspects of carbon management. Additionally, in April 2007, the Supreme Court decided that the U.S. Environmental Protection Agency (EPA) has the authority to regulate carbon dioxide emissions from cars and that the agency cannot bypass its authority to regulate greenhouse gases that contribute to global climate change unless it provides a scientific basis for its refusal. For more information on this Supreme Court decision go to www.supremecourtus.gov/opinions/06pdf/05-1120.pdf.

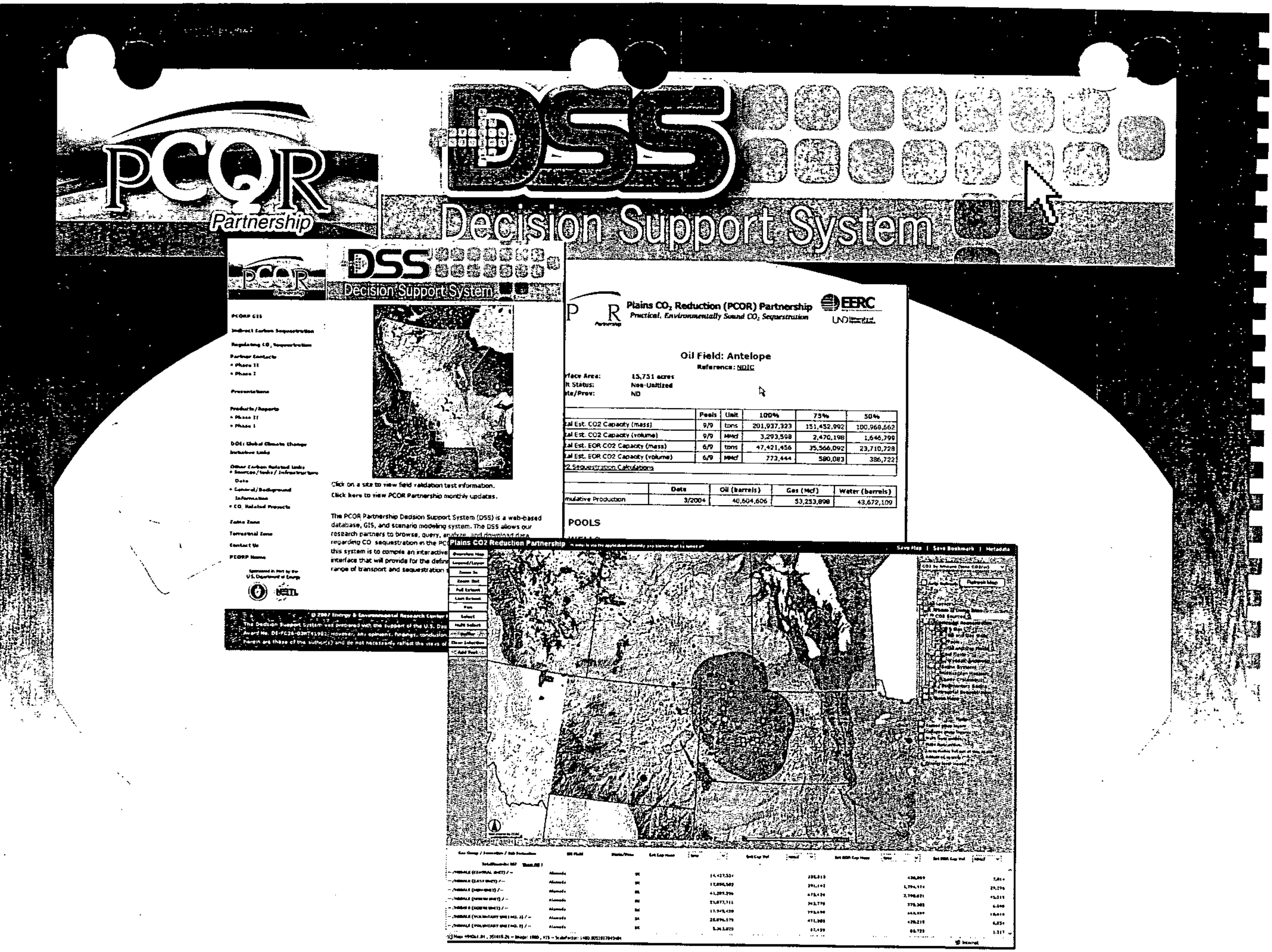
To ensure the safe and effective terrestrial and geological storage of $CO_2$, projects must identify and evaluate potential ecological and environmental impacts, effectively monitor and assess storage efficiency, and be prepared to take remedial action in the event of failure.

Assessing the effectiveness of terrestrial or geologic sinks for storing $CO_2$ is critical. Monitoring, mitigation, and verification (MMV) strategies will be required through all phases of $CO_2$ sequestration, including capture and separation, transportation, injection, and long-term storage.

The implementation of MMV serves to 1) protect worker health and safety; 2) ensure environmental and ecological safety; 3) verify safe and effective storage, including providing assurances of carbon credits of transactions in a carbon-trading market; 4) track plume migration; 5) provide early warning for failure; and 6) confirm model predictions.

What is known to date concerning risks of $CO_2$ sequestration includes the following:

- $CO_2$ can be safely stored in geological formations over long periods of time as observed with naturally existing $CO_2$ reservoirs.
- Environmental and ecological health effects are well understood.
- The largest risks of $CO_2$ capture and storage have been identified.
- Local hazards are generally more dependent on the nature of the release than the size of the release.
- $CO_2$ poses no health and safety risk at low concentrations.
- $CO_2$ is not flammable or explosive but does react with water.
- $CO_2$ is denser than air and has the potential to pool in low-lying areas or poorly ventilated spaces.


PCOR Partnership
DSS
Decision Support System
PCORP GIS
Indirect Carbon Sequestration
Regulating CO2 Sequestration
Partner Contacts
Presentations
Products/Reports
DOE: Global Climate Change Initiative Links
Zama Zone
Terrestrial Zone
Contact Us
PCORP Home
Click on a site to view field validation test information.
Click here to view PCOR Partnership monthly updates.
The PCOR Partnership Decision Support System (DSS) is a web-based database, GIS, and scenario modeling system. The DSS allows our research partners to browse, query, analyze, and download data regarding CO2 sequestration in the PC
this system is to compile an interactive
interface that will provide for the defin
range of transport and sequestration
Plains CO2 Reduction (PCOR) Partnership
Practical, Environmentally Sound CO2 Sequestration
EERC
Oil Field: Antelope
Reference: NDIC
15,751 acres
Non-Unitized
ND
Pools
Unit
100%
75%
50%
9/9
tons
201,937,323
151,452,992
100,968,662
9/9
MMcf
3,293,598
2,470,198
1,646,799
6/9
tons
47,421,456
35,566,092
23,710,728
6/9
MMcf
773,444
580,083
386,722
Date
Oil (barrels)
Gas (Mcf)
Water (barrels)
3/2004
40,604,606
53,253,898
43,672,109
POOLS
Plains CO2 Reduction Partnership
Save Map
Save Bookmark
Metadata

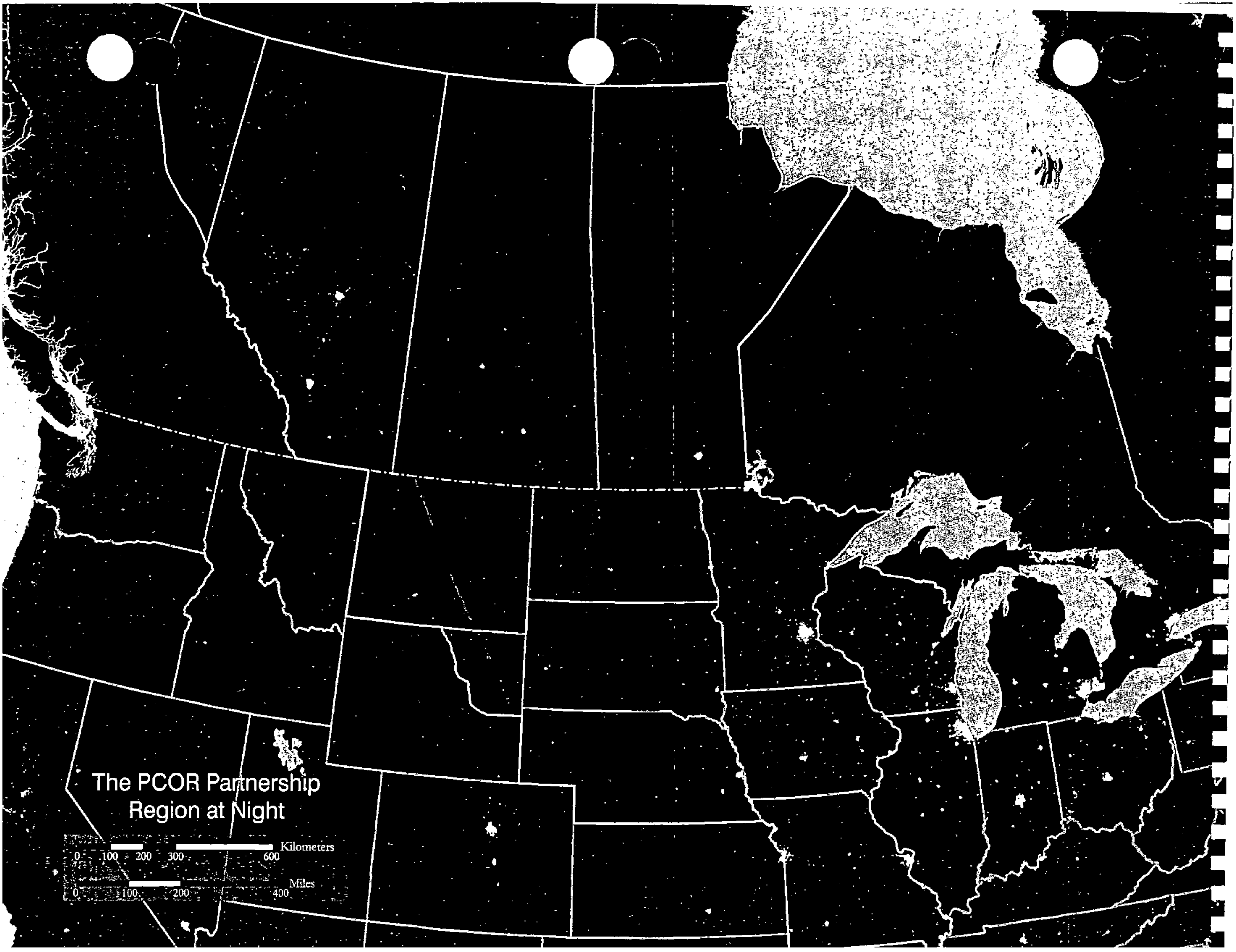
# The PCOR Partnership Decision Support System (DSS)

The PCOR Partnership has accumulated a wealth of data in characterizing the partnership region with respect to $CO_2$ sequestration opportunities. Major components of this characterization include creating an inventory of large stationary sources of $CO_2$ and identifying and mapping geologic and terrestrial targets, or sinks, for $CO_2$ sequestration across the PCOR Partnership region. Knowledge of the character and spatial relationships of sources, sinks, and regional infrastructure is crucial to developing and assessing approaches to economical and environmentally sound $CO_2$ sequestration.

The most efficient way to communicate this information to the partners has been through a geographic information system (GIS)-enabled Web site. This site is a major component of a larger Web-based Decision Support System (DSS, © 2007 EERC Foundation), that provides the PCOR Partnership with a single point of access to a wide variety of research data for evaluation and the development of potential sequestration scenarios. This password-protected (members only) Web-based platform contains the tools and capabilities designed to deliver functional and dynamic access to data acquired through the project. The data are housed in a relational database and accessed through a map-based portion of the Web site. More traditional Web pages provide access to relatively static data, such as reports, $CO_2$-related Web sites, terrestrial maps, and snapshots of regional data.

GIS technology enhances the users' understanding of regional opportunities by allowing them to visualize the spatially distributed nature of the data. The Web-based GIS interface contains several analytical methods that allow members of the research teams to browse, query, analyze, and download data regarding $CO_2$ generation and sequestration in the PCOR Partnership region. Researchers can use the GIS to:

- Examine attributes of individual features or groups of features and their spatial relationships to other features.
- Query the underlying data to analyze the region and export selected data for manipulation in other software.
- Explore the nature of the data through thematic maps.

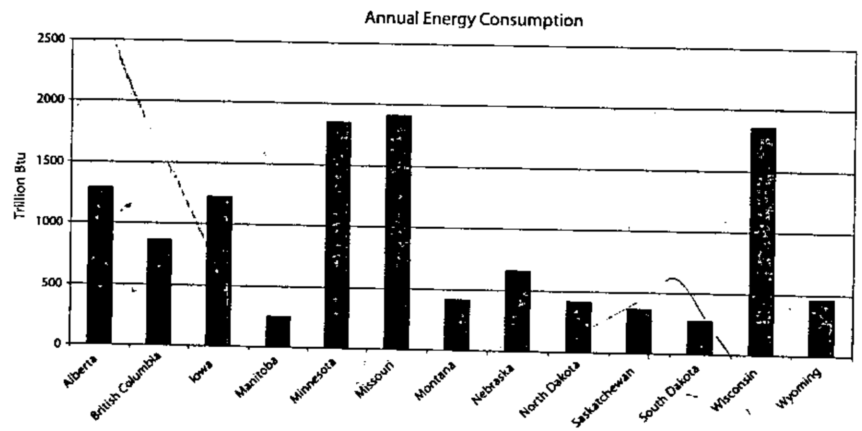

The PCOR Partnership
Region at Night
0 100 200 300 600 Kilometers
0 100 200 400 Miles

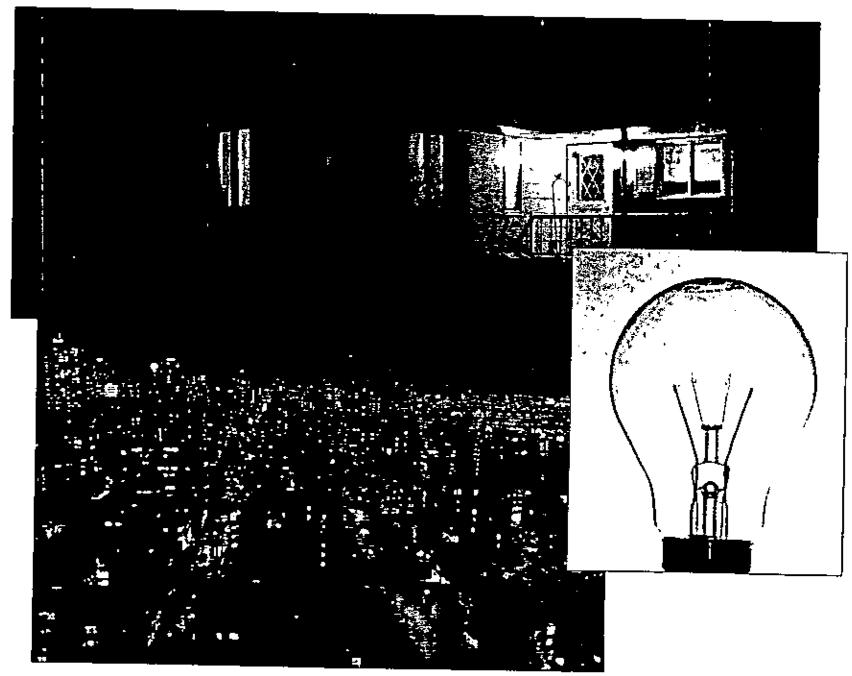
# Keeping the Lights On

Affordable energy not only fuels our vehicles and electrical plants, it also fuels our economy and our quality of life. Collectively, the states and provinces of the PCOR Partnership region use approximately 12,000 trillion Btu of energy a year.[31,32] At the most basic level, energy is essential, but to use our resources in a sensible way without damaging our planet requires a balance between energy and the environment.

