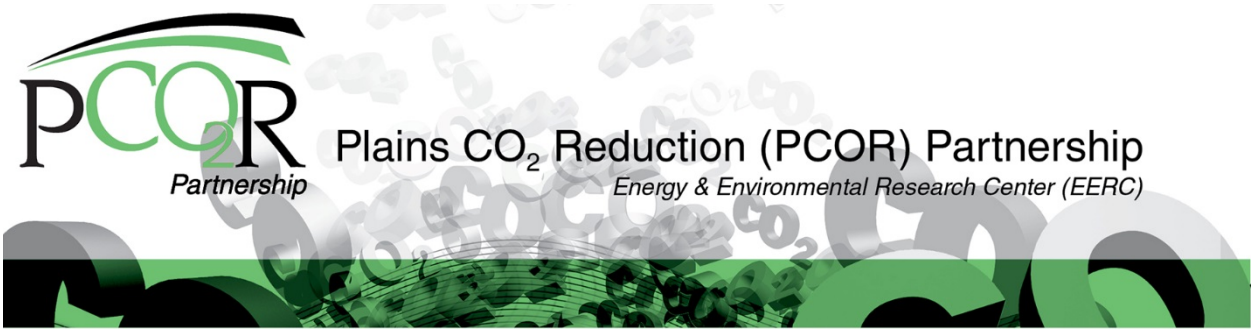

PUBLIC SITE UPDATES

Plains CO_2 Reduction (PCOR) Partnership Phase III
Task 2 – Deliverable D13

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Approved

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ACKNOWLEDGMENT

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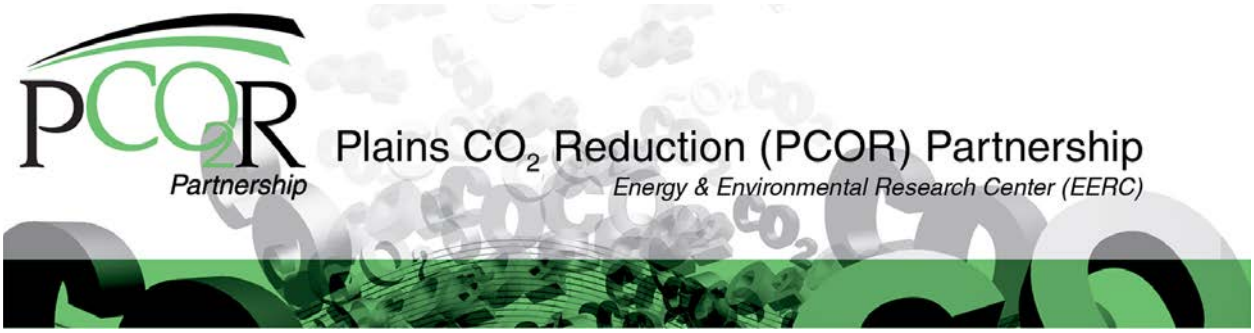
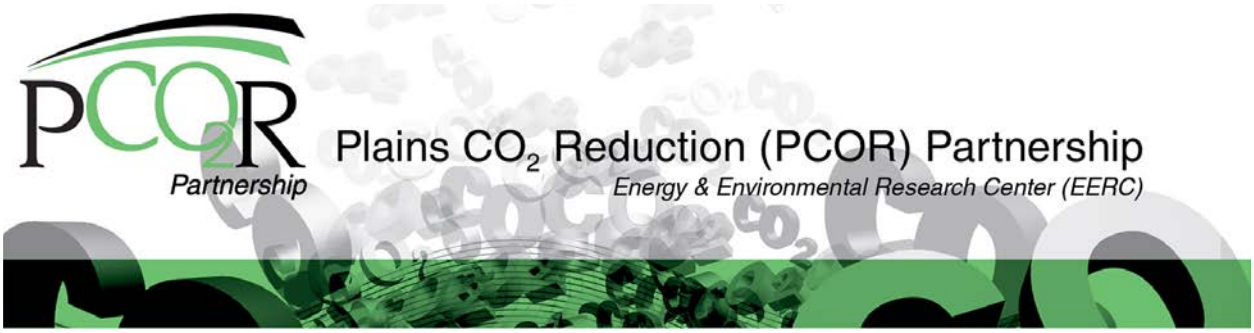


PUBLIC SITE UPDATES

EXECUTIVE SUMMARY

This report summarizes the 2018 contractual update to the Plains CO_2 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_2 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_2 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_2 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_2? What Is CO_2 Sequestration? Terrestrial Sinks, CO_2 Sequestration Projects, Technical Publications, Technical Reports, Documentaries, Video Clip Library, and Carbon and CO_2 on Earth – Things Have Changed! Eleven additional Web pages received minor updates: About the Partnership; Become a Partner; PCOR Partnership Partners; Climate, CO_2, 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_2 EOR LCA Model Page

The CO_2 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_2 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.

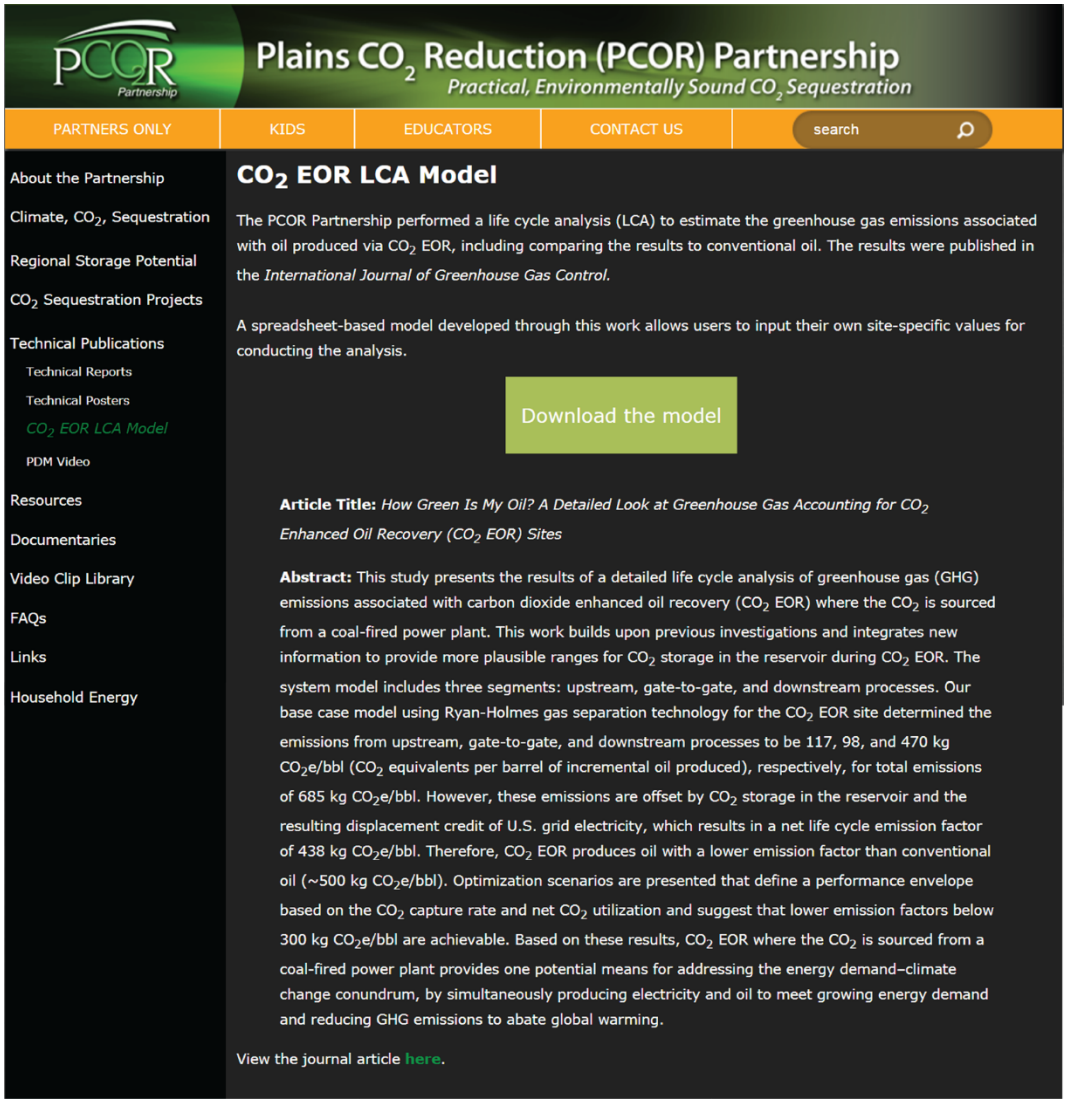


Figure 1. New CO_2 EOR LCA Model page.
Existing link: undeerc.org/PCOR/technicalpublications/CO2-EOR-Life-Cycle-Analysis.aspx.

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.

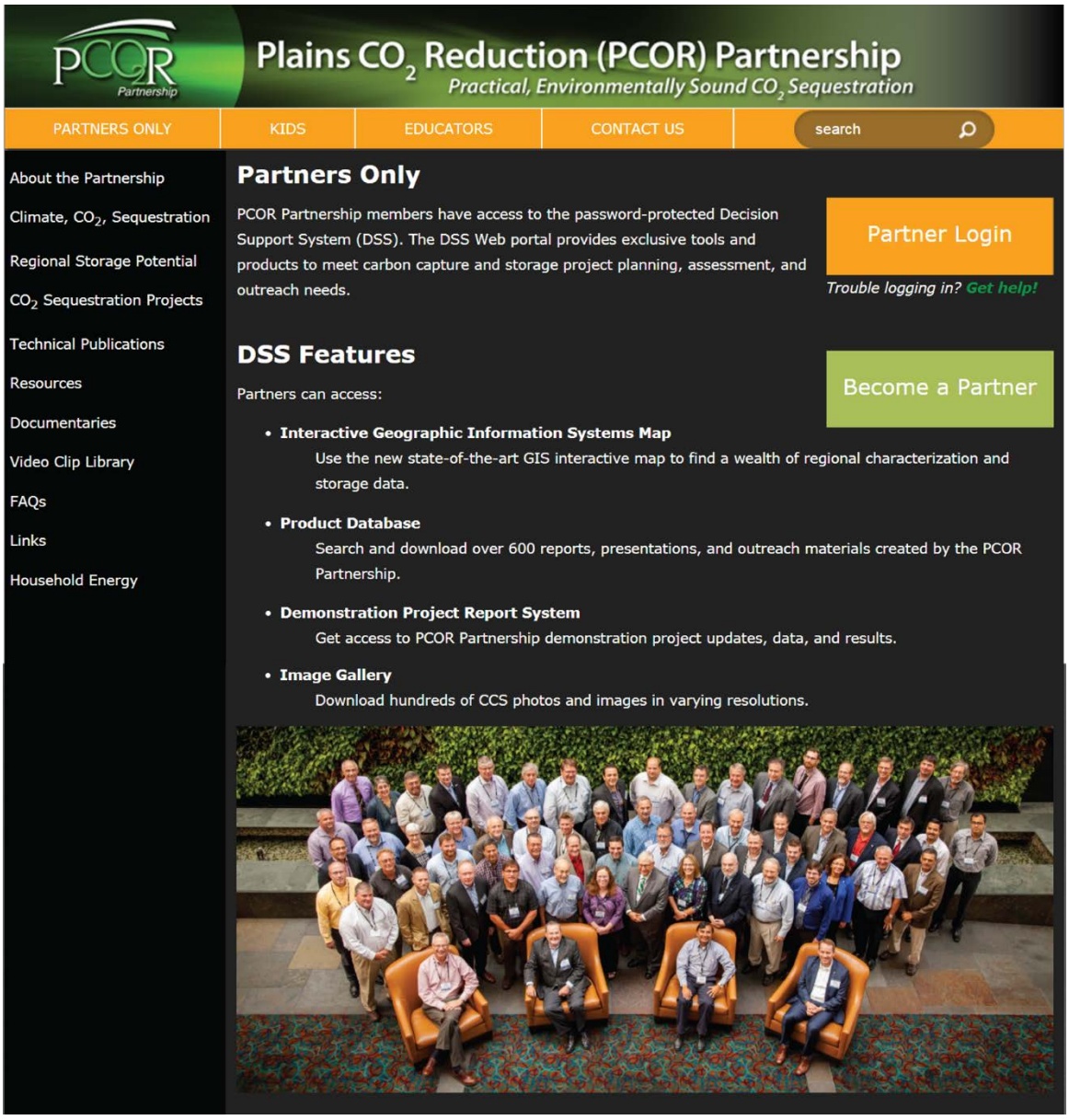


Figure 2. New Partners Only landing page.
Existing link: www.undeerc.org/pcor/PartnersOnly.aspx.

