



Plains CO<sub>2</sub> Reduction (PCOR) Partnership  
Energy & Environmental Research Center (EERC)

## PUBLIC SITE UPDATES

### Plains CO<sub>2</sub> Reduction (PCOR) Partnership Phase III Task 2 – Deliverable D13

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## TABLE OF CONTENTS

LIST OF FIGURES .....	ii
EXECUTIVE SUMMARY .....	iv
INTRODUCTION .....	1
NEW WEB PAGES .....	3
CO <sub>2</sub> EOR LCA Model Page.....	3
Partners Only Landing Page.....	4
North Dakota CCS Feasibility Study Page .....	5
Nebraska CCS Pre-Feasibility Study .....	6
CCS for North Dakota Ethanol Production.....	7
<i>The Bell Creek Story</i> Documentary Page.....	8
CONTENT UPDATES FOR WEB PAGES.....	9
Home Page .....	9
About the Partnership Page .....	10
Become a Partner Page.....	11
PCOR Partnership Partners Page .....	12
Climate, CO <sub>2</sub> , Sequestration Page.....	14
What Is CO <sub>2</sub> ? Page.....	15
What Is CO <sub>2</sub> Sequestration? Page .....	17
Terrestrial Sinks .....	18
Wetlands Page .....	19
Regulations and Permitting .....	20
CO <sub>2</sub> Sequestration Projects Page.....	22
Technical Publications Page.....	28
Technical Reports Page .....	29
The PCOR Partnership Regional Atlas Page .....	31
Fact Sheets Page.....	32
Documentaries Page.....	34
Video Clip Library .....	35
Carbon and CO <sub>2</sub> on Earth – Things Have Changed! Page.....	36
Request Information Page .....	38
Educators Web Page.....	39
Site Map .....	40
FUTURE WORK.....	42
PRINT-FRIENDLY PAGES OF THE SPECIALLY FORMATTED PAGES ON THE PCOR PARTNERSHIP WEB SITE .....	Appendix A

## LIST OF FIGURES

1	New CO <sub>2</sub> EOR LCA Model page .....	3
2	New Partners Only landing page.....	4
3	New North Dakota CCS Feasibility Study page .....	5
4	New Nebraska CCS Pre-Feasibility Study page .....	6
5	New CCS for North Dakota Ethanol Production page.....	7
6	New <i>The Bell Creek Story: CO<sub>2</sub> in Action</i> documentary page.....	8
7	Updated home page .....	9
8	Updated About the Partnership page.....	10
9	Updated Become a Partner page .....	11
10	New partners added to the PCOR Partnership Partners page.....	12
11	Updated Climate, CO <sub>2</sub> , Sequestration page .....	14
12	Content updated in What Is CO <sub>2</sub> ? page with tool tip content .....	15
13	New look for What Is CO <sub>2</sub> ? page with expanded accordion content.....	16
14	New look for What Is CO <sub>2</sub> Sequestration? page with the tool tips associated with “Geologic Sequestration” and “Terrestrial Sequestration” .....	17
15	Content update for Terrestrial Sequestration page with new tool tip content .....	18
16	Content update in Wetlands page.....	19
17	Updated Regulations and Permitting page with new tool tip content .....	20
18	Updated Regulations and Permitting page with hover box text.....	21
19	Updated CO <sub>2</sub> Sequestration Projects landing page .....	22

Continued . . .



## LIST OF FIGURES (continued)

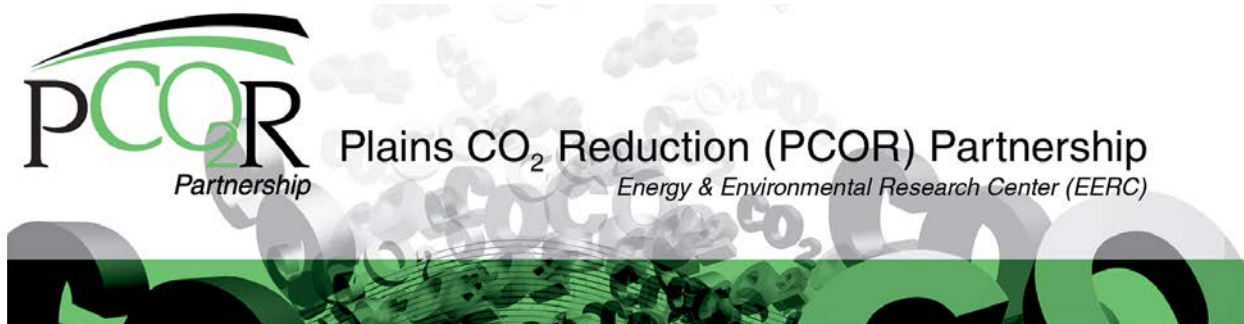
20	Project information boxes that pop up when the cursor hovers over project titles on the landing page.....	23
21	Content update Aquistore Project page .....	24
22	Content update Fort Nelson CCS Feasibility Project page .....	25
23	Content update SaskPower Boundary Dam Carbon Capture Project page .....	26
24	Content update Weyburn–Midale CO <sub>2</sub> Project page.....	27
25	Updated Technical Publications page .....	28
26	Updated Technical Reports page.....	29
27	Updated Atlas page .....	31
28	Updated Fact Sheets page.....	33
29	Updated content in Documentaries page.....	34
30	Video Clip Library page.....	35
31	Updated Carbon and CO <sub>2</sub> on Earth page.....	36
32	Updated Request Information page.....	38
33	Updated Educators Web page .....	39
34	Updated Site Map page .....	40



## **PUBLIC SITE UPDATES**

### **EXECUTIVE SUMMARY**

This report summarizes the 2018 contractual update to the Plains CO<sub>2</sub> Reduction (PCOR) Partnership public Web site for the period of July 1, 2016, through January 31, 2018. The central focus of this deliverable (D13) consisted of new pages and updates to existing pages. Several new Web pages were added, including the CO<sub>2</sub> EOR Life Cycle Analysis (LCA) Model page, the Partners Only landing page, and three pages describing new carbon capture and storage (CCS) projects in the PCOR Partnership region: the North Dakota CCS Feasibility Study, the Nebraska CCS Pre-Feasibility Study, and CCS for North Dakota Ethanol Production. Significant content and/or appearance modifications were made to ten existing Web pages. Minimal updates were made to 11 other pages. All changes were approved piecemeal throughout the reporting period. Thus, this report does not include a request for approval of any draft changes.



## **PUBLIC SITE UPDATES**

### **INTRODUCTION**

The U.S. Department of Energy (DOE) Office of Fossil Energy National Energy Technology Laboratory's (NETL's) Regional Carbon Sequestration Partnership (RCSP) Program requires that each regional partnership have a public Web site to inform and educate the general public regarding sequestration in general and regional RCSP activities. The Plains CO<sub>2</sub> Reduction (PCOR) Partnership's public Web site has been live since the second quarter of 2004, and the PCOR Partnership outreach team is continuously striving to keep the public Web site content up to date, characterize the attributes of Web site use, and provide content in a clear and understandable format to the general public. The PCOR Partnership, active since the fall of 2003, is led by the Energy & Environmental Research Center (EERC) at the University of North Dakota. The PCOR Partnership public Web site team members include Dan Daly (Outreach and Education task leader), Charlene Crocker, and Janet Crossland. The Web site update was supported by the Programming, Communications, and Graphics groups at the EERC as well as other PCOR Partnership personnel. The most recent Web site update was provided July 31, 2016.

This report comprises activities completed and approved in batches throughout the period of July 1, 2016, through January 31, 2018. Work on the Web site was implemented in two areas as follows:

- New Web pages
- Content updates for existing Web pages

During the reporting period, four new Web pages were added, including CO<sub>2</sub> EOR LCA Model, Partners Only landing page, and three pages describing new carbon capture and storage (CCS) projects in the PCOR Partnership region: North Dakota CCS Feasibility Study and Nebraska CCS Pre-Feasibility Study and CCS for North Dakota Ethanol Production. Significant content and/or appearance modifications were made to ten existing Web pages, including the Home page, What Is CO<sub>2</sub>? What Is CO<sub>2</sub> Sequestration? Terrestrial Sinks, CO<sub>2</sub> Sequestration Projects, Technical Publications, Technical Reports, Documentaries, Video Clip Library, and Carbon and CO<sub>2</sub> on Earth – Things Have Changed! Eleven additional Web pages received minor updates: About the Partnership; Become a Partner; PCOR Partnership Partners; Climate, CO<sub>2</sub>, Sequestration; Wetlands; Regulations and Permitting; Atlas; Fact Sheets; Request Information form, Educators; and the Site Map. All of these changes were approved by the DOE NETL program manager piecemeal through the update period in order to keep the site as current as possible. The dates when changes were added to the live site are noted in the information that follows.

In addition, the PCOR Outreach team responded to issues with the Adobe *Flash* player (the video player on the public Web site) and news that major Web browsers (e.g. Chrome, Firefox, etc.) are phasing out *Flash*. Issues fell into two categories each with a separate resolution. First, the fact that users were not able to view video clips on the public Web site was addressed by the development and implementation of a script embedded on the Web pages with videos that checks whether *Flash* is installed on the user's Web browser and provides a simple "Click to activate" message for visitors to install *Flash*. Second, for the long term, the Outreach Team and EERC programmers have determined that HTML5 will be an effective replacement player for video clips and have begun to prepare a technical upgrade of the entire site that will be completed after this reporting period.

## NEW WEB PAGES

### CO<sub>2</sub> EOR LCA Model Page

The CO<sub>2</sub> enhanced oil recovery (EOR) life cycle analysis (LCA) Model page was added to the Technical Publications section of the public Web site. It includes the publication abstract, hyperlink to the journal article published in the *International Journal of Greenhouse Gas Control*, and access to the spreadsheet-based model that PCOR Partnership researchers developed to estimate greenhouse gas emissions associated with oil produced at CO<sub>2</sub> EOR sites. This page is the only Web-based access to the model, allowing users to download the model and input their own site-specific values for conducting analysis. This new page shown in Figure 1 went live on July 21, 2016.

The screenshot displays the PCOR Partnership website. The header includes the PCOR logo and the text 'Plains CO<sub>2</sub> Reduction (PCOR) Partnership Practical, Environmentally Sound CO<sub>2</sub> Sequestration'. Below the header is a navigation bar with links for 'PARTNERS ONLY', 'KIDS', 'EDUCATORS', 'CONTACT US', and a search bar. The sidebar on the left lists various categories: 'About the Partnership', 'Climate, CO<sub>2</sub>, Sequestration', 'Regional Storage Potential', 'CO<sub>2</sub> Sequestration Projects', 'Technical Publications' (with sub-links for 'Technical Reports', 'Technical Posters', 'CO<sub>2</sub> EOR LCA Model', and 'PDM Video'), 'Resources', 'Documentaries', 'Video Clip Library', 'FAQs', 'Links', and 'Household Energy'. The main content area is titled 'CO<sub>2</sub> EOR LCA Model'. It contains a paragraph describing the life cycle analysis (LCA) performed by the PCOR Partnership to estimate greenhouse gas emissions associated with oil produced via CO<sub>2</sub> EOR. Below this is a green button labeled 'Download the model'. Further down, the 'Article Title' is listed as 'How Green Is My Oil? A Detailed Look at Greenhouse Gas Accounting for CO<sub>2</sub> Enhanced Oil Recovery (CO<sub>2</sub> EOR) Sites'. The 'Abstract' follows, detailing the study's findings on greenhouse gas (GHG) emissions and the resulting displacement credit of U.S. grid electricity. At the bottom of the main content area, there is a link to 'View the journal article [here](#)'.

Figure 1. New CO<sub>2</sub> EOR LCA Model page.

Existing link: [undeerc.org/PCOR/technicalpublications/CO2-EOR-Life-Cycle-Analysis.aspx](http://undeerc.org/PCOR/technicalpublications/CO2-EOR-Life-Cycle-Analysis.aspx).

## Partners Only Landing Page

The Partners Only landing page (see Figure 2) was created to facilitate PCOR Partnership partners logging into the Partners Only Web site, the Decision Support System (DSS), by incorporating a “Get help!” hyperlink for partners having trouble accessing the DSS. The page also provides more information and welcoming appearance to nonmembers who may click on the link accidentally or out of curiosity. Included are benefits of becoming a partner and a link to the Become a Partner page, which went live on November 10, 2016.

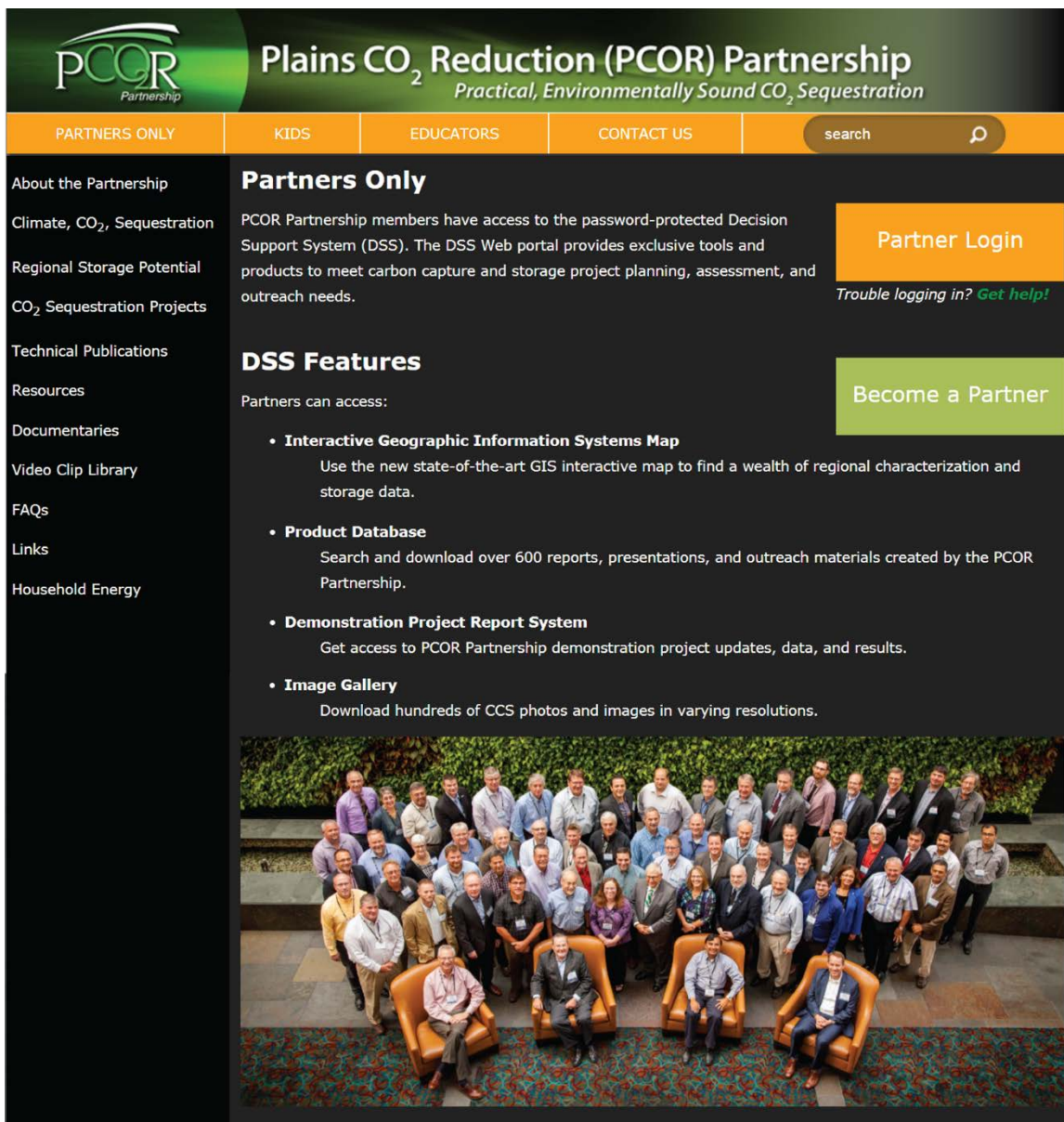


Figure 2. New Partners Only landing page.  
Existing link: [www.undeerc.org/pcor/PartnersOnly.aspx](http://www.undeerc.org/pcor/PartnersOnly.aspx).



## North Dakota CCS Feasibility Study Page

The North Dakota CCS Feasibility Study page shown in Figure 3 provides information on a new project in the PCOR Partnership region. It was added to the CO<sub>2</sub> Sequestration Projects landing page on August 8, 2017. Two Activity FAQs (frequently asked questions) PDFs and one fact sheet PDF were added to the bottom of this page on December 20, 2017.

**PCOR Partnership**  
Plains CO<sub>2</sub> Reduction (PCOR) Partnership  
Practical, Environmentally Sound CO<sub>2</sub> Sequestration

PARTNERS ONLY | KIDS | EDUCATORS | CONTACT US | search

**North Dakota CCS Feasibility Study**

**About the Partnership**  
Climate, CO<sub>2</sub>, Sequestration  
Regional Storage Potential  
CO<sub>2</sub> Sequestration Projects  
Technical Publications  
Resources  
Documentaries  
Video Clip Library  
FAQs  
Links  
Household Energy

As part of the effort to address CO<sub>2</sub> emissions from large stationary sources like coal-based energy facilities, this research is addressing the technical, financial, legal, and political challenges associated with developing a commercial-scale geologic CO<sub>2</sub> storage site to facilitate the continued use of North Dakota's abundant lignite resources as a fuel or industrial feedstock.

The 2-year project includes the collection of two deep geologic core samples—one in Oliver County and one in Mercer County—to better understand the geology that could be used for safe, permanent storage of carbon dioxide. Once the core holes are drilled and geologic samples are retrieved, the core holes will be filled with concrete and the land restored to its original appearance according to state and federal regulations. The formation of interest is about 6000 feet below the surface, and one of the objectives of this project is a preliminary look at the geology to see if further study is warranted.

The North Dakota CarbonSAFE project is a first step to evaluate commercial readiness for geologic storage of CO<sub>2</sub>. Open houses and other activities will communicate the details of the project and gather public input.

This project is managed by the Energy & Environmental Research Center (EERC) in Grand Forks, North Dakota, on behalf of the project partners, which include the U.S. Department of Energy (DOE), the North Dakota Industrial Commission's Lignite Research Program, Basin Electric Power Cooperative, Minnkota Power Cooperative, ALLETE Clean Energy, BNI Energy, and North American Coal Corporation.

The 2-year feasibility study runs from spring 2017 to spring 2019 and is part of DOE's nationwide, multiyear CarbonSAFE initiative structured to facilitate the development of commercial-scale carbon capture and storage projects ready to accept at least 50 million metric tons of CO<sub>2</sub> emissions from human activity by 2025. If the assessment of the technical and nontechnical aspects of the CarbonSAFE study suggests that a CO<sub>2</sub> storage project in this area may be feasible, the next step would be a detailed examination of the geology at possible specific storage sites.

For more information, contact Wes Peck, Project Manager, EERC, [wpeck@undeerc.org](mailto:wpeck@undeerc.org), 701-777-5195.

**Downloads**

Feasibility Study Fact Sheet  
Geophysical Survey FAQ  
Geologic Study FAQ

**Geological Cross-Section Diagram:**


Depth (ft)	Geological Feature
0	Fresh Water Aquifer
1350	Fresh and Saline Formations
1750	Seal
4000	Potential Storage Zone
4700	Seal
5800	Target Storage Zone
6100	Seal

*The CarbonSAFE project is assessing potential storage for CO<sub>2</sub> at about 6000 feet. The target rock layers include a sandstone (target storage zone) and adjacent shale layers (seals).*

Figure 3. New North Dakota CCS Feasibility Study page.  
Existing link: [undeerc.org/pcor/co2sequestrationprojects/NDCarbonSafe.aspx](http://undeerc.org/pcor/co2sequestrationprojects/NDCarbonSafe.aspx).

## Nebraska CCS Pre-Feasibility Study

The Nebraska CCS Pre-Feasibility Study page shown in Figure 4 provides information on a new CO<sub>2</sub> sequestration project occurring in the PCOR Partnership region. This project was added to the CO<sub>2</sub> Sequestration Projects landing page on December 20, 2017.