The abundant, affordable energy provided by the PCOR Partnership region's fossil fuel resources powers a very productive part of the world. For example, the three Canadian provinces of the PCOR Partnership produce over 90% of Canada's wheat, while the U.S. portion of the PCOR Partnership contributes over 30% of U.S. wheat production.[33,34] Most of the continent's barley crop, which is critical to the breweries of Milwaukee and Saint Louis, comes from North Dakota and Minnesota. Wisconsin, as the top producer of paper in the United States, generates over $12 billion in annual shipments of paper products.[35] The Missouri and Mississippi Rivers, railways, and highways of the region transport industrial output which includes heavy machinery, construction materials, and many other consumer goods.

The PCOR Partnership is working to develop technologies that will allow for $CO_2$ capture and sequestration. It is critical that technologies to reduce the environmental effects of fossil fuel use continue to be evaluated and developed while we explore and further develop future energy sources. The wise stewardship of our technological, social, and natural resources is essential to the future of our culture. Our challenge is to keep the lights on while simultaneously ensuring that our environment and economy stay strong.



1 Sequestration PowerPoint presentations geared to general audiences, educators, students, and decision makers

2 PCOR Partnership's public access Web site with sequestration background, streaming video, educational resources, and information links

3 PCOR Partnership's Members-Only Web site with DSS and Sequestration Project Resources

4 PCOR Partnership's Technical Reports on a variety of sequestration topics in the PCOR Partnership region

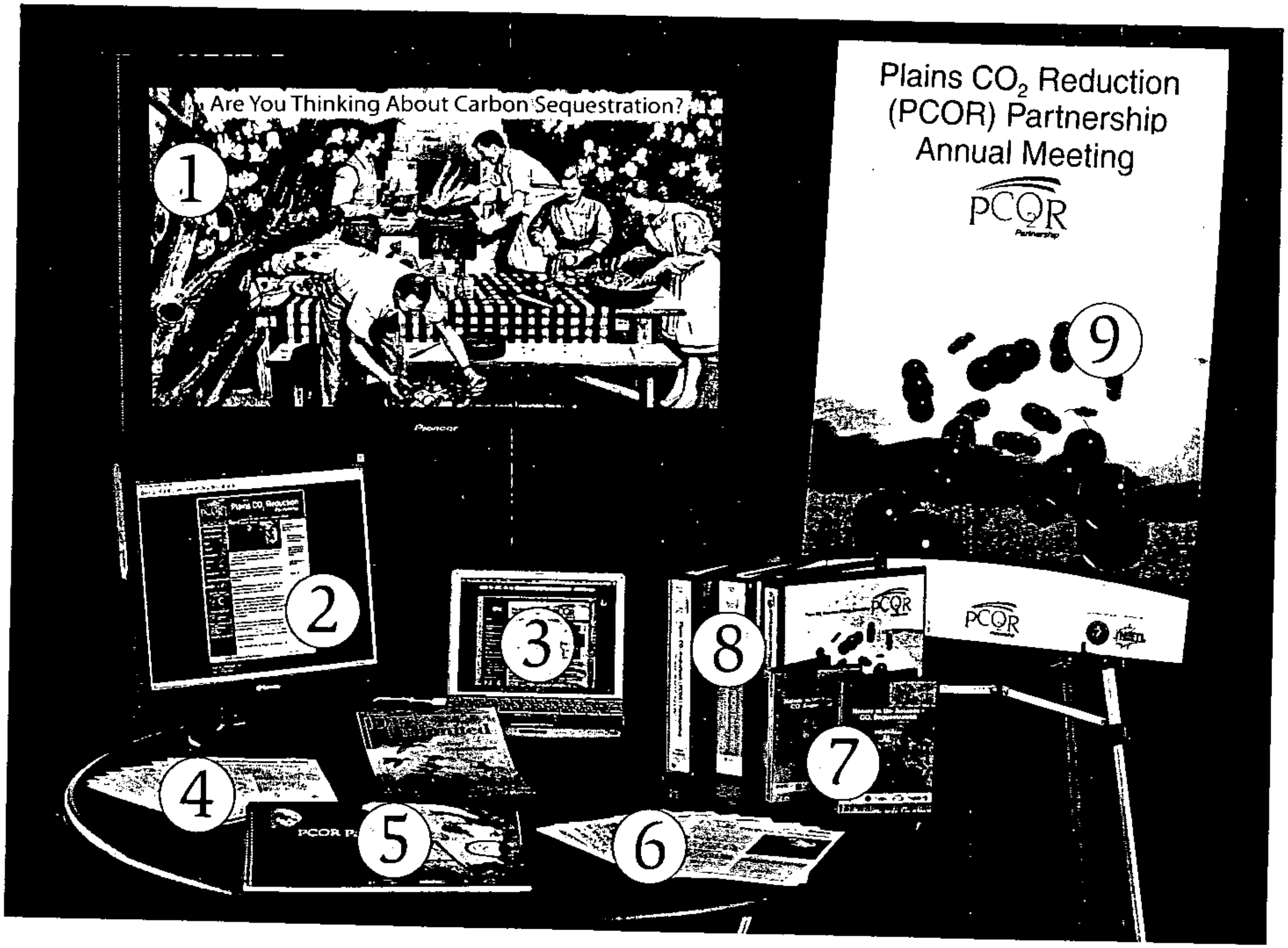
5 A Sequestration Atlas for the PCOR Partnership region designed to inform the general public, educators, and decision makers

6 Fact sheets that summarize key sequestration topics and projects in the PCOR Partnership region

7 30-minute, broadcast-quality documentaries, coproduced by Prairie Public Broadcasting and the PCOR Partnership, on key sequestration topics

8 Proceedings of the PCOR Partnership's annual meetings featuring PowerPoint presentations and program updates

9 PCOR Partnership's display booth and tailored outreach packets available for informational meetings and educational venues



# Education and Outreach – $CO_2$ Sequestration

The PCOR Partnership fully recognizes that the changes in land management, industrial operations, and $CO_2$ transport infrastructure needed to make large-scale, practical, and environmentally sound $CO_2$ sequestration a reality in the region cannot occur without an informed and supportive public.

For this reason, the PCOR Partnership has developed a number of outreach tools intended to educate and inform the public and decision makers about issues related to $CO_2$ and sequestration:

- A variety of PowerPoint presentations
- Display booth and materials
- Public Web site
- Members-only Web site
- Knowledge in brief – fact sheets on key topics and validation projects
- Knowledge in depth – scientific and technical reports
- Documentaries, available on DVD—coproductions of Prairie Public Broadcasting and the PCOR Partnership
- Proceedings from the annual PCOR Partnership meetings and access to other meeting materials

The PCOR Partnership also may have speakers for your meeting, school, or community group.

For more information regarding our outreach program or the content of this atlas and the Plains $CO_2$ Reduction Partnership, contact:

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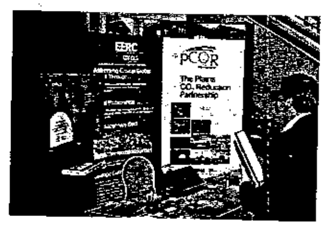
Or visit our Web site at www.undeerc.org/pcor.

More information concerning DOE NETL's Regional Carbon Sequestration Partnerships can be found at www.netl.doe.gov/technologies/carbon_seq/partnerships/partnerships.html.




PCOR Partnership

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# Photo and Image Cre its

t for those noted below, all photos and images created by the EERC.

Dragline with coal-fired electric generation station: Rick Craig
Gas processing plant: Wolfgang Schlegl

Page 2. Barnyard lignite: Vachon, John, 1940, FSA supervisor looking at pile of "barnyard lignite," America from the Great Depression to World War II: Photographs from the FSA-OWI, 1935–1945. http://memory.loc.gov/ammem/fsowhome.html (fsa 8c18205) (accessed July 2005)
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Page 6. Image of global carbon cycle: www.pmel.noaa.gov/co2/gif/globcar.png

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Page 41. Top: Prairie Pothole Region: Ducks Unlimited, bottom: www.fws.gov/Midwest/EcoSystemConservation/wetland.html (accessed July 2008)

Page 42. Circle with wetland: Photo by Lynn Betts, USDA Natural Resources Conservation Service
Circle with shovel of soil: Photo by Lynn Betts, USDA Natural Resources Conservation Service
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Page 45. Top left: BP p.l.c., top right: www.uop.com/objects/97%20Selexol.pdf, middle: http://library.enbridge.com
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Back cover: A map of North America, by J. Palairet and L. Delarochette, with considerable alterations and improvements. From d'Anville, Mitchell, and Bellin. Printed for John Bowles at the Black Horse in Cornhill and Carington Bowles in St. Pauls Church Yard, London.

# A Much Earlier Map of the PCOR Partnership Region

Attachment #5

**Senate Bill 2139**

**Senate Natural Resources Committee**
**January 16, 2009**

**Testimony of Charles Carvell**
**Assistant Attorney General**
**N.D. Attorney General's Office**

Storing carbon dioxide underground is a novel venture. Novel uses of land can produce novel questions of property law. This bill's foremost purpose is to address an uncertainty in property law. If that's done, the law will be better understood by property owners and industry will have a more stable environment within which to make investment decisions.

One of the first things that must be done when crafting a regulatory regime, particularly one for a new activity, is to determine who the players are. If we are going to provide a hearing right we need know who is entitled to get notice of the hearing and participate in it. If we require that a permit applicant get consent from interested parties, we need to know who those parties are.

An interested party in carbon dioxide storage is the owner of the subterranean cavities into which the carbon dioxide will be injected and then stored. But who owns that pore space? Nothing specific in North Dakota law answers that question. The law in other states is, largely, also silent.

But property disputes in other states have led to court decisions that inform analyzing the question. Those disputes didn't involve carbon dioxide storage but rather such matters as storing hazardous wastes and natural gas and injecting substances to re-pressurize oil reservoirs. Because of the growing interest in carbon dioxide storage, lawyers have been studying these cases and property law principles and reporting their research in conference papers and law review articles.

The consensus is that surface owners own the pore space under their land. This is consistent with the view of lawyers who participated in the Carbon Dioxide Storage Workgroup. We could wait for the North Dakota Supreme Court to confirm that view, but the wait might be long. To provide immediate certainty, the Workgroup thought it best that the legislature confirm that surface owners own the pore space under their land; hence this bill.

The second primary feature of the bill is to take this opportunity—while we develop the legal regime for carbon dioxide storage—to avoid problems that burden related activities, in particular, problems associated with severed minerals. Severed minerals are minerals owned by someone who does not own the surface. Because the mineral and surface estates overlap but are in different hands, because mineral owners need the surface to access their minerals, there can be conflicts between the two estates, though our law seeks to order the relationship by declaring the mineral estate dominant.

Severed minerals have also lead to fragmented mineral estates. Thus, in a section land the surface may be owned by just a handful of people, usually North Dakota residents, while the underlying minerals may be owned by dozens or even hundreds of persons, scattered throughout the country. When their consent is needed for mineral development the time and expense searching for them can be considerable.

And so this bill limits a surface owner's ability to sever the pore space estate from the surface estate. It requires that title to pore space remain joined with title to the surface.

I will briefly discuss the bill's seven provisions, and an amendment that proposes an eighth.

**1. Policy** - This expresses policies I have discussed.

**2. Pore space defined** - This is the same definition as in S.B. 2095.

**3. Title to pore space** - This provision recognizes that the surface owner owns underlying pore space.

**4/5. Conveyance of real property conveys pore space/Severing pore space prohibited** – These two provisions address the bill's secondary purpose, that is, to maintain unitary title to surface and pore space.

**6. Transactions allowed** – A concern was expressed that merely leasing pore space could be deemed a prohibited severance. We don't, however, intend that maintaining unitary title would deny pore space owners the right to issue a lease.

**7. Application** – This grandfathers in transactions prior to the bill's effective date by which pore space was severed from the surface estate.

The Workgroup proposes that one more section be added to the bill.

**8. Mineral and pore space estates – Relationship** - There was a concern that recognizing pore space ownership and novel uses for pore space might adversely affect existing interests, particularly those of the mineral estate. Our law, as stated, provides that the mineral estate is dominant. This amendment would maintain that relationship as it pertains to the pore space estate.

Proposed Amendment to Senate Bill No. 2139

Page 1, line 22, after "estate." insert, "**Mineral and pore space estates – Relationship.** In the relationship between a severed mineral estate and a pore space estate, the mineral estate is dominant."

Renumber accordingly

Attachment #6

**Curtis Jabs - Basin Electric Power Cooperative**
**North Dakota Senate Bill 2095 and 2139**
**Senate Natural Resources Committee**
**January 16, 2009**

Mr. Chairman and members of the committee, my name is Curtis Jabs and I am here representing Basin Electric Power Cooperative. Basin Electric supports both SB 2095 and SB 2139.

It is probable that in the next Congress, legislation or Environmental Protection Agency (EPA) regulation will place restrictions on carbon dioxide emissions. Coal must be a part of our energy future, and to accomplish that in a carbon-constrained world, technology needs to be developed to capture and sequester carbon on both new and existing coal-based power plants. Basin Electric is a leader is this effort, capturing approximately half of the $CO_2$ from the Great Plains Synfuels Plant in North Dakota and developing a commercial demonstration to capture 1 million tons of $CO_2$ per year from the Antelope Valley Station, which will be the largest post-combustion $CO_2$ capture project to date. The Great Plains Synfuels Plant captures $CO_2$ from the gasification process. The Antelope Valley Station (AVS) project will capture the $CO_2$ from the flue gas stream after the coal is burned. This "post-combustion" $CO_2$ capture technology is thus an important step in developing technology that will allow existing coal-based power plants to remain in production in a $CO_2$-emission-constrained world.

In 2000 Dakota Gasification Company (DGC) began capturing the $CO_2$ produced at the Synfuels Plant, and shipping it through a 205-mile pipeline to Weyburn, Saskatchewan to be used for enhanced oil recovery (EOR) in an aging oil field. Through 2008, Dakota

Gasification has successfully captured and marketed over 15 million tons of $CO_2$ to two Canadian customers for EOR. The $CO_2$ is expected to be permanently sequestered in the oil reservoir and is being monitored by the International Energy Agency (IEA) Weyburn $CO_2$ Monitoring and Storage Project.

The AVS project will demonstrate the removal of $CO_2$ from the flue gas of a lignite-based boiler. The AVS project is designed to capture $CO_2$ on a 120 MW slipstream from the AVS Unit 1. The system works by first removing sulfur dioxide ($SO_2$) using a polishing scrubber technology, and then absorbing $CO_2$ using an ammonia-based technology. For the Project, $SO_2$ will be reduced from 170 parts per million (ppm) to approximately 1 ppm upstream of the $CO_2$ capture system. The net result of the process is 90 percent removal of $CO_2$ from the treated flue gas, yielding 3,000 tons per day of pipeline quality $CO_2$, and a liquid stream of ammonium sulfate for reuse.