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_2 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.

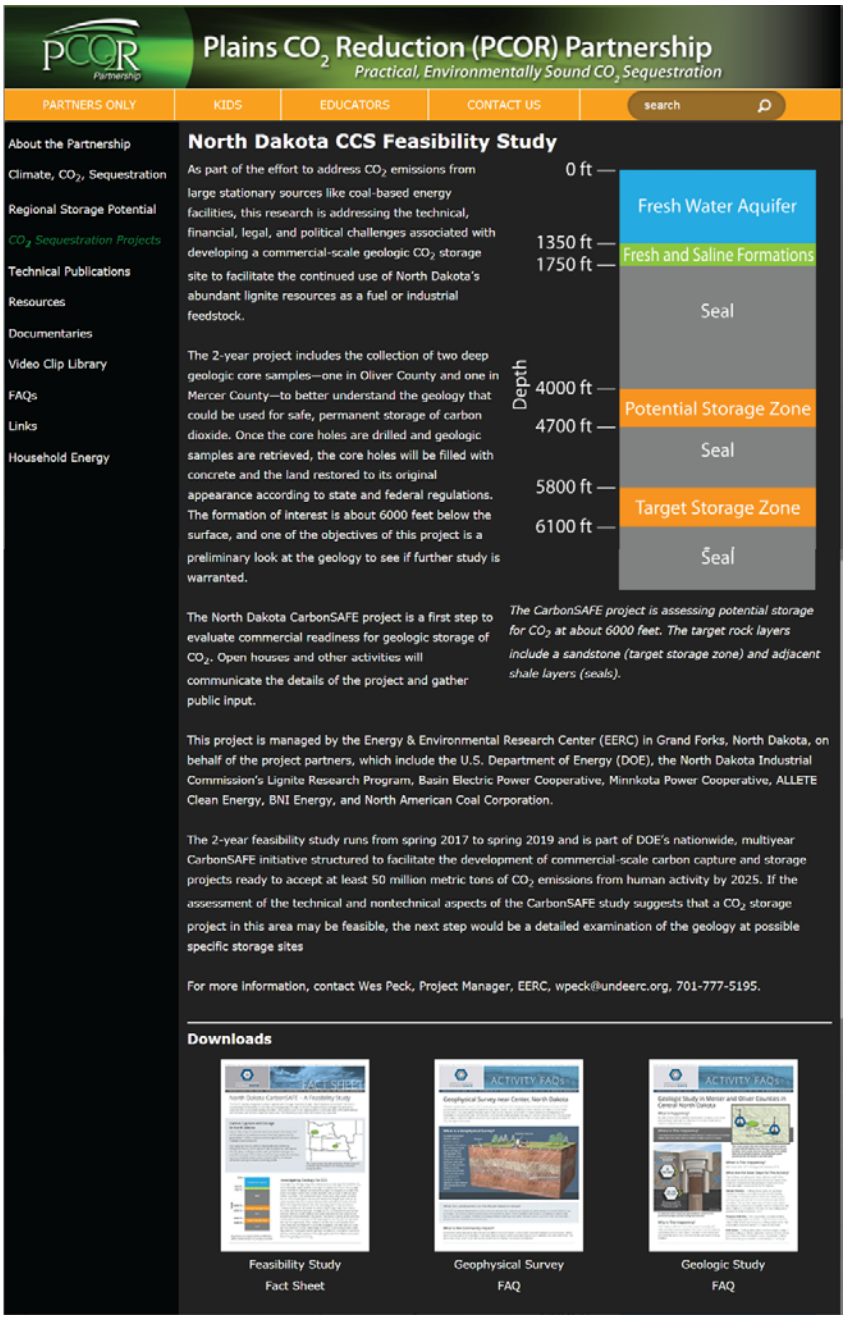


Figure 3. New North Dakota CCS Feasibility Study page.
Existing link: undeerc.org/pcor/co2sequestrationprojects/NDCarbonSafe.aspx.

Nebraska CCS Pre-Feasibility Study

The Nebraska CCS Pre-Feasibility Study page shown in Figure 4 provides information on a new CO_2 sequestration project occurring in the PCOR Partnership region. This project was added to the CO_2 Sequestration Projects landing page on December 20, 2017.

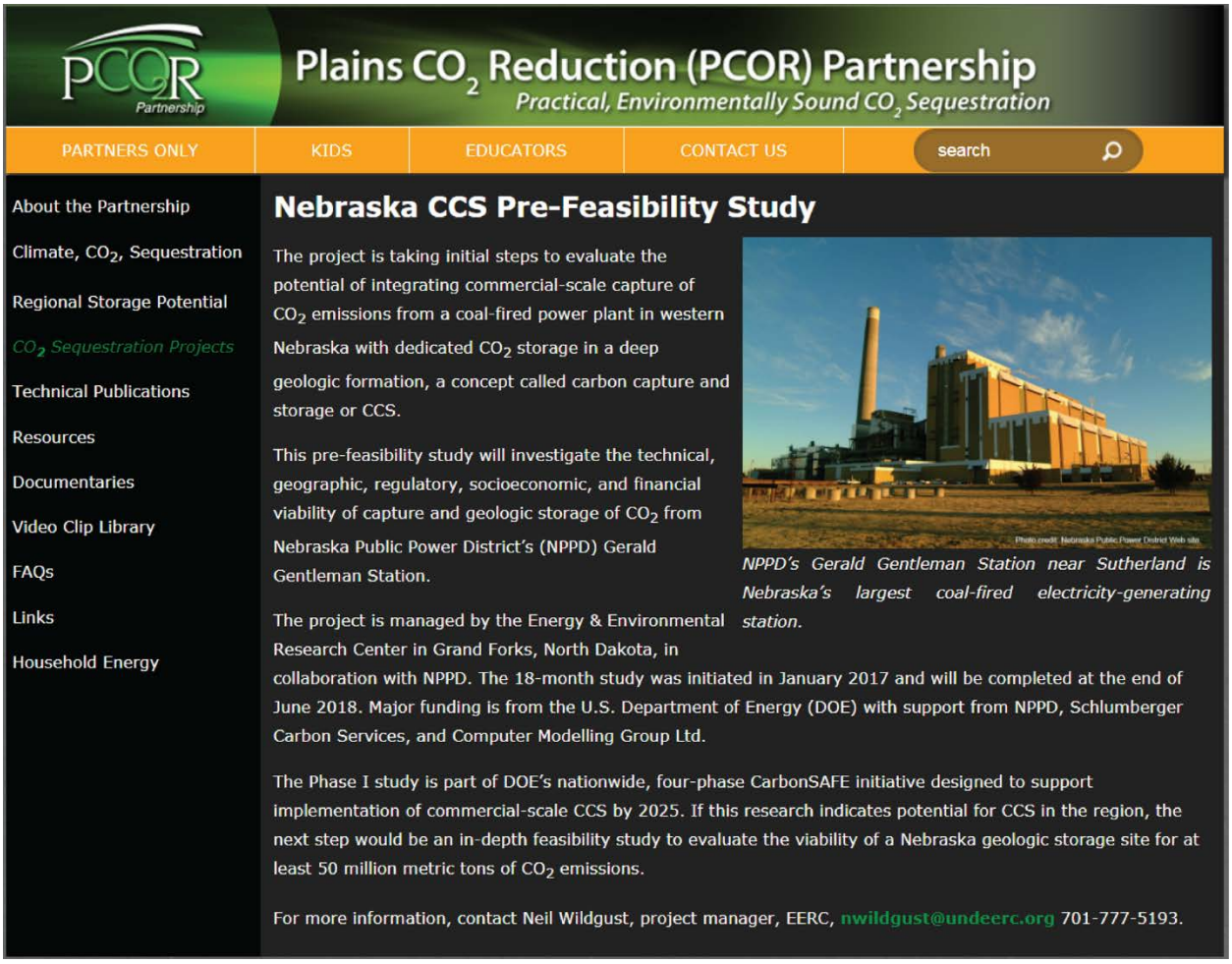


Figure 4. New Nebraska CCS Pre-Feasibility Study page.
Existing link: undeerc.org/pcor/co2sequestrationprojects/CarbonSafe-NE.aspx.

CCS for North Dakota Ethanol Production

The CCS for North Dakota Ethanol Production page shown in Figure 5 provides information on a new CO_2 sequestration prefeasibility project occurring in the PCOR Partnership region. This project was added to the CO_2 Sequestration Projects landing page on January 22, 2018.

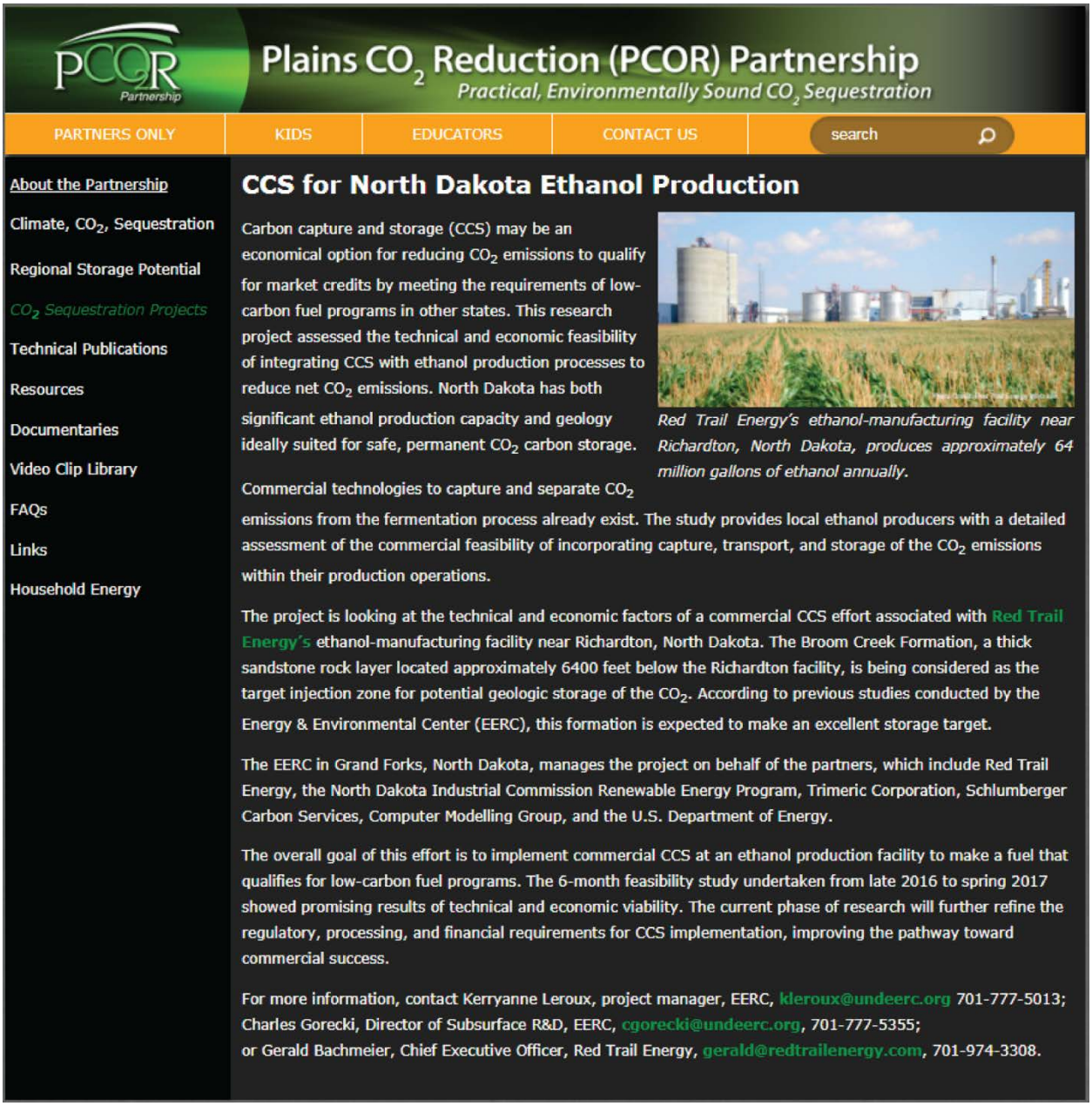


Figure 5. New page CCS for North Dakota Ethanol Production page.
Existing link: undeerc.org/pcor/co2sequestrationprojects/RedTrail.aspx.