# Plains CO<sub>2</sub> Reduction (PCOR) Partnership

Practical, Environmentally Sound CO<sub>2</sub> Sequestration

[PARTNERS ONLY](#)[KIDS](#)[EDUCATORS](#)[CONTACT US](#)

- About the Partnership
- Climate, CO<sub>2</sub>, Sequestration
- Regional Storage Potential
- CO<sub>2</sub> Sequestration Projects**
- Technical Publications
- Resources
- Documentaries
- Video Clip Library
- FAQs
- Links
- Household Energy

## Nebraska CCS Pre-Feasibility Study


The project is taking initial steps to evaluate the potential of integrating commercial-scale capture of CO<sub>2</sub> emissions from a coal-fired power plant in western Nebraska with dedicated CO<sub>2</sub> storage in a deep geologic formation, a concept called carbon capture and storage or CCS.

This pre-feasibility study will investigate the technical, geographic, regulatory, socioeconomic, and financial viability of capture and geologic storage of CO<sub>2</sub> from Nebraska Public Power District's (NPPD) Gerald Gentleman Station.

The project is managed by the Energy & Environmental Research Center in Grand Forks, North Dakota, in collaboration with NPPD. The 18-month study was initiated in January 2017 and will be completed at the end of June 2018. Major funding is from the U.S. Department of Energy (DOE) with support from NPPD, Schlumberger Carbon Services, and Computer Modelling Group Ltd.

The Phase I study is part of DOE's nationwide, four-phase CarbonSAFE initiative designed to support implementation of commercial-scale CCS by 2025. If this research indicates potential for CCS in the region, the next step would be an in-depth feasibility study to evaluate the viability of a Nebraska geologic storage site for at least 50 million metric tons of CO<sub>2</sub> emissions.

For more information, contact Neil Wildgust, project manager, EERC, [nwildgust@undeerc.org](mailto:nwildgust@undeerc.org) 701-777-5193.




*NPPD's Gerald Gentleman Station near Sutherland is Nebraska's largest coal-fired electricity-generating station.*

Figure 4. New Nebraska CCS Pre-Feasibility Study page.  
Existing link: [undeerc.org/pcor/co2sequestrationprojects/CarbonSafe-NE.aspx](http://undeerc.org/pcor/co2sequestrationprojects/CarbonSafe-NE.aspx).



## CCS for North Dakota Ethanol Production

The CCS for North Dakota Ethanol Production page shown in Figure 5 provides information on a new CO<sub>2</sub> sequestration prefeasibility project occurring in the PCOR Partnership region. This project was added to the CO<sub>2</sub> Sequestration Projects landing page on January 22, 2018.




# Plains CO<sub>2</sub> Reduction (PCOR) Partnership

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- [About the Partnership](#)
- [Climate, CO<sub>2</sub>, Sequestration](#)
- [Regional Storage Potential](#)
- [CO<sub>2</sub> Sequestration Projects](#)
- [Technical Publications](#)
- [Resources](#)
- [Documentaries](#)
- [Video Clip Library](#)
- [FAQs](#)
- [Links](#)
- [Household Energy](#)

## CCS for North Dakota Ethanol Production



Carbon capture and storage (CCS) may be an economical option for reducing CO<sub>2</sub> emissions to qualify for market credits by meeting the requirements of low-carbon fuel programs in other states. This research project assessed the technical and economic feasibility of integrating CCS with ethanol production processes to reduce net CO<sub>2</sub> emissions. North Dakota has both significant ethanol production capacity and geology ideally suited for safe, permanent CO<sub>2</sub> carbon storage.

Commercial technologies to capture and separate CO<sub>2</sub> emissions from the fermentation process already exist. The study provides local ethanol producers with a detailed assessment of the commercial feasibility of incorporating capture, transport, and storage of the CO<sub>2</sub> emissions within their production operations.

The project is looking at the technical and economic factors of a commercial CCS effort associated with **Red Trail Energy's** ethanol-manufacturing facility near Richardton, North Dakota. The Broom Creek Formation, a thick sandstone rock layer located approximately 6400 feet below the Richardton facility, is being considered as the target injection zone for potential geologic storage of the CO<sub>2</sub>. According to previous studies conducted by the Energy & Environmental Center (EERC), this formation is expected to make an excellent storage target.

The EERC in Grand Forks, North Dakota, manages the project on behalf of the partners, which include Red Trail Energy, the North Dakota Industrial Commission Renewable Energy Program, Trimeric Corporation, Schlumberger Carbon Services, Computer Modelling Group, and the U.S. Department of Energy.

The overall goal of this effort is to implement commercial CCS at an ethanol production facility to make a fuel that qualifies for low-carbon fuel programs. The 6-month feasibility study undertaken from late 2016 to spring 2017 showed promising results of technical and economic viability. The current phase of research will further refine the regulatory, processing, and financial requirements for CCS implementation, improving the pathway toward commercial success.

For more information, contact Kerryanne Leroux, project manager, EERC, [kleroux@undeerc.org](mailto:kleroux@undeerc.org) 701-777-5013; Charles Gorecki, Director of Subsurface R&D, EERC, [cgorecki@undeerc.org](mailto:cgorecki@undeerc.org), 701-777-5355; or Gerald Bachmeier, Chief Executive Officer, Red Trail Energy, [gerald@redtrailenergy.com](mailto:gerald@redtrailenergy.com), 701-974-3308.

Figure 5. New page CCS for North Dakota Ethanol Production page.  
Existing link: [undeerc.org/pcor/co2sequestrationprojects/RedTrail.aspx](http://undeerc.org/pcor/co2sequestrationprojects/RedTrail.aspx).

With the broadcast premiere of *The Bell Creek Story: CO<sub>2</sub> in Action*, this page was added to provide a brief description and link to play the 30-minute documentary *The Bell Creek Story: CO<sub>2</sub> in Action*. The page also contains hyperlinks to Web site related to documentary content, the back of the DVD jacket, and a link to the Web site request form for requesting a free copy of the Bell Creek DVD. The new Web page, shown in Figure 6, was added to the public Web site on June 19, 2017.

Figure 6. New *The Bell Creek Story: CO<sub>2</sub> in Action* documentary page.  
Existing link: [undeerc.org/pcor/Documentary/Bell-Creek-Story.aspx](http://undeerc.org/pcor/Documentary/Bell-Creek-Story.aspx).



## CONTENT UPDATES FOR WEB PAGES

### Home Page

Several elements make up the changes to the home page (Figure 7). The *PCOR Partnership Atlas*, 5th edition revised, went live December 20, 2017. Since its broadcast premier in June 2017, the most recent PCOR Partnership documentary *The Bell Creek Story: CO<sub>2</sub> in Action* has been featured immediately below the projects map. Clicking on the image opens an overlaid page containing video-playing controls and the streaming documentary. This video went live on the existing public Web site home page on June 19, 2017.



Figure 7. Updated home page.  
Existing link: [www.undeerc.org/PCOR/default](http://www.undeerc.org/PCOR/default).

## About the Partnership Page

Updates to the About the Partnership page, shown in Figure 8, included updating the Phase III Prospectus and Phase III Fact Sheet under “More on Phase III.” Updates were implemented on February 13, 2017, and December 20, 2017, respectively.

**PCOR Partnership**  
**Plains CO<sub>2</sub> Reduction (PCOR) Partnership**  
*Practical, Environmentally Sound CO<sub>2</sub> Sequestration*

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**About the Partnership**

The Plains CO<sub>2</sub> Reduction (PCOR) Partnership is a multiyear collaboration of over 80 U.S. and Canadian stakeholders that is laying the groundwork for practical and environmentally sound carbon dioxide (CO<sub>2</sub>) sequestration projects in the **PCOR Partnership Region** in the heartland of North America. Meet the **PCOR Partnership Partners**.

**Phase I - PCOR Partnership Program** - In the fall of 2003, the PCOR Partnership embarked on a 2-year, \$3.3 million Phase I program focused on characterizing sequestration opportunities in the region.

**Phase II - PCOR Partnership Program** - In the fall of 2005, the PCOR Partnership launched its 4-year, \$21 million Phase II program focused on **carbon sequestration field validation projects**. The Phase II sequestration field projects are designed to build the core of local technical expertise and experience needed to facilitate future large-scale CO<sub>2</sub> sequestration efforts in the region's subsurface and terrestrial settings. **See the Phase II prospectus** (337 KB PDF).

**Phase III - PCOR Partnership Program** - In the fall of 2007, the PCOR Partnership was selected for a 10-year, multimillion dollar Phase III program focused on implementing two commercial-scale geologic carbon sequestration demonstration projects in the region.

**More on Phase III**

- **See the Phase III Prospectus** (5380 KB PDF)
- **See the Phase III Fact Sheet** (823 KB PDF)
- **News Archives**

The PCOR Partnership is led by the **Energy & Environmental Research Center** at the University of North Dakota. Meet the **PCOR Partnership Team**.

The PCOR Partnership is one of seven regional partnerships under the U.S. Department of Energy (DOE), Office of Fossil Energy, National Energy Technology Laboratory's (NETL) **Regional Carbon Sequestration Partnership (RCSP) Program**.

**Membership in the PCOR Partnership** provides unique opportunities to develop working relationships with stakeholders that represent a diverse cross section of CO<sub>2</sub> producers, end users, environmental groups, and regulators. **Become a partner!**


**Watch Video Clip**

**About the Partnership**

Figure 8. Updated About the Partnership page.  
Existing link: [www.undeerc.org/PCOR/About/](http://www.undeerc.org/PCOR/About/).

## Become a Partner Page

Updates to the Become a Partner page shown in Figure 9 included updating the PCOR Partnership Annual Meeting photo and caption. Both updates went live on December 20, 2017.



# Plains CO<sub>2</sub> Reduction (PCOR) Partnership

Practical, Environmentally Sound CO<sub>2</sub> Sequestration

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## Become a Partner

The PCOR Partnership is the nexus for carbon dioxide (CO<sub>2</sub>) reduction activities in the North-Central Interior of North America. The PCOR Partnership provides a forum where government agencies, industry, engineering firms, associations and nonprofit organizations, and universities can come together, share knowledge and build the collaborations needed for effective, safe CO<sub>2</sub> sequestration projects. The PCOR Partnership's data management systems and technical reports provide data, information and assessments to partners. The PCOR Partnership's outreach tool kit provides products that can help tell the sequestration story in the classroom, town hall, or boardroom. Annual meetings, monthly updates, and workshops help keep partners informed and up to date regarding technologies, regulations, and projects.

The PCOR Partnership is one of seven regional partnerships under the U.S. Department of Energy's (DOE's) [Regional Carbon Sequestration Partnership \(RCSPP\) Program](#), which represents more than 350 organizations in 42 states, three Indian nations, and four Canadian provinces.

"Joining the Plains [CO<sub>2</sub> Reduction] Partnership is an approach that will dovetail nicely with our own carbon management policy and other carbon sequestration projects."

- Xcel Energy Chairman and CEO Wayne Brunetti



Attendees at the PCOR Partnership 2017 Annual Meeting, Plano, Texas

### Partner Benefits

- Timely access to developments and lessons learned at the regional and national level with regard to sequestration and other evolving strategies to reduce CO<sub>2</sub> emissions.
- Access to "Partners Only" data and information on regional CO<sub>2</sub> sources, sequestration options, regulatory assessments, environmental issue assessments, and project modeling.
- Access to the PCOR Partnership Decision Support System (DSS), is a Web-based geographic information system that contains detailed information with regard to the major stationary CO<sub>2</sub> sources and sinks in the region.
- Regular contact with others in the region and at the national level who have a stake in developing efficient and environmentally sound options for sequestration.
- Input on improvements to the PCOR Partnership DSS.
- Immediate access to all reports and information generated.
- Information on events, conferences, and workshops.

### Examples of Partner Contributions

- Sharing data, capabilities, and/or expertise
- Providing matching funds
- Involvement in advisory and outreach activities

For more information about becoming a partner, contact:

Charles Gorecki Director of Subsurface R&D PCOR Partnership Program Manager (701) 777-5355 <a href="mailto:cgorecki@undeerc.org">cgorecki@undeerc.org</a>	Ed Steadman Vice President for Research (701) 777-5279 <a href="mailto:esteadman@undeerc.org">esteadman@undeerc.org</a>	John Harju Vice President for Strategic Partnerships (701) 777-5157 <a href="mailto:jharju@undeerc.org">jharju@undeerc.org</a>
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Figure 9. Updated Become a Partner page.

Existing link: [www.undeerc.org/pcor/About/BecomeAPartner.aspx](http://www.undeerc.org/pcor/About/BecomeAPartner.aspx).



## PCOR Partnership Partners Page

Since the last D13 update, two new partners have been added to the partner's page. Listed alphabetically, they are Statoil and Tri-State Generation and Transmission Association. These updates are shown in Figure 10 below. This page was last updated on December 31, 2016.

**PCOR Partnership Partners (Phase I - III)**

- Abengoa Bioenergy New Technology, Inc.
- Air Products and Chemicals, Inc.
- Alberta Department of Energy
- Alberta Energy Research Institute
- Alberta Innovates – Technology Futures
- ALLETE
- Ameren Corporation
- American Coalition for Clean Coal Electricity (ACCCE)
- American Lignite Energy
- Apache Canada Ltd.
- Aquistore c/o Petroleum Technology Research Centre
- Baker Hughes Incorporated
- Ballantyne Oil, LLC
- Basin Electric Power Cooperative
- Bechtel Corporation
- BillyJack Consulting Inc.
- Biorecro AB
- Blue Source, LLC
- BNI Coal, Ltd.
- British Columbia Ministry of Energy, Mines and Petroleum Resources
- British Columbia Oil & Gas Commission
- C12 Energy Inc.
- Chicago Climate Exchange
- Computer Modelling Group, Inc.
- Continental Resources, Inc.
- Dakota Gasification Company
- Denbury Resources Inc.
- Ducks Unlimited Canada
- Ducks Unlimited, Inc.
- Eagle Operating, Inc.
- Eastern Iowa Community College District
- Enbridge Inc.
- Encore Acquisition Company
- Energy Resources Conservation Board/Alberta Geological Survey
- Environment Canada
- Excelsior Energy Inc.
- Fischer Oil and Gas, Inc.
- GE Global Research
- Great Northern Project Development, LP
- Great River Energy
- Halliburton
- Hess Corporation
- Huntsman Corporation
- Husky Energy
- Indian Land Tenure Foundation
- Interstate Oil and Gas Compact Commission
- Iowa Department of Natural Resources - Geological Survey
- Kiewit Mining Group
- Lignite Energy Council
- Manitoba Geological Survey
- Manitoba Hydro
- Marathon Oil Company
- MBI Energy Services

Figure 10. New partners added to the PCOR Partnership Partners page (continued).  
Existing link: [undeerc.org/PCOR/About/Partners.aspx](http://undeerc.org/PCOR/About/Partners.aspx).



Figure 10 (continued). New partners added to the PCOR Partnership Partners page.  
Existing link: [undeerc.org/PCOR/About/Partners.aspx](http://undeerc.org/PCOR/About/Partners.aspx).

## Climate, CO<sub>2</sub>, Sequestration Page

Updates to the Climate, CO<sub>2</sub>, Sequestration page included updating the text and organizing the links at the bottom using the headings Learn about Earth's natural CO<sub>2</sub> and Learn about cutting CO<sub>2</sub> emissions. The updated page with new layout is shown in Figure 11. These changes went live on September 13, 2017.

The screenshot shows the website for the Plains CO<sub>2</sub> Reduction (PCOR) Partnership. The header features the PCOR logo and the title "Plains CO<sub>2</sub> Reduction (PCOR) Partnership" with the tagline "Practical, Environmentally Sound CO<sub>2</sub> Sequestration". A navigation bar includes links for "PARTNERS ONLY", "KIDS", "EDUCATORS", and "CONTACT US", along with a search bar. The left sidebar lists various topics: "About the Partnership", "Climate, CO<sub>2</sub>, Sequestration" (highlighted), "What Is CO<sub>2</sub>?", "Global Carbon Cycle", "What Is CO<sub>2</sub> Sequestration?", "Carbon Capture and Storage", "Regional Storage Potential", "CO<sub>2</sub> Sequestration Projects", "Technical Publications", "Resources", "Documentaries", "Video Clip Library", "FAQs", "Links", and "Household Energy". The main content area is titled "Climate, CO<sub>2</sub>, Sequestration" and contains several paragraphs of text. It discusses the existence of earth-warming gases, the impact of anthropogenic GHGs, the role of carbon dioxide, and the concept of carbon management. A video clip titled "Balancing Energy and the Environment" is featured on the right. At the bottom, there are sections for "Learn about Earth's natural CO<sub>2</sub>", "Learn about cutting CO<sub>2</sub> emissions", and "References".

**PCOR Partnership**  
Plains CO<sub>2</sub> Reduction (PCOR) Partnership  
Practical, Environmentally Sound CO<sub>2</sub> Sequestration

PARTNERS ONLY KIDS EDUCATORS CONTACT US search

About the Partnership  
**Climate, CO<sub>2</sub>, Sequestration**  
What Is CO<sub>2</sub>?  
Global Carbon Cycle  
What Is CO<sub>2</sub> Sequestration?  
Carbon Capture and Storage  
Regional Storage Potential  
CO<sub>2</sub> Sequestration Projects  
Technical Publications  
Resources  
Documentaries  
Video Clip Library  
FAQs  
Links  
Household Energy

### Climate, CO<sub>2</sub>, Sequestration

Although earth-warming gases exist naturally in the atmosphere, human activities are adding more of these greenhouse gases or GHGs. Many scientists are concerned that these additional GHGs from human activities, called anthropogenic GHGs, are affecting Earth's climate.

Chief among these is carbon dioxide. **Anthropogenic CO<sub>2</sub>** comes from burning fossil fuels, industrial practices like making cement and processing natural gas, and agricultural activities like plowing. Anthropogenic CO<sub>2</sub> emissions have grown from a few million tons per year in 1850 to over 40 billion tons (36 billion metric tonnes) per year today mainly as the global use of fossil energy has continued to increase.<sup>1</sup> And, these emissions keep growing.

The effort to cut annual anthropogenic CO<sub>2</sub> emissions is called carbon management. Carbon management is a complex issue because most of our CO<sub>2</sub> comes from making and using energy, and energy is critical to maintaining our quality of life.

Cutting CO<sub>2</sub> emissions will require many actions, which might include energy conservation and efficiency, increased use of renewable and nuclear energy, more energy-efficient electricity generation, and CO<sub>2</sub> sequestration.<sup>2</sup>

Learn about Earth's natural CO<sub>2</sub>:

- **Greenhouse Effect**
- **Climate Change**
- **Natural Geologic Accumulations of CO<sub>2</sub>**
- **Carbon and CO<sub>2</sub> on Earth – Things Have Changed!**

Learn about cutting CO<sub>2</sub> emissions:

- **CO<sub>2</sub> from Human Action (anthropogenic CO<sub>2</sub>)**
- **Options to Reduce CO<sub>2</sub>**
- **What Is CO<sub>2</sub> Sequestration?**
- **Carbon Capture and Storage**

**References**

1. Carbon Dioxide Information Analysis Center, 2017, Fossil-fuel CO<sub>2</sub> emissions:  
[http://cdiac.ornl.gov/trends/emis/meth\\_reg.html](http://cdiac.ornl.gov/trends/emis/meth_reg.html)  
(accessed June 2017).
2. Pacala, S., and Socolow, R., 2004, Stabilization wedges—solving the climate problem for the next 50 years with current technologies: Science, v. 305, p. 968-972.

**Watch Video Clip**  
**Balancing Energy and the Environment**

Figure 11. Updated Climate, CO<sub>2</sub>, Sequestration page.  
Existing link: [undeerc.org/PCOR/Sequestration/](http://undeerc.org/PCOR/Sequestration/).