As stated before, the rules and regulation are in place to conduct EOR in North Dakota. Basin Electric intends to market the $CO_2$ from the AVS demonstration for EOR. DGC has been in discussions with several oil companies in North Dakota. Basin Electric would utilize the Dakota Gasification Companies' existing pipeline system and build a new pipeline off a tap to the oilfield.

There is good potential for EOR in North Dakota. However, the capacity to store $CO_2$ used in EOR will be filled eventually as more $CO_2$ is captured. Fortunately North Dakota has a huge storage capacity to store $CO_2$ in other secure geological formations such as saline aquifers. This bill will provide the statutory framework for rules and regulations that will allow $CO_2$ storage in those geological formations with appropriate oversight by the state. The bill also has a provision to allow EOR projects to be converted to long-term $CO_2$ storage pending commission approval. I believe these bills are necessary for North Dakota to take a proactive step to accommodate $CO_2$ storage in the future.

Thank you and I will try to answer any questions from the committee.

Attachment #7

**Testimony**
**Senate Bill 2095**
**Natural Resources Committee**
**Friday, January 16, 2009; 9 a.m.**
**North Dakota Department of Health**

Good morning, Chairman Lyson and members of the Natural Resources Committee. My name is L. David Glatt, and I am chief of the Environmental Health Section for the North Dakota Department of Health. I am here today to testify in support of Senate Bill 2095.

As you know, issues of energy development and independence, environmental quality, and climate change were all discussed during the recent presidential campaign. It is quite clear that these issues will continue to be on the agenda of the new administration and will result in some form of federal legislation most likely to include carbon constraints.

The Department of Health was an active member of the committee that drafted the legislation before you today. Senate Bill 2095 will enable the state to better address future federal carbon legislation. Senate Bill 2095 provides a potentially viable option for storage of carbon dioxide from carbon emission sources in the state. This is the first step in addressing the issue of carbon storage. Development of viable technologies, drafting of rules and public input will follow.

We also support the reference to multi-agency involvement and cooperation in Senate Bill 2095.

This concludes my testimony. I am happy to answer any questions you may have.

Attachment #8

NORTH DAKOTA
CHAMBER of COMMERCE

**Testimony of Jeb Oehlke**
**North Dakota Chamber of Commerce**
**Presented to the**
**Senate Natural Resources Committee**
**January 16, 2009**

**Senate Bill 2095**

Mr. Chairman and members of the Senate Natural Resources Committee, my name is Jeb Oehlke. I am here today representing a business coalition which includes the North Dakota Chamber of Commerce as well as local chambers of commerce and their member businesses to ask you to **support** Senate Bill 2095.

The business community supports this bill because it creates the structure for a regulatory system within which this state's energy sector businesses can operate. Passage of this bill will provide theses businesses with some certainty as they move forward and further develop technology to capture and sequester carbon dioxide.

From a general business standpoint, although excessive regulation is detrimental, a certain amount is needed to let all of the players know the rules of the game. Senate Bill 2095 sets forth those rules and the business community urges the committee to give this bill a **DO PASS** recommendation.

Thank you Mr. Chairman and committee members. I am happy to answer any questions at this time.

*THE VOICE OF NORTH DAKOTA BUSINESS*

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SB 2095

# 26

EERC Energy & Environmental Research Center

UND University of North Dakota

P R

Partnership

# Plains $CO_2$ Reduction (PCOR) Partnership

***Practical, Environmentally Sound $CO_2$ Sequestration***

## What Is CCS?

Carbon dioxide ($CO_2$) is a major by-product of energy use. Carbon capture and storage (CCS) means capturing $CO_2$ and putting it into environmentally sound temporary or permanent storage. Terrestrial sequestration is capturing $CO_2$ from the air and storing it for some period of time in soils or vegetation. Geological CCS is capturing $CO_2$ from exhaust or process gas from large stationary facilities like factories and power plants and placing it in relatively permanent storage, usually in underground geological formations.

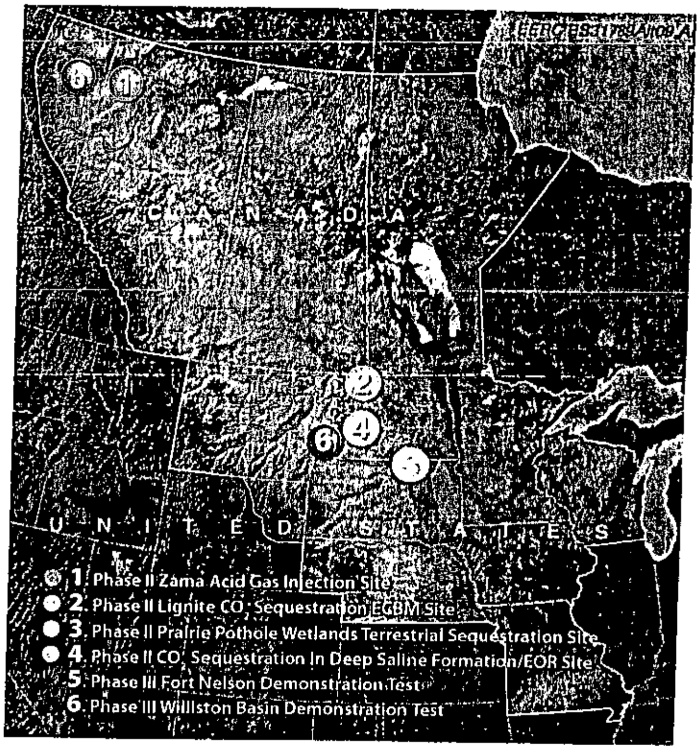
## What Is the PCOR Partnership?

The Plains $CO_2$ Reduction (PCOR) Partnership is one of seven regional partnerships operating under the U.S. Department of Energy National Energy Technology Laboratory Regional Carbon Sequestration Partnership (RCSP) Program. The RCSP program is a government–industry effort tasked with determining the most suitable technologies, regulations, and infrastructure needs for CCS on the North American continent. The RCSP Program initiative is being implemented in three phases:

- Phase I – Characterization Phase (2003–2005): characterized opportunities for carbon sequestration
- Phase II – Validation Phase (2005–2009): small-scale field tests currently under way
- Phase III – Deployment Phase (2007–2017): large-volume carbon storage tests

The PCOR Partnership is managed by the Energy & Environmental Research Center (EERC) at the University of North Dakota in Grand Forks, North Dakota. The PCOR Partnership's many public and private sector stakeholders have expertise in agriculture, forestry, economics, energy exploration and production, geology, engineering, and the environment. Since its inception in 2003, the PCOR Partnership's more than 90 members have provided data, guidance, financial resources, and practical experience with CCS and terrestrial sequestration. The PCOR Partnership region includes all or part of nine states (Iowa, Minnesota, Missouri, Montana, Nebraska, North Dakota, South Dakota, Wisconsin, and Wyoming) and four Canadian provinces (Alberta, British Columbia, Manitoba, and Saskatchewan).

Phase I activities were completed in September 2005. During Phase I, the PCOR Partnership assessed and prioritized the opportunities for sequestration in the region and helped to identify and assess the technical, regulatory, and environmental




*PCOR Partnership Region*

barriers to the most promising sequestration opportunities. At the same time, the PCOR Partnership helped inform policy makers and the public regarding $CO_2$ sources, sequestration strategies, and sequestration opportunities.

Phase II is a 4-year project running from October 1, 2005, to September 30, 2009. The activities for Phase II of the PCOR Partnership include four field validation tests along with regional characterization, regulatory and permitting activities, and outreach. Three of these field-based demonstration projects focus on injecting $CO_2$ into geologic formations for the dual purpose of $CO_2$ sequestration and enhanced hydrocarbon production. The goals of these demonstrations are twofold: 1) to develop approaches and attendant data sets that verify the ability of the target formations to store $CO_2$ as well as the potential to produce additional hydrocarbons through $CO_2$ injection and 2) to develop a scientifically defendable, engineering- and science-based methodology and mechanism by which carbon credits can be monetized for $CO_2$ sequestered in geologic formations. The monetization of carbon credits will enhance the economics of $CO_2$ enhanced oil recovery operations in the region. PCOR Partnership activities will also support the implementation of technologies to capture

$CO_2$ at existing facilities throughout the region as well as technologies to support safe transportation and geologic $CO_2$ storage.

The EERC was awarded a contract for PCOR Partnership Phase III activities in late September 2007. Phase III is a 10-year project running from October 1, 2007, to September 30, 2017. The activities for Phase III of the PCOR Partnership include two commercial-scale geologic CCS demonstrations, along with continued regional characterization and outreach. These two demonstrations, the Fort Nelson Demonstration in northeastern British Columbia and the Williston Basin Demonstration in western North Dakota, are designed to sequester a total of over 15 million tons of $CO_2$ by 2017 in deep, well-characterized, underground storage reservoirs.

## Why CCS?

There is concern that the ongoing accumulation of $CO_2$ and other greenhouse gases in the atmosphere from human activity will affect global climate. The President's Global Climate Change Initiative, issued in the spring of 2003, calls for an 18% reduction in U.S. $CO_2$ intensity by 2012. Conservation, more efficient power systems, renewable energy, and CCS are all tools to help reduce $CO_2$ intensity.

## Purpose of the Project

The PCOR Partnership is helping to develop technologies to reduce $CO_2$ emissions to the atmosphere from large-scale sources as well as implement projects to help reduce the level of $CO_2$ already in the atmosphere without adversely affecting economic growth or disrupting energy supply. The results of the PCOR Partnership's field tests will be used to 1) demonstrate the effectiveness of using $CO_2$ to enhance the production of hydrocarbons in reservoirs, 2) exhibit the cost-effective use of oil reservoirs and lignite coal seams for safe storage of $CO_2$, and 3) establish a means by which carbon markets can facilitate more recovery of oil and gas from the region.

## PCOR Partnership Accomplishments

PCOR Partnership accomplishments and activities include:

- A comprehensive regional assessment of $CO_2$ sources and sinks.
- The development of the PCOR Partnership Decision Support System (DSS, © 2007 EERC Foundation), a geographic information system (GIS)-based database trust 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.
- Six CCS demonstrations under way.
- Outreach materials, including:
  - 33 technical topical reports
  - 15 fact sheets on key regional sequestration topics
  - Five 30-minute documentaries for public television:
    - Nature in the Balance: $CO_2$ Sequestration (completed May 2005)
    - Reducing Our Carbon Footprint: The Role of Markets (completed April 2008)
    - Terrestrial $CO_2$ Sequestration (completed September 2008)
    - Geologic $CO_2$ Sequestration (in production)
    - $CO_2$ Sequestration and Global Warming: Overview of Phase II Results from NETL's Regional Partnerships (in preparation)
  - The PCOR Partnership Regional Atlas (copyright 2005–2008), which provides a general overview of $CO_2$ sequestration and a graphic summary of major $CO_2$ sources and sinks in the PCOR Partnership region
  - Public and members-only Web sites.


Attendees at the PCOR Partnership Annual Meeting held September 16–18, 2008, in Maple Grove, Minneapolis.

The PCOR Partnership is a collaborative framework to assess regional sequestration opportunities. New members are welcome. To learn more, contact:

**Edward N. Steadman,** Senior Research Advisor, (701) 777-5279; esteadman@undeerc.org
**John A. Harju,** Associate Director for Research, (701) 777-5157; jharju@undeerc.org

Visit the PCOR Partnership Web site at www.undeerc.org/PCOR.

Sponsored in Part by the U.S. Department of Energy

# Plains $CO_2$ Reduction (PCOR) Partnership

PCOR Partnership

*Practical, Environmentally Sound $CO_2$ Sequestration*

EERC Energy & Environmental Research Center

UND University of North Dakota

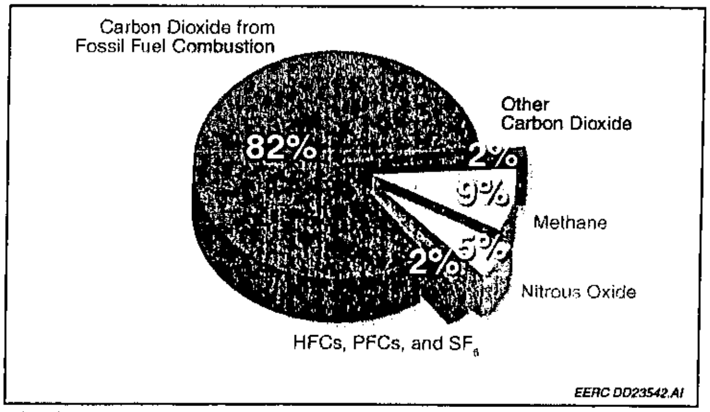
## $CO_2$ Sequestration – Controlling $CO_2$ Emissions to the Atmosphere Through Capture and Long-Term Storage

### What Is $CO_2$?

Carbon dioxide ($CO_2$) is a gas composed of one atom of carbon and two atoms of oxygen. $CO_2$ occurs naturally in the atmosphere, is essential to plant life and, as a greenhouse gas (GHG), helps create the greenhouse effect that keeps our planet livable.[1] $CO_2$ is exhaled by humans and is used to put the bubbles in soft drinks, as a coolant (dry ice), and in fire extinguishers.

### Why Consider Carbon Management?

Greenhouse gases, including $CO_2$, trap a portion of the sun's energy in the Earth's atmosphere and make our planet warm enough to support life. Human (anthropogenic) activity, including the use of fossil fuel, generates a significant volume of GHGs like $CO_2$. There is concern that the anthropogenic GHG entering the atmosphere are causing increased warming and that this warming will affect climate on a global scale. $CO_2$ sequestration—the capture and long-term storage of $CO_2$—is one of several actions that would help to control anthropogenic $CO_2$ emissions to the atmosphere.



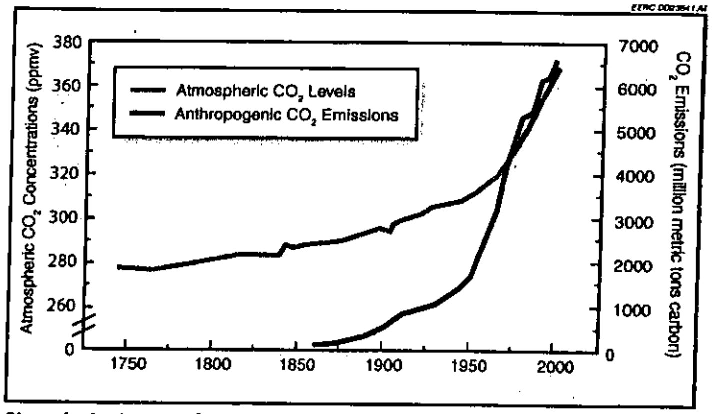

*The diagram shows the contribution to global warming potential by gas type for the anthropogenic GHG emitted by the United States in 2001. Although a relatively weak GHG, $CO_2$ is emitted in such large quantities that it constitutes 84% of the global warming potential of the emissions.*

### What Is $CO_2$ Sequestration?

Sequestration is the capture and long-term storage of $CO_2$ either before or after it has entered the atmosphere. Sequestration is one of several actions aimed at controlling the release of anthropogenic $CO_2$. There are two types of sequestration: direct and indirect.[2]

### Direct $CO_2$ Sequestration

Direct, or geologic, sequestration involves capturing $CO_2$ at a source before it can be emitted to the atmosphere.[2-4] The most efficient concept would use specialized equipment to capture $CO_2$ at large stationary sources like factories or power plants and then inject the $CO_2$ into secure storage zones deep underground (geologic sequestration) or into the deep ocean.