The Bell Creek Story Documentary Page

With the broadcast premiere of *The Bell Creek Story: CO_2 in Action*, this page was added to provide a brief description and link to play the 30-minute documentary *The Bell Creek Story: CO_2 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.

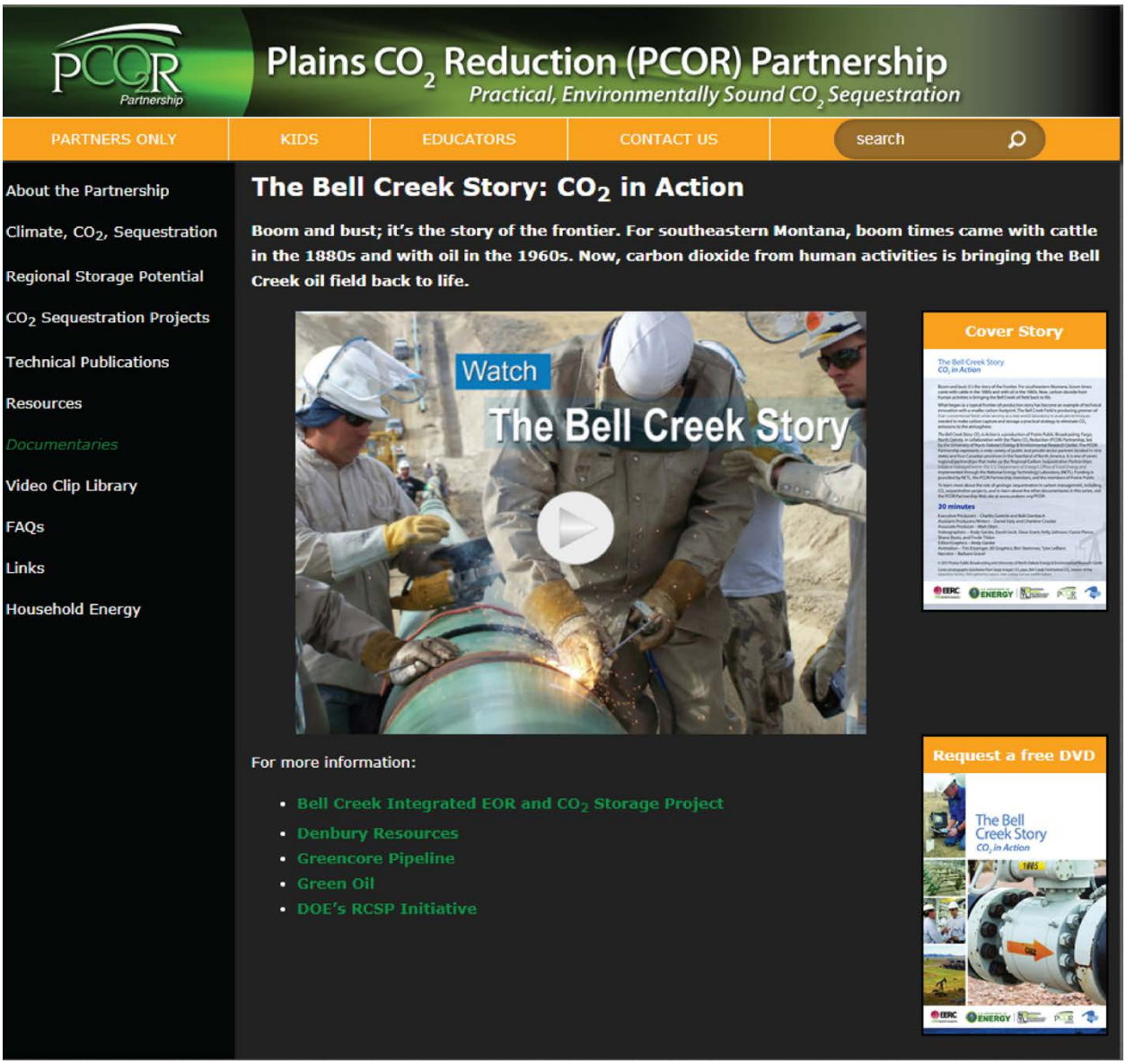


Figure 6. New *The Bell Creek Story: CO_2 in Action* documentary page.
Existing link: undeerc.org/pcor/Documentary/Bell-Creek-Story.aspx.

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_2 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.

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.

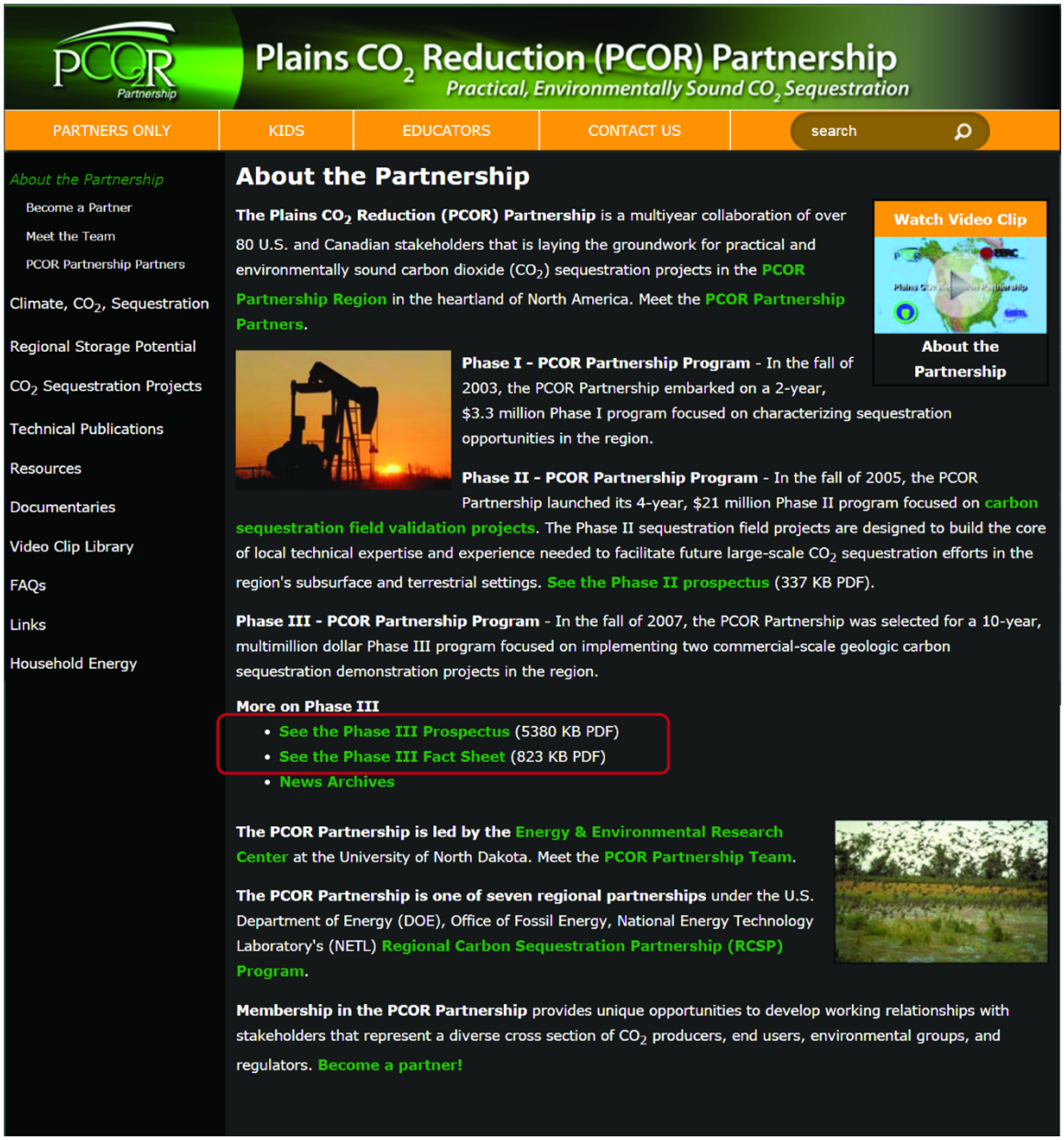


Figure 8. Updated About the Partnership page.
Existing link: www.undeerc.org/PCOR/About/.

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.

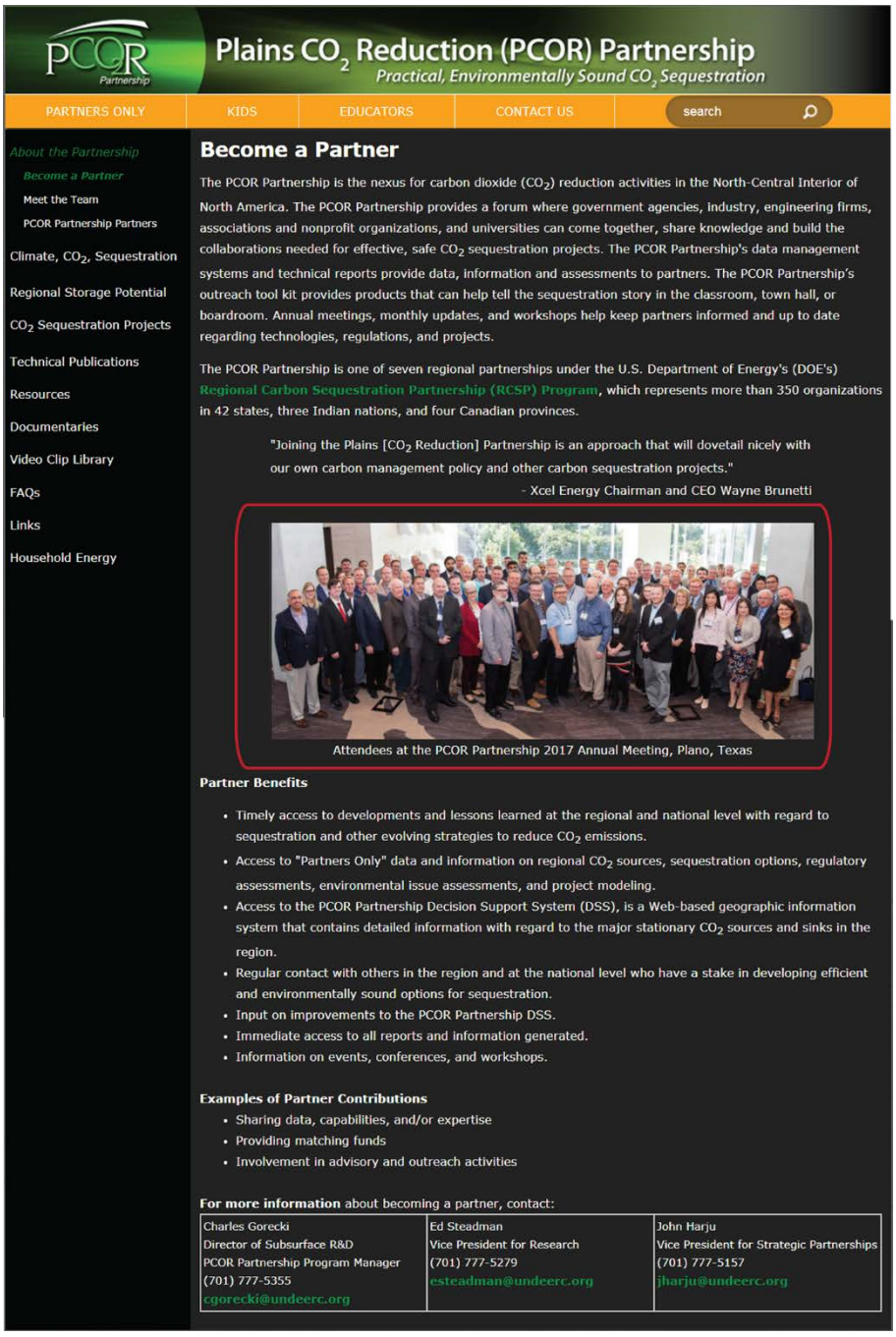


Figure 9. Updated Become a Partner page.
Existing link: www.undeerc.org/pcor/About/BecomeAPartner.aspx.

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.