## What Is CO<sub>2</sub>? Page

The What Is CO<sub>2</sub>? page shown in Figures 12 and 13 features a new look. Page content was simplified and organized into three categories using a collapsible accordion interface to break up the large amount of information on this page, thus making the information easier to absorb. A video clip entitled “Energy, CO<sub>2</sub>, and Our Carbon Footprint” was added to the bottom of the page. A tool tip defining “normal conditions,” referenced to the icon of a question mark in a green circle, was added near the top. These changes went live on November 10, 2016. Because the information on this page cannot be printed all at once, a print-friendly version of this page with icon (upper right corner) was added as a PDF (attached in Appendix A) to the live site on May 15, 2017.


The screenshot displays the Plains CO<sub>2</sub> Reduction (PCOR) Partnership website. The header features the PCOR logo and the title "Plains CO<sub>2</sub> Reduction (PCOR) Partnership" with the tagline "Practical, Environmentally Sound CO<sub>2</sub> Sequestration". A navigation bar includes links for "PARTNERS ONLY", "KIDS", "EDUCATORS", and "CONTACT US", along with a search bar. The left sidebar lists various topics such as "About the Partnership", "Climate, CO<sub>2</sub>, Sequestration", "What Is CO<sub>2</sub>?", "Global Carbon Cycle", "What Is CO<sub>2</sub> Sequestration?", "Carbon Capture and Storage", "Regional Storage Potential", "CO<sub>2</sub> Sequestration Projects", "Technical Publications", "Resources", "Documentaries", "Video Clip Library", "FAQs", "Links", and "Household Energy".

The main content area is titled "What Is CO<sub>2</sub>?" and includes a molecular model of CO<sub>2</sub> (one carbon atom bonded to two oxygen atoms). Below this is an accordion interface with three sections: "CO<sub>2</sub> Exists Naturally", "Humans Use and Make CO<sub>2</sub>", and "Is CO<sub>2</sub> a Pollutant?". The "Reference:" section lists two sources:

1. [nssdc.gsfc.nasa.gov/planetary/factsheet/earthfact.html](http://nssdc.gsfc.nasa.gov/planetary/factsheet/earthfact.html) (accessed August 2006).
2. Boden, T.A., Marland, G., and Andres, R.J., 2016, Global, regional, and national fossil-fuel CO<sub>2</sub> emissions: Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tennessee, U.S.A. doi 10.3334/CDIAC/00001\_V2016, [http://cdiac.ornl.gov/trends/emis/tre\\_glob\\_2013.html](http://cdiac.ornl.gov/trends/emis/tre_glob_2013.html) (accessed June 16, 2016).

A video clip titled "Energy, CO<sub>2</sub>, and Our Carbon Footprint" is shown at the bottom right. A tool tip is visible at the bottom, defining "Normal conditions" as temperatures and pressures at or near the Earth's surface and in its atmosphere. The tool tip also explains that CO<sub>2</sub> can exist as solid, liquid, and gas, and provides details about its behavior under different conditions.

Figure 12. Content updated in What Is CO<sub>2</sub>? page with tool tip content (bottom).  
Existing link: [undeerc.org/PCOR/Sequestration/co2onearth.aspx](http://undeerc.org/PCOR/Sequestration/co2onearth.aspx).



# Plains CO<sub>2</sub> Reduction (PCOR) Partnership

Practical, Environmentally Sound CO<sub>2</sub> Sequestration

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About the Partnership

Climate, CO<sub>2</sub>, Sequestration

What Is CO<sub>2</sub>?

Global Carbon Cycle

What Is CO<sub>2</sub> Sequestration?

Carbon Capture and Storage

Regional Storage Potential

CO<sub>2</sub> Sequestration Projects

Technical Publications

Resources

Documentaries

Video Clip Library

FAQs

Links

Household Energy

## What Is CO<sub>2</sub>?

Carbon dioxide is a naturally occurring substance composed of one atom of carbon (C) and two atoms of oxygen (O<sub>2</sub>). Its chemical formula is CO<sub>2</sub>. CO<sub>2</sub> is gas under **normal conditions**.

### CO<sub>2</sub> Exists Naturally

CO<sub>2</sub> occurs naturally in small amounts (about 0.04%) in the Earth's atmosphere.<sup>1</sup>

As a major greenhouse gas, CO<sub>2</sub> helps create and maintain the natural **greenhouse effect** that keeps our planet hospitable to life.

CO<sub>2</sub> is essential to plant life. Plants take in CO<sub>2</sub>, exhale the oxygen, and use the carbon to live and grow. When the plant dies or burns, the carbon recombines with oxygen in the atmosphere, and CO<sub>2</sub> is formed again. This process is a key part of the **global carbon cycle**.

CO<sub>2</sub> is a by-product of our body's metabolism. Our lungs absorb oxygen from the air we breathe and exhale CO<sub>2</sub> as a waste product of cellular respiration.

CO<sub>2</sub> is produced naturally by processes deep in the earth. This CO<sub>2</sub> might be trapped in **underground geologic CO<sub>2</sub> deposits** similar to the underground deposits of oil and natural gas. Or it might be released at the surface by volcanoes or through natural ground seeps.

Naturally carbonated waters have historically been highly sought after for their supposed curative properties because these waters are high in mineral content.

Some bottled water is from naturally carbonated springs. Some examples are Apollinaris, Badoit, Gerolsteiner, Wattwiller, Ferrarelle, Borsec, and Perrier.

### Humans Use and Make CO<sub>2</sub>

CO<sub>2</sub> is added to soft drinks to make them bubbly.

Dry ice (frozen CO<sub>2</sub>) is used to keep things cold.

CO<sub>2</sub> is also used in fire extinguishers (CO<sub>2</sub> displaces the oxygen the fire needs to burn).

Every day, millions of tons of CO<sub>2</sub> are injected into underground geologic zones to help produce oil in a well-known industry practice called "**CO<sub>2</sub> flooding**" or enhanced oil recovery.


### Is CO<sub>2</sub> a Pollutant?

CO<sub>2</sub> formed by human action is called **anthropogenic CO<sub>2</sub>**. Plowing the land, making cement, and burning fossil fuels for energy all create anthropogenic CO<sub>2</sub>, which adds carbon to the **global carbon cycle**. Between 1751 and 2013, approximately 1440 billion metric tons of CO<sub>2</sub> has been emitted to the atmosphere from these sources.<sup>2</sup> This is raising concerns about climate change.

The U.S. Environmental Protection Agency has ruled CO<sub>2</sub> a pollutant in order to be able to regulate anthropogenic CO<sub>2</sub> emissions from human activities under the Clean Air Act of 1970.

**Reference:**

1. [nssdc.gsfc.nasa.gov/planetary/factsheet/earthfact.html](https://nssdc.gsfc.nasa.gov/planetary/factsheet/earthfact.html) (accessed August 2006).
2. Boden, T.A., Marland, G., and Andres, R.J., 2016, Global, regional, and national fossil-fuel CO<sub>2</sub> emissions: Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tennessee, U.S.A. doi 10.3334/CDIAC/00001\_V2016, [https://cdiac.ornl.gov/trends/emis/tre\\_glob\\_2013.html](https://cdiac.ornl.gov/trends/emis/tre_glob_2013.html) (accessed June 16, 2016).



Energy, CO<sub>2</sub>, and Our Carbon Footprint

Figure 13. New look for What Is CO<sub>2</sub>? page with expanded accordion content.  
Existing link: [undeerc.org/PCOR/sequestration/whatisco2.aspx](https://undeerc.org/PCOR/sequestration/whatisco2.aspx).

## What Is CO<sub>2</sub> Sequestration? Page

The What Is CO<sub>2</sub> Sequestration? page shown in Figure 14, was given a new look. Page content was simplified and updated. Tool tips describing terrestrial sequestration and geologic sequestration, referenced to the icon of a question mark in a green circle, were added. The updated page went live on November 10, 2016. Because the information on this page cannot be printed all at once, a print-friendly version of this page with icon (upper right corner) was added as a PDF (attached in Appendix A) to the live site on September 13, 2017.

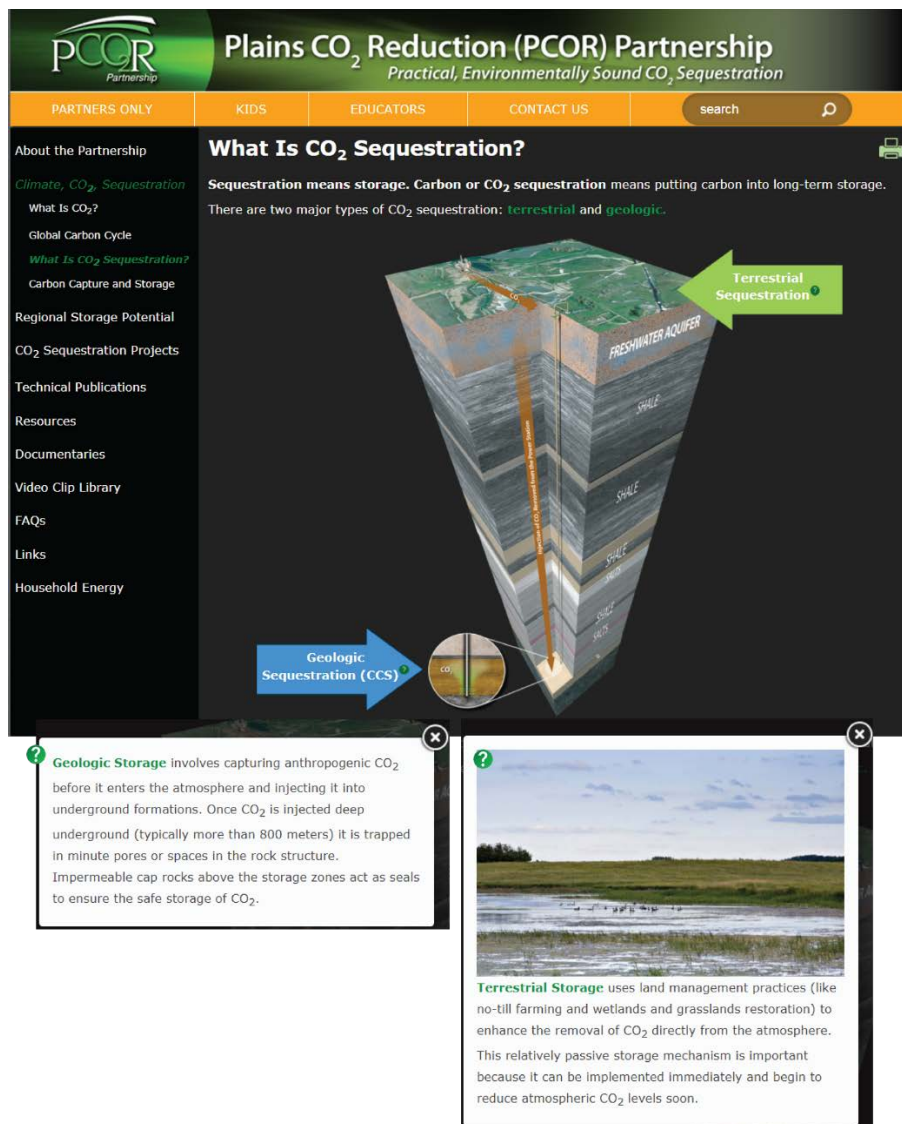


Figure 14. New look for What Is CO<sub>2</sub> Sequestration? page with the tool tips associated with Geologic Sequestration (left) and Terrestrial Sequestration (right).  
Existing link: [undeerc.org/pcor/sequestration/whatissequestration.aspx](http://undeerc.org/pcor/sequestration/whatissequestration.aspx).

## Terrestrial Sinks

The Web page Terrestrial Sinks was renamed Terrestrial Sequestration to better describe page content. The page was redesigned to make it more visually appealing to the Web user. Content was updated and simplified as shown in Figure 15. Video clips were enlarged and hyperlinks to other relevant Web pages were made into green buttons to add visual interest to the page. A tool tip referenced to the icon of a question mark in a green circle states that terrestrial sequestration stores on the carbon atom of the CO<sub>2</sub> molecule, and was added to the page redesign. These page changes were implemented on November 10, 2016. Because the information on this page cannot be printed all at once, a print-friendly version of this page with icon (upper right corner) was added as a PDF (attached in Appendix A) to the live site on May 15, 2017.

**Plains CO<sub>2</sub> Reduction (PCOR) Partnership**  
Practical, Environmentally Sound CO<sub>2</sub> Sequestration

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**Terrestrial Sequestration**

Terrestrial (or biologic) sequestration means using plants to capture CO<sub>2</sub> from the atmosphere and then storing it as carbon in the stems and roots of the plants as well as in the soil. In photosynthesis, plants take in CO<sub>2</sub> and give off the oxygen (O<sub>2</sub>) to the atmosphere as a waste gas. The plants retain and use the carbon to live and grow. When the plant winters or dies, part of the carbon from the plant is preserved (stored) in the soil. Terrestrial sequestration is a set of land management practices that maximizes the amount of carbon that remains stored in the soil and plant material for the long term. No-till farming, wetland management, rangeland management, and reforestation are examples of terrestrial sequestration practices that are already in use.

**Benefits of terrestrial storage may include improved soil and water quality, reduced erosion, reduced evaporative water loss, reduced pest problems, and overall ecosystem improvement.**

**Steady State**  
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.<sup>1</sup> Once this "steady state" has been reached, the carbon will remain stored in the soil as long as the land is undisturbed and conservation land management practices are continued.

**Mechanisms for Terrestrial Storage**  
Promising land and water management practices that can enhance the terrestrial storage of carbon include the following:

- Conservation tillage
- Reducing soil erosion and minimizing soil disturbance
- Using buffer strips along waterway
- Enrolling land in conservation programs
- Restoring and better managing wetlands and degraded soils
- Eliminating summer fallow
- Using perennial grasses and winter cover crops
- Fostering an increase in forests (2,3)

**Terrestrial Carbon Sink Variables**

**References:**

1. Paustian, K.H., and Cole, C.V., 1998, CO<sub>2</sub> mitigation by agriculture – an overview: Climatic Change, v. 40, p. 135–162, Netherlands, Kluwer Academic Publishers.
2. Peterson, E.B., Bonnor, G.M., Robinson, G.C., and Peterson, N.M., 1999, Carbon sequestration aspects of an afforestation program in Canada's prairie provinces: Submitted to Joint Forest Sector Table/Sinks Table, National Climate Change Process, published by Nawitka Renewable Resource Consultants Ltd., p. 1–98, www.nccp.ca/NCCP/pdf/Afforest\_Prairies.pdf (accessed September 2004).
3. de Silva, L.L., Chacek, L.J., Leistritz, F.L., Faller, T.C., Bangsund, D.A., Sorensen, J.A., Steadman, E.N., and Harju, J.A., 2005, The contribution of soils to carbon sequestration: Plains CO<sub>2</sub> Reduction (PCOR) Partnership topical report for U.S. Department of Energy and multiclients, Grand Forks, North Dakota, Energy & Environmental Research Center, June.

**What is Terrestrial CO<sub>2</sub> Sequestration?**

**Carbon Not CO<sub>2</sub>**

**Sequestration Potential in Our Region**

**Field Projects**

**Sequestration Potential in the Prairies**

**Wetland Upland**

**Carbon Storage in the Landscape**

**Carbon – Not CO<sub>2</sub>**  
It is important to remember that terrestrial storage does not store CO<sub>2</sub> as a gas but stores the carbon portion of the CO<sub>2</sub>. 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<sub>2</sub> to form CO<sub>2</sub> gas and reenter the atmosphere, reducing the amount of carbon in storage.

Figure 15. Content update for Terrestrial Sequestration page with new tool tip content (bottom).  
Existing link: [undeerc.org/pcor/region/terrestrial.aspx](http://undeerc.org/pcor/region/terrestrial.aspx).



## Wetlands Page

The Wetlands page, shown in Figure 16, underwent several changes. Content was updated and simplified for Web users, and the video clip “Sequestering Carbon in Wetlands” from the PCOR Partnership documentary *Out of the Air – Into the Soil: Land Practices That Reduce Atmospheric Carbon Levels* was inserted on the page. These page changes went live on November 10, 2016.



Figure 16. Content update in Wetlands page.  
Existing link: [undeerc.org/pcor/region/terrestrial/wetlands.aspx](http://undeerc.org/pcor/region/terrestrial/wetlands.aspx).

## Regulations and Permitting

The Regulations and Permitting page shown in Figures 17 and 18 includes updated text and PDF elements. Under the Federal Regulations section, both the United States and Canada PDFs were updated. Under the State and Provincial Regulations section, hover text was updated. A new tool tip referenced to the icon of a question mark in a green circle provides details on EOR project regulations. Because the information on this page cannot be printed all at once, a print-friendly version of this page with printer icon (upper right corner) was added as a PDF (attached as Appendix A). Updates for this page went live on May 15, 2017

**Plains CO<sub>2</sub> Reduction (PCOR) Partnership**  
*Practical, Environmentally Sound CO<sub>2</sub> Sequestration*

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**CCS Regulations and Permitting**

Carbon capture and storage (CCS) projects are subject to regulation at the source of CO<sub>2</sub>, during transportation to the injection site, and at the site, whether for enhanced oil recovery (EOR) projects or long-term geologic storage of anthropogenic CO<sub>2</sub>. Before any physical work can begin, federal and state/provincial regulatory requirements must be met, the public must have an opportunity to comment, and any necessary permits must have been issued.

**Federal Regulations**

- **United States** (34kb) pdf
- **Canada** (23kb) pdf

**State and Provincial Regulations**

Hover over a location below to view information on laws and regulations specifically addressing CCS.

In 2014, 136 CO<sub>2</sub> EOR projects in the United States were regulated under the U.S. Environmental Protection Agency (EPA) federal regulations and by state oil and gas regulations. The regulatory framework for projects involving geologic storage of anthropogenic CO<sub>2</sub> is specifically addressed at the federal level under Class VI injection wells. Protection of groundwater resources and human health is a focus of both EOR and geologic storage regulations.

**State and Provincial CCS Regulations** (22kb) pdf

\*All information is current as of April 1, 2017.

Figure 17. Updated Regulations and Permitting page with new tool tip content (bottom).  
Existing link: [undeerc.org/pcor/Region/Regulation.aspx](http://undeerc.org/pcor/Region/Regulation.aspx).



# Plains CO<sub>2</sub> Reduction (PCOR) Partnership

Practical, Environmentally Sound CO<sub>2</sub> Sequestration

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## About the Partnership

Climate, CO<sub>2</sub>, Sequestration

*Regional Storage Potential*

CO<sub>2</sub> Sources and Emissions

Geologic CO<sub>2</sub> Storage

Terrestrial Sequestration

*Regulations and Permitting*

CO<sub>2</sub> Sequestration Projects

Technical Publications

Resources

Documentaries

Video

FAQs

Links

House

## CCS Regulations and Permitting

Carbon capture and storage (CCS) projects are subject to regulation at the source of CO<sub>2</sub>, during transportation to the injection site, and at the site, whether for enhanced oil recovery (EOR) projects or long-term geologic storage of anthropogenic CO<sub>2</sub>. Before any physical work can begin, federal and state/provincial regulatory requirements must be met, the public must have an opportunity to comment, and any necessary permits must have been issued.

### Federal Regulations

- [United States](#) (34kb) pdf
- [Canada](#) (23kb) pdf

### State and Provincial Regulations

Hover over a location below to view information on laws and regulations specifically addressing CCS.



**British Columbia** is reviewing regulatory framework for CCS. Additional legislation may be considered for clarification purposes.

**Alberta** has developed regulations for storage, pore space ownership, and long-term stewardship.

**Saskatchewan** has adapted existing oil and gas regulations for CO<sub>2</sub> storage.

**Manitoba** does not have any legislation in place or rules adopted or under development.

**Montana** has legislation in place for pore space issues and long-term stewardship. Rule development will begin once primacy for underground injection of CO<sub>2</sub> for storage purposes is received from EPA.

**Wyoming** has legislation in place for pore space ownership.

**North Dakota** has legislation in place for pore space issues and long-term stewardship and has applied for Class VI primacy.