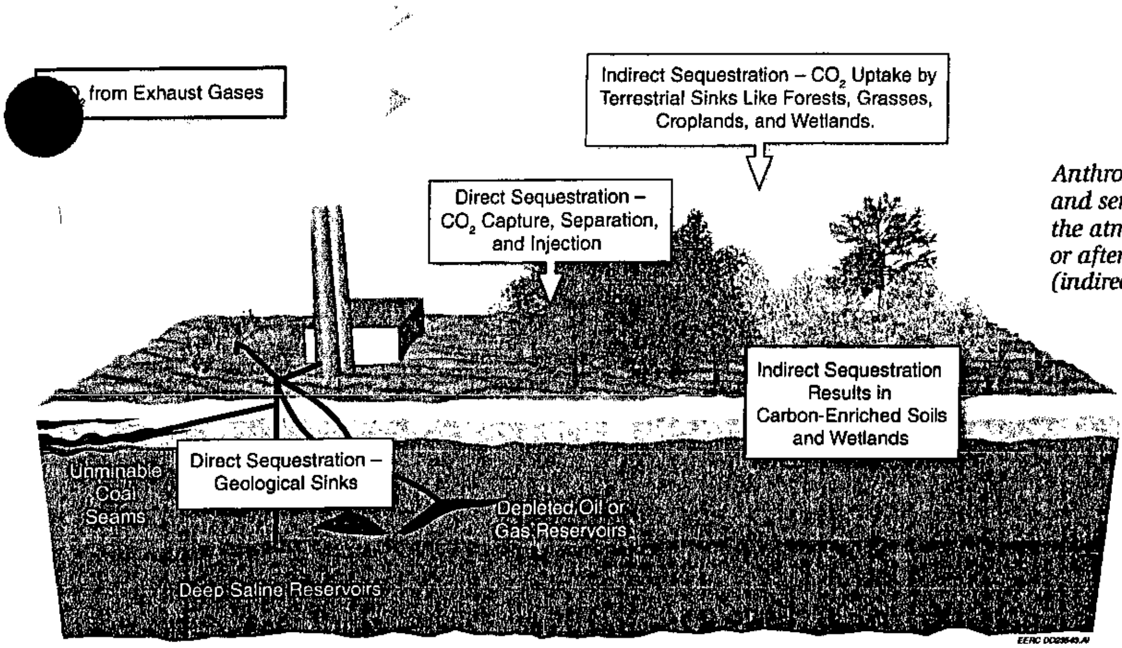

*Since the beginning of large-scale industrialization about 150 years ago, the level of $CO_2$ in the atmosphere increased by about 25%.*[1,5]

### Indirect $CO_2$ Sequestration

Indirect, or terrestrial, sequestration involves removing $CO_2$ from the atmosphere.[4,6] Indirect sequestration uses land management practices that boost the ability of natural $CO_2$ sinks like plants and soils to remove carbon as $CO_2$ from the atmosphere, regardless of its source. Opportunities for indirect sequestration can be found in forests, grasslands, wetlands, and croplands.

### What Is the Status of Direct Sequestration?

The injection and control of $CO_2$ in underground formations has been done safely for more than 30 years by oil companies.[7] Issues currently being addressed for direct $CO_2$ sequestration include developing $CO_2$ capture systems, determining the best underground storage sites for long-term storage of $CO_2$, determining the best way to monitor sites to guard against $CO_2$ migration, and determining a workable regulatory framework for sequestration projects.




*Anthropogenic $CO_2$ can be captured and sent to storage before it enters the atmosphere (direct sequestration) or after it has entered the atmosphere (indirect sequestration).*[12]

## Direct Sequestration Projects in the Great Plains Region

The Weyburn oil field in Saskatchewan is currently the site of active $CO_2$ flooding to improve oil production. Weyburn is also the site of a major international effort, coordinated by the Petroleum Technology Research Centre, located in Re[illegible] Saskatchewan, to assess geologic sequestration pr[illegible]. Thus far, studies have demonstrated the site to be sa[illegible]e and secure for sequestration, and it is expected that r[illegible] than 20 million metric tons of $CO_2$ will be success-[illegible]equestered there by 2025.[8]

## What Is the Status of Indirect Sequestration?

Land use practices can cause soils to trap carbon (sinks) or release carbon (sources). Agricultural practices like no-till and low-till keep more carbon in the soil than conventional practices. Current research activities in the Great Plains include determining the amount of $CO_2$ that can be taken up in different settings like forests, grasslands, croplands, or wetlands; developing monitoring practices to determine the amount of carbon staying in place; and determining optimal land management practices for carbon storage in different ecoregions and settings.[9–11]

## What Is the Role of the PCOR Partnership?

The Plains $CO_2$ Reduction (PCOR) Partnership is currently characterizing $CO_2$ sources and sequestration opportunities in the central interior of North America. This includes cataloging $CO_2$ sources, identifying sequestration opportunities, assessing monitoring technologies, and assessing regulatory needs for successful sequestration projects in the region. The PCOR Partnership is one of seven partnerships funded by the U.S. Department of Energy's National Energy Technology Laboratory that are working to move $CO_2$ sequestration activities to full-scale deployment.

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Th[illegible] $CO_2$ Reduction (PCOR) Partnership is a group of public and private sector stakeholders working together to better understand the technical and economic feasibility of [illegible]ing $CO_2$ emissions from stationary sources in the central interior of North America. The PCOR Partnership is managed by the Energy & Environmental Research Center ([illegible]) at the University of North Dakota and is one of seven regional partnerships under the U.S. Department of Energy's National Energy Technology Laboratory Regional Carbon Sequestration Partnership Initiative. To learn more, contact:


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# Plains $CO_2$ Reduction (PCOR) Partnership

*Practical, Environmentally Sound $CO_2$ Sequestration – Phase II*

## Regional $CO_2$ Sequestration Potential – Field Validation Tests

Experts agree that it may take decades to implement the full range of options under consideration to effectively manage $CO_2$ released from human activities like transportation, home and commercial heating and cooling, and manufacturing and electrical generation. Billions of tons of $CO_2$ may require long-term storage. The Plains $CO_2$ Reduction (PCOR) Partnership region has significant capacity for a variety of projects for long-term $CO_2$ storage in underground geologic formations, as well as in vegetation and soils.

## Global Issue – Dynamic Regional Partnership

Since its inception in 2003, the PCOR Partnership has brought together over 85 public and private sector groups working to lay the groundwork for practical and environmentally sound $CO_2$ sequestration in the heartland of North America. Covering a region of all or part of nine states and four Canadian provinces, the PCOR Partnership is one of seven regional partnerships in the U.S. Department of Energy's (DOE's) Regional Carbon Sequestration Partnership Initiative. The PCOR Partnership is managed by the Energy & Environmental Research Center at the University of North Dakota and supported by DOE, as well as its many U.S. and Canadian members.

## $CO_2$ Facts

Carbon dioxide ($CO_2$) is a gas that occurs naturally in small amounts in the Earth's atmosphere. $CO_2$ is important to plant life and to the natural greenhouse effect that makes earth livable. Humans add to the level of $CO_2$ in the atmosphere through agriculture, burning fossil fuels, and industrial activity. The concern that $CO_2$ from human activities could impact global climate and weather is the basis for $CO_2$ management efforts. $CO_2$ management options include greater efficiency in energy systems, greater use of renewable and alternative fuels, energy conservation, and the focus of the PCOR Partnership activities: $CO_2$ sequestration.

## What Is $CO_2$ Sequestration?

$CO_2$ sequestration is a way of managing $CO_2$ from human activities. Specifically, sequestration means capturing $CO_2$ and putting it into temporary or permanent storage. Terrestrial sequestration is using plants to capture $CO_2$ from the air and then storing it in vegetation or soils. Geologic sequestration is capturing $CO_2$ from exhaust or process gas and placing it in permanent storage in suitable underground geologic formations.

## Phase II – Validation Tests to Clear the Way

In the fall of 2005, the PCOR Partnership embarked on a 4-year, multimillion-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 four field validation tests (illustrated on the back of this page) were developed to test the efficacy of $CO_2$ sequestration in our region. The region will also 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.

## Outcomes

The results of the PCOR Partnership's Phase II activities will include 1) technical data and reports on its four field verification activities; 2) television documentaries on the field verification activities and other topics; 3) enhanced working relationships between government, regulatory, industry, and citizen groups with respect to sequestration project opportunities; 4) an enhanced assessment of the terrestrial and geologic sequestration capacity and opportunities in the region; and 5) an improved assessment of the economic opportunities to the region represented by $CO_2$ sequestration, particularly with respect to enhanced production of oil and gas resources and the monetization of $CO_2$ emission credits.

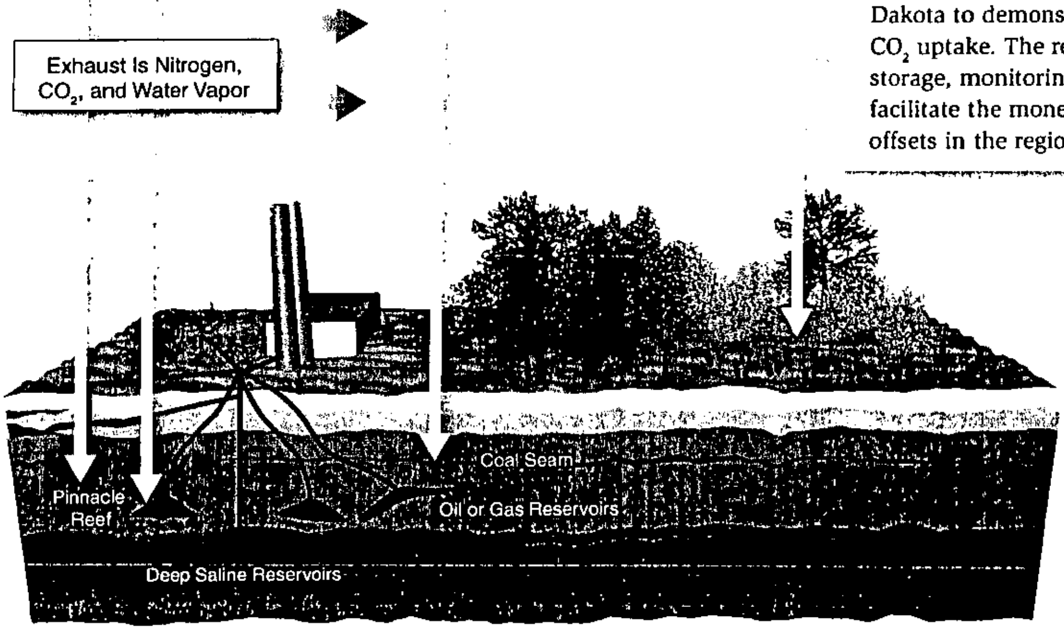
## Phase II: Field Validation Test Sites

**rich gas in a pinnacle reef structure** – Acid gas roximately 70% $CO_2$, 30% hydrogen sulfide [$H_2S$]) from natural gas-processing plants in northern Alberta, 'anada, is being injected into an oil-producing zone i an underground pinnacle reef structure. Results will help to determine the best practices to support sequestration in these unique geologic structures as well as further our understanding of the effects of $H_2S$ on tertiary oil recovery and $CO_2$ sequestration.


**$CO_2$ in a deep oil reservoir** - $CO_2$ will be injected into an oil-bearing zone at great depth in the Williston Basin in western North Dakota. The activity will be used to determine the efficacy of $CO_2$ sequestration and the use of $CO_2$ to produce additional oil from other deep carbonate source rocks.

**$CO_2$ in an unminable lignite seam** - $CO_2$ will be injected into unminable lignite seams in northwestern North Dakota. The injected $CO_2$ will be trapped by naturally bonding to the surfaces of the fractured lignite. The injected $CO_2$ also has the potential to displace methane occupying the coal fractures. This validation test will provide valuable information regarding lignites for both $CO_2$ sequestration and enhanced coalbed methane production.

**Out of the air – into the soil** – A managed wetland is being implemented in north-central South Dakota to demonstrate practices that will improve $CO_2$ uptake. The results will help to optimize $CO_2$ storage, monitoring and verification methods, and facilitate the monetization of terrestrial carbon offsets in the region and elsewhere.




*The PCOR Partnership has launched a 4-year program to evaluate the feasibility of storing $CO_2$ in a variety of settings from wetlands to subsurface oil reservoirs and unminable coals.*

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Plains $CO_2$ Reduction (PCOR) Partnership

PCOR Partnership *Practical, Environmentally Sound $CO_2$ Sequestration*

EERC Energy & Environmental Research Center

UND University of North Dakota

# $CO_2$ Sequestration Validation Test in a Deep, Unminable Lignite Seam in Western North Dakota

## Background

In response to increasing levels of carbon dioxide ($CO_2$) in the atmosphere, the U.S. Department of Energy has developed the Regional Carbon Sequestration Partnership (RCSP) Program. The RCSP includes seven regional partnerships focused on conducting comprehensive evaluations of the opportunities for $CO_2$ capture and storage in North America. One of the options for storage is the injection of $CO_2$ into underground geological formations such as oil reservoirs, brine-saturated formations, and coal seams. The Plains $CO_2$ Reduction (PCOR) Partnership, led by the Energy & Environmental Research Center at the University of North Dakota, has been assessing the northern Great Plains region for potential geological storage opportunities. The PCOR Partnership region includes all or part of nine states and four Canadian provinces.

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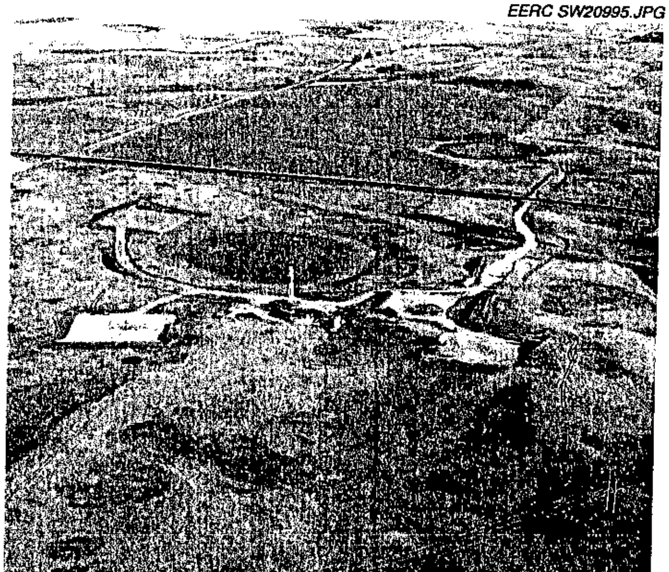

*Figure 1. Burke County test site.*

Characterization activities conducted in 2003 and 2004 confirmed that a variety of geological options exist in the region, including storage in deep brine-saturated formations, depleted and producing oil fields, and unminable coal beds. The latter two options may have an economic benefit through the enhancement of oil or natural gas recovery.

In 2007, the PCOR Partnership initiated a field-based test in Burke County in northwestern North Dakota to evaluate the potential to simultaneously store $CO_2$ and enhance natural gas recovery from a lignite coal seam (Figure 1). The goals of the test are to 1) ensure that the $CO_2$ can be safely injected and permanently trapped in lignite by means of adsorption (physical attachment), 2) assess the feasibility and economics of $CO_2$-enhanced methane production from lignite, and 3) develop protocols for similar operations in other coal seams in the region.