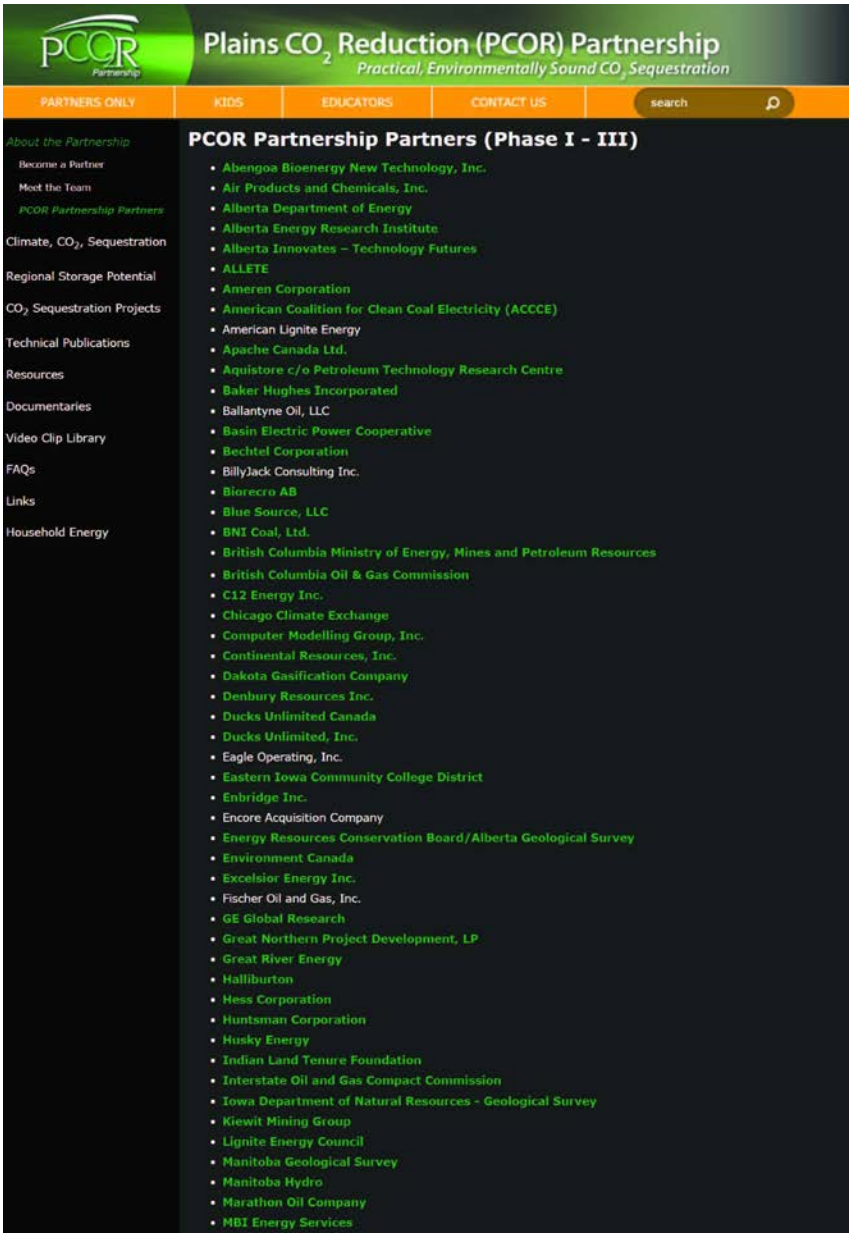


Figure 10. New partners added to the PCOR Partnership Partners page (continued). Existing link: undeerc.org/PCOR/About/Partners.aspx.

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

Climate, CO_2, Sequestration Page

Updates to the Climate, CO_2, Sequestration page included updating the text and organizing the links at the bottom using the headings Learn about Earth's natural CO_2 and Learn about cutting CO_2 emissions. The updated page with new layout is shown in Figure 11. These changes went live on September 13, 2017.

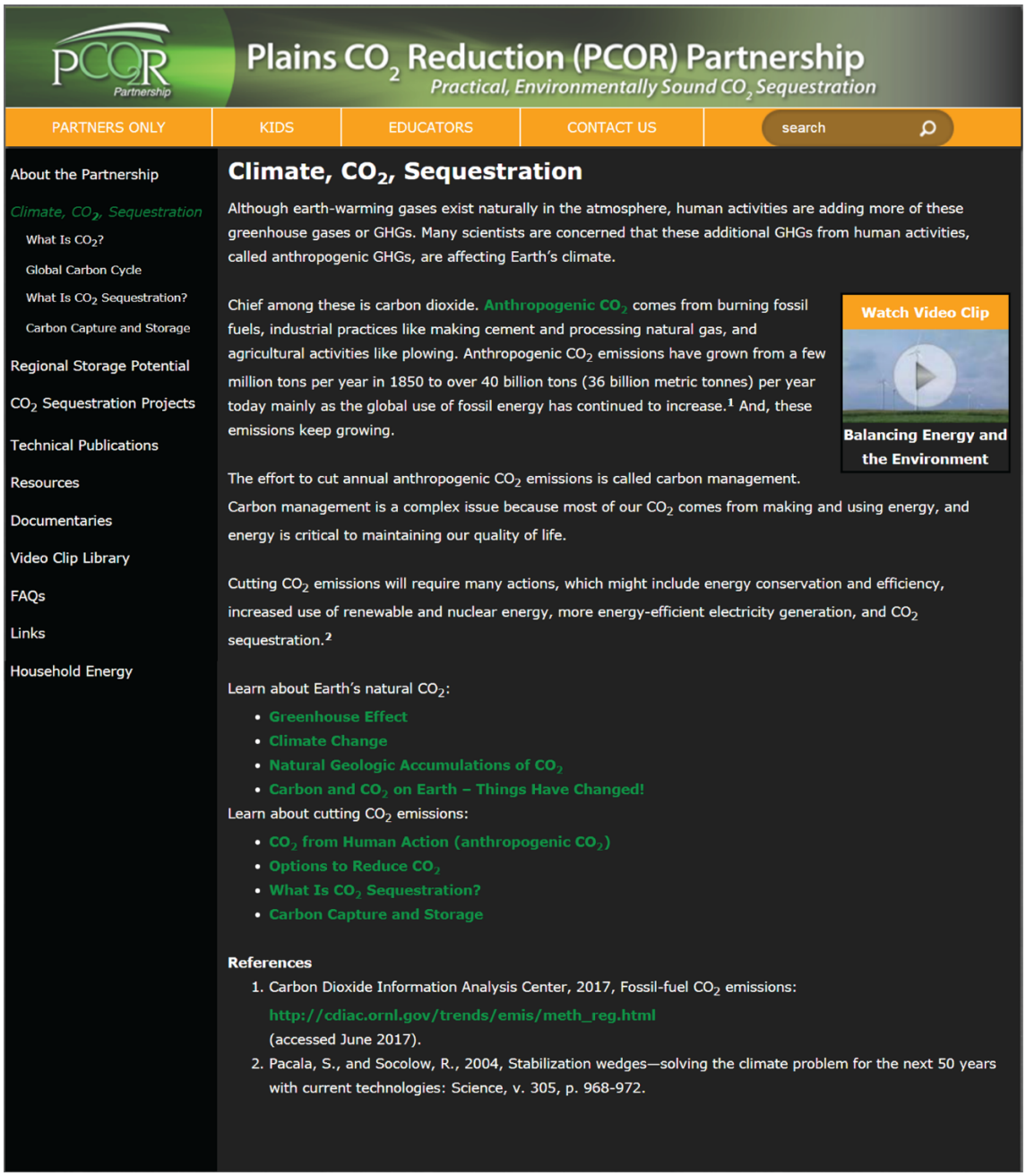


Figure 11. Updated Climate, CO_2, Sequestration page.
Existing link: undeerc.org/PCOR/Sequestration/.

What Is CO_2? Page

The What Is CO_2? 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_2, 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.

Figure 12. Content updated in What Is CO_2? page with tool tip content (bottom). Existing link: undeerc.org/PCOR/Sequestration/co2onearth.aspx.

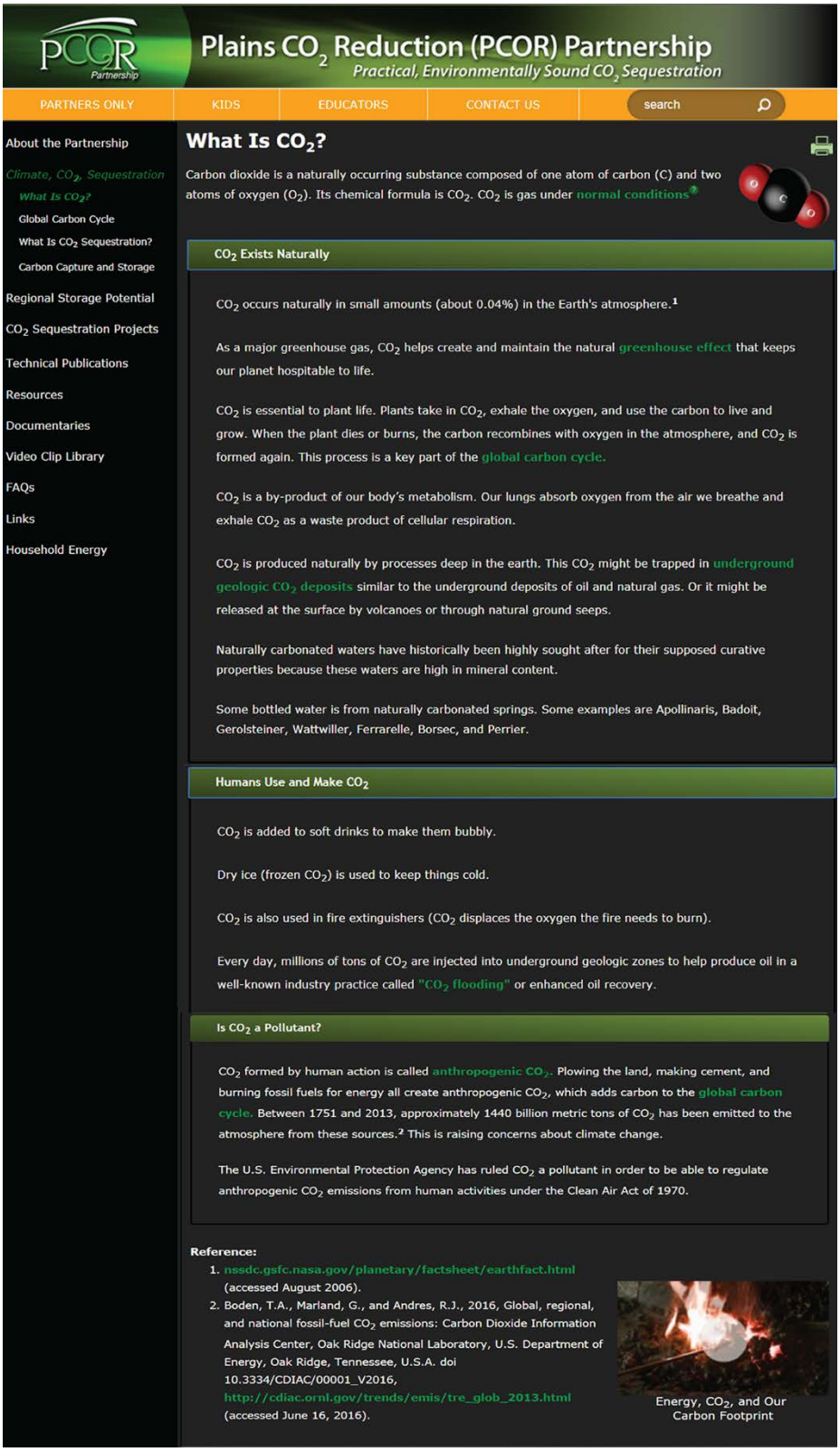


Figure 13. New look for What Is CO_2? page with expanded accordion content. Existing link: undeerc.org/PCOR/sequestration/whatisco2.aspx.

What Is CO_2 Sequestration? Page

The What Is CO_2 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.