**South Dakota** does not have any legislation in place or rules adopted or under development.

**Nebraska** does not have any legislation in place or rules adopted or under development.

**Minnesota** does not have any legislation in place or rules adopted or under development.

**Wisconsin** does not have any legislation in place or rules adopted or under development.

**Iowa** does not have any legislation in place or rules adopted or under development.

**Missouri** does not have any legislation in place or rules adopted or under development.

[State and Provincial CCS Regulations](#) (22kb) pdf

\*All information is current as of April 1, 2017.

Figure 18. Updated Regulations and Permitting page with hover box text.  
Existing link: [undeerc.org/pcor/Region/Regulation.aspx](http://undeerc.org/pcor/Region/Regulation.aspx).



## CO<sub>2</sub> Sequestration Projects Page

The CO<sub>2</sub> Sequestration Projects page shown in Figure 19 is the main landing page for all CCS projects in the PCOR Partnership region. This page has undergone several changes. The most noticeable change includes an updated map with five additional CSS projects. Because the information on this page cannot be printed all at once, a print-friendly version of this page accessed with a printer icon (upper right corner) was added as a PDF (attached in Appendix A).

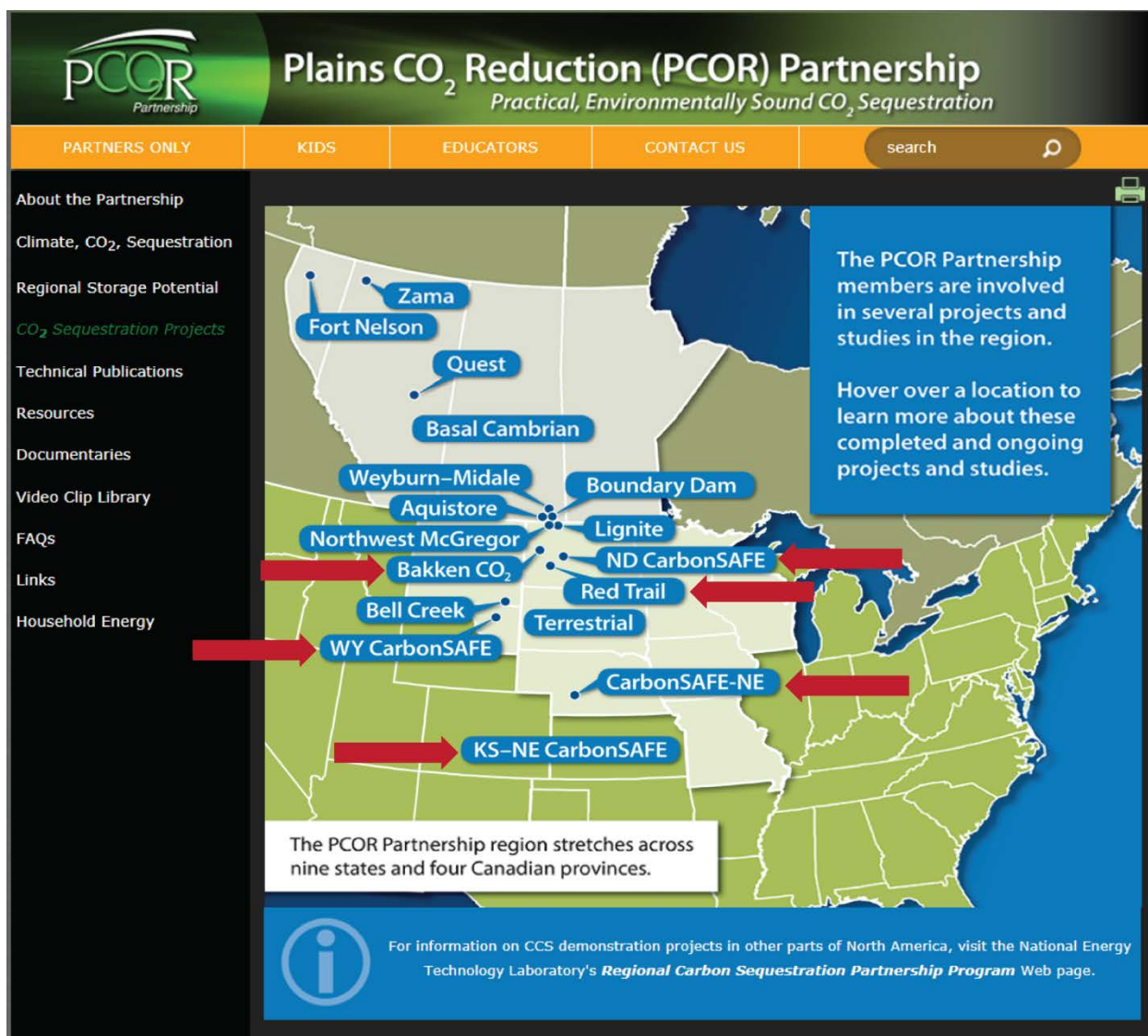


Figure 19. Updated CO<sub>2</sub> Sequestration Projects landing page.  
Existing link: [undeerc.org/PCOR/CO2SequestrationProjects/](http://undeerc.org/PCOR/CO2SequestrationProjects/).



Figure 20 shows all of the project hover boxes, which open separately on top of the existing page. All text for the hovers has been updated piecemeal with the most recent going live on January 22, 2018.



Figure 20. Project information boxes that pop up when the cursor hovers over project titles on the landing page (Figure 19).

Four pages profiling active projects or now completed projects underwent content and status updates so that the content is accurate as of September 2017. These pages include Aquistore Project (Figure 21), Fort Nelson CCS Feasibility Project (Figure 22), SaskPower Boundary Dam Carbon Capture Project (Figure 23), and Weyburn–Midale CO<sub>2</sub> Project (Figure 24). These updates went live September 13, 2017.

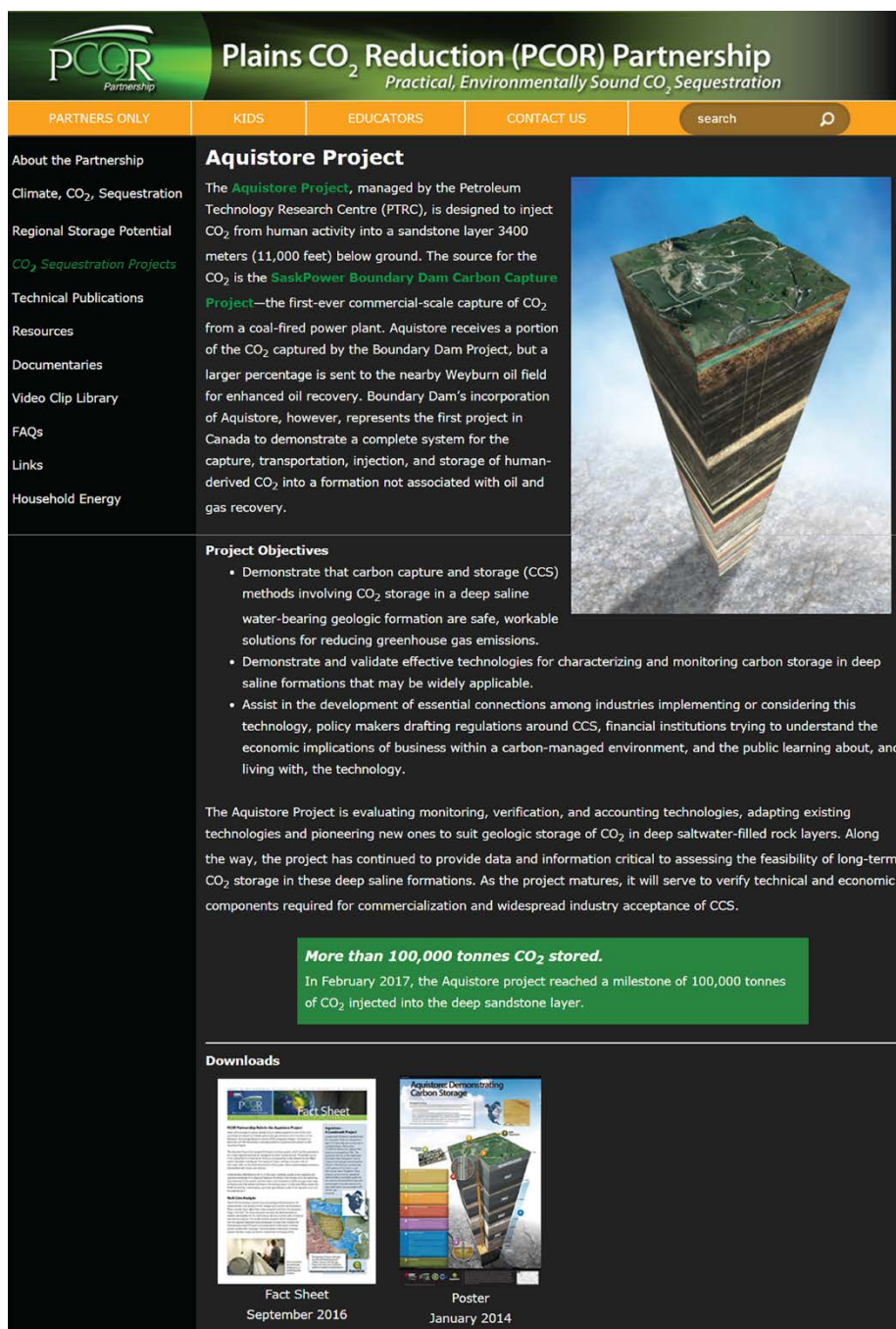



Figure 21. Content update Aquistore Project page.  
 Existing link: [undeerc.org/PCOR/CO2SequestrationProjects/Aquistore.aspx](http://undeerc.org/PCOR/CO2SequestrationProjects/Aquistore.aspx).





# Plains CO<sub>2</sub> Reduction (PCOR) Partnership

Practical, Environmentally Sound CO<sub>2</sub> Sequestration

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About the Partnership

Climate, CO<sub>2</sub>, Sequestration

Regional Storage Potential

CO<sub>2</sub> Sequestration Projects

Technical Publications

Resources

Documentaries

Video Clip Library


FAQs

Links

Household Energy

## Fort Nelson CCS Feasibility Project

As part of a larger effort to investigate CO<sub>2</sub> mitigation strategies, the **Fort Nelson Carbon Capture and Storage (CCS) Feasibility Project** investigated the technical and economic feasibility of a commercial-scale geologic storage project near Fort Nelson, British Columbia. At the time of the research, Spectra Energy's Fort Nelson natural gas processing facility was the largest point source of CO<sub>2</sub> in the province.



The objectives were to 1) determine the geologic characteristics of the potential storage and sealing rock formations near the injection site; 2) model the effects that large-scale injection of CO<sub>2</sub> may have on those rock formations and on wellbore integrity; 3) evaluate the geologic risks of the injection process at local and regional scales based on results of the modeling effort; and 4) design site-specific, risk-based monitoring, verification, and accounting plans to ensure safe and cost-efficient, long-term CO<sub>2</sub> storage in the Fort Nelson study area.


The Fort Nelson CCS Feasibility Project was an international collaboration that included industry, government (Natural Resources Canada, the U.S. Department of Energy, and the province of British Columbia), universities, and an experienced, multidisciplinary technical team. The PCOR Partnership collaborated with Spectra Energy on the 2009–2012 feasibility study as part of its Phase III activities.

### Status

Although the site is an exceptional candidate for commercial-scale, long-term geologic storage of CO<sub>2</sub>, the economics of carbon management in British Columbia did not support the financial case for moving forward with a CCS project at the time of the study.

---


The Fort Nelson CCS Feasibility Project is recognized by the international **Carbon Sequestration Leadership Forum** (CSLF) as being uniquely qualified to fill technological gaps with regard to geologic storage of CO<sub>2</sub>.




CSLF is a ministerial-level international climate change initiative focused on the development of improved cost-effective CCS technologies. The mission of CSLF is to facilitate the development and deployment of such technologies via collaborative efforts that address key technical, economic, and environmental obstacles.

---

### Downloads



Fact Sheet  
August 2016



Poster  
April 2012

Figure 22. Content update Fort Nelson CCS Feasibility Project page.  
Existing link: [undeerc.org/PCOR/CO2SequestrationProjects/FortNelson.aspx](http://undeerc.org/PCOR/CO2SequestrationProjects/FortNelson.aspx).



# Plains CO<sub>2</sub> Reduction (PCOR) Partnership

Practical, Environmentally Sound CO<sub>2</sub> Sequestration

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About the Partnership

Climate, CO<sub>2</sub>, Sequestration

Regional Storage Potential

CO<sub>2</sub> Sequestration Projects

Technical Publications

Resources

Documentaries

Video Clip Library

FAQs

Links

Household Energy

## SaskPower Boundary Dam Carbon Capture Project

In the fall of 2014, **Boundary Dam Power Station** in Estevan, Saskatchewan, became the first generating station in the world to successfully use carbon capture and storage (CCS) technology on one of its full-scale units. The facility can capture up to 1.3 million tonnes of carbon dioxide emissions per year while simultaneously removing sulfur and other pollutants. The captured CO<sub>2</sub> either goes to oil fields for enhanced oil recovery or is injected into a 3400-m deep sandstone formation through the Petroleum Technology Research Centre's **Aquistore Project**. In both cases, the CO<sub>2</sub> is permanently stored deep underground.

The Boundary Dam Power Station has four electricity generation units. Boundary Dam's Carbon Capture Plant processes the flue gas from Unit 3 (BD 3). This first-of-its-kind carbon capture plant has shown the technical feasibility of CCS technology as well as having documented its costs and challenges. At the same time, the power unit, BD 3, is producing 115 MW of electricity with a reduced carbon footprint—enough to power 100,000 homes in the province.

### Project Benefits

- A pathway toward economically and environmentally sustainable power generation.
- One million tonnes per year of greenhouse gas emission reductions from an existing power station.
- A domestic, integrated, commercial-scale carbon capture utilization and storage project—the first and largest of its kind in the world.
- A means to keep coal in the electricity supply mix, thus utilizing an existing supply of reliable, low-cost fuel.
- The reuse of existing fuel supplies and structures within the footprint of an operating industrial site.
- A demonstration project for the development of sound regulation and policies.

SaskPower led the development of the world's first carbon capture facility retrofit to an existing generating unit. The facility was designed and constructed as the Boundary Dam Integrated Carbon Capture and Storage Demonstration Project, a \$1.24 billion government–industry partnership between the Government of Canada, the Government of Saskatchewan, SaskPower, and private industry.




Figure 23. Content update SaskPower Boundary Dam Carbon Capture Project page.  
Existing link: [undeerc.org/PCOR/CO2SequestrationProjects/SaskPower.aspx](http://undeerc.org/PCOR/CO2SequestrationProjects/SaskPower.aspx).





# Plains CO<sub>2</sub> Reduction (PCOR) Partnership

Practical, Environmentally Sound CO<sub>2</sub> Sequestration

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About the Partnership

Climate, CO<sub>2</sub>, Sequestration

Regional Storage Potential

CO<sub>2</sub> Sequestration Projects

Technical Publications

Resources

Documentaries

Video Clip Library

FAQs

Links

Household Energy

## Weyburn–Midale CO<sub>2</sub> Project

### Assessing CO<sub>2</sub> behavior in an ongoing commercial CO<sub>2</sub> EOR project

The **Weyburn** and Midale oil fields in the southern portion of the Canadian province of Saskatchewan are the sites of major commercial enhanced oil recovery (EOR) operations using CO<sub>2</sub>. Since 2000, industrial-grade CO<sub>2</sub> has traveled 205 miles (330 km) by pipeline from the **Great Plains Synfuels Plant** in Beulah, North Dakota, to the Weyburn and Midale oil fields. Since October 2014, CO<sub>2</sub> also began coming from SaskPower's coal-fired **Boundary Dam Power Station**.<sup>1</sup> The EOR operations will eventually produce an additional 200 million barrels of oil<sup>2</sup> and permanently store 44 million tons of CO<sub>2</sub> deep underground in the oil-producing rocks.

As of February 2017, the Weyburn project had safely injected approximately 30 million tonnes of CO<sub>2</sub>. This effective storage of greenhouse gas emissions is equal to taking more than six million cars off the road for an entire year. Approximately 2 million tonnes of new CO<sub>2</sub> is injected and stored at Weyburn every year.<sup>2</sup>

The behavior of the CO<sub>2</sub> accumulating in the underground oil-producing zones during the commercial EOR operation was the focus of the IEA Greenhouse Gas R&D Programme (IEAGHG) Weyburn–Midale CO<sub>2</sub> Monitoring and Storage Project, an 11-year, \$85 million scientific assessment completed in 2011. The assessment program was managed by the Petroleum Technology Research Centre in Regina, Saskatchewan, and was funded by numerous government and industry sources, including the IEAGHG, Natural Resources Canada, and the U.S. Department of Energy. A final report on the project, *Best Practices for Validating CO<sub>2</sub> Geological Storage: Observations and Guidance from the IEAGHG Weyburn–Midale CO<sub>2</sub> Monitoring and Storage Project*, was released in 2012.

#### References

1. [www.cenovus.com/technology/co2-enhanced-oil-recovery.html](http://www.cenovus.com/technology/co2-enhanced-oil-recovery.html) (accessed June 2017).
2. [www.cenovus.com/operations/conventional-oil-natural-gas/weyburn.html](http://www.cenovus.com/operations/conventional-oil-natural-gas/weyburn.html) (accessed June 2017).

Watch Video Clip



CO<sub>2</sub> Goes Canadian




Figure 24. Content update Weyburn–Midale CO<sub>2</sub> Project page.  
Existing link: [undeerc.org/PCOR/CO2SequestrationProjects/Weyburn.aspx](http://undeerc.org/PCOR/CO2SequestrationProjects/Weyburn.aspx).

On the Bell Creek Integrated EOR and CO<sub>2</sub> Storage Project page, the fact sheet “Bell Creek Project – Enhanced Oil Recovery Resulting in Associated CO<sub>2</sub> Storage” replaced a previous version at the bottom of the Web page (current as of October 1, 2017). This fact sheet went live on December 20, 2017.

## Technical Publications Page

The Technical Publications page provides public access to technical materials on terrestrial and geologic sequestration prepared by the PCOR Partnership. This landing page shown in Figure 25 was updated to include a hyperlink to the new Web page: CO<sub>2</sub> EOR LCA Model. Changes to this page went live on July 21, 2016, to coincide with the publication of the journal article featured.