## Update on the Progress of the Test

In August 2007, five wells were drilled on the Burke County test site (Figure 2). Prior to drilling, a public meeting was held in Bowbells, North Dakota. The purpose of the meeting was to inform local residents about the commencement of the field operations.

In August and September 2007, a series of tests were conducted on the wells. Geophysical information on the properties of the subsurface system was collected. In November 2007, operations were shut down for the winter. It is anticipated that activities will resume in April or May 2008, depending on weather conditions.

The analysis of the data collected in the fall of 2007 confirmed that the targeted coal seam has sufficient thickness to provide enough storage capacity to conduct a relevant $CO_2$ injection test. The target coal seam is overlain and underlain by relatively impermeable rocks that will prevent vertical migration of the injected $CO_2$, thereby confining it to the zone of injection. Additionally, gas samples and approximately 30 feet of rock and coal core samples, ten of which were the primary coal seam of interest, were retrieved from one of the wells.

Analysis of all data collected in the field is ongoing. The nd core samples (Figure 3) are being analyzed for the ving parameters:

- Gas content
- Gas specific gravity
- Methane and $CO_2$ isotherms
- Diffusion coefficient
- Gas desorption time
- Coal ash and moisture contents
- Coal density and compressibility
- Rock porosity and permeability

The next steps in the study are to conduct a series of tests in the field to more fully determine the ability of the coal seam to support $CO_2$ injection and to compare and calibrate the laboratory data with the data generated in those field tests. The results of laboratory- and field-scale experiments will be used to design an optimum injection program to ensure safety of the operations. Additionally, a numerical computer model of the geologic system will be created and will serve as a means to predict the fate of the $CO_2$ within the coal seam.

Currently, it is planned that the injection of $CO_2$ will be conducted in the summer or fall of 2008. At that time, a monitoring, mitigation, and verification (MMV) plan will be implemented to monitor the underground movement of $CO_2$. The MMV data may also be used to modify and improve the injection design, if needed.

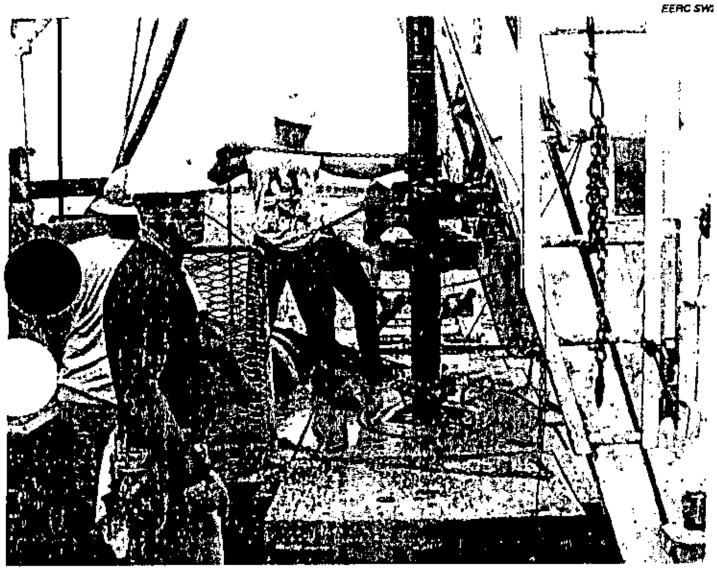

*Figure 2. Drilling a well at the Lignite Field Validation Test Site.*


*Figure 3. Collecting the core at the test site.*

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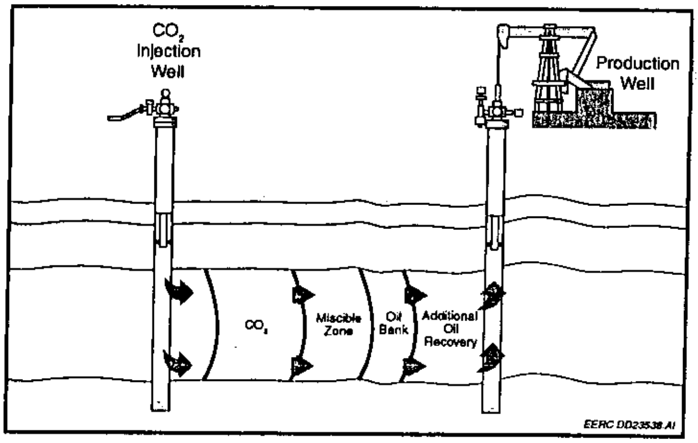
# Plains $CO_2$ Reduction (PCOR) Partnership

*Practical, Environmentally Sound $CO_2$ Sequestration*

# $CO_2$ Sequestration Validation Test in a Deep Oil Field in the Williston Basin

## $CO_2$, Oil Fields, and Sequestration

Oil is typically extracted from underground reservoirs in three phases: primary, secondary, and tertiary (or enhanced) recovery. Typically, during the primary phase, natural pressures within the reservoir drive the oil to the well, and pumps bring the oil to the surface. On average, primary recovery produces 10% to 15% of the oil. Injecting water into the formation (secondary recovery) helps recover another 10% to 20%. Enhanced oil recovery (EOR) methods, including $CO_2$ EOR, have the potential to recover an additional 10%–20% of the oil in the reservoir (Figures 1 and 2). Most of the $CO_2$ currently used in EOR operations is produced from geologic formations. Because most of the $CO_2$ from EOR operations remains in permanent storage underground at the end of the EOR ·ration, replacing the geologic $CO_2$ used today in EOR ·h anthropogenic $CO_2$ ($CO_2$ from human activities) would reduce anthropogenic emissions by putting the ·uman-produced $CO_2$ into long-term storage in depleted oil ·eservoirs underground. At the same time, the oil revenue generated through the anthropogenic $CO_2$ EOR could provide economic incentive to undertake these types of sequestration projects. The wide implementation of this value-added strategy for sequestering anthropogenic $CO_2$ could be an effective hedge against climate change.




·ure 1. *Each day, 1.75 billion cubic feet of $CO_2$, most of it from ·al geologic sources, is transported through 3500 miles of ·ine to the more than 4600 injection wells involved in the 80 active $CO_2$ EOR operations in North America. EOR operations ·ically leave 90% of the $CO_2$ in permanent storage in the ·pleted oil reservoir.*[1]

### What Is "Value-Added"?

The term value-added is used to describe the economic value of an action or product that has been increased through a change in process or practice. Operations that use $CO_2$ to enhance the production of oil or natural gas can also add value by using the oil or natural gas reservoir as a storage site for the $CO_2$. The sale of the additional oil or natural gas can provide the economic return needed to provide incentive for companies to undertake value-added sequestration projects under today's market conditions.

## Williston Basin Field Validation Test

The Energy & Environmental Research Center's Plains $CO_2$ Reduction (PCOR) Partnership will be conducting a multiyear field validation test of $CO_2$ sequestration in an oil field in the North Dakota portion of the Williston Basin (Figure 3). A preliminary analysis indicates that

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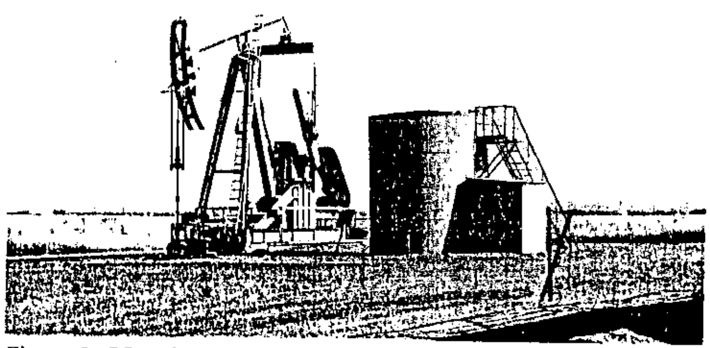

*Figure 2. $CO_2$ EOR operations have been proven effective in prolonging the life of oil fields in areas from West Texas to the northern Great Plains.*

a significant number of deep oil fields in the Williston Basin may hold promise for $CO_2$ EOR operations that will permanently sequester $CO_2$. The knowledge gained through pioneering $CO_2$ EOR/$CO_2$ geologic sequestration projects in deep reservoirs in the Williston Basin could facilitate expansion of $CO_2$ EOR projects in deeper oil fields globally.


F *Location of the Williston Basin in the PCOR Partnership Region.*

The Williston Basin Field Validation Test will be conducted in an oil voir nearly 2 miles below the earth's surface, making it the deepest based EOR project in North America.[2] As a result, this project will provide valuable information that will help customize operations for $CO_2$ EOR and $CO_2$ sequestration under geologic conditions of high pressure and temperature elsewhere in the basin and in the world. The Williston Basin Field Validation Test is among the four field validation tests currently under way in the PCOR Partnership region in the northern Great Plains of North America and one of the nearly three dozen field demonstrations under the U.S. Department of Energy National Energy Technology Laboratory's Regional Carbon Sequestration Partnership Program.

## Test Goals and Approach

The overall goal of the Williston Basin Field Validation Test is to develop the practical knowledge necessary to undertake $CO_2$ EOR and $CO_2$ geologic sequestration in deep oil reservoirs. Specifically, the test is designed to determine the following:

- The effect of the naturally high-pressure and high-temperature conditions in a deep oil reservoir on the ability to conduct EOR using $CO_2$.
- The effect of the naturally high-pressure and high-temperature conditions in a deep oil reservoir on the volume of $CO_2$ that could be left in permanent storage in the reservoir.
- The applicability of adapting the existing methodologies for $CO_2$ EOR and $CO_2$ sequestration that have been developed for use at relatively shallow depths for use in deeper zones.
- The effects of the conditions in the deep reservoir on the economics of the EOR and sequestration operations.

## Test Operation

Since the spring of 2007, the PCOR Partnership team has been gathering detailed information on the geological and engineering characteristics of candidate oil fields in the Williston Basin. Once this geological characterization is completed and after close consultation with the operators of the candidate oil fields, a test site will be chosen, and a $CO_2$ injection plan will be developed and finalized. This plan will include a customized approach for monitoring the fate of $CO_2$ at the site.

$CO_2$ injection is scheduled to begin in late 2008. The monitoring activities will be conducted before, during, and after the $CO_2$ injection to verify and validate the effectiveness of both the EOR and sequestration components of the test, as well as to ensure the protection of potable groundwater resources in the test area.

## Project Deliverables

The project is designed to result in two key deliverables:

- A technical report that summarizes test results and findings, including overall performance and a statement of $CO_2$ storage capacity.
- A best practices manual for use in $CO_2$ sequestration projects in deep oil reservoirs and value-added projects in oil fields that combine EOR with the sequestration of $CO_2$.

## References and Notes

1. Melzer, L.S., 2007, An oil industry perspective on carbon capture and storage (CCS): Presented at the PCOR Partnership 2007 Annual Meeting, Grand Forks, North Dakota, October.
2. Jerrell, P.M., Fox, C.E., Stein, M.H., and Webb, S.L., 2002, Practical aspects of $CO_2$ flooding: Richardson, Texas, Society of Petroleum Engineers, Inc., p. 8.

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# Plains $CO_2$ Reduction (PCOR) Partnership

*Practical, Environmentally Sound $CO_2$ Sequestration*

## $CO_2$ EOR and $CO_2$ Sequestration – The Case for Collaboration

### Introduction

Events currently unfolding at national and state levels have strong implications with regard to the pace of deployment of carbon dioxide ($CO_2$) emission reductions. $CO_2$ capture and sequestration (CCS) policies are under rapid development. It is critical to the economy that the right decisions be made in this important area of energy policy.

One very serious concern has to do with any policy that might marginalize enhanced oil recovery (EOR) as a sequestration tool. The emission reduction potential and sequestration associated with EOR is immense, and revenues from oil produced partially offset the cost to the public and, ultimately, accelerate more widespread deployment of CCS.

With the growing energy and carbon management concerns in North America, the contributions of $CO_2$ EOR need to be placed front and center in the policy debate. This fact sheet addresses the key principles of $CO_2$ EOR policy in the sequestration arena.

### The Case for $CO_2$ EOR

EOR involves injecting substances into a reservoir through thermal, chemical, and/or gas-miscible processes. One very important and growing example of a gas-miscible process is that of a $CO_2$ flood. $CO_2$ is injected into an oil reservoir whereupon it mixes with the oil, creating a mixture of oil and $CO_2$, freeing the oil from the rock, and driving additional oil to producing wells. EOR can recover an average of 35% of the oil remaining after the previous stages of production. Some of the injected $CO_2$ returns with the recovered oil and is reinjected into the reservoir to minimize operating costs while maximizing economic and environmental benefits.

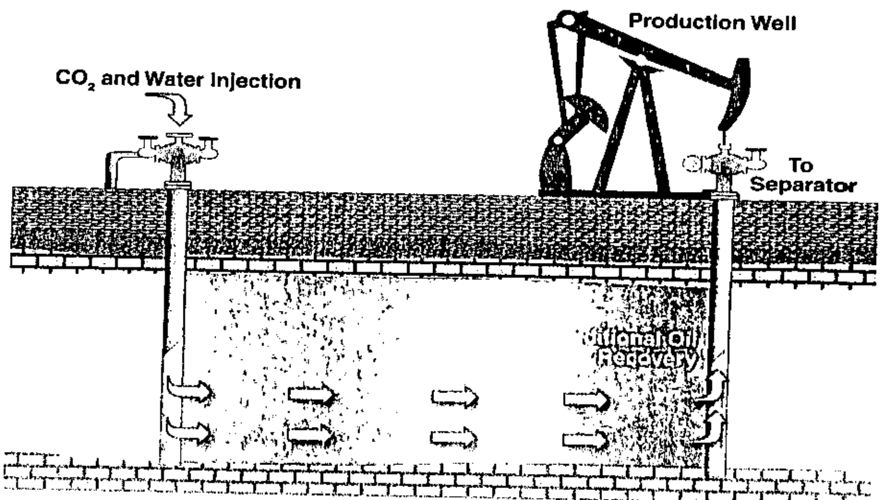
The era of $CO_2$ EOR effectively began with two large-scale floods in west Texas in the 1970s. The industry has grown since then to become a major production component in Texas, Wyoming, New Mexico, and Mississippi and produces over 90 million barrels of oil a year for the U.S. economy. Historically, the chief limiting factors of growth in most other areas with oil production have been low oil prices and the lack of ready and reliable sources of $CO_2$.

Industry experience from the Permian Basin region of West Texas and New Mexico demonstrates that 6 to 8 mcf of $CO_2$ is permanently stored per barrel of oil recovered. And since over a billion barrels have been recovered there, that represents 6 to 8 tcf (340–460 gigatons) of stored $CO_2$.

### CCS and $CO_2$ EOR

So what does this all mean for CCS? First, an existing industry has evolved that possesses the operational practices to handle huge volumes of $CO_2$ safely and effectively. The industry's best practices can be extended into the field of CCS almost seamlessly. Surface $CO_2$ handling (including gas processing, compression, and transportation), well designs, injection practices, and surveillance of emplaced $CO_2$ are all directly applicable. Key to its success is that net stored volumes need to be documented and long-term storage must be assured.