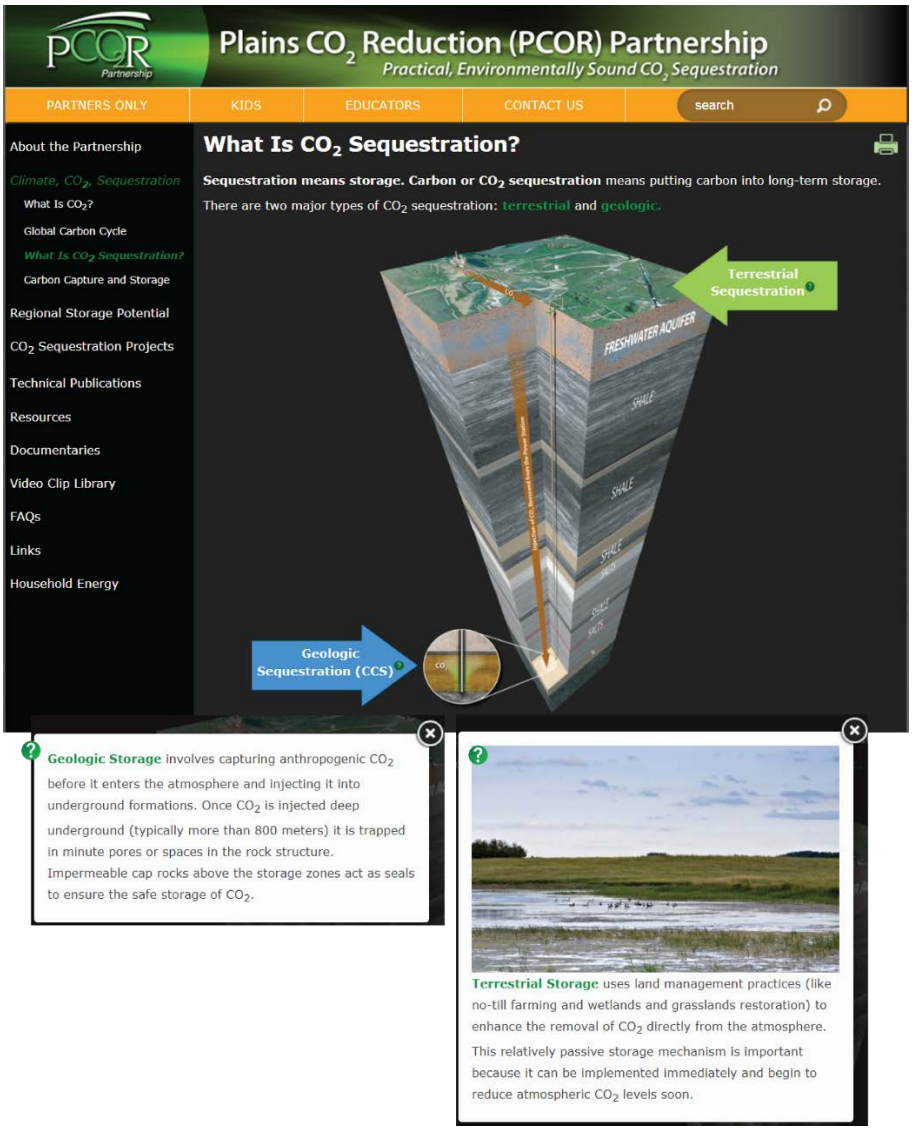


Figure 14. New look for What Is CO_2 Sequestration? page with the tool tips associated with Geologic Sequestration (left) and Terrestrial Sequestration (right).
Existing link: undeerc.org/pcor/sequestration/whatissequestration.aspx.

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_2 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.

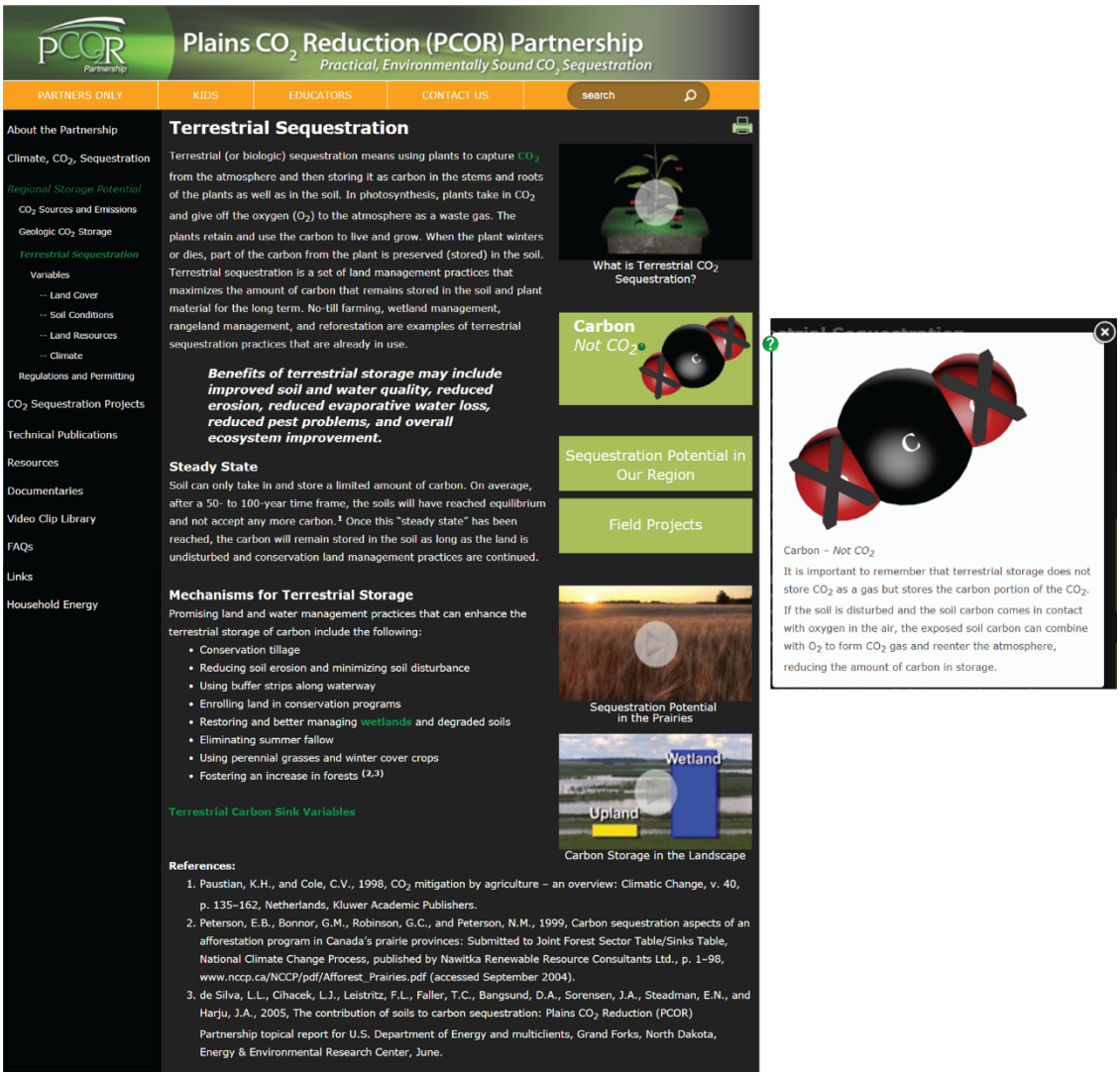


Figure 15. Content update for Terrestrial Sequestration page with new tool tip content (bottom). Existing link: undeerc.org/pcor/region/terrestrial.aspx.

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.

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

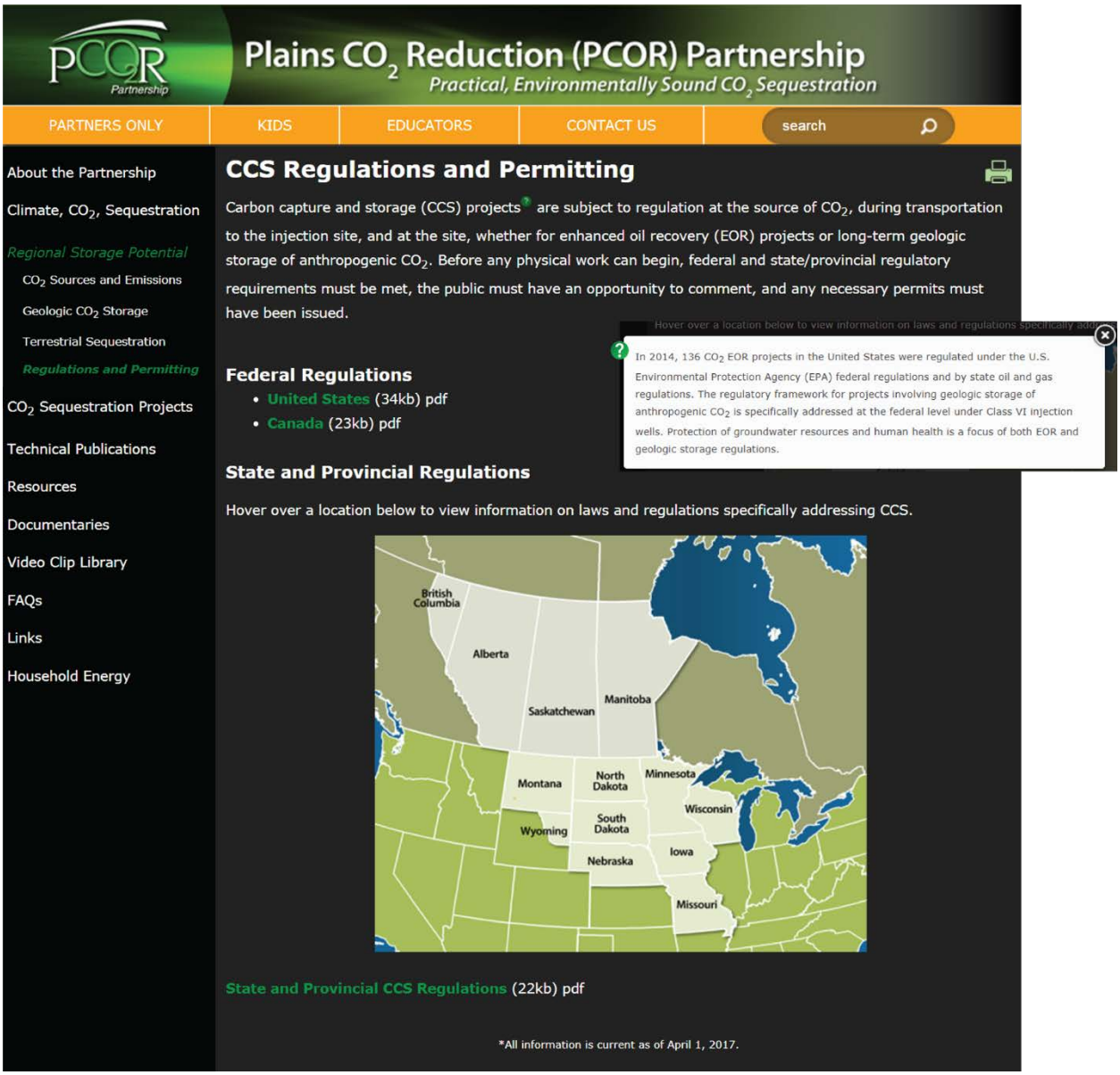


Figure 17. Updated Regulations and Permitting page with new tool tip content (bottom). Existing link: undeerc.org/pcor/Region/Regulation.aspx.

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

CO_2 Sequestration Projects Page

The CO_2 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).