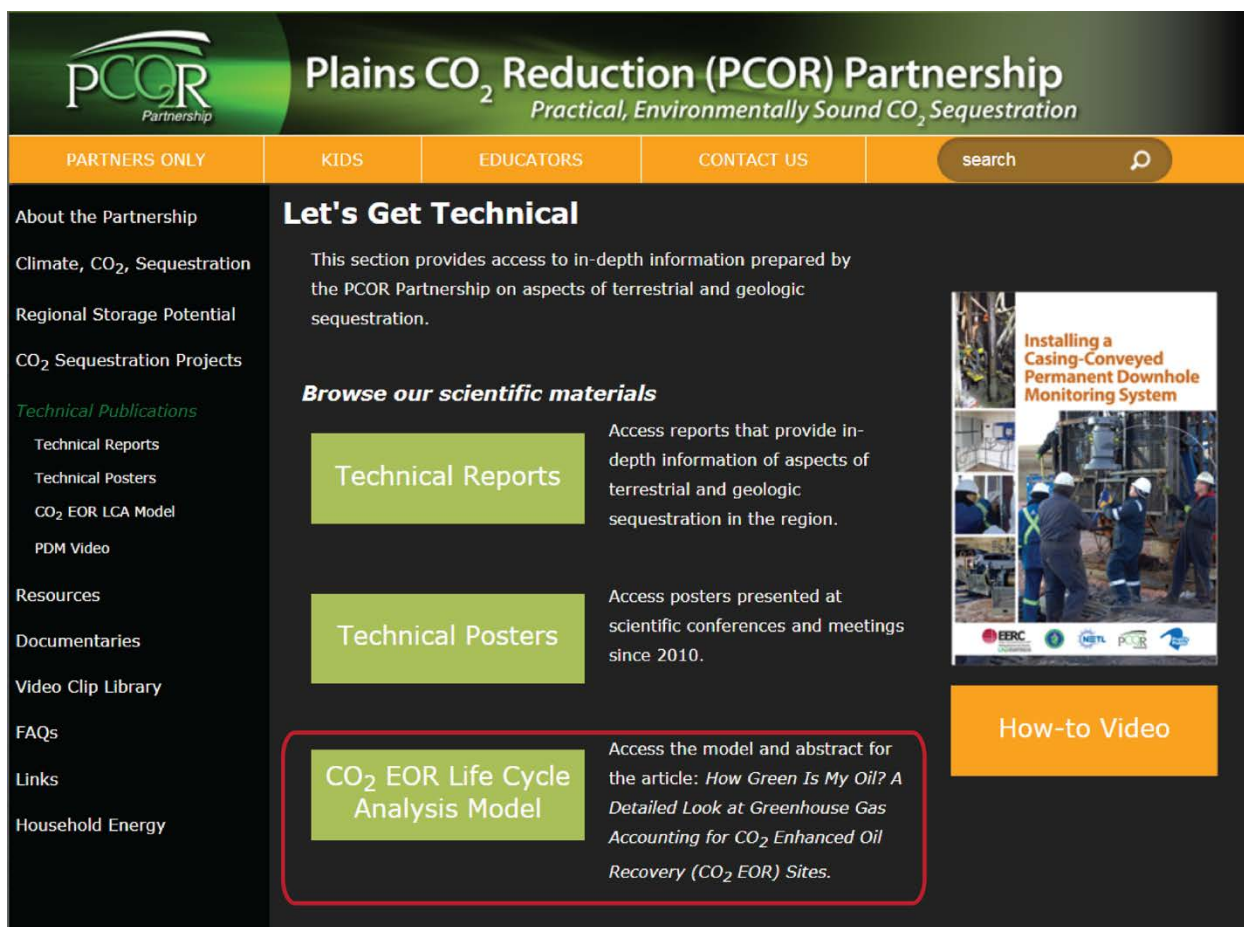


Figure 25. Updated Technical Publications page.  
Existing link: <http://www.undeerc.org/pcor/technicalpublications/>.

## Technical Reports Page

The Technical Reports page shown in Figure 26 offers viewing and downloading access to 58 PCOR Partnership reports. This page underwent several changes. A total of 31 new reports were added to this page, and all reports were organized into eight headings. Publication years now follow the report title so reports can be arranged chronologically from newest to oldest under each category heading. Changes to this page went live on July 7, 2017.

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*Practical, Environmentally Sound CO<sub>2</sub> Sequestration*

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**Technical Reports**

**PCOR Partnership Region (General)**

- Review of CO<sub>2</sub> Point Source Attributes in the PCOR Partnership (2013)
- Regional Emissions and Capture Opportunities Assessment – Plains CO<sub>2</sub> Reduction (PCOR) Partnership (2009)
- Estimates of CO<sub>2</sub> Storage Capacity in Selected Oil Fields of the Northern Great Plains Region of North America (2007)
- CO<sub>2</sub> Source Characterization of the PCOR Partnership Region (2005)
- Deployment Issues Related to Geological and Terrestrial CO<sub>2</sub> Sequestration in the PCOR Partnership Region (2005)
- Geologic CO<sub>2</sub> Sequestration Potential of the Wyodak-Anderson Coal Zone in the Powder River Basin (2005)
- Geologic Sequestration Potential of the PCOR Partnership Region (2005)
- Identification of CO<sub>2</sub> Sequestration Strategies for the PCOR Partnership Region (2005)
- Potential CO<sub>2</sub> Storage Capacity of the Lower Cretaceous Aquifer System in the PCOR Partnership Region (2005)

**Bell Creek Demonstration Site**

- Bell Creek Test Site – Carbon Dioxide (CO<sub>2</sub>) Procurement Efforts for a Large-Scale CO<sub>2</sub> Storage and CO<sub>2</sub> Enhanced Oil Recovery Project (2013)
- Bell Creek Test Site – First Full-Field Operational Phase Soil Gas- and Groundwater-Sampling Event Completed (2013)
- Bell Creek Test Site – Geological Characterization Data Collection Completed (2013)
- Bell Creek Test Site – Monitoring Experimental Design Package (2013)
- Bell Creek Test Site – MVA Equipment Installation and Baseline MVA Activities Completed (2013)
- Bell Creek Test Site – Initiation of Production and Injection Simulation (2012)
- Bell Creek Test Site – Baseline Hydrogeological Experimental Design Package (2011)
- Bell Creek Test Site – Baseline MVA Initiated (2011)
- Bell Creek Test Site – Simulation (2011)

**Carbon Capture Storage**

- Current Status of CO<sub>2</sub> Capture Technology Development and Application (2012)
- Opportunities and Challenges Associated with CO<sub>2</sub> Compression and Transportation During CCS Activities (2011)
- Preliminary Design of Advanced Compression Technology (2009)
- Using Wind Power to Offset the Energy Requirements of CO<sub>2</sub> Compression for Sequestration: A Best Practices Manual (2007)

Figure 26. Updated Technical Reports page.

Existing link: <http://www.undeerc.org/pcor/technicalpublications/technicalreports.aspx>.



	<p><b>Field Validation – Regional Technology Implementation Plans</b></p> <ul style="list-style-type: none"> <li>• CO<sub>2</sub> Sequestration Validation Test in a Deep, Unminable Lignite Seam in Western North Dakota – Regional Technology Implementation Plan (2009)</li> <li>• Terrestrial Field Validation Test – Regional Technology Implementation Plan (2009)</li> <li>• Williston Basin Field Demonstration, Northwest McGregor CO<sub>2</sub> Huff 'n' Puff – Regional Technology Implementation Plan (2009)</li> <li>• Zama Field Validation Test – Regional Technology Implementation Plan (2009)</li> </ul> <p><b>Fort Nelson Feasibility Study</b></p> <ul style="list-style-type: none"> <li>• Fort Nelson Test Site – Simulation Report (Status Update 1) (2012)</li> <li>• Fort Nelson Test Site – Site Characterization, Modeling, and Monitoring Plan (2010)</li> </ul> <p><b>Geologic Sequestration</b></p> <ul style="list-style-type: none"> <li>• Carbon Dioxide Storage Capacity in Uneconomical Coal Beds in Alberta: Potential and Site Identification (2009)</li> <li>• Carbon Dioxide Storage Capacity in Uneconomical Coal Beds in Alberta: Potential and Site Identification (2006)</li> <li>• Carbon Dioxide Storage Capacity in Upper Cretaceous – Tertiary Ardley Coals in Alberta (2006)</li> <li>• Factors Affecting the Potential for CO<sub>2</sub> Leakage from Geologic Sinks (2005)</li> </ul> <p><b>Permitting – CCS</b></p> <ul style="list-style-type: none"> <li>• Permitting Review – Update 1 (2013)</li> <li>• Permitting Review – Basic EPA Requirements (2011)</li> <li>• PCOR Partnership Phase II Road Map Document (2009)</li> </ul> <p><b>Williston Basin</b></p> <ul style="list-style-type: none"> <li>• Basal Cambrian Dynamic Capacity Estimation Completed (2013)</li> <li>• Geochemical Evaluation of the Basal Cambrian System (2013)</li> <li>• Wellbore Evaluation of the Basal Cambrian System (2013)</li> <li>• Geological Characterization of the Basal Cambrian System in the Williston Basin (2012)</li> <li>• Site Characterization and 3-D Geologic Modeling of the Rival Field (2012)</li> <li>• Basal Cambrian Baseline Geological Characterization Completed (2011)</li> <li>• Basal Cambrian Static Geological Model Completed (2011)</li> <li>• Site Characterization of the Dickinson Lodgepole Mounds for Potential CO<sub>2</sub> Enhanced Oil Recovery (2009)</li> <li>• Formation Characteristics by Geologic Formation <ul style="list-style-type: none"> <li>◦ Black Island Formation Outline</li> <li>◦ Broom Creek Formation Outline</li> <li>◦ Deadwood Formation Outline</li> <li>◦ Duperow Formation Outline</li> <li>◦ Inyan Kara Formation Outline</li> <li>◦ Mission Canyon Formation Outline</li> <li>◦ Newcastle Formation Outline</li> <li>◦ Red River Formation Outline</li> <li>◦ Skull Creek Formation Outline</li> <li>◦ Winnipegosis Formation Outline</li> </ul> </li> <li>• Overview of Williston Basin Geology as It Relates to CO<sub>2</sub> (2005)</li> <li>• Sequestration Potential of the Madison of the Northern Great Plains Aquifer System (Madison Geological Sequestration Unit) (2005)</li> <li>• Geologic CO<sub>2</sub> Sequestration Potential of Lignite Coal in the U.S. Portion of the Williston Basin (2005)</li> <li>• Sequestration Potential of Petroleum Reservoirs in the Williston Basin (2005)</li> <li>• The Influence of Tectonics on the Potential Leakage of CO<sub>2</sub> from Deep Geological Sequestration Units in the Williston Basin (2005)</li> </ul>
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Figure 26 (continued). Updated Technical Reports page.  
Existing link: <http://www.undeerc.org/pcor/technicalpublications/technicalreports.aspx>.



## The PCOR Partnership Regional Atlas Page

The PCOR Partnership Regional Atlas page (accessed via the home page and the Resources on the left navigation) has been updated with content in each of the seven chapters and the reference section for the Atlas, 5th edition (published 2016). These updates went live April 25, 2017. Minor updates to Atlas 5 were published in an online version only, which is shown in Figure 27. The Atlas, 5th edition revised (published 2017), went live on the public Web site on December 20, 2017.

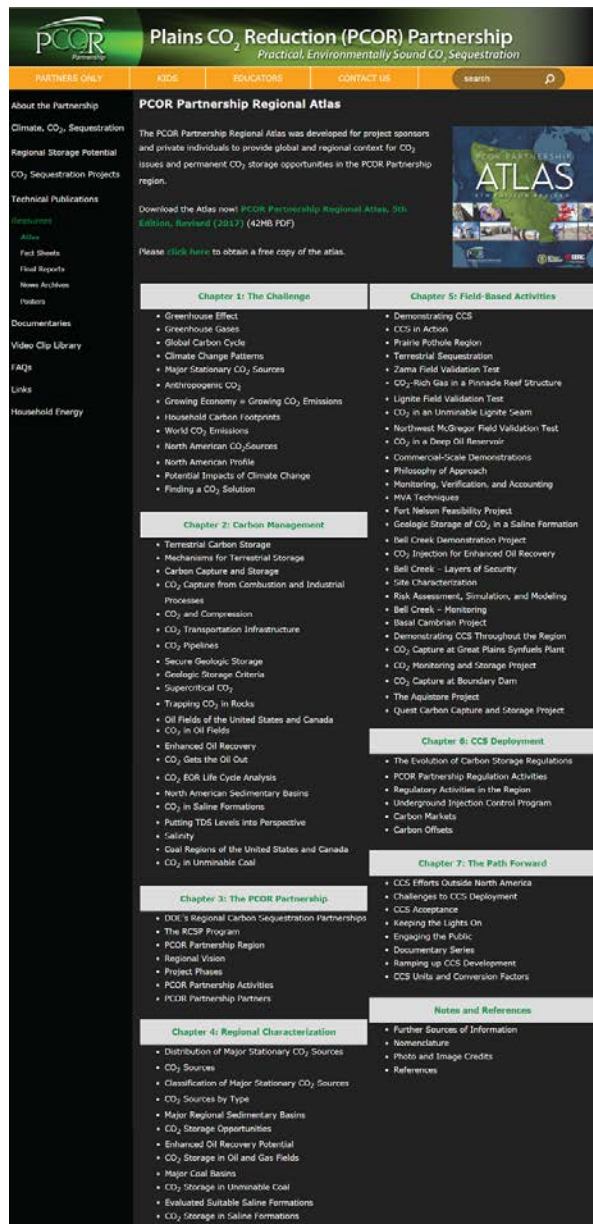



Figure 27. Updated Atlas page.  
Existing link: <http://www.undeerc.org/pcor/newsandpubs/atlas.aspx>.

## **Fact Sheets Page**

Several fact sheets on the Fact Sheets Web page, shown in Figure 28 were replaced with up-to-date information. The following went live February 13, 2017: “Fort Nelson CCS Feasibility Project,” PCOR Partnership Role in the Aquistore Project,” “What Is the PCOR Partnership,” “Terrestrial Carbon Sequestration Field Validation Test,” and “CO<sub>2</sub> Sequestration Test in a Deep, Unminable Lignite Seam.”

The PCOR Partnership Phase III general fact sheet “PCOR Partnership Demonstrating CO<sub>2</sub> Storage in the Northern Great Plains” was uploaded on February 13, 2017, and December 20, 2017, and “Bell Creek Project – Enhanced Oil Recovery Resulting in Associated CO<sub>2</sub> Storage” was uploaded on December 20, 2017.



# Plains CO<sub>2</sub> Reduction (PCOR) Partnership

Practical, Environmentally Sound CO<sub>2</sub> Sequestration

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- About the Partnership
- Climate, CO<sub>2</sub>, Sequestration
- Regional Storage Potential
- CO<sub>2</sub> Sequestration Projects
- Technical Publications
- Resources
  - Atlas
  - Fact Sheets
  - Final Reports
  - News Archives
  - Posters
- Documentaries
- Video Clip Library
- FAQs
- Links
- Household Energy

## Fact Sheets

The fact sheets were developed to provide concise background information on CO<sub>2</sub> issues and CO<sub>2</sub> sequestration opportunities in the PCOR Partnership region.

### PCOR Partnership Program

- PCOR Partnership Phase III - Demonstrating CO<sub>2</sub> Storage in the Northern Great Plains (2017)
- Plains CO<sub>2</sub> Reduction Partnership - Development Phase Large-Scale Field Tests (NETL, 2015)
- Plains CO<sub>2</sub> Reduction Partnership - Validation Phase (NETL, 2012)

### Commercial Demonstration of CO<sub>2</sub> Sequestration

- Bell Creek Project - Enhanced Oil Recovery Resulting in Associated CO<sub>2</sub> Storage (2017)
- Fort Nelson CCS Feasibility Project (2016)
- PCOR Partnership Role in the Aquestore Project (2016)

### Water and CO<sub>2</sub> Sequestration

- Long-Term Protection of Freshwater Resources Following CO<sub>2</sub> Storage (2014)
- Monitoring, Verification, and Accounting Plans for Protection of Water Resources During the Geologic Storage of Carbon Dioxide (2013)
- Carbon Capture and Storage: Protecting Freshwater Resources (2013)
- Regional Carbon Sequestration Partnership Water Working Group (2011)

### Field Validation - Regional Technology Implementation Plans - Executive Summaries

- CO<sub>2</sub> Sequestration Validation Test in a Deep, Unminable Lignite Seam in Western North Dakota - Regional Technology Implementation Plan (2009)
- Williston Basin Field Demonstration, Northwest McGregor CO<sub>2</sub> Huff 'N' Puff - Regional Technology Implementation Plan (2009)
- Zama Field Validation Test - Regional Technology Implementation Plan (2009)
- Terrestrial Field Validation Test - Regional Technology Implementation Plan (2009)

### Background on CO<sub>2</sub> Sequestration

- What is the PCOR Partnership (2016)
- CO<sub>2</sub> Sequestration - Controlling CO<sub>2</sub> Emissions to the Atmosphere Through Capture and Long-Term Storage (2008)
- Identifying CO<sub>2</sub> Sequestration Opportunities (2008)

### Enhanced Oil Recovery (EOR) using CO<sub>2</sub> leading to Permanent CO<sub>2</sub> Storage (Sequestration)

- CO<sub>2</sub> "Huff 'n' Puff" Validation Test (NW McGregor) (2016)
- CO<sub>2</sub> EOR and CO<sub>2</sub> Sequestration - The Case for Collaboration (2008)
- The Weyburn Oil Field - A Model for Value-Added Direct CO<sub>2</sub> Sequestration (2008)
- Zama Acid Gas EOR, CO<sub>2</sub> Sequestration, and Monitoring Project (2008)

### Terrestrial Sequestration

- Terrestrial Carbon Sequestration Field Validation Test (2017)
- Wetland Carbon Sinks in the Glaciated North American Prairie (Terrestrial) (2008)
- CO<sub>2</sub> Sequestration Through Habitat Restoration-Defining Best Terrestrial Sequestration Practices for Landowners (2008)
- Cobenefits of Terrestrial Carbon Sequestration in the PCOR Partnership Region (2008)
- Best Management Practices for Terrestrial Carbon Sequestration on Private Lands in the Prairie Pothole Region (2008)

### Field Validation of CO<sub>2</sub> Sequestration

- Terrestrial Carbon Sequestration Field Validation Test (2017)
- CO<sub>2</sub> "Huff 'n' Puff" Validation Test (NW McGregor) (2016)
- CO<sub>2</sub> Sequestration Test in a Deep, Unminable Lignite (2016)
- Regional CO<sub>2</sub> Sequestration Potential-Field Validation Tests (2008)
- Zama Acid Gas EOR, CO<sub>2</sub> Sequestration, and Monitoring Project (2008)

Figure 28. Updated Fact Sheets page.  
Existing link: [www.undeerc.org/pcor/NewsAndPubs/factsheets.aspx](http://www.undeerc.org/pcor/NewsAndPubs/factsheets.aspx).

## Documentaries Page

The Documentaries page shown in Figure 29 was updated to include the latest documentary, *The Bell Creek Story: CO<sub>2</sub> in Action*. Visitors can access the Bell Creek documentary Web page, play the entire video, and view the documentary trailer using buttons to the right of the thumbnail.




Figure 29. Updated content in Documentaries page.  
Existing link: [undeerc.org/pcor/Documentary/](http://undeerc.org/pcor/Documentary/).



## Video Clip Library


The Video Clip Library was updated to include seven clips from the documentary *The Bell Creek Story: CO<sub>2</sub> in Action*. In addition to the list shown in Figure 30, clips were added to the clip list and various topic categories as indicated in the figure. The updates went live on January 22, 2018.



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*Practical, Environmentally Sound CO<sub>2</sub> Sequestration*


Home > Video Clip Library


Welcome to the PCOR Partnership Video Clip Library


By Topic
By Documentary
By Clip Title



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**The Bell Creek Story: CO<sub>2</sub> in Action**




**Clip Title:** Oil Boom at Bell Creek  
**Description:** A brief history of the first boom in the Bell Creek oil field in the 1960s.  
**Length:** 01:05  
*Also added to the category:*  
[Oil Production](#)




**Clip Title:** Oil Production: Nature, Water, and CO<sub>2</sub>  
**Description:** The three stages of oil production historically and in relation to the Bell Creek oil field.  
**Length:** 03:55  
*Also added to the category:*  
[Oil Production](#)




**Clip Title:** Denbury and CO<sub>2</sub>: Bringing Bell Creek Back to Life  
**Description:** Denbury Resources' oil production strategy and the steps needed to develop an enhanced oil recovery operation in the Bell Creek oil field.  
**Length:** 06:38  
*Also added to the categories:* [Geologic CO<sub>2</sub> Sequestration](#)  
[Oil Production](#)




**Clip Title:** Carbon Capture and Storage: Research at Bell Creek  
**Description:** Scientists and engineers are using the Bell Creek enhanced oil recovery operation to learn about the behavior of injected CO<sub>2</sub> and to develop practical monitoring, verification, and accounting techniques that ensure safe, permanent geologic storage of CO<sub>2</sub>.  
**Length:** 06:39  
*Also added to the category:*  
[Geologic CO<sub>2</sub> Sequestration](#)



**Clip Title:** PCOR Partnership at Bell Creek  
**Description:** Scientists and engineers from the PCOR Partnership are using the Bell Creek enhanced oil recovery operation to learn about the behavior of injected CO<sub>2</sub> and to develop practical monitoring, verification, and accounting techniques that ensure safe, permanent geologic storage of CO<sub>2</sub>.  
**Length:** 03:59  
*Because this clip is an excerpt from the clip above, it has not added to any Topic category.*



**Clip Title:** Producing Energy - Reducing Carbon  
**Description:** Enhanced oil recovery using CO<sub>2</sub> from human activities helps us produce more oil with a lower carbon footprint.  
**Length:** 01:52  
*Also added to the categories:*  
[Geologic CO<sub>2</sub> Sequestration](#)  
[CO<sub>2</sub>, Energy, and Climate Change](#)



**Clip Title:** Bell Creek's Greener Oil  
**Description:** Producing more oil from existing fields using CO<sub>2</sub> captured from human activities has a smaller carbon footprint than oil produced conventionally or using CO<sub>2</sub> from a natural dome source.  
**Length:** 03:59  
*Also added to the categories:*  
[Geologic CO<sub>2</sub> Sequestration](#)  
[CO<sub>2</sub>, Energy, and Climate Change](#)

Figure 30. Video Clip Library page.