Second, expansion of the EOR industry is seriously constrained by the availability of $CO_2$. With coal plants and other industrial facilities seeking to find a home for their emitted $CO_2$, it becomes a matter of $CO_2$ capture technology, economics, and mutual trust to develop joint




*This diagram illustrates $CO_2$ EOR.*

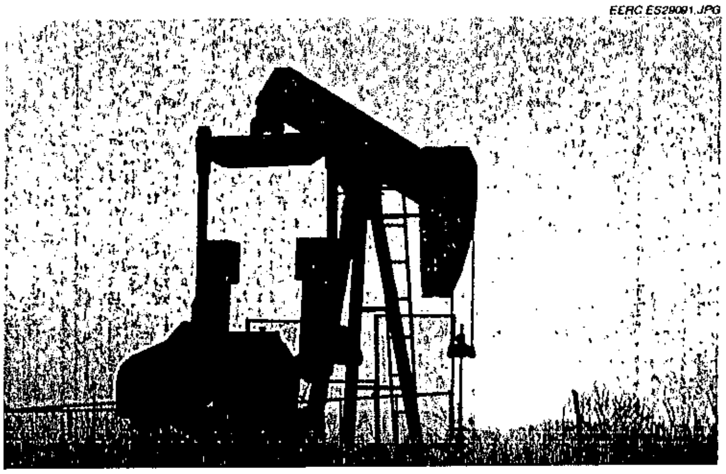
ventures between these two industries that are so critical to America's future and provide a transition to next-
ation energy technology.

Third, the American oil produced from EOR has been the
revenue stream available to fund U.S. EOR projects—
would include the capture and processing from the source of $CO_2$ to the funding of pipelines to move it to the injection site to produce the oil. With EOR qualified as sequestration, the oil revenue acts as a large and critical revenue stream to offset the huge infrastructure costs that otherwise need to be funded by the public through higher energy costs. Storing the $CO_2$ and funding the infrastructure from the additional oil recovery occurs at the same time that important low- to zero-carbon barrels of oil contribute to North American energy security and a cleaner energy future.

Fourth, $CO_2$-based EOR is important in that it extends the life of existing oil fields. Up to an additional 30 years of life can be gained by $CO_2$-based EOR. This provides valuable employment, reduces the need to develop as many new fields, and greatly enhances our North American oil supply.

## Barriers

Nature provides examples of deeply sourced, geologically t d $CO_2$, thereby demonstrating that some s face sites will permanently secure $CO_2$. However, at other sites, $CO_2$ will vertically migrate, which may
y not prove to be problematic. $CO_2$ is a naturally
rring substance; generation and migration within the subsurface are very common. Rather than trying to fashion rules that protect against surface escape in any subsurface condition, regulatory oversight needs to recognize the ubiquitous occurrence and presence of the molecule while screening out the high-risk sites for injection and providing flexibility of regulatory rules to accommodate the attendant levels of risk.




*EOR can extend an oil field's life by decades.*

The $CO_2$ EOR experience within the oil and gas industry can provide the pathways to successful sequestration on the needed operational scales. The oil and gas industry can provide the experience with the tools of exploration, the science and experience to assess risks of site security and, very importantly, the tools and techniques to design the wells for emplacement.

One of the largest potential barriers to deployment of sequestration projects is the specification of overly complex well designs and excessive levels of monitoring of sites. Experience shows that exotic well designs add little benefit while, on the other hand, judicious site selection adds greatly to the security of emplacement. For example, subsurface sequestration formations overlain by bedded salts provide optimal conditions for long-term storage.

## EOR and Sequestration: Separate Paths?

Examples of recent policy actions appear to be charting separate paths for $CO_2$ EOR and sequestration. For reasons stated earlier, recognizing EOR as a $CO_2$ storage event is critical. Advancements in using fossil fuels such as coal in such a way as to capture the by-product $CO_2$ are important steps for North America's energy future. Disqualifying $CO_2$ stored during EOR as an offset to emissions will do nothing but delay the necessary commercial demonstrations of those technologies and further burden an already-distressed energy infrastructure. One example of an action working against this progress is separate well design requirements for sequestration as compared to the time-tested designs currently used in $CO_2$ EOR.

## Conclusions

Industry participation in the ongoing policy debates about qualifying storage during $CO_2$ injection projects is critical. Particular contributions are needed in rating potential sequestration sites, specifying well design requirements, volumetric $CO_2$ storage accounting, and in situ surveillance and monitoring.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# Plains $CO_2$ Reduction (PCOR) Partnership

***Practical, Environmentally Sound $CO_2$ Sequestration***

## PCOR Partnership Phase III – Commercial-Scale Demonstrations of Geologic $CO_2$ Storage in the Northern Great Plains

Just like the natural underground accumulations of oil and natural gas, many natural accumulations of carbon dioxide ($CO_2$) gas have been held in place for millions of years in secure underground geologic reservoirs. Modeled on these natural accumulations, geologic $CO_2$ sequestration, the permanent underground storage of $CO_2$ from human activities, is emerging as a promising strategy for managing the large amount of $CO_2$ gas generated as a by-product of fossil energy use at power plants or other industrial facilities. Geologic $CO_2$ sequestration, also called carbon capture and storage (CCS), is only one of the many actions that may be taken in the upcoming years to address concerns over climate change by reducing the output of $CO_2$ and other greenhouse gases that result from human activity.

The 10-year Phase III program of the Plains $CO_2$ Reduction (PCOR) Partnership, initiated in the fall of 2007, features two commercial-scale demonstrations of geologic sequestration of $CO_2$ from human activities (Figure 1). These two demonstrations, the Western Canadian Basin Demonstration in northeastern British Columbia and the Williston Basin Demonstration in western North Dakota, are designed to sequester a total of over 15 million tons of $CO_2$ by 2017 in deep, well-characterized, underground storage reservoirs.[1] These commercial-scale demonstrations are in addition to the four medium-scale field verification tests currently under way through the PCOR Partnership's Phase II program (Figure 1) and the more than 30 other geologic $CO_2$ sequestration tests and demonstrations under way in the United States and around the world.

### Western Canadian Basin Demonstration

Most geologic sequestration projects are designed to emplace $CO_2$ into an underground geologic structure, referred to as a trap, which may have previously contained oil or natural gas for millions of years. However, another type of geologic setting, known as deep brine reservoirs, are believed to offer even greater potential for $CO_2$ storage because of their regionally extensive nature. The Western Canadian Basin Demonstration will be one of the first commercial-scale geologic sequestration projects to emplace $CO_2$ into a North American brine reservoir. To accomplish this, over one million tons of $CO_2$ from an existing gas-processing facility in northeastern British Columbia, Canada, will be compressed to a supercritical state ($CO_2$ gas will be put under high pressure so that it behaves like a fluid; the pressure is similar to the conditions in the underground geologic injection zone) before being transported via pipeline approximately 3 miles (5 km) to an injection site. The $CO_2$ is from an acid gas stream (85% $CO_2$, 15% $H_2S$). Once at the injection site, the $CO_2$ will be sent into the ground to a depth of approximately 6500 ft (2000 meters). There the supercritical $CO_2$ will be injected into the carbonate rocks (limestone and dolomite) of the Elk Point Group rock formations and dissolve into the highly saline water that fills the pores of the Elk Point Group rocks. Once the $CO_2$ enters the pores of the carbonate rocks, the naturally high pressure and temperature conditions in the Elk Point Group will maintain the $CO_2$ in the supercritical state permanently. The injection zone in Elk Point is capped by a substantial shale layer that provides a

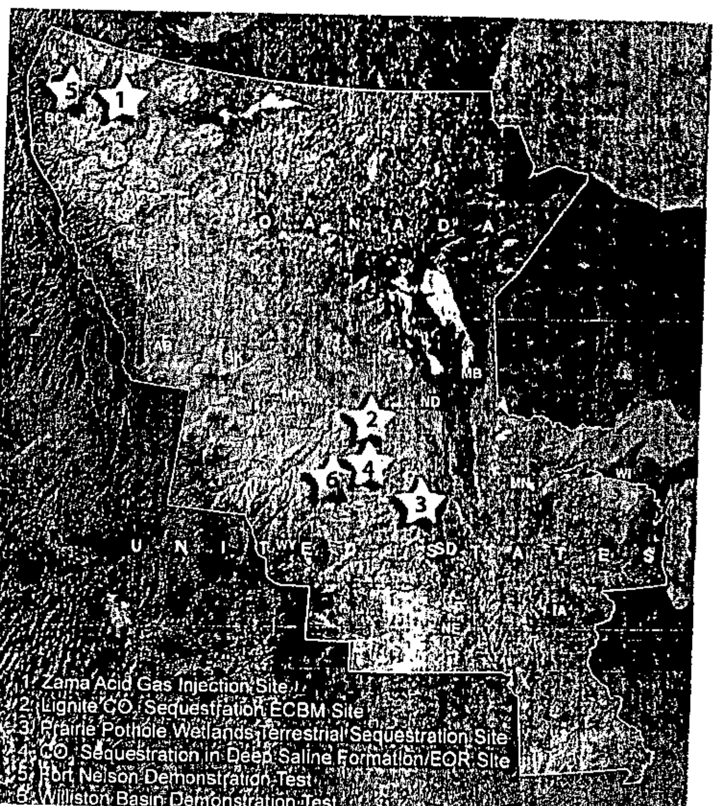


*Figure 1. Sequestration activities in the PCOR Partnership region (ECBM [enhanced coalbed methane], EOR [enhanced oil recovery]).*

very competent seal. Other geologic layers, including the thick shales of the Banff Formation, act as seals in the ...sands of feet of rock between the top of the Elk Point ...p and the base of the zone of drinkable groundwater. ...aracterization of the geology of the region has shown ...at there are many suitable sites for $CO_2$ storage in the ...gion and that capacities exceed several million tons of $CO_2$ per square mile. The demonstration is designed to provide improved understanding of the following:

- Cost-effective monitoring, mitigation, and verification (MMV) strategies for large-scale $CO_2$ sequestration in deep brine reservoirs.
- Testing and refinement of reservoir modeling intended to predict and estimate $CO_2$ injectivity (the potential for emplacing $CO_2$ into the reservoir), areal extent and mobility of the supercritical $CO_2$ plume in the reservoir, and improved methodologies to ensure that site characterization and MMV results better support modeling efforts.
- Testing strategies to predict the effects of $CO_2$ on the integrity of overlying sealing formations, including the testing and modeling of key geomechanical and geochemical parameters.

## Williston Basin Demonstration

The cost-effective separation of $CO_2$ from flue gases is ...or barrier to the widespread implementation of ...gic sequestration at conventional power plants and other large-scale stationary sources of $CO_2$. The Williston ...in Demonstration will be the first large-scale CCS ...ject utilizing $CO_2$ from a retrofitted conventional coal-fired power plant. A portion of the flue gas output of Basin Electric Power Cooperative's Antelope Valley Station will be processed to capture its $CO_2$. This $CO_2$ will then be dehydrated, compressed to supercritical conditions, and combined with additional supercritical $CO_2$ from the adjacent Great Plains Synfuels Plant before being transported about 150 miles (220 km) via pipeline to the sequestration site. Once at the sequestration site, the $CO_2$ will be injected at a depth of nearly 2 miles (approximately 10,000 ft or 3000 meters) into the pore space of an oil reservoir. In the pore space, the $CO_2$ will dissolve into the oil and allow the oil to more easily flow to the production wells. At the end of economical oil production, most of the purchased $CO_2$ will be left permanently trapped in the underground reservoir. The demonstration will emplace approximately 1 million tons of $CO_2$ a year. The characterization of the Williston Basin in western North Dakota indicates there are many millions of tons of additional storage capacity in these types of geologic settings.

The primary objective of the PCOR Partnership Phase III Williston Basin Demonstration is to verify and validate the concept of utilizing the region's large number of oil fields for large-scale injection of anthropogenic $CO_2$ for the purposes of enhanced oil recovery leading to permanent $CO_2$ storage. Other objectives include:

- Improved understanding of the engineering effects of extreme depth (greater than 2 miles) on EOR and $CO_2$ sequestration design and operation.
- Opportunities for expansion of commercial anthropogenic carbon management through the initiation of large-scale $CO_2$ injection operations in oil fields.
- Analysis to determine if deep geologic sinks can provide sufficient storage capacity and commercialization opportunities for large stationary $CO_2$ sources throughout the region.
- Improved approaches for capacity estimates for the thousands of potential sequestration candidates represented by the oil fields in the region.
- Testing and refinement of reservoir modeling.
- Testing strategies to predict the effects of $CO_2$ on the integrity of overlying sealing formations, including the testing and modeling of key geomechanical and geochemical parameters.
- Assessment of potential leakage pathways and documentation of any observed leakage (if present).

## Proposed Schedule

Phase III activities will last from the fall of 2007 to the fall of 2017. The sites for geologic $CO_2$ sequestration will be chosen in Year 1, infrastructure including injection wells and monitoring equipment will be emplaced in Years 2 and 3, injection will occur from Years 4 through 10, and assessment will be completed in Year 10.

## Notes

[1]The sequestration of approximately 15 million metric tons of $CO_2$ would equate to the removal of approximately 2.8 million passenger vehicles from the highway for a year, as calculated assuming 5.32 metric tons of $CO_2$ per passenger vehicle per year with passenger vehicle $CO_2$ output calculated using the average output for Daimler-Chrysler, Ford, and GM passenger vehicles for 2002 (1.0289 lb per mile) from Figure 7 at http://earthtrends.wri.org/features/view_feature.cfm?theme=3&fid=53 and average annual residential vehicle mileage (11,400 miles) for 1994 from www.eia.doe.gov/emeu/rtecs/Chapter3.html.

Th... $CO_2$ Reduction (PCOR) Partnership is a group of public and private sector stakeholders working together to better understand the technical and economic feasibility of seques...g $CO_2$ emissions from stationary sources in the central interior of North America. The PCOR Partnership is managed by the Energy & Environmental Research Center (EERC) a... University of North Dakota and is one of seven regional partnerships under the U.S. Department of Energy's National Energy ...gy Laboratory Regional Carbon Sequestration Partnership Initiative. To learn more, contact:

...ward N. Steadman, Senior Research Advisor, (701) 777-5279; esteadman@undeerc.org
John A. Harju, Associate Director for Research, (701) 777-5157; jharju@undeerc.org

Visit the PCOR Partnership Web site at www.undeerc.org/PCOR. New members are welcome.

Sponsored in Part by the U.S. Department of Energy

Attachment #1

## House Natural Resources Committee

**Testimony on Engrossed SB 2095 and Engrossed SB 2139**

**Presented by Sandi Tabor**
Lignite Energy Council

February 26, 2009

Senate Bill 2095 and Senate Bill 2139 are companion bills that establish the key components necessary for the regulation of the underground storage of carbon dioxide and associated greenhouse gases[1]. The bills were drafted by a committee formed in late 2007 called the ND $CO_2$ Storage Workgroup (Workgroup). Members of the Workgroup included representatives from the Attorney General's Office, the Department of Health, the Oil and Gas Division of the ND Industrial Commission, the Lignite Energy Council, the ND Petroleum Council, and the Energy and Environmental Research Center (EERC).

Why did we take on this task? Presently, the debate over "how" (not "if") greenhouse gas emissions will be regulated is taking place in the halls of Congress and in the halls of state legislatures across the country. In fact in 2007 Minnesota passed a goal to reduce greenhouse gas emissions by 80% by 2050. The first phase of the Minnesota goal is to reduce emissions by 15% by 2015. With this in mind, the challenge for the lignite industry is to develop a comprehensive plan not only dealing with how to capture $CO_2$, but also considering how captured $CO_2$ can be commercially used or stored.