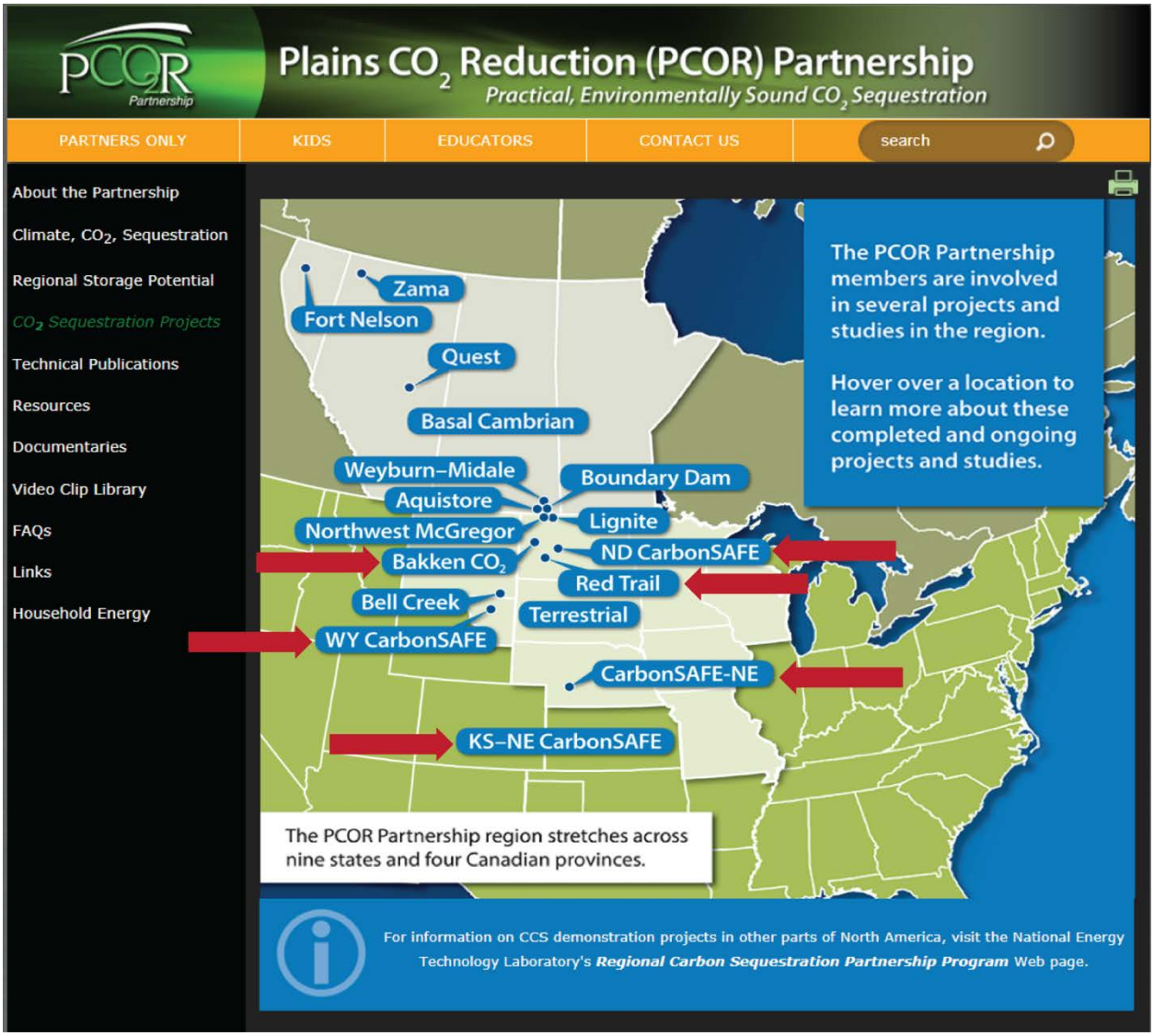


Figure 19. Updated CO_2 Sequestration Projects landing page.
Existing link: undeerc.org/PCOR/CO2SequestrationProjects/.

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_2 Project (Figure 24). These updates went live September 13, 2017.

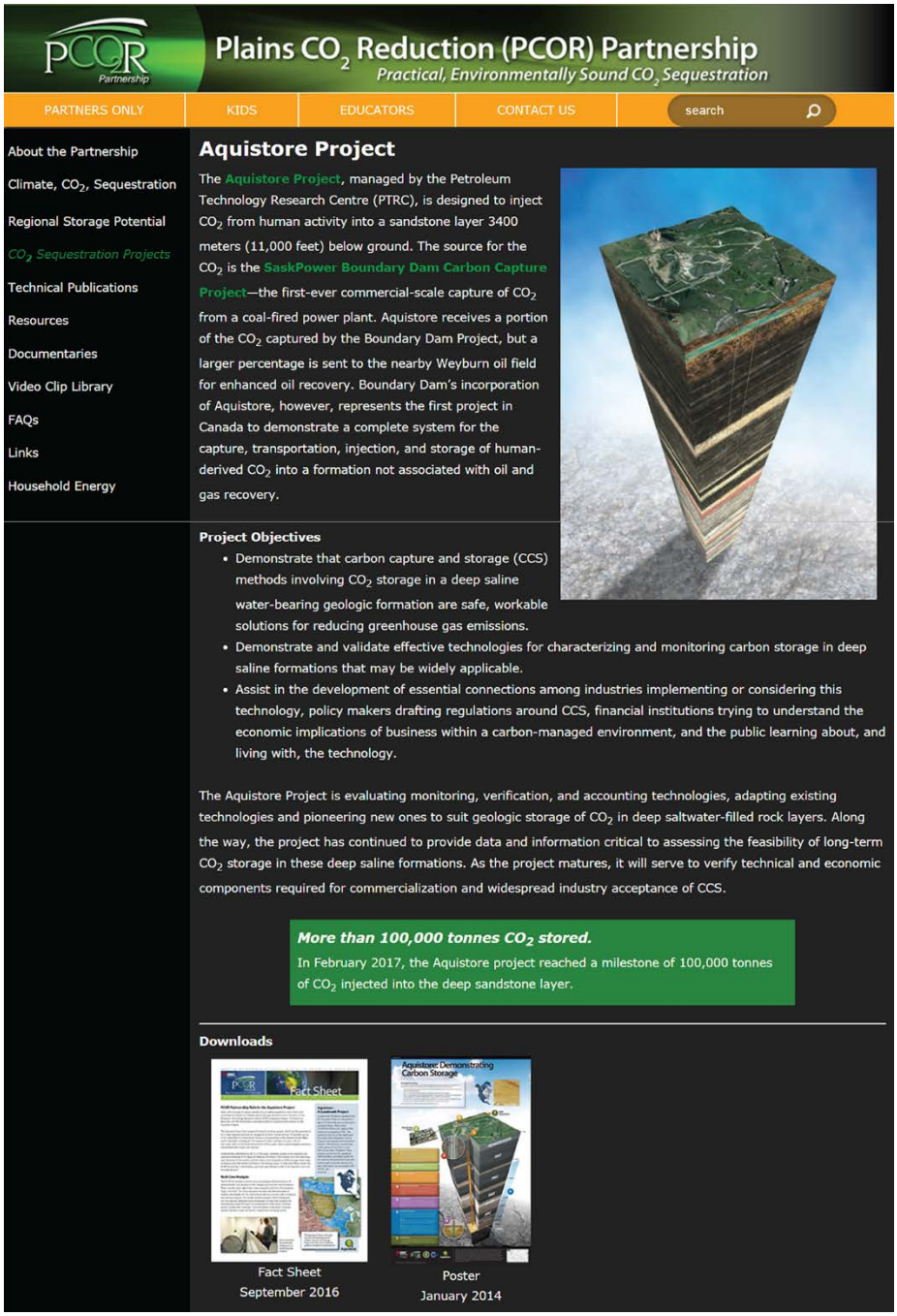


Figure 21. Content update Aquistore Project page.
Existing link: undeerc.org/PCOR/CO2SequestrationProjects/Aquistore.aspx.

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

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

Figure 24. Content update Weyburn–Midale CO_2 Project page.
Existing link: undeerc.org/PCOR/CO2SequestrationProjects/Weyburn.aspx.

On the Bell Creek Integrated EOR and CO_2 Storage Project page, the fact sheet "Bell Creek Project – Enhanced Oil Recovery Resulting in Associated CO_2 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_2 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.

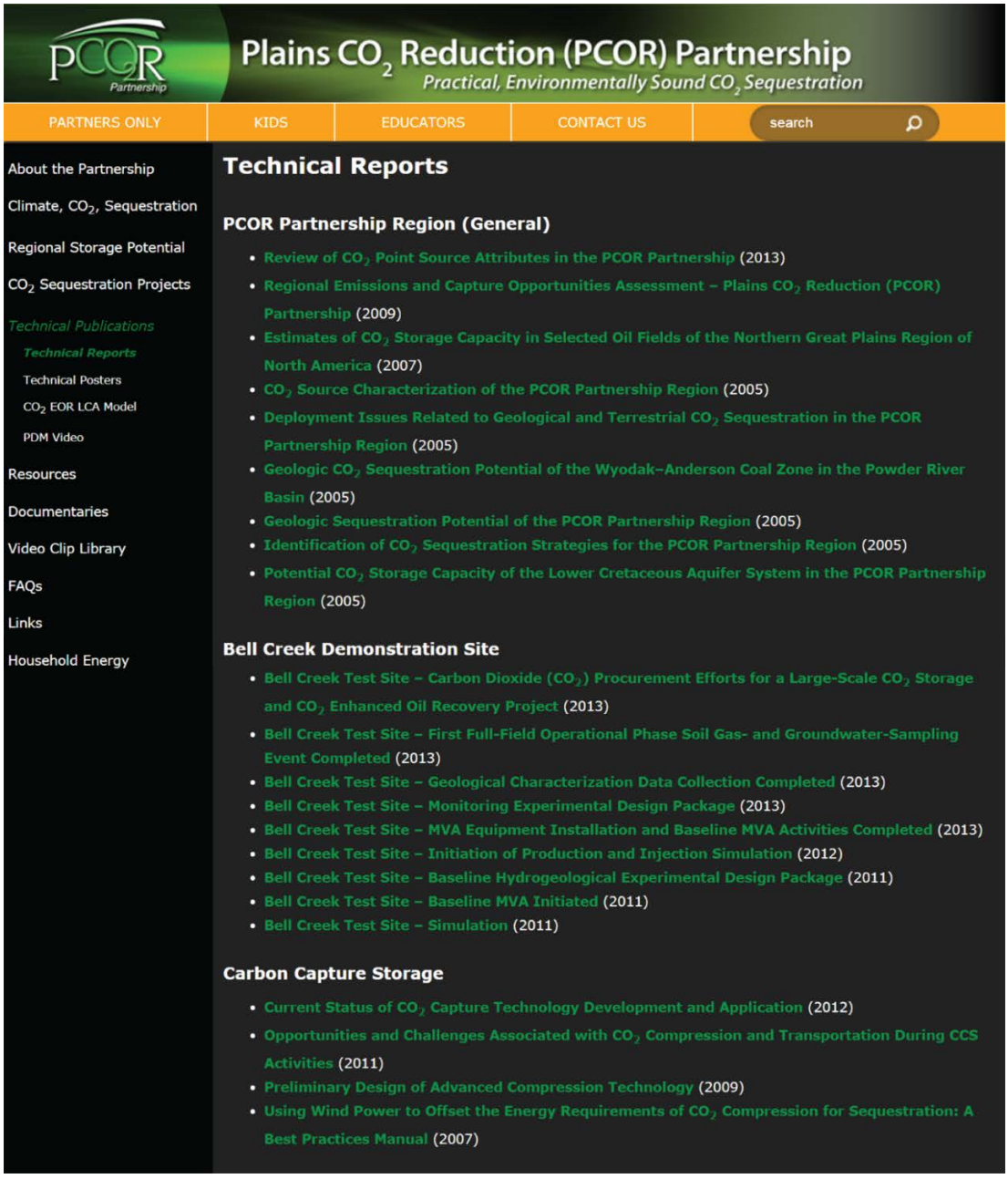


Figure 26. Updated Technical Reports page.
Existing link: http://www.undeerc.org/pcor/technicalpublications/technicalreports.aspx.