Existing link: <http://undeerc.org/pcor/Video-Clip-Library/#tabs-2requestinfo.aspx>.

## Carbon and CO<sub>2</sub> on Earth – Things Have Changed! Page

The Carbon and CO<sub>2</sub> on Earth page shown in Figures 31 and 32 features a new look. Page content was simplified and organized into four categories using a collapsible accordion interface to break up the large amount of information on this page, thus making the information easier to absorb. A tool tip describing the amount of CO<sub>2</sub> on Earth, referenced to the icon of a question mark in a green circle, was added near the top. Because the information on this page cannot be printed all at once, a print-friendly version of this page with icon (upper right corner) was added as a PDF (attached in Appendix A). These changes went live on January 22, 2018.

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### Carbon and CO<sub>2</sub> on Earth – Things Have Changed!

Carbon is a naturally occurring element on Earth and in other places in the universe. The amount of carbon today is the same as when Earth was formed. Over time, the carbon atoms have been relocating and recombining, and the result has been major changes to Earth's atmosphere, biosphere, and surface.

Scientists tell us that Earth started out about 4.5 billion years ago as a ball of hot gases. About 3.5 billion years ago, Earth was cool enough to have a solid crust as well as a primitive atmosphere. At the same time, CO<sub>2</sub> was being formed deep in the earth by geologic processes, and this CO<sub>2</sub> was being released to the atmosphere through volcanic eruptions. During the subsequent 2 billion years, biological activities began developing, evolving, and expanding, fed by the CO<sub>2</sub> in the atmosphere. As biological production exploded over the last billion years, much of that atmospheric CO<sub>2</sub> was absorbed by plants and animals and buried in ocean sediments.

Earth contains about 121,000,000 GtC, which is 121 million gigatons of carbon or 121 million billion metric tons of carbon.

**CO<sub>2</sub> in the Atmosphere, parts per million**

**Million Years Ago**

Estimated atmospheric CO<sub>2</sub> concentrations over the most recent 600 million years (up to 1950).  
Modified from [earthguide.ucsd.edu](http://earthguide.ucsd.edu).

CO<sub>2</sub> Sequestered in Limestone

CO<sub>2</sub> Sequestered in Coal

CO<sub>2</sub> Sequestered in Oil

Sequestered CO<sub>2</sub> Returns to the Atmosphere

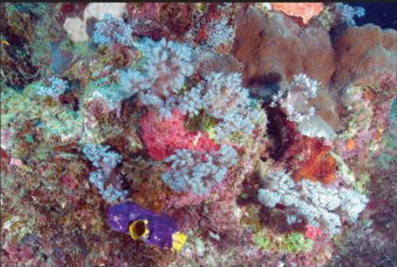
**References**

1. Pacala, S., and Socolow, R., 2004, Stabilization wedges—solving the climate problem for the next 50 years with current technologies: Science, v. 305, p. 968–972.

Figure 31. Updated Carbon and CO<sub>2</sub> on Earth page (continued).  
Existing link: <http://undeerc.org/pcor/Sequestration/co2onearth.aspx>.

CO<sub>2</sub> Sequestered in Limestone


According to scientists, the atmosphere of half a billion years ago contained about **20 times** the CO<sub>2</sub> it contains now. This was just at the time that aquatic animals were developing hard shells. Carbon was the major chemical building block in animals. Animals developing the ability to make hard structures used carbon dioxide dissolved in the oceans. For example, tiny coral animals combined the CO<sub>2</sub> with calcium to make their skeletons. Over time, massive accumulations of these skeletons made thick, carbon-rich deposits we call coral reefs. Many of these reefs were buried, preserving them in the geologic record; we know them as limestone. A lot of the carbon that was once in the atmosphere is trapped in the limestone rock now buried deep underground.



*Coral Garden, Great Barrier Reef, Cairns, Queensland, Australia*

CO<sub>2</sub> Sequestered in Coal

Plants live by absorbing carbon dioxide using the carbon (with water and energy from the sun) as food and building materials—photosynthesis. As plants became plentiful on the land, they were removing more and more CO<sub>2</sub> from the atmosphere. Geologists call the time period of 400 million years ago the Carboniferous Period ("full of carbon") because so much carbon was taken from the air by plants. This carbon was sequestered when the plants were buried and eventually preserved in deposits of carbon-rich coal.



*Carbon-Rich Coal.*

CO<sub>2</sub> Sequestered in Oil and Gas

The oceans teem with tiny organisms like algae, bacteria, and plankton. When they die, their bodies sink to the bottom of the ocean and are buried in sediments. When conditions are right (for example, a very low level of dissolved oxygen in the water), they may be preserved. If buried under more than 10,000 feet of sediments and with sufficient temperature and pressure, the bodies of these marine animals may eventually be transformed into oil and gas. Although the process continues today, most of the oil we produce comes from organisms that lived and died either 400 million or 60 million years ago. Major deposits of oil and gas are distributed across our planet.

Sequestered CO<sub>2</sub> Returns to the Atmosphere

Scientists tell us that the amount of CO<sub>2</sub> in the atmosphere has ranged considerably over the last half billion years. At the beginning of the age of mammals about 60 million years ago, CO<sub>2</sub> levels were about twice what they are today.

The long-term trend has been a decrease in carbon in the atmosphere. Over the last 200 years, CO<sub>2</sub> levels have been increasing, and human activity may be part of the reason. When humans burn fossil fuels, heat limestone to make lime for cement, or plow land for farming, carbon sequestered long ago is released to the atmosphere. These practices have made **humans** a participant in the carbon redistribution game. Scientists are now attempting to address the increasing CO<sub>2</sub> concentrations in the atmosphere by looking at the natural processes that lead to carbon storage and developing sequestration strategies as part of the larger effort to address concerns about climate change.<sup>1</sup>

References

1. Pacala, S., and Socolow, R., 2004, Stabilization wedges—solving the climate problem for the next 50 years with current technologies: Science, v. 305, p. 968–972.

Figure 31. (continued) Updated Carbon and CO<sub>2</sub> on Earth page.  
Existing link: <http://undeerc.org/pcor/Sequestration/co2onearth.aspx>.

## Request Information Page

The list of items on the Request Information page shown in Figure 32 now includes a DVD of the latest PCOR Partnership documentary, *The Bell Creek Story: CO<sub>2</sub> in Action* (2017, DVD) and the Atlas, 5th edition. The updates went live on June 19, 2017, and April 25, 2017, respectively.

**PCOR Partnership** Plains CO<sub>2</sub> Reduction (PCOR) Partnership  
Practical, Environmentally Sound CO<sub>2</sub> Sequestration

PARTNERS ONLY KIDS EDUCATORS CONTACT US search

About the Partnership  
Climate, CO<sub>2</sub>, Sequestration  
Regional Storage Potential  
CO<sub>2</sub> Sequestration Projects  
Technical Publications  
Resources  
Documentaries  
Video Clip Library  
FAQs  
Links  
Household Energy

### Request Information

Please fill in the form, select the items you would like to receive, and click on "Submit Request". You will receive an e-mail when the materials are sent.

Prefix: ☐ Mr. ☐ Ms. ☐ Dr.

\*Full Name:

Organization:

Title:

\*Street Address:

\*City:

\*State:

\*Zip Code:

\*Country:

Phone:

\*E-mail Address:

\*Required Field

**Requests:**  
I would like to receive the following PCOR Partnership products:

- ☒ The Bell Creek Story: CO<sub>2</sub> in Action (2017, DVD)
- ☒ PCOR Partnership Regional Atlas, 5th Edition (2016)
- ☐ Installing a Casing-Conveyed Permanent Downhole Monitoring System (2013, DVD)
- ☐ Global Energy and Carbon: Tracking Our Footprint (2010, DVD)
- ☐ Managing Carbon Dioxide: The Geologic Solution (2009, DVD)
- ☐ Out of the Air – Into the Soil: Land Practices that Reduce Atmospheric Carbon (2008, DVD)
- ☐ Reducing Our Carbon Footprint: The Role of Markets (2008, DVD)
- ☐ Nature in the Balance: CO<sub>2</sub> Sequestration (2005, DVD)

Please send me more information on:

- ☐ Becoming a PCOR Partnership partner

Comments or Additional instructions:


Submit Request Reset

Figure 32. Updated Request Information page.  
Existing link: [undeerc.org/pcor/Documentary/requestinfo.aspx](http://undeerc.org/pcor/Documentary/requestinfo.aspx).



## Educators Web Page

The Educators Web page shown in Figure 33 is updated as needed to inform educators about events where the PCOR Partnership presents. The page was last updated on December 20, 2017.



# Plains CO<sub>2</sub> Reduction (PCOR) Partnership

Practical, Environmentally Sound CO<sub>2</sub> Sequestration

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## About the Partnership

Climate, CO<sub>2</sub>, Sequestration

Regional Storage Potential

CO<sub>2</sub> Sequestration Projects

Technical Publications

Resources

Documentaries

Video Clip Library

FAQs


Links

Household Energy

## Educators

The PCOR Partnership is committed to providing classroom resources that address the role of practical and environmentally safe ways to reduce anthropogenic CO<sub>2</sub> emissions and the level of CO<sub>2</sub> in the atmosphere.

Carbon management is a great topic to study because it integrates so many subjects: energy, environment, geography, politics, chemistry, biology, economics, and more. It requires students to use analytical tools to exercise their abilities to research, think, and understand complex issues.



Dan Daly, PCOR Partnership Outreach Manager, presents during the Prairie Energy & Carbon Teacher Training Institute.


### Schedule for 2017-2018 to be announced.

### Previous Educational Events for Teachers

<p><b>Ugnite Energy Council Education Seminar</b> June 2003-2017 Bismarck State College Bismarck, North Dakota</p> <p><b>International Workshop on Public Education, Training, and Community Outreach for Carbon Capture, Utilization, and Storage</b> July 30-31, 2014 National Sequestration Education Center Decatur, Illinois</p> <p><b>North Dakota Petroleum Council Teacher Education Seminar</b> June 2008-2012 Bismarck State College Bismarck, North Dakota</p> <p><b>Missouri Minerals Education Foundation</b> Teacher Workshop July 15-20, 2012 Mineral Area College Park Hills, Missouri</p>	<p><b>Integrating Regional History, Culture, Science, and the Arts: Prairie Public Broadcasting Teacher Training Institute</b> June 2013-2015 Concordia College Moorhead, Minnesota</p> <p><b>North Dakota-Minnesota Geographic Alliance Education Seminar</b> June 2014 Concordia College Moorhead, Minnesota</p> <p><b>The Changing Face of North Dakota</b> North Dakota Geographic Alliance June 4-8, 2012 Dickinson State University Dickinson, North Dakota</p> <p><b>Teaching About Energy &amp; Our Carbon Footprint: Regional &amp; Global Issues Prairie Public Broadcasting Teacher Training Institute</b> November 9-10, 2011 Energy &amp; Environmental Research Center Grand Forks, North Dakota</p>
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### Recommended Curriculum Sources

- In collaboration with Prairie Public Broadcasting, the PCOR Partnership participated in three teacher training institutes. Check out the [lesson plans](#) developed during these institutes.



Teachers tour the EERC during the Prairie Energy & Carbon Teacher Training Institute.

- The Keystone Center** developed middle and high school [climate lesson plans](#). Each year, several curriculum training workshops are held across the United States. In July 2009, a 2-day training session was held in Omaha, Nebraska, in conjunction with the PCOR Partnership.
- The Northwest Sustainable Energy Association** has K-12 climate lesson plans that cover many options for reducing CO<sub>2</sub> emissions.
- The Institute for Global Environmental Strategies** developed extensive classroom resources for educators to provide students in grade levels 1-12 with an understanding of and activities focused on the potential consequences of climate variability and change.
- The Teachers' Guide to High-Quality Educational Materials on Climate Change and Global Warming** points K-12 educators to the best online resources for teaching about climate change: several that offer first-rate background materials and include detailed lesson plans and experiments.

[Educator Links >](#)

Figure 33. Updated Educators Web page.  
Existing link: <http://www.undeerc.org/PCOR/Educators/>.

## Site Map

Throughout this period, updates to the Site Map page reflect changes made to Web page names and/or their order, as well as the addition of new pages and/or new sections to the public Web site. New additions shown in Figure 34 include the CarbonSAFE-NE, ND CarbonSAFE, and Red Trail Energy under the CO<sub>2</sub> Sequestration Projects section; *The Bell Creek Story: CO<sub>2</sub> in Action* under the Documentaries section; and CO<sub>2</sub> EOR LCA Model under the Technical Publications section.

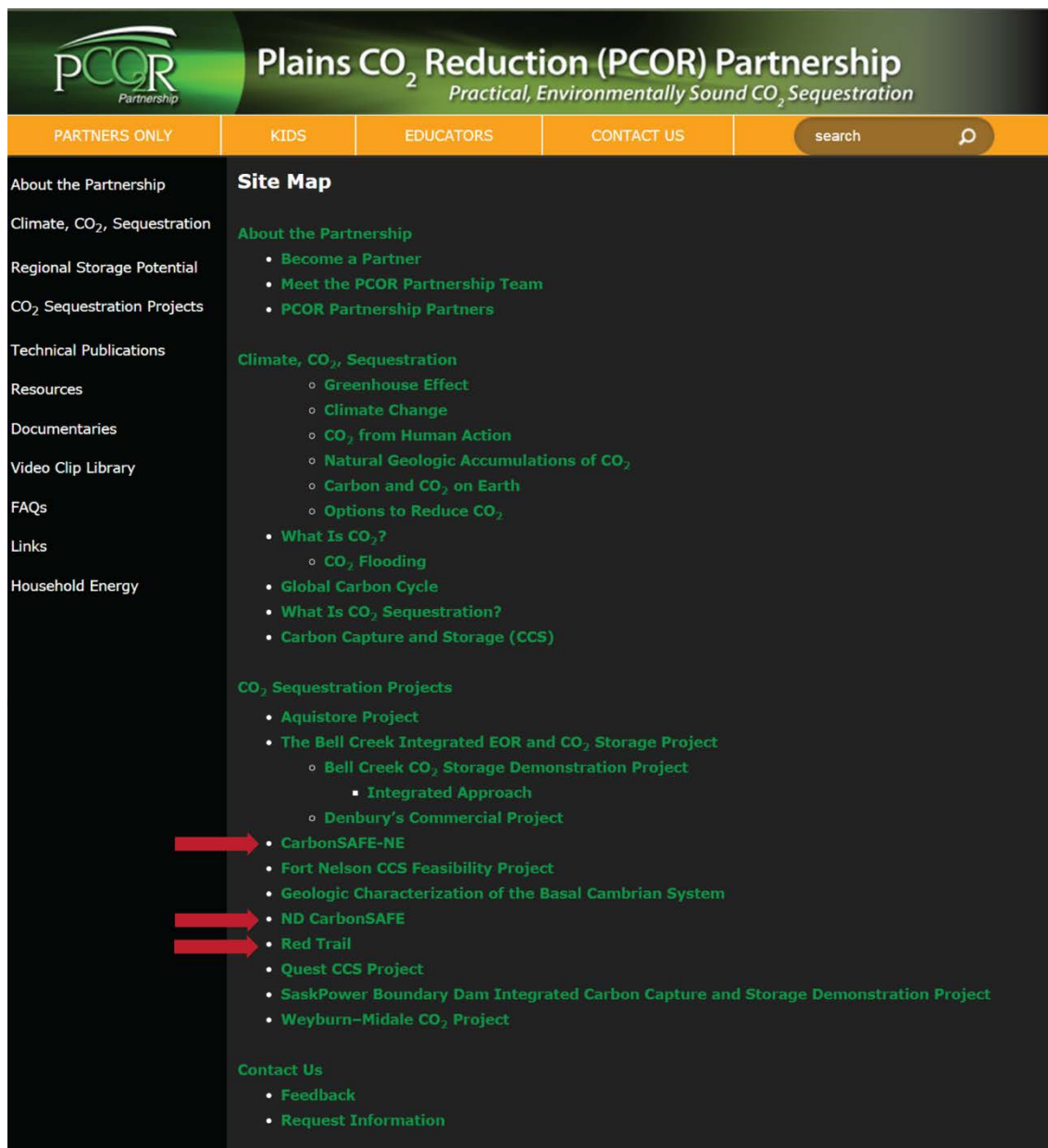


Figure 34. Updated Site Map page (continued).  
Existing Link: [undeerc.org/PCOR/SiteMap.aspx](http://undeerc.org/PCOR/SiteMap.aspx).

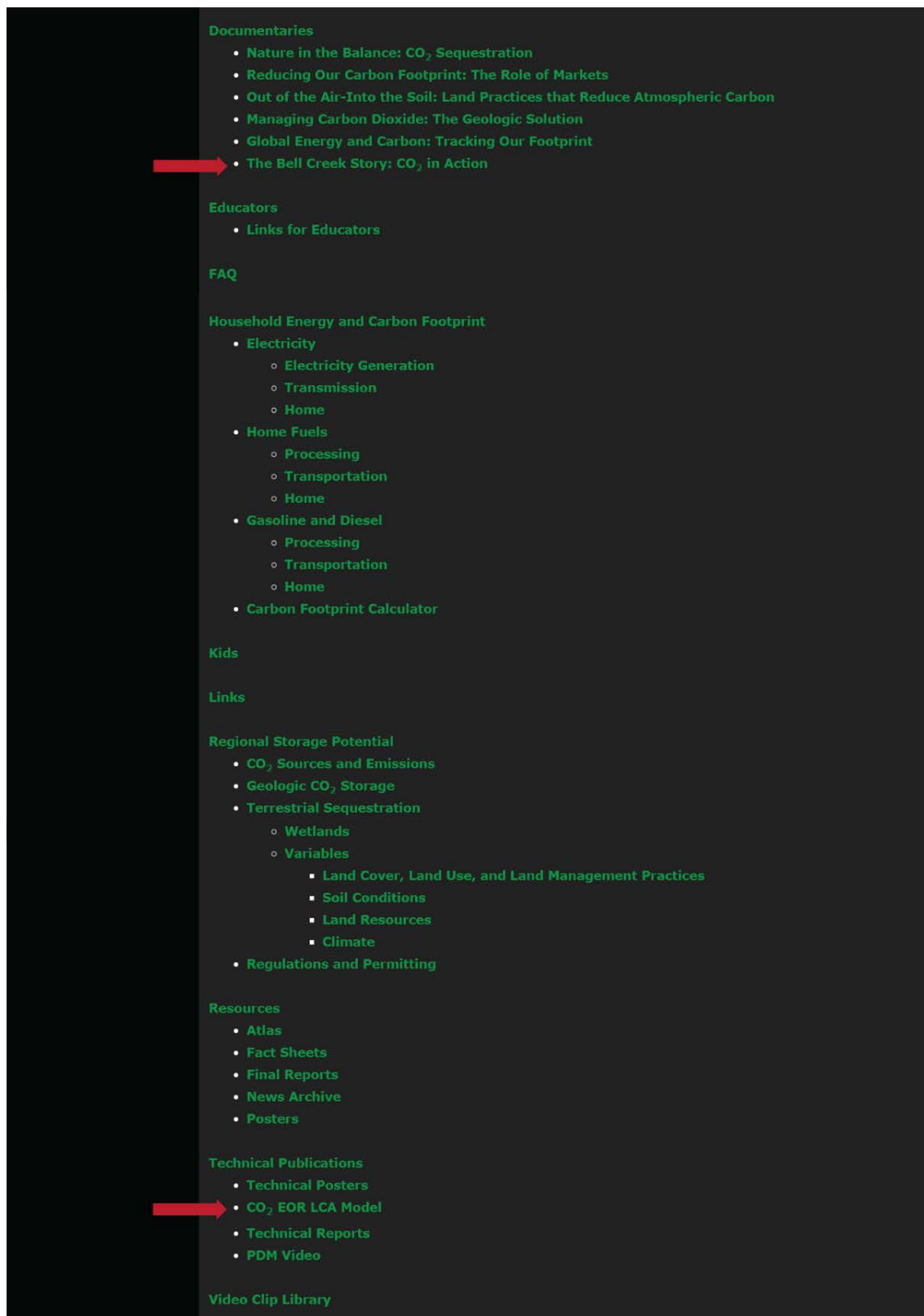


Figure 34. (continued) Updated Site Map page.  
Existing Link: [undeerc.org/PCOR/SiteMap.aspx](http://undeerc.org/PCOR/SiteMap.aspx).