The lignite industry is one of the North Dakota's major industries. The future of our industry is dependent upon the state and the industry working together as partners to find solutions to the thorny issue of climate change. As such, the interest of the State of North Dakota in geologic storage of $CO_2$ and other greenhouse gases arises because, in addition to conservation, it is among the most immediate and viable strategies available for mitigating the release of $CO_2$ into the atmosphere. The passage of these bills ensures that North Dakota will have in place the critical legal and regulatory infrastructure for the safe and secure storage of $CO_2$.

To facilitate our efforts we took advantage of the work product of a task force formed by the Interstate Oil and Gas Compact Commission (IOGCC). Its membership included representatives from IOGCC member states, **including North Dakota**, international affiliate provinces, state and provincial oil and gas agencies, the U.S. Department of Energy (DOE), DOE-sponsored Regional Carbon Sequestration Partnerships, **including the PCOR partnership**[2], the Association of

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[1] Associated greenhouse gases include methane, nitrous oxide, chlorofluorocarbons and ozone.
[2] The "PCOR Partnership" is the Plains $CO_2$ Reduction Partnership which is a collaborative effort of over 80 US and Canadian stakeholders whose mission is to develop the groundwork for practical and environmentally sound underground storage of $CO_2$. The EERC administers the program.

American State Geologists and independent experts. Funded by DOE and its National Energy Technology Laboratory, the Task Force undertook an examination of the technical, policy and regulatory issues related to the safe and effective long-term storage of $CO_2$ in oil and gas fields, coal seams and deep saline formations. The end result of the task force work was the development of a model statute and a set of model rules to govern the underground storage of $CO_2$.

The Workgroup used the model statute as a starting point for the development of SB 2095. During the course of the Workgroup's deliberations it became clear that a companion bill clarifying the ownership of pore space was also necessary. SB 2139 was drafted to further clarify what we believe is the existing common law in North Dakota --- that the surface owner owns the pore space.

This morning the Workgroup would like to provide you with a brief primer on $CO_2$ storage which will be presented by John Harju from the PCOR Partnership. After John's presentation, Lynn Helms will provide a section by section analysis of SB 2095. Charles Carvell will explain SB 2139 and Curtis Jabs from Basin Electric Power Cooperative will provide insight as to the practical application of the bills in relation to future $CO_2$ capture projects.

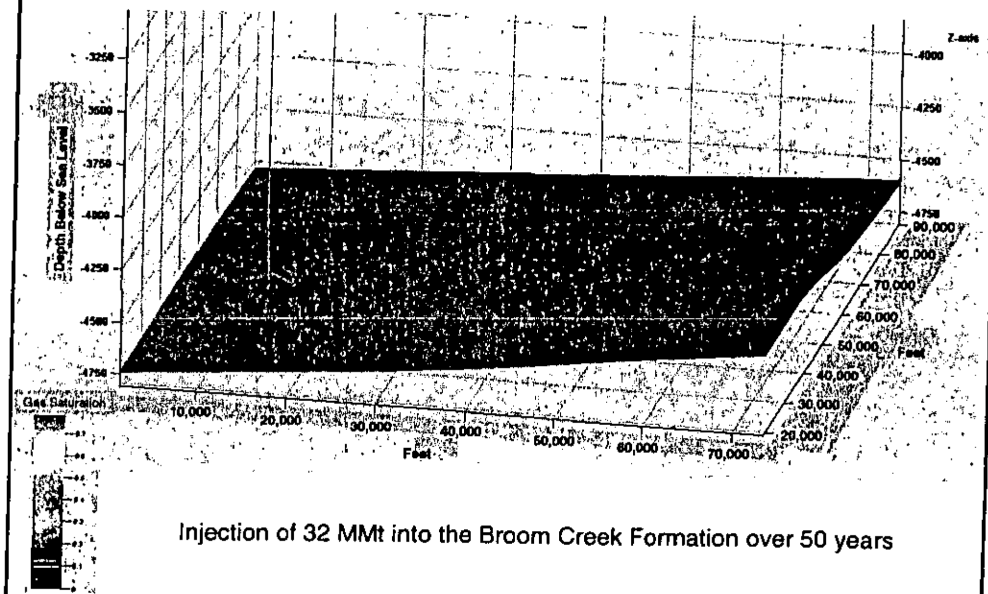
Both bills were amended by the Senate at the request of the Workgroup. Two technical amendments were made to SB 2095 --- the new chapter number was corrected and the phrase "mineral lessees" was inserted on lines 22 and on lines 23 and 24 on page 4 of the Engrossed Bill. In SB 2139 language was inserted on page 2, lines 1-4 to clarify that the bill does not alter the common law regarding the rights of the mineral estate. The Senate Natural Resource Committee also placed the emergency clause on the bill.

In closing, in November the ND Industrial Commission voted unanimously to support the bills and have the bills introduced as Industrial Commission bills.

Both bills received unanimous support in the Senate, and we hope the House will see fit to do likewise. The Lignite Energy Council urges the Committee to vote a "do pass" recommendation on SB 2095 and SB 2139.

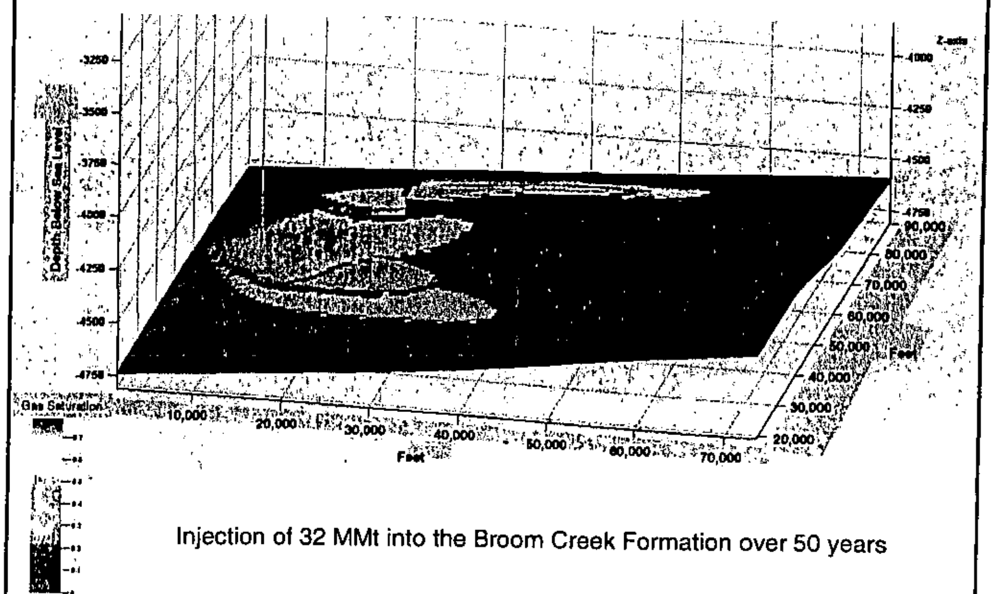
Pages 1-12 same as Senate.

T= 1 Year




Injection of 32 MMt into the Broom Creek Formation over 50 years

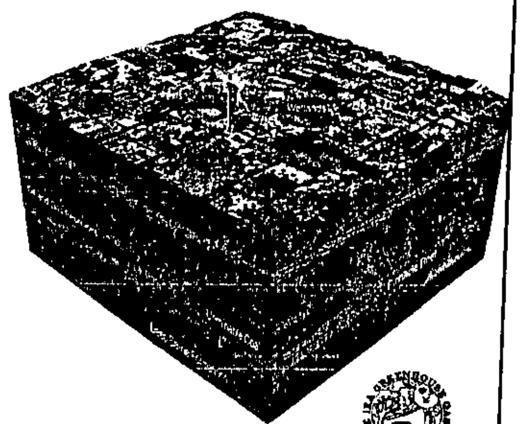
T= 7500 years



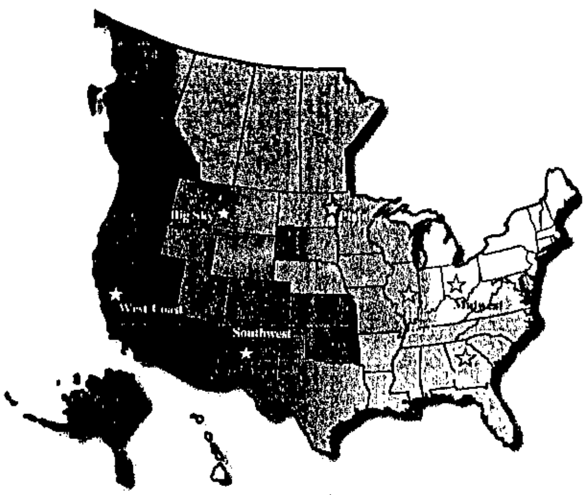

Injection of 32 MMt into the Broom Creek Formation over 50 years

## EERC $CO_2$ CCS Work

- The EERC is one of seven Regional Carbon Sequestration Partnerships that the US DOE and other partners are funding to demonstrate CCS across North America.
- We are finishing four Phase II small-scale demonstrations and developing two Phase III commercial-scale demonstrations.



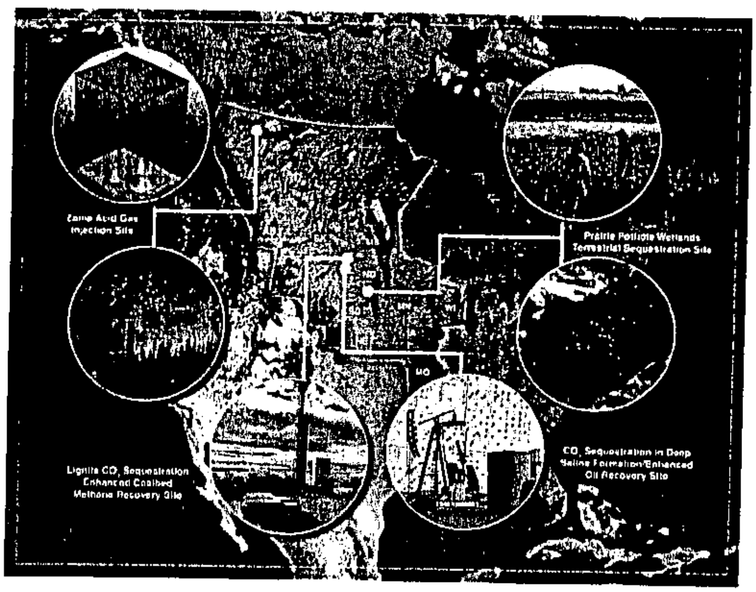
## Regional Carbon Sequestration Partnerships



The PCOR Partnership has brought together the key stakeholders to make geologic $CO_2$ sequestration a viable option for carbon management in our region.

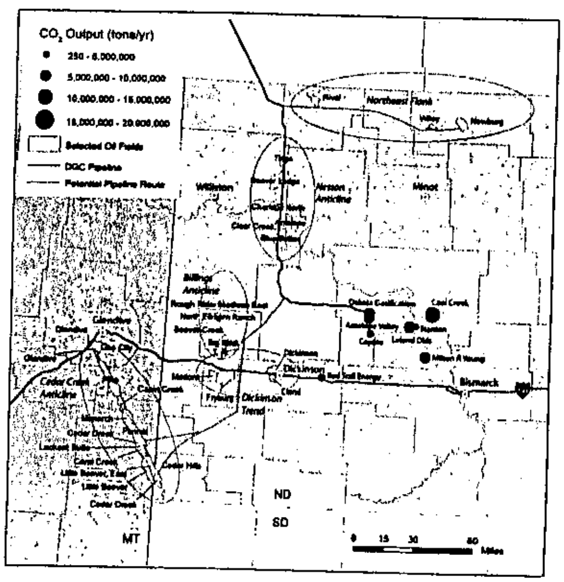
PCOR Partnership 2003–Present

# PCOR Phase II Field Validation Tests



## We Are Planning Two Phase III Efforts


## Williston Basin Candidate Oil Fields



## Williston Basin $CO_2$-Based EOR Potential

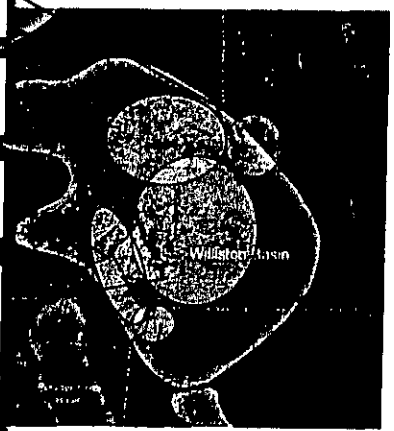
**Selected Manitoba Oil Fields**
- Three fields
- Potential incremental oil = 39 million bbl
- Total $CO_2$ needed for EOR = 319 Bcf

**Selected Saskatchewan Oil Fields**
- 11 fields
- Potential incremental oil = 331 million bbl
- Total $CO_2$ needed for EOR = 2652 Bcf

**Selected Montana Oil Fields**
- Ten fields
- Potential incremental oil = 390 million bbl
- Total $CO_2$ needed for EOR = 3120 Bcf

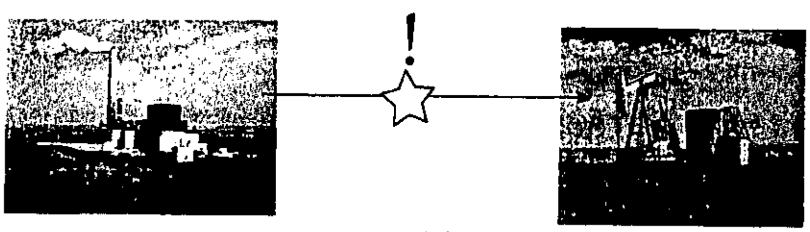
**Selected North Dakota Oil Fields**
- 26 fields
- Potential incremental oil = 262 million bbl
- Total $CO_2$ needed for EOR = 2095 Bcf

**Buffalo Field, South Dakota**
- Portions of this field are currently undergoing tertiary recovery operations using air injection.
- $CO_2$-based EOR may be technically feasible.

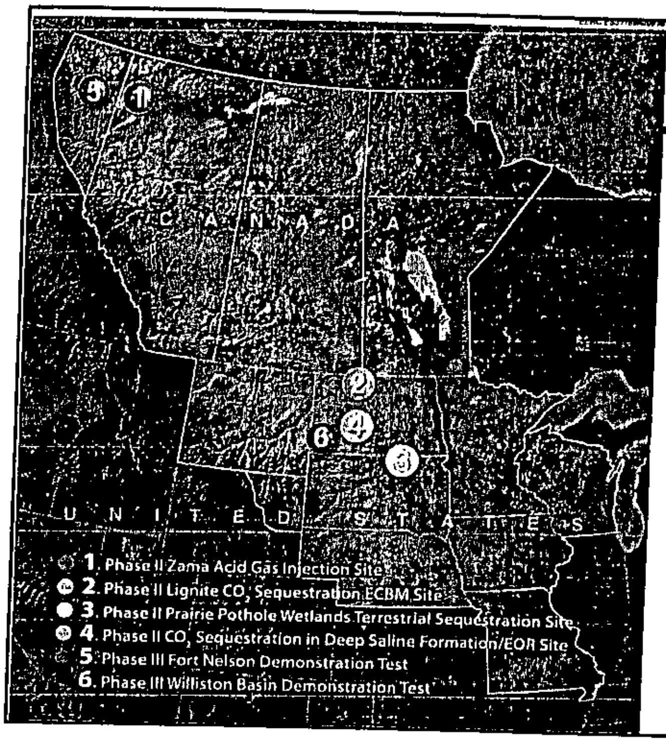


## Williston Basin Phase III – Concept

- Capture approximately 1 Mt/yr of $CO_2$ at an existing coal-fired power plant in central North Dakota.
- Transport via pipeline to Williston Basin oil field.
- Meet or exceed all of the U.S. Department of Energy Phase III objectives.
- Conduct MMV activities to document integrity of storage.
- Ultimately monetize credits.