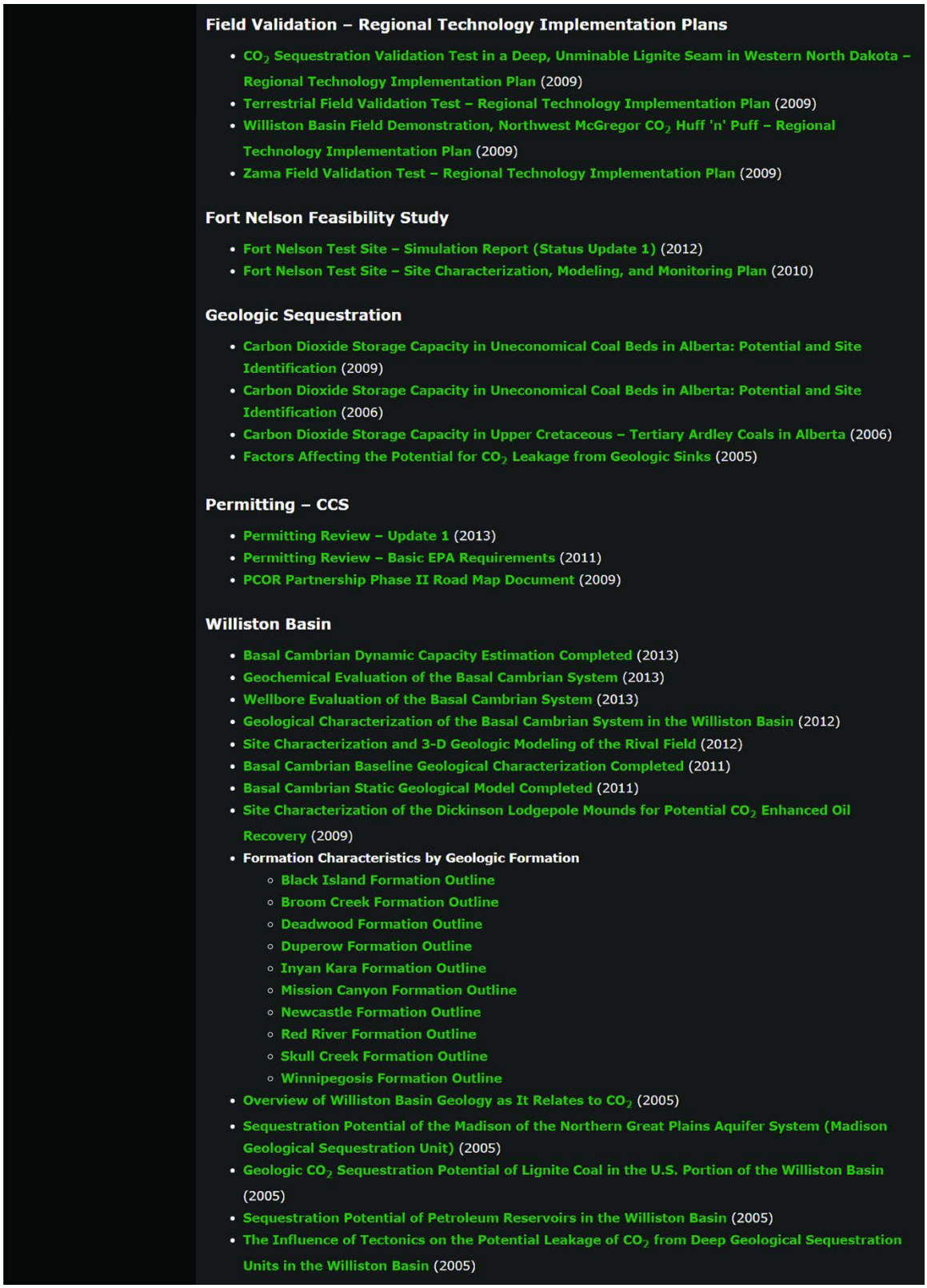


Figure 26 (continued). Updated Technical Reports page.
Existing link: http://www.undeerc.org/pcor/technicalpublications/technicalreports.aspx.

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.

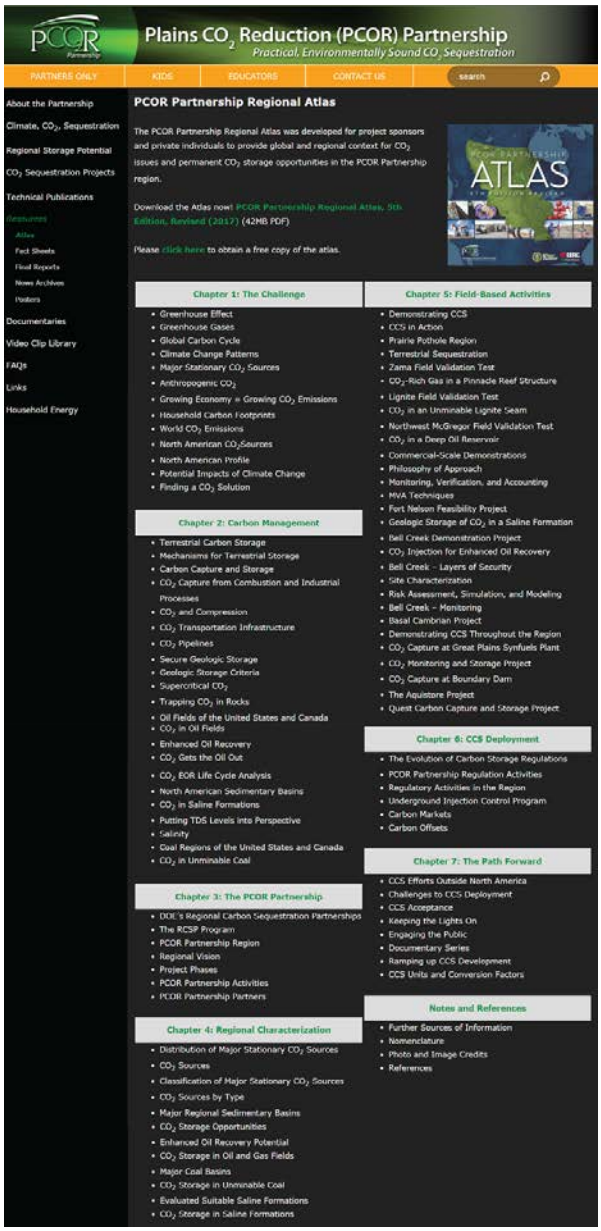


Figure 27. Updated Atlas page.
Existing link: http://www.undeerc.org/pcor/newsandpubs/atlas.aspx.

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_2 Sequestration Test in a Deep, Unminable Lignite Seam.”

The PCOR Partnership Phase III general fact sheet “PCOR Partnership Demonstrating CO_2 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_2 Storage” was uploaded on December 20, 2017.

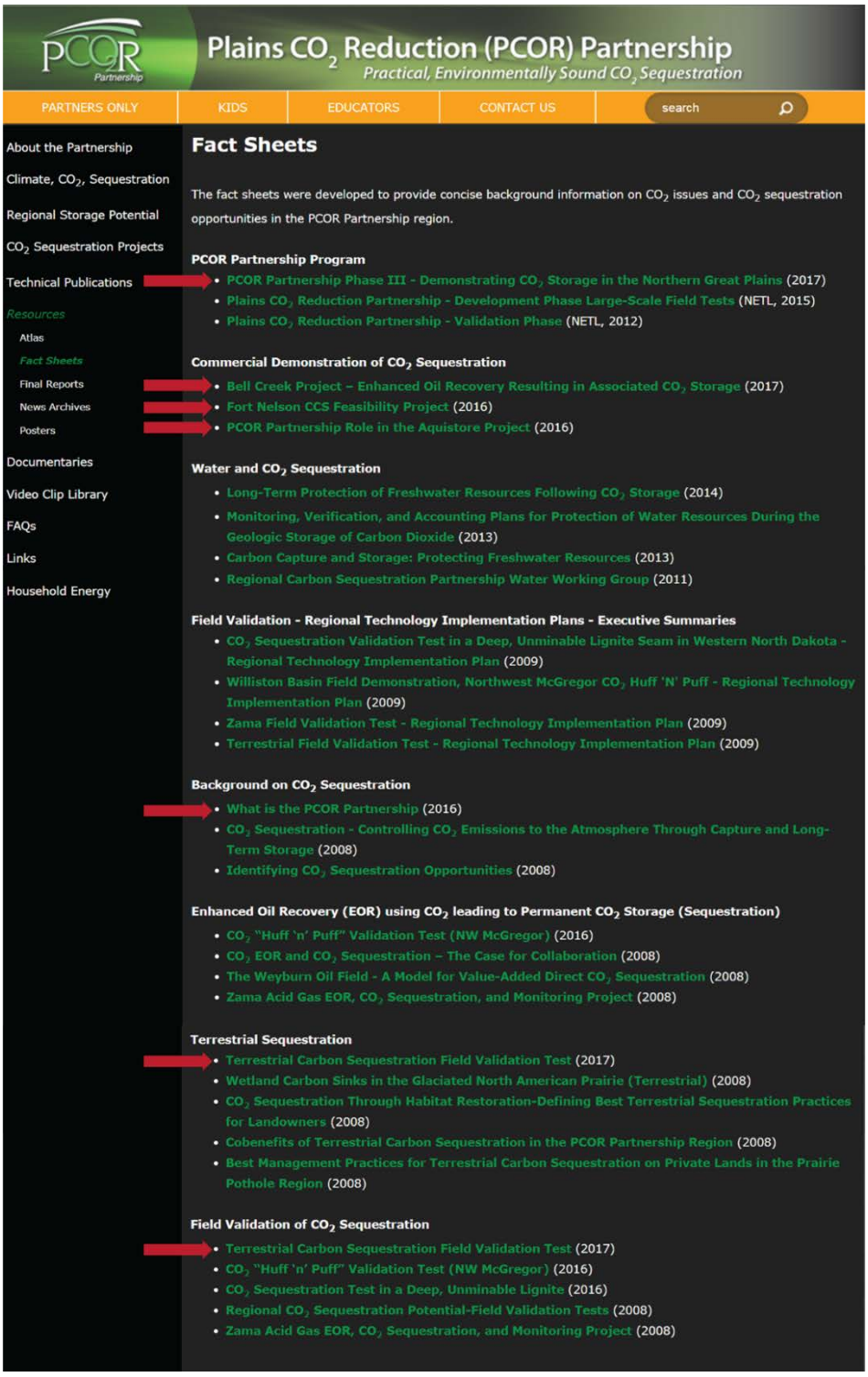


Figure 28. Updated Fact Sheets page.
Existing link: www.undeerc.org/pcor/NewsAndPubs/factsheets.aspx.

Documentaries Page

The Documentaries page shown in Figure 29 was updated to include the latest documentary, *The Bell Creek Story: CO_2 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/.

Video Clip Library

The Video Clip Library was updated to include seven clips from the documentary *The Bell Creek Story: CO_2 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.

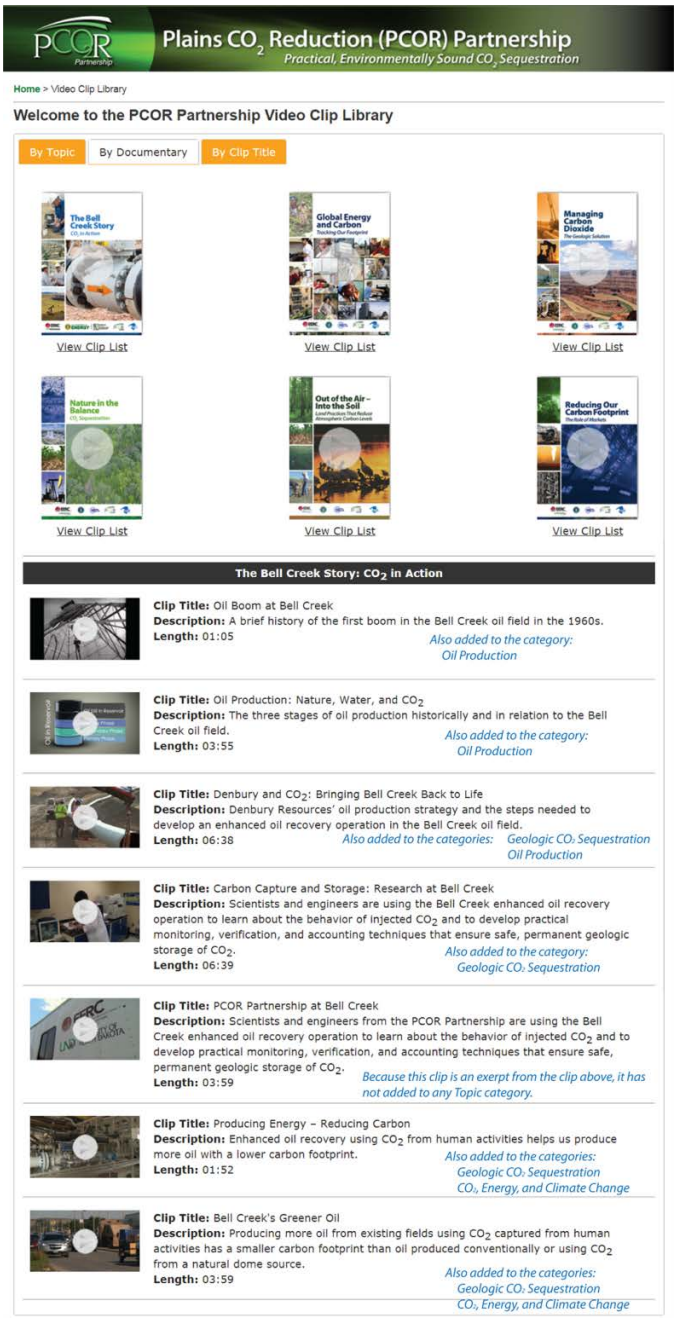


Figure 30. Video Clip Library page.
Existing link: http://undeerc.org/pcor/Video-Clip-Library/#tabs-2requestinfo.aspx.