## **FUTURE WORK**

As the program wraps up, the focus has been to update page content to the most recent information available. Additionally, the Web site, which has been updated piecemeal since its inception in 2004, is undergoing a technical update to 1) ensure that video clips currently running on Adobe *Flash* will continue to play after *Flash* is phased out later this year, and 2) provide the greatest possible longevity to the site once the program has ended. The updated Web site with improved video clip streaming capability, faster loading, and continued page content and visitor tracking capability is expected to launch by the end of March 2018.



## **APPENDIX A**

# **PRINT-FRIENDLY PAGES OF THE SPECIALLY FORMATTED PAGES ON THE PCOR PARTNERSHIP WEB SITE**



## Plains CO<sub>2</sub> Reduction (PCOR) Partnership

Practical, Environmentally Sound CO<sub>2</sub> Sequestration

### What Is CO<sub>2</sub>?

Carbon dioxide is a naturally occurring substance composed of one atom of carbon (C) and two atoms of oxygen (O<sub>2</sub>). Its chemical formula is CO<sub>2</sub>. CO<sub>2</sub> is gas under normal conditions<sup>?</sup>.

<sup>?</sup> **Normal conditions** are temperatures and pressures at or near the Earth's surface and in its atmosphere.

Like all substances, CO<sub>2</sub> can exist as solid, liquid, and gas. At temperatures below -78°C (-109°F), CO<sub>2</sub> condenses into a white solid called dry ice. Under normal conditions, dry ice vaporizes directly from a solid to CO<sub>2</sub> gas in a process called sublimation. Liquid CO<sub>2</sub> can be formed under pressure (pressures above 5.1 atmospheres, roughly the pressure at 165 feet of depth in the ocean).

At conditions above 31°C (88°F) and 73 atmospheres, CO<sub>2</sub> becomes a supercritical fluid. This occurs naturally at around 2500 feet below the Earth's surface.

### CO<sub>2</sub> Exists Naturally

CO<sub>2</sub> occurs naturally in small amounts (about 0.04%) in the Earth's atmosphere.<sup>1</sup>

As a major greenhouse gas, CO<sub>2</sub> helps create and maintain the natural **greenhouse effect** that keeps our planet hospitable to life.

CO<sub>2</sub> is essential to plant life. Plants take in CO<sub>2</sub>, exhale the oxygen, and use the carbon to live and grow. When the plant dies or burns, the carbon recombines with oxygen in the atmosphere, and CO<sub>2</sub> is formed again. This process is a key part of the **global carbon cycle**.

CO<sub>2</sub> is a by-product of our body's metabolism. Our lungs absorb oxygen from the air we breathe and exhale CO<sub>2</sub> as a waste product of cellular respiration.

CO<sub>2</sub> is produced naturally by processes deep in the earth. This CO<sub>2</sub> might be trapped in **natural underground geologic CO<sub>2</sub> deposits** similar to the underground deposits of oil and natural gas. Or it might be released at the surface by volcanoes or through natural ground seeps.

Naturally carbonated waters have historically been highly sought after for their supposed curative properties because these waters are high in mineral content.

Some bottled water is from naturally carbonated springs. Some examples are Apollinaris, Badoit, Gerolsteiner, Wattwiller, Ferrarelle, Borsec, and Perrier.

## Humans Use and Make CO<sub>2</sub>

CO<sub>2</sub> is added to soft drinks to make them bubbly.

Dry ice (frozen CO<sub>2</sub>) is used to keep things cold.

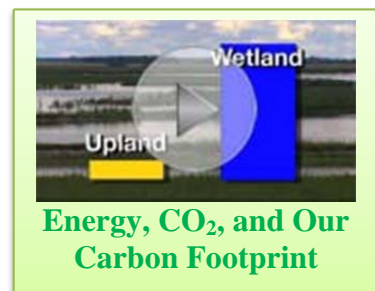
CO<sub>2</sub> is also used in fire extinguishers (CO<sub>2</sub> displaces the oxygen the fire needs to burn).

Every day, millions of tons of CO<sub>2</sub> are injected into underground geologic zones to help produce oil in a well-known industry practice called “**CO<sub>2</sub> flooding**” or enhanced oil recovery.

## Is CO<sub>2</sub> a Pollutant?

CO<sub>2</sub> formed by human action is called **anthropogenic CO<sub>2</sub>**. Plowing the land, making cement, and burning fossil fuels for energy all create anthropogenic CO<sub>2</sub>, which adds carbon to the **global carbon cycle**. Between 1751 and 2013, approximately 1440 billion metric tons of CO<sub>2</sub> has been emitted to the atmosphere from these sources.<sup>2</sup> This is raising concerns about climate change.

The U.S. Environmental Protection Agency has ruled CO<sub>2</sub> a pollutant in order to be able to regulate anthropogenic CO<sub>2</sub> emissions from human activities under the Clean Air Act of 1970.



### References:

1. [nssdc.gsfc.nasa.gov/planetary/factsheet/earthfact.html](https://nssdc.gsfc.nasa.gov/planetary/factsheet/earthfact.html) (accessed August 2006).
2. Boden, T.A., Marland, G., and Andres, R.J., 2016, *Global, regional, and national fossil-fuel CO<sub>2</sub> emissions: Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tennessee, U.S.A.* doi 10.3334/CDIAC/00001\_V2016, [http://cdiac.ornl.gov/trends/emis/tre\\_glob\\_2013.html](http://cdiac.ornl.gov/trends/emis/tre_glob_2013.html) (accessed June 16, 2016).

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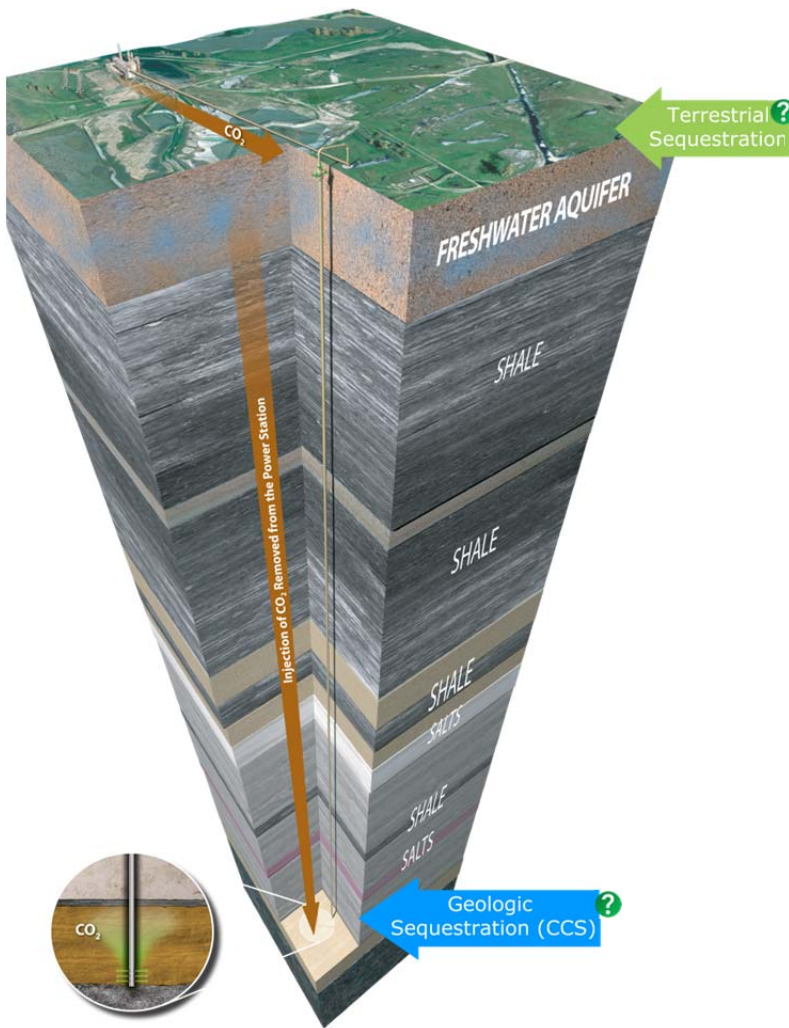
## Plains CO<sub>2</sub> Reduction (PCOR) Partnership

Practical, Environmentally Sound CO<sub>2</sub> Sequestration

### What Is CO<sub>2</sub> Sequestration?

**S**equestration means storage. Carbon or CO<sub>2</sub> sequestration means putting carbon into long-term storage.

There are two major types of CO<sub>2</sub> sequestration: **terrestrial** and **geologic**.



**Terrestrial Sequestration** uses land management practices (like no-till farming and wetlands and grasslands restoration) to enhance the removal of CO<sub>2</sub> directly from the atmosphere. This relatively passive storage mechanism is important because it can be implemented immediately and begin to reduce atmospheric CO<sub>2</sub> levels soon.

**Geologic Storage** involves capturing anthropogenic CO<sub>2</sub> before it enters the atmosphere and injecting it into underground formations. Once CO<sub>2</sub> is injected deep underground (typically more than 800 meters) it is trapped in minute pores or spaces in the rock structure. Impermeable cap rocks above the storage zones act as seals to ensure the safe storage of CO<sub>2</sub>.

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## Plains CO<sub>2</sub> Reduction (PCOR) Partnership

Practical, Environmentally Sound CO<sub>2</sub> Sequestration

### Terrestrial Sequestration

**T**errestrial (or biologic) sequestration means using plants to capture CO<sub>2</sub> from the atmosphere and then storing it as carbon<sup>?</sup> in the stems and roots of the plants as well as in the soil. In photosynthesis, plants take in CO<sub>2</sub> and give off the oxygen to the atmosphere as a waste gas. The plants retain and use the carbon to live and grow. When the plant winters or dies, part of the carbon from the plant is preserved (stored) in the soil. Terrestrial sequestration is a set of land management practices that maximizes the amount of carbon that remains stored in the soil and plant material for the long term. No-till farming, wetland management, rangeland management, and reforestation are examples of terrestrial sequestration practices that are already in use.

*Benefits of terrestrial storage may include improved soil and water quality, reduced erosion, reduced evaporative water loss, reduced pest problems, and overall ecosystem improvement.*

#### Steady State

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.<sup>1</sup> Once this “steady state” has been reached, the carbon will remain stored in the soil as long as the land is undisturbed and conservation land management practices are continued.

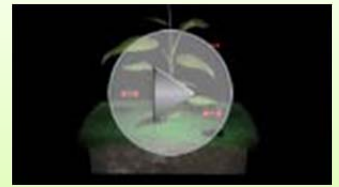
#### Mechanisms for Terrestrial Storage

Promising land and water management practices that can enhance the terrestrial storage of carbon include the following:

- Conservation tillage
- Reducing soil erosion and minimizing soil disturbance
- Using buffer strips along waterways
- Enrolling land in conservation programs
- Restoring and better managing **wetlands** and degraded soils
- Eliminating summer fallow
- Using perennial grasses and winter cover crops
- Fostering an increase in forests<sup>(2,3)</sup>

#### Links:

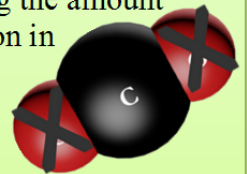
- [Sequestration Potential in Our Region](#)
- [Field Projects](#)



#### What is Terrestrial CO<sub>2</sub> Sequestration?

##### **?** Carbon – *Not* CO<sub>2</sub>

It is important to remember that terrestrial storage does not store CO<sub>2</sub> as a gas but stores the carbon portion of the CO<sub>2</sub>. 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<sub>2</sub> to form CO<sub>2</sub> gas and reenter the atmosphere, reducing the amount of carbon in storage.



#### Sequestration Potential in the Prairies



#### Carbon Storage in the Landscape

## References:

1. Paustian, K.H., and Cole, C.V., 1998, CO<sub>2</sub> mitigation by agriculture – an overview: Climatic Change, v. 40, p. 135–162, Netherlands, Kluwer Academic Publishers.
2. Peterson, E.B., Bonnor, G.M., Robinson, G.C., and Peterson, N.M., 1999, Carbon sequestration aspects of an afforestation program in Canada's prairie provinces: Submitted to Joint Forest Sector Table/Sinks Table, National Climate Change Process, published by Nawitka Renewable Resource Consultants Ltd., p. 1–98, [www.nccp.ca/NCCP/pdf/Afforest\\_Prairies.pdf](http://www.nccp.ca/NCCP/pdf/Afforest_Prairies.pdf) (accessed September 2004).
3. de Silva, L.L., Cihacek, L.J., Leistritz, F.L., Faller, T.C., Bangsund, D.A., Sorensen, J.A., Steadman, E.N., and Harju, J.A., 2005, The contribution of soils to carbon sequestration: Plains CO<sub>2</sub> Reduction (PCOR) Partnership topical report for U.S. Department of Energy and multiclients, Grand Forks, North Dakota, Energy & Environmental Research Center, June.

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## Plains CO<sub>2</sub> Reduction (PCOR) Partnership

*Practical, Environmentally Sound CO<sub>2</sub> Sequestration*

### CCS Regulations and Permitting

Carbon capture and storage (CCS) projects are subject to regulation at the source of CO<sub>2</sub>, during transportation to the injection site, and at the site, whether for enhanced oil recovery (EOR) projects or long-term geologic storage of anthropogenic CO<sub>2</sub>. Before any physical work can begin, federal and state/provincial regulatory requirements must be met, the public must have an opportunity to comment, and any necessary permits must have been issued.

#### Federal Regulations

- [United States](#) (34kb) pdf
- [Canada](#) (26kb) pdf

#### State and Provincial Regulations



**CCS Projects.** In 2014, 136 CO<sub>2</sub> EOR projects in the United States were regulated under the U.S. Environmental Protection Agency (EPA) federal regulations and by state oil and gas regulations. The regulatory framework for projects involving geologic storage of anthropogenic CO<sub>2</sub> is specifically addressed at the federal level under [Class VI](#) injection wells. Protection of groundwater resources and human health is a focus of both EOR and geologic storage regulations.

[State and Provincial CCS Regulations](#) (22kb) pdf

## U.S. Federal Legislation That Could Affect Carbon Sequestration Projects in the United States

National Environmental Policy Act (NEPA, 1969) <a href="https://energy.gov/sites/prod/files/nepapub/nepa_documents/RedDont/Req-NEPA.pdf">https://energy.gov/sites/prod/files/nepapub/nepa_documents/RedDont/Req-NEPA.pdf</a>	Requires preparation of an environmental impact statement when federal funds are used for a project or when a federal government agency is the developer of, or issues a permit for, a project.
Clean Water Act (CWA, 1977) <a href="https://www.epa.gov/laws-regulations/summary-clean-water-act">https://www.epa.gov/laws-regulations/summary-clean-water-act</a>	The objective of this act is to restore and maintain the chemical, physical, and biological integrity of the nation's waters. Sets the standard of nondegradation of the beneficial uses of water. An example is the "total maximum daily load" approach.
Clean Air Act (CAA, 1963, 1970, 1990, 1997) <a href="https://www.epa.gov/laws-regulations/summary-clean-air-act">https://www.epa.gov/laws-regulations/summary-clean-air-act</a>	Requires control of 1) particulate matter from industry combustion sources, 2) total reduced sulfur compound emissions, and 3) hazardous air pollutant emissions from production sources. New Source Review (NSR) is a preconstruction permitting program that is operated at federal and state levels.
Safe Drinking Water Act (SDWA, 1974) <a href="https://www.epa.gov/sdwa">https://www.epa.gov/sdwa</a>	The U.S. Environmental Protection Agency (EPA) sets standards for drinking water quality and oversees the states, localities, and water suppliers implementing those standards. The SDWA led to EPA's Underground Injection Control (UIC) Program, setting requirements for different class injection wells.
Endangered Species Act (ESA, 1973) <a href="https://www.fws.gov/laws/lawsdigest/ESACT.html">https://www.fws.gov/laws/lawsdigest/ESACT.html</a>	Administered by the U.S. Fish and Wildlife Service (USFWS) of the U.S. Department of the Interior and the National Marine Fisheries Service (NMFS) of the U.S. Department of Commerce. The purpose of ESA is to conserve the ecosystems upon which endangered and threatened species depend and to conserve and recover listed species.
The Migratory Bird Treaty Act (MBTA, 1918) <a href="https://www.fws.gov/laws/lawsdigest/migtrea.html">https://www.fws.gov/laws/lawsdigest/migtrea.html</a> and the Bald Eagle Protection Act (BEPA, 1940) <a href="https://www.fws.gov/midwest/eagle/protect/laws.html">https://www.fws.gov/midwest/eagle/protect/laws.html</a>	Both acts are administered by USFWS. The first act protects migratory birds from unlawful taking. The second act protects the bald eagle and the golden eagle by prohibiting, except in specified conditions, their taking, possession, and commerce. In January 2001, an Executive Order was issued to further protect migratory birds by requiring federal agencies that take actions having a negative effect on these populations to develop and implement a memorandum of understanding (MOU) to promote their conservation (Executive Order, 2001).
Executive Order on Invasive Species (EOIS, 1999) <a href="https://www.invasivespeciesinfo.gov/laws/execorder.shtml">https://www.invasivespeciesinfo.gov/laws/execorder.shtml</a>	Federal resource agencies are required to develop invasive species management strategies as well as strategies to restore native species and habitat conditions in invaded ecosystems.



### **Canadian Federal Legislation That Could Affect Carbon Sequestration Projects in Canada**

Canadian Environmental Assessment Act (CEAA, 2012) <a href="http://laws-lois.justice.gc.ca/eng/acts/C-15.21/">http://laws-lois.justice.gc.ca/eng/acts/C-15.21/</a>	The purpose of the act is to encourage responsible authorities to take actions that promote sustainable development and achieve or maintain a healthy environment and economy (supersedes CEAA, 1992)
Canadian Environmental Protection Act (CEPA 1999) <a href="http://laws-lois.justice.gc.ca/eng/acts/C-15.31/">http://laws-lois.justice.gc.ca/eng/acts/C-15.31/</a>	The primary purpose of this act is to contribute to sustainable development through pollution prevention.
Transportation of Dangerous Goods Act (1992) <a href="http://laws-lois.justice.gc.ca/eng/acts/T-19.01/">http://laws-lois.justice.gc.ca/eng/acts/T-19.01/</a>	This act applies in relation to all matters within the legislative authority of Parliament, including dangerous goods outside Canada that are carried on a ship or aircraft registered in Canada. This act does not apply in relation to commodities transported by a pipeline governed by the <i>National Energy Board Act</i> or the <i>Oil and Gas Production and Conservation Act</i> or by the law of a province; or dangerous goods confined only by the permanent structure of a ship.
National Energy Board Act (1985) <a href="http://laws-lois.justice.gc.ca/eng/acts/N-7/">http://laws-lois.justice.gc.ca/eng/acts/N-7/</a>	This act establishes the National Energy Board, an independent federal agency that regulates several aspects of Canada's energy industry. Its purpose is to promote safety, environmental protection, and economic efficiency in the Canadian public interest within the mandate set by Parliament in the regulation of pipelines, energy development, and trade.
Fisheries Act (1985) <a href="http://laws-lois.justice.gc.ca/eng/acts/F-14/">http://laws-lois.justice.gc.ca/eng/acts/F-14/</a>	This act applies to fish habitat protection and pollution prevention as well as several other aspects of fishery regulation.
Canada Labour Code (1985) <a href="http://laws-lois.justice.gc.ca/eng/acts/L-2/">http://laws-lois.justice.gc.ca/eng/acts/L-2/</a>	An act to consolidate certain statutes respecting labor, including industrial relations and occupational health and safety.