PCOR Partnership NETL EERC UND University of North Dakota




PCO2R Partnership

**For more information on the PCOR Partnership please contact:**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EERC
UND University of North Dakota

ATTachment #3

# SENATE BILL NO. 2095

House Natural Resources Committee
February 26, 2009

Testimony of Lynn D. Helms, Director
Department of Mineral Resources
North Dakota Industrial Commission

**Summary** – Senate Bill 2095 creates a new chapter in the North Dakota Century Code that establishes the policies and priorities necessary to store carbon dioxide geologically. This chapter is based on the model developed by an Interstate Oil and Gas Compact Commission working group during a 2 year study of the issue that you have already heard about. The Interstate Oil and Gas Compact Commission has assisted states in writing model statutes and regulations for the conservation of oil and gas since 1935. North Dakota has been a member since 1953. There are currently 30 member states, 8 affiliated member states, and 9 international member affiliates.

**Section 38-22-01** – is the statement of policy behind the legislation. It describes the environmental, industry, and economic benefits that will ensue as well as the need to promote cooperative management of the various property interests involved.

**Section 38-22-02** – provides the definitions required to properly interpret the new statute.

**Section 38-22-03** – sets out the Industrial Commission's authority to set up, regulate the operation, and oversee the closure of geologic storage sites. The powers described here are very similar to the statutory unitization authority the commission has exercised for more than 40 years.

**Section 38-22-04** - establishes the requirement to obtain a geologic storage permit from the Industrial Commission and to get commission approval to transfer such permit to a new operator.

**Section 38-22-05** - establishes Industrial Commission authority to set permit requirements, charge a permit fee, and recover notice and hearing costs. It also directs the commission to give priority to carbon dioxide produced in North Dakota.

**Section 38-22-06** – set out the storage permit notice and hearing requirements.

**Section 38-22-07** – requires the Industrial Commission to consult the Department of Health before issuing a storage permit.

**Section 38-22-08** – identifies what the Industrial Commission must investigate and find to issue a storage permit. Note part 5 requires that 60% of the pore space ownership has given consent. This is the same percentage now required to unitize and oil and gas reservoir so that a process to increase recovery can be utilized.

**Section 38-22-09** – grants the Industrial Commission the authority to include in a permit or order all of the things necessary to carry out this chapter's objectives and to protect and adjust the rights and obligations of persons affected.

**Section 38-22-10** – gives the Industrial Commission the authority to amalgamate the ownership. This process would be very similar to the one utilized today to unitize an oil and gas reservoir.

**Section 38-22-11** – requires the Industrial Commission to issue a certificate stating the permit has been issued and to file that certificate with the county recorder(s).

**Section 38-22-12** – sets out the requirement for the Industrial Commission to take action to prevent pollution or nuisance, explicitly states the policy that properly stored carbon dioxide is neither a pollutant nor a nuisance, and preserves the full jurisdiction of the department of health.

**Section 38-22-13** – preserves the rights of property not committed to the storage facility and mineral owners under and near it.

**Section 38-22-14** – grants the Industrial Commission the authority to set a per ton of carbon dioxide fee through the administrative rule process for paying the commission's anticipated expenses for regulating storage facilities during their construction, operational, and pre-closure phases or a cooperating agency's actual expenses for the same.

**Section 38-22-15** – grants the Industrial Commission the authority to set a per ton of carbon dioxide fee through the administrative rule process for paying the commission's or a cooperating agency's expenses for regulating the long term monitoring and management of a closed storage facilities. The status of the fund is to be reported to the Legislative council in 2014 and every four years thereafter.

**Section 38-22-16** – set out the ownership of the carbon dioxide and who is responsible for it prior to project completion.

**Section 38-22-17** – identifies what the Industrial Commission must determine in order to issue a certificate of project completion. Note part 4 requires a minimum time period of ten years after injection ends before the commission can consider this issue. This section also transfers title to the facility and carbon dioxide as well as responsibility to the state at the time the certificate of project completion is issued, but provides for future transfer of these items to the federal government should the federal government decide to assume responsibility for long-term monitoring and management.

**Section 38-22-18** – grants authority to the Industrial Commission to assess civil penalties for violations in the same amount and in a similar process to current oil and gas laws and regulations.

**Section 38-22-19** – exempts oil and gas enhanced oil recovery projects from this chapter and leaves them under chapter 38-08, but allows the Industrial Commission to convert those projects into storage projects under the provisions of this chapter.

**Section 38-22-20** – grants authority for the Industrial Commission to enter into the inter-governmental and inter agency agreements as well as the private contracts that it determines are necessary to carry out the objectives of this chapter.

**Section 38-22-21** – exempts geologic storage facility cooperative agreements from trust, monopoly, and restraint of trade statutes.

**Section 38-22-22** – grants officials controlling state or political subdivision interests the authority to consent to and participate in geologic storage projects.

**Section 38-22-23** – gives the Industrial Commission the authority to determine how much of the carbon dioxide injected into an enhanced oil or gas recovery project is being stored. This will allow the parties to claim carbon storage credits should the federal government set up such a system. The commission can set a reasonable fee to be deposited into the fund set up in 38-22-14 for making such a determination.

**Section 2** of this bill repeals chapter 38-08-24 which required the industrial commission, department of mineral resources, public service commission, or any other state entity that approved a carbon sequestration or storage project to give priority to an operation located in this state for the expected life of the operation.

ATTachment #4

**Senate Bill 2139**

**House Natural Resources Committee**
**February 26, 2009**

**Testimony of Charles Carvell**
**Assistant Attorney General**
**N.D. Attorney General's Office**

Storing carbon dioxide underground is novel, and novel uses of land can produce new questions of property law. This bill's foremost purpose is to address an uncertainty in property law. If the legislature acts, the law will be better understood by property owners and will give industry a more stable environment for investment decisions.

One of the first things that must be done when crafting a regulatory regime for a new activity is to determine who the players are. If we are, for example, going to provide a right to a hearing we need to know who is entitled to notice of the hearing and who will be allowed to participate in it.

An interested party in carbon dioxide storage is the owner of the subterranean cavities into which the carbon dioxide will be injected and stored. But who owns that underground pore space? Nothing specific in North Dakota law answers that question, and the law in other states doesn't provide much help.

But property disputes in other states have led to court decisions that provide some guidance. Those disputes didn't involve carbon storage but rather such matters as storing natural gas and hazardous wastes and injecting substances to re-pressurize oil reservoirs. Because of the growing interest in carbon dioxide storage, lawyers have been studying these cases and property law principles and reporting their research in conference papers and law review articles.

The consensus is that surface owners own the pore space under their land. This is consistent with the view of lawyers who participated in the group that worked on this bill. We could wait for the North Dakota Supreme Court to confirm that view, but the wait might be long. To provide immediate certainty, the group thought it best that the legislature confirm that surface owners own the pore space under their land.

The second primary purpose of Bill 2139 is to take this opportunity—while we develop the legal regime for carbon dioxide storage—to avoid problems that have arisen with severed minerals, which are minerals owned by someone other than the surface owner. Because the mineral and surface estates overlap but are in different hands there can be conflicts between the two estates. And we've seen in this legislative session bills that seek to address and rectify problems related to severed minerals.

Severed minerals have also lead to fragmented mineral estates. Thus, in a section of land the surface may be owned by just a handful of people, usually North Dakota residents, while the underlying minerals may be owned by dozens or even hundreds of persons, scattered throughout the country. When their consent is needed for mineral development the time and expense searching for them can be considerable.

And so this bill limits a surface owner's ability to sever the pore space estate from the surface estate. It requires that title to pore space remain joined with title to the surface.

I will briefly discuss the bill's eight provisions.

1. **Policy** - This expresses policies I have discussed.

2. **Pore space defined** - This is the same definition as in S.B. 2095.

3. **Title to pore space** - This declares that the surface owner owns underlying pore space.

4/5. **Conveyance of real property conveys pore space/Severing pore space prohibited** – These two provisions address the bill's secondary purpose, that is, to maintain unitary title to the surface and to pore space.

6. **Transactions allowed** – A concern was expressed that merely leasing pore space could be deemed a prohibited severance. We don't, however, intend that unitary title would deny pore space owners the right to issue a lease.

7. **Application** – This "grandfathers in" transactions that have already severed pore space from the surface estate.

8. **Mineral and pore space estates – Relationship** – Presently, our law declares that in the relationship between the surface and mineral estates, minerals are dominant. This provision explains that the mineral estate maintains that preferred position in its relationship with the pore space estate.

Attachment #5

**Curtis Jabs - Basin Electric Power Cooperative**
**North Dakota SB 2095 and 2139**
**House Natural Resources Committee**
**February 26, 2009**

Mr. Chairman and members of the committee, my name is Curtis Jabs and I am here representing Basin Electric Power Cooperative. Basin Electric supports both SB 2095 and SB 2139.

It is probable that in the next Congress, legislation or the Environmental Protection Agency regulation will place restrictions on carbon dioxide emissions. Coal must be a part of our energy future, and to accomplish that in a carbon-constrained world, technology needs to be demonstrated to capture and sequester carbon on both new and existing coal-based power plants. Basin Electric is a leader is this effort, capturing approximately half of the carbon dioxide from the Great Plains Synfuels Plant in North Dakota and developing a commercial demonstration to capture 1 million tons of carbon dioxide per year from the Antelope Valley Station, which, if successful, will be the largest post-combustion carbon dioxide capture project to date. The Great Plains Synfuels Plant captures carbon dioxide from the gasification process. The Antelope Valley Station Project will capture the carbon dioxide from the flue gas stream after the coal is burned. This "post-combustion" carbon dioxide capture technology is thus an important step in developing technology that will provide a pathway for existing coal-based power plants to remain in production in a carbon dioxide-emission-constrained world.

In 2000 Dakota Gasification Company began capturing the carbon dioxide produced at the Great Plains Synfuels Plant, and shipping it through a 205-mile pipeline to Weyburn, Saskatchewan to be used for enhanced oil recovery in an aging oil field. Through 2008, Dakota Gasification has successfully captured and marketed over 15 million tons of carbon dioxide to two Canadian customers for enhanced oil recovery. The carbon dioxide is expected to be permanently sequestered in the oil reservoir and is being monitored by the International Energy Agency Weyburn $CO_2$ Monitoring and Storage Project.

The Antelope Valley Station Project will demonstrate the removal of carbon dioxide from the flue gas of a lignite-based boiler. The Antelope Valley Station Project is designed to capture carbon dioxide on a 120 megawatt slipstream from Antelope Valley's 450 megawatt Unit 1. The system works by first removing sulfur dioxide using a polishing scrubber technology, and then absorbing carbon dioxide using an ammonia-based technology. For the Antelope Valley Station Project, sulfur dioxide will be reduced from 170 parts per million to approximately 1 part per million upstream of the carbon dioxide capture system. The net result of the carbon dioxide capture process is 90 percent removal of carbon dioxide from the treated flue gas, yielding 3,000 tons per day of pipeline quality carbon dioxide, and a liquid stream of ammonium sulfate for reuse.

As stated before, the rules and regulation are in place to conduct enhanced oil recovery in North Dakota. Basin Electric intends to market the carbon dioxide from the Antelope Valley Station demonstration project for enhanced oil recovery. The Dakota

Gasification Company has been in discussions with several oil companies in North Dakota. Basin Electric would utilize the Dakota Gasification Companies' existing pipeline system and build a new pipeline off a tap to the oilfield.

There is good potential for enhanced oil recovery in North Dakota. However, the capacity to store carbon dioxide used in enhanced oil recovery will be filled eventually as more carbon dioxide is captured. Fortunately North Dakota has extensive storage capacity to store carbon dioxide in other secure geological formations such as saline aquifers. This bill will provide the statutory framework for rules and regulations that will allow carbon dioxide storage in those geological formations with appropriate oversight by the state. The bill also has a provision to allow enhanced oil recovery projects to be converted to long-term carbon dioxide storage pending commission approval. I believe these bills are necessary for North Dakota to take a proactive step to accommodate carbon dioxide storage in the future.

Thank you and I will try to answer any questions from the committee.

ATTachment #6

**Testimony**
**Senate Bill 2095**
**Natural Resources Committee**
**Thursday, February 26, 2009; 10 a.m.**
**North Dakota Department of Health**

Good morning, Chairman Porter and members of the Natural Resources Committee. My name is L. David Glatt, and I am chief of the Environmental Health Section for the North Dakota Department of Health. I am here today to testify in support of Senate Bill 2095.

As you know, issues of energy development and independence, environmental quality, and climate change were all discussed during the recent presidential campaign. It is quite clear that these issues will continue to be on the agenda of the new administration and will result in some form of federal legislation most likely to include carbon emission constraints. Senate Bill 2095 will provide the state and industry an opportunity to comply with future federal legislation and address concerns relating to climate change and the use of fossil fuels.

The Department of Health was an active member on the committee that drafted the legislation before you today. Senate Bill 2095 provides a potentially viable option for storage of carbon dioxide in the state. This bill establishes a framework where agencies can cooperate and exchange information, particularly in the rule development and environmental monitoring processes.

This concludes my testimony. I am happy to answer any questions you may have.

ATTachment # 7

NORTH DAKOTA
CHAMBER of COMMERCE

**Testimony of Jeb Oehlke**
**North Dakota Chamber of Commerce**
**February 26, 2009**
**Senate Bill 2095**

Mr. Chairman and committee members my name is Jeb Oehlke. I represent the North Dakota Chamber of Commerce, the voice of North Dakota Business. Our organization is an economic and geographical cross section of North Dakota's private sector and also includes state associations, local chambers of commerce, development organizations, convention and visitors bureaus and public sector organizations. For purposes of this hearing we also represent fifteen local chambers with total membership over 6,500 members. A list of those associations is attached. As a group we stand in support of SB 2095 and urge a Do Pass recommendation.

The business community supports this bill because it creates the structure for a regulatory system within which this state's energy sector businesses can operate. Passage of this bill will provide theses businesses with some certainty as they move forward and further develop technology to capture and sequester carbon dioxide.

From a general business standpoint, although excessive regulation is detrimental, a certain amount is needed to let all of the players know the rules of the game. Senate Bill 2095 sets forth those rules and the business community urges the committee to give this bill a favorable recommendation.

Thank you Mr. Chairman and committee members. I am happy to answer any questions at this time.

*THE VOICE OF NORTH DAKOTA BUSINESS*

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NORTH DAKOTA
CHAMBER of COMMERCE

**The following chambers are members of a coalition that support our 2009 Legislative Policy Statements:**

Beulah Chamber of Commerce

Bismarck-Mandan Chamber of Commerce

Chamber of Commerce of Fargo Moorhead

Devils Lake Area Chamber of Commerce

Grafton Area Chamber of Commerce

Greater Bottineau Area Chamber of Commerce

Harvey Area Chamber of Commerce

Hettinger Area Chamber of Commerce

Jamestown Area Chamber of Commerce

Kenmare Association of Commerce

Minot Chamber of Commerce

North Dakota Chamber of Commerce

Oakes Area Chamber of Commerce

Wahpeton Breckenridge Chamber of Commerce

Williston Chamber of Commerce

Total Businesses Represented = 6,500 members



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