## State and Provincial Regulations

Several states and provinces in the region have put into effect laws and regulations specifically addressing CCS.\*

**Alberta** has developed regulations for storage, pore space ownership, and long-term stewardship.

**British Columbia** is reviewing regulatory framework for CCS. Additional legislation may be considered for clarification purposes.

**Manitoba** does not have any legislation in place or rules adopted or under development.

**Saskatchewan** has adapted existing oil and gas regulations for CO<sub>2</sub> storage.

**Minnesota** does not have any legislation in place or rules adopted or under development.

**Iowa** does not have any legislation in place or rules adopted or under development.

**Missouri** does not have any legislation in place or rules adopted or under development.

**Montana** has legislation in place for pore space issues and long-term stewardship. Rule development will begin once primacy for underground injection of CO<sub>2</sub> for storage purposes is received from EPA.

**North Dakota** has legislation in place for pore space issues and long-term stewardship and has applied for Class VI primacy.

**Nebraska** does not have any legislation in place or rules adopted or under development.

**South Dakota** does not have any legislation in place or rules adopted or under development.

**Wisconsin** does not have any legislation in place or rules adopted or under development.

**Wyoming** has legislation in place for pore space ownership.

\*All information is current as of April 28, 2017.

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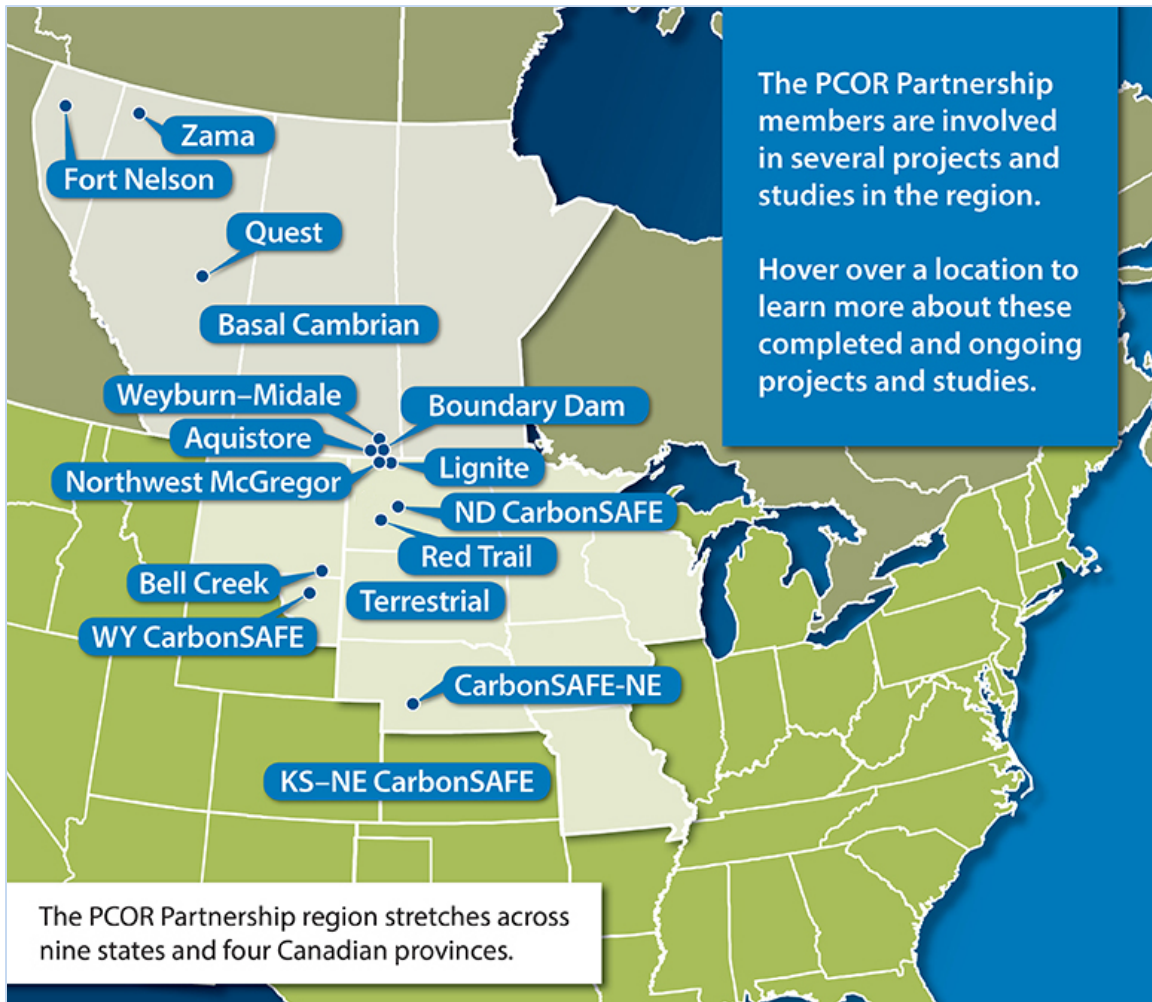
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## Plains CO<sub>2</sub> Reduction (PCOR) Partnership

*Practical, Environmentally Sound CO<sub>2</sub> Sequestration*

### CO<sub>2</sub> Sequestration Projects



#### Aquistore

##### **Aquistore Project**

Location: Southeastern Saskatchewan, Canada

CO<sub>2</sub> Injection: ~2300 tons (2100 tonnes) a day

This project stores CO<sub>2</sub> from the Boundary Dam Power Station in Estevan in the Basal Cambrian System, a deep saline formation.

Status: Active (as of September 2017)

## Basal Cambrian

### Basal Cambrian Characterization Project

Location: 1.34 million km<sup>2</sup> spanning the U.S. and Canadian border

This collaboration between Canadian and U.S. researchers found excellent potential for long-term CO<sub>2</sub> storage in the deep rock layer known as the Basal Cambrian System.

Status: Completed 2014

## Bell Creek

### Bell Creek EOR

Location: Southeastern Montana, United States

CO<sub>2</sub> Injection: ~1.1 million tons (1 million tonnes) a year

This commercial project is setting a new standard for safely and efficiently using CO<sub>2</sub> for enhanced oil recovery with associated CO<sub>2</sub> storage.

Status: Active (as of September 2017)

## Boundary Dam

### The Boundary Dam Carbon Capture Project

Location: Estevan, Saskatchewan, Canada

CO<sub>2</sub> Injection: 1.1 million tons (1 million tonnes) a year The first of its kind, this SaskPower project has equipped a coal-fired generation unit at the Boundary Dam Power Station with a fully integrated system to capture CO<sub>2</sub> for enhanced oil recovery and permanent storage.

Status: Active (as of September 2017)

## CarbonSAFE-NE

### Nebraska CCS Pre-Feasibility Study

Location: Western Nebraska, United States

Potential Size: 55 million tons (50 million tonnes) of CO<sub>2</sub>

This pre-feasibility study investigates the regulatory, socioeconomic and technical aspects for carbon capture and storage (CCS) potential in Nebraska as a Phase I effort in DOE's nationwide, multiyear CarbonSAFE initiative designed to support the development of commercial-scale CO<sub>2</sub> storage projects by 2025.

Status: End date June 2018

## Fort Nelson

### Fort Nelson CCS Feasibility Project

Location: British Columbia, Canada

This feasibility project evaluated the potential for safe, cost-effective geologic storage of CO<sub>2</sub> from a natural gas-processing facility

Status: Completed 2012



## KS–NE CarbonSAFE

### **Integrated Mid-Continent Carbon Stacked Storage Hub**

Location: Kansas and Nebraska, United States

Potential Size: 55 million tons (50 million tonnes) of CO<sub>2</sub>

The project will concentrate on identifying specific stacked storage sites in southwest Nebraska and central Kansas and assessing their potential as a first step in DOE's nationwide, multiyear CarbonSAFE initiative designed to result in commercial-scale carbon capture and storage (CCS) projects by 2025.

Status: End date June 2018

## Lignite

### **Lignite Field Validation Test**

Location: Northwestern North Dakota, United States

CO<sub>2</sub> Injected: 90 tons (82 tonnes)

This small-scale test demonstrated that unminable lignite coal seams may act as permanent underground storage zones for CO<sub>2</sub>.

Status: Completed October 2013.

## ND CarbonSAFE

### **North Dakota CCS Feasibility Study**

Location: Central North Dakota, United States

Project Size: 55 million tons (50 million tonnes) of CO<sub>2</sub>

The 2-year feasibility study focuses on practical aspects of developing a carbon capture and storage (CCS) project in North Dakota as part of DOE's nationwide, multiyear CarbonSAFE initiative designed to result in commercial-scale CCS projects by 2025.

Status: End date June 2019

## Northwest McGregor

### **CO<sub>2</sub> Huff 'n' Puff Field Validation Test**

Location: Northwestern North Dakota, United States

CO<sub>2</sub> Injected: 440 tons (400 tonnes)

This small-scale test demonstrated CO<sub>2</sub> huff 'n' puff for enhanced oil recovery and associated CO<sub>2</sub> storage for isolated wells in deep oil-bearing limestone rocks.

Status: Completed 2009

## Quest

### **Quest CCS Project**

Location: Fort Saskatchewan, Alberta, Canada

CO<sub>2</sub> Injection: 1.1 million tons (1 million tonnes) a year

CO<sub>2</sub> from Shell's Scotford Upgrader, which processes heavy oil from the Athabasca oil sands, is transported by pipeline to an injection location north of Shell Scotford.

Status: Active (as of September 2017)

## Red Trail

### **CCS for North Dakota Ethanol Production**

Location: Western North Dakota, United States

Potential size: 180,000 tons (160,000 tonnes) of CO<sub>2</sub>

This feasibility study examined the technical and economic factors associated with potential commercial deployment of carbon capture and storage (CCS) at a North Dakota ethanol facility.

Status: Phase I completed 2017

## Terrestrial

### **Terrestrial Field Validation Test**

Location: Prairie Pothole Region, United States

CO<sub>2</sub> Storage: 1.1 tons of soil organic carbon per acre per year (0.4 tonnes per hectare)

The diverse activities of this test demonstrated methods to store atmospheric CO<sub>2</sub> in prairie ecosystems as a means to mitigate anthropogenic CO<sub>2</sub> emissions.

Status: Completed 2009

## Weyburn–Midale

### **Weyburn–Midale CO<sub>2</sub> Project**

Location: Saskatchewan, Canada

CO<sub>2</sub> Injection: 2.2 million tons (2 million tonnes) a year CO<sub>2</sub> captured at Dakota Gasification

Company's Great Plains Synfuels Plant in Beulah, North Dakota, is piped 205 miles into the Weyburn and Midale oil fields for enhanced oil recovery with associated CO<sub>2</sub> storage.

Status: Active (as of September 2017)

## WY CarbonSAFE

### **Wyoming CCS Pre-Feasibility Study**

Location: Eastern Wyoming, United States

Potential Size: 55 million tons (50 million tonnes) of CO<sub>2</sub>

This pre-feasibility study looking at large-scale stationary CO<sub>2</sub> sources and potential storage sites is a first step in DOE's nationwide, multiyear CarbonSAFE initiative designed to result in commercial-scale carbon capture and storage (CCS) projects by 2025.

Status: End date June 2018

## Zama

### **Zama Field Validation Test**

Location: Alberta, Canada

CO<sub>2</sub> Injected: 93,000 tons (85,000 tonnes) through May 2012

This project demonstrates that acid gases, obtained during the purification of natural gas, can be safely injected underground to produce additional oil and permanently store CO<sub>2</sub>.

Status: Completed 2012

Last updated 9/1/2017

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## Plains CO<sub>2</sub> Reduction (PCOR) Partnership

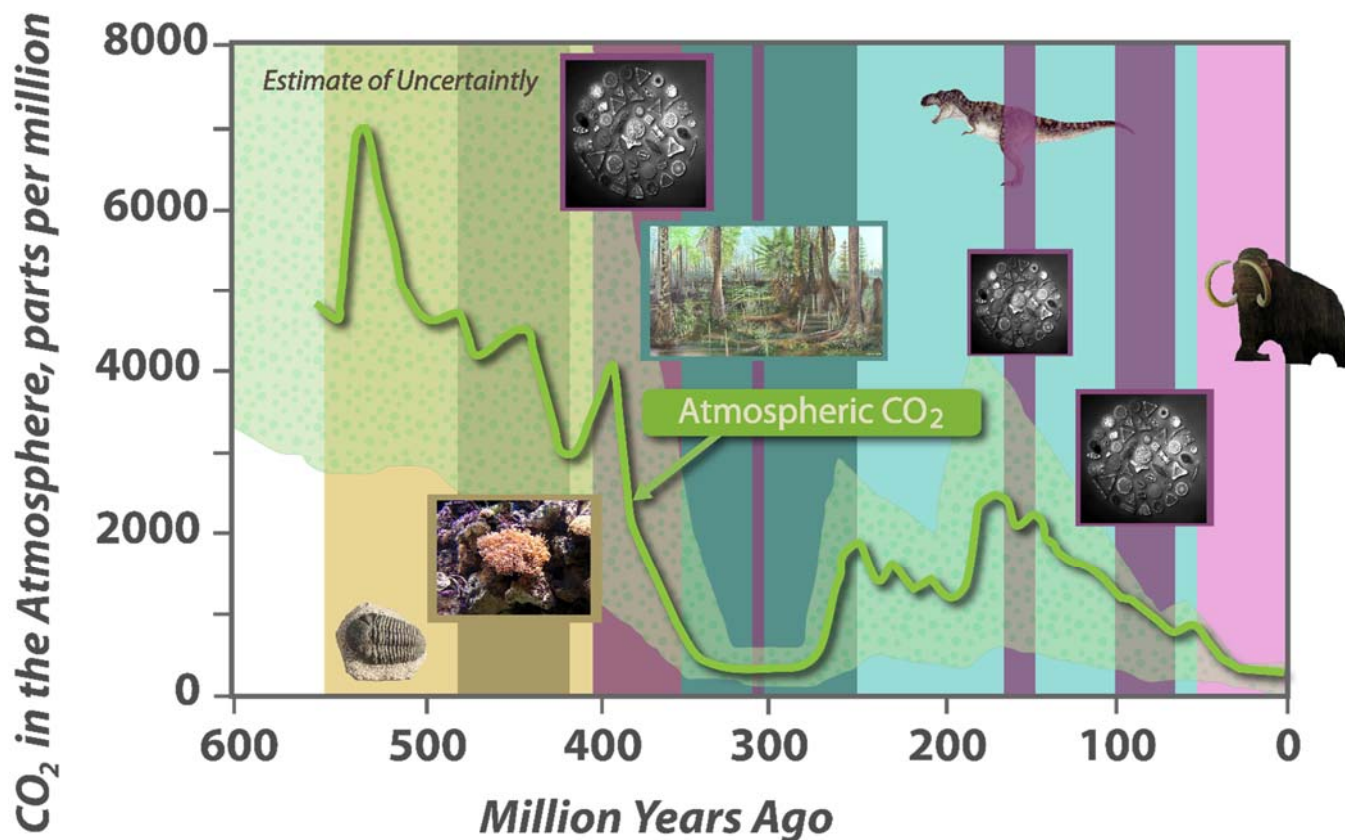
Practical, Environmentally Sound CO<sub>2</sub> Sequestration

### Carbon and CO<sub>2</sub> on Earth – Things Have Changed!

Carbon is a naturally occurring element on Earth and in other places in the universe. The amount of carbon today is the same as when Earth was formed<sup>?</sup>. Over time, the carbon atoms have been relocating and recombining, and the result has been major changes to Earth's atmosphere, biosphere, and surface.

Scientists tell us that Earth started out about 4.5 billion years ago as a ball of hot gases. About 3.5 billion years ago, Earth was cool enough to have a solid crust as well as a primitive atmosphere. At the same time, carbon dioxide was being formed deep in the earth by geologic processes, and this CO<sub>2</sub> was being released to the atmosphere through volcanic eruptions. During the subsequent 2 billion years, biological activities began developing, evolving, and expanding, fed by the CO<sub>2</sub> in the atmosphere. As biological production exploded over the last billion years, much of that atmospheric CO<sub>2</sub> was absorbed by plants and animals and buried in ocean sediments.

<sup>?</sup> Earth contains about 121,000,000 GtC, which is 121 million gigatons of carbon or 121 million billion metric tons of carbon.



*Estimated atmospheric CO<sub>2</sub> concentrations over the most recent 600 million years (up to 1950).  
Modified from [earthguide.ucsd.edu](http://earthguide.ucsd.edu).*



## CO<sub>2</sub> Sequestered in Limestone

According to scientists, the atmosphere of half a billion years ago contained about **20 times** the CO<sub>2</sub> it contains now. This was just at the time that aquatic animals were developing hard shells. Carbon was the major chemical building block in animals. Animals developing the ability to make hard structures used carbon dioxide dissolved in the oceans. For example, tiny coral animals combined the CO<sub>2</sub> with calcium to make their skeletons. Over time, massive accumulations of these skeletons made thick carbon-rich deposits we call coral reefs. Many of these reefs were buried, preserving them in the geologic record; we know them as limestone. A lot of the carbon that was once in the atmosphere is trapped in the limestone rock now buried deep underground.

*Coral Garden, Great Barrier Reef,  
Cairns, Queensland, Australia.*



## CO<sub>2</sub> Sequestered in Coal

Plants live by absorbing carbon dioxide using the carbon (with water and energy from the sun) as food and building materials—photosynthesis. As plants became plentiful on the land, they were removing more and more CO<sub>2</sub> from the atmosphere. Geologists call the time period of 400 million years ago the Carboniferous Period (“full of carbon”) because so much carbon was taken from the air by plants. This carbon was sequestered when the plants were buried and eventually preserved in deposits of carbon-rich coal.

*Carbon-Rich Coal*



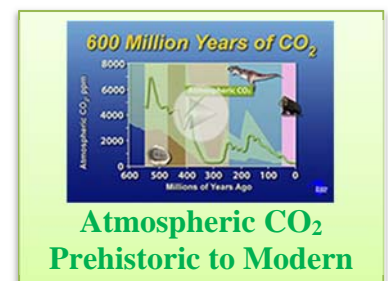
## CO<sub>2</sub> Sequestered in Oil and Gas

The oceans teem with tiny organisms like algae, bacteria, and plankton. When they die, their bodies sink to the bottom of the ocean and are buried in sediments. When conditions are right (for example, a very low level of dissolved oxygen in the water), they may be preserved. If buried under more than 10,000 feet of sediments and with sufficient temperature and pressure, the bodies of these marine animals may eventually be transformed into oil and gas. Although the process continues today, most of the oil we produce comes from organisms that lived and died either 400 million or 60 million years ago. Major deposits of oil and gas are distributed across our planet.

## Sequestered CO<sub>2</sub> Returns to the Atmosphere

Scientists tell us that the amount of CO<sub>2</sub> in the atmosphere has ranged considerably over the last half billion years. At the beginning of the age of mammals about 60 million years ago, CO<sub>2</sub> levels were about twice what they are today.

The long-term trend has been a decrease in carbon in the atmosphere. Over the last 200 years, CO<sub>2</sub> levels have been increasing, and human activity may be part of the reason. When humans burn fossil fuels, heat limestone to make lime for cement, or plow land for farming, carbon sequestered long ago is released to the atmosphere. These practices have made **humans** a participant in the carbon redistribution game. Scientists are now attempting to address the increasing CO<sub>2</sub> concentrations in the atmosphere by looking at the natural processes that lead to carbon storage and developing sequestration strategies as part of the larger effort to address concerns about climate change.<sup>1</sup>



### References:

1. Pacala, S., and Socolow, R., 2004, Stabilization wedges—solving the climate problem for the next 50 years with current technologies: Science, v. 305, p. 968–972.

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