Carbon and CO_2 on Earth – Things Have Changed! Page

The Carbon and CO_2 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_2 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.

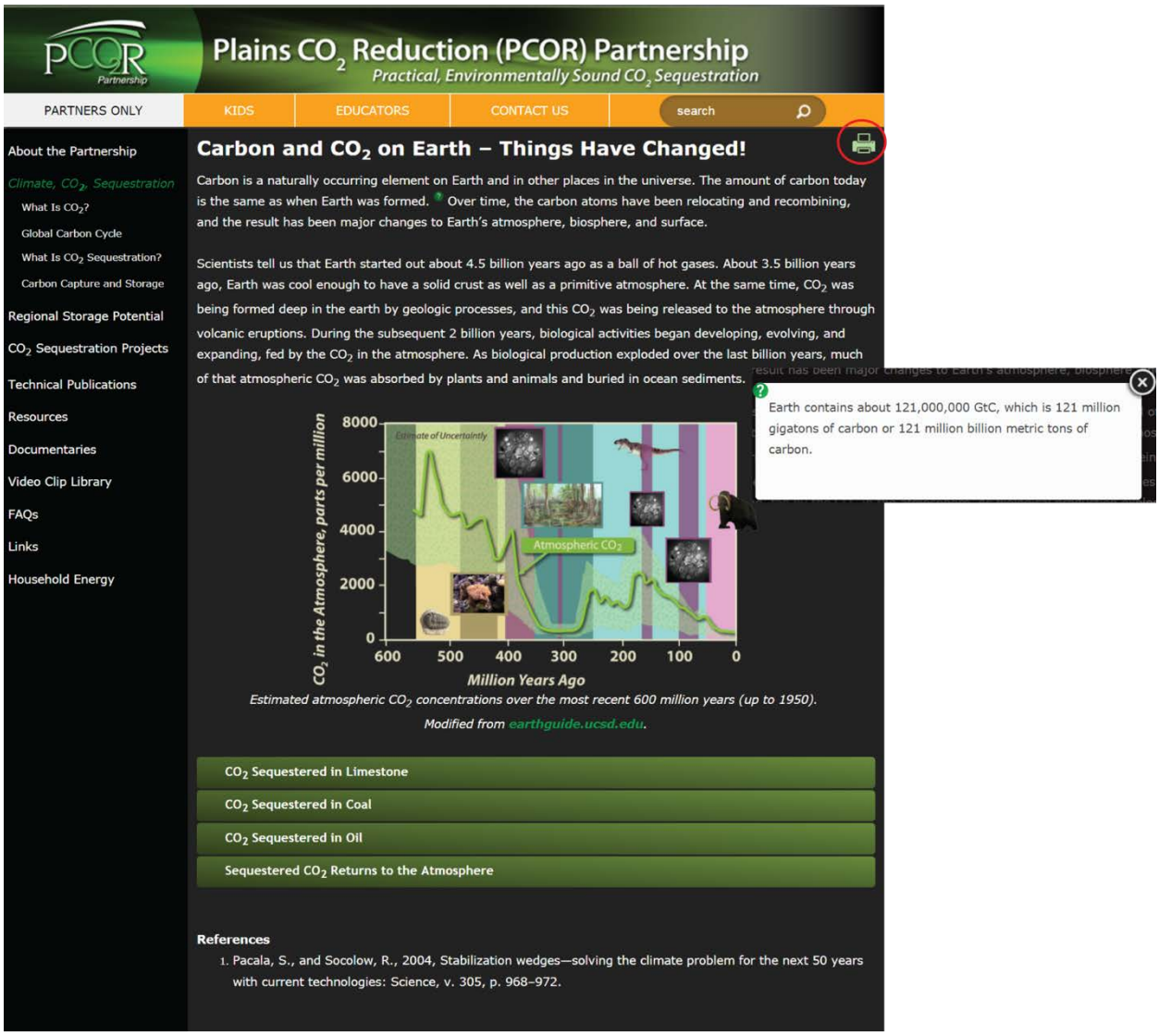


Figure 31. Updated Carbon and CO_2 on Earth page (continued).
Existing link: http://undeerc.org/pcor/Sequestration/co2onearth.aspx.

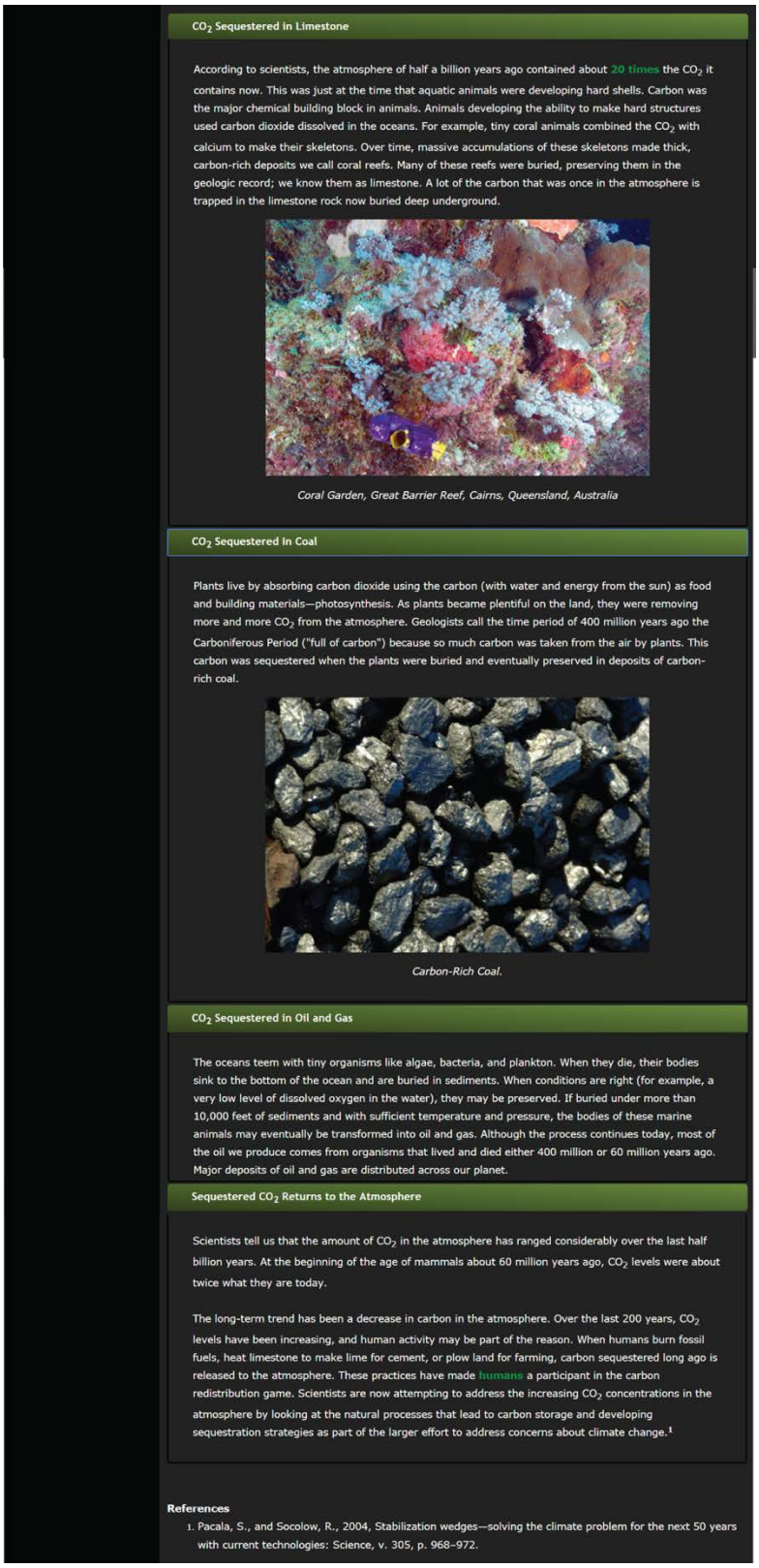


Figure 31. (continued) Updated Carbon and CO_2 on Earth page.
Existing link: http://undeerc.org/pcor/Sequestration/co2onearth.aspx.

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_2 in Action* (2017, DVD) and the Atlas, 5th edition. The updates went live on June 19, 2017, and April 25, 2017, respectively.

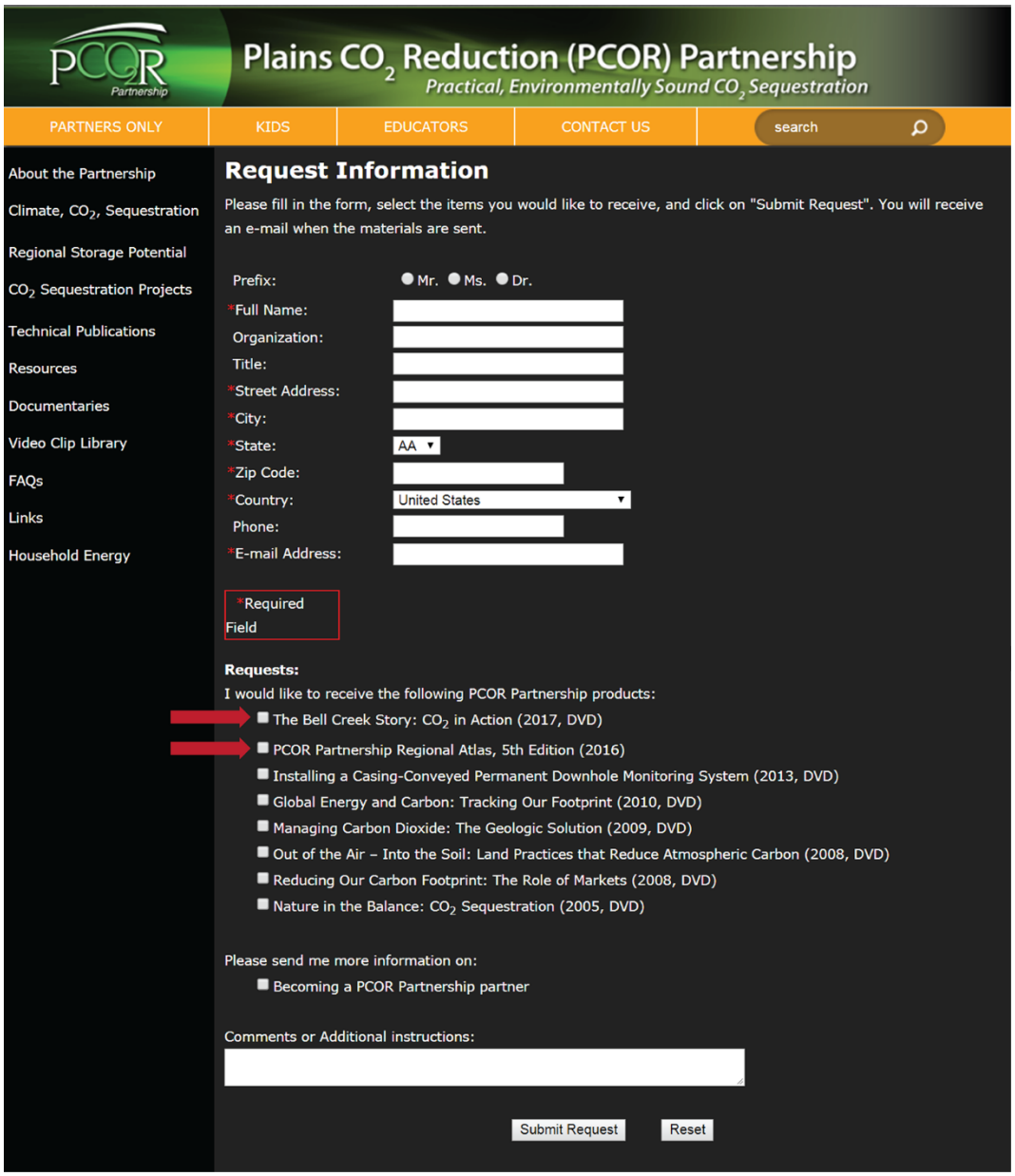


Figure 32. Updated Request Information page.
Existing link: undeerc.org/pcor/Documentary/requestinfo.aspx.

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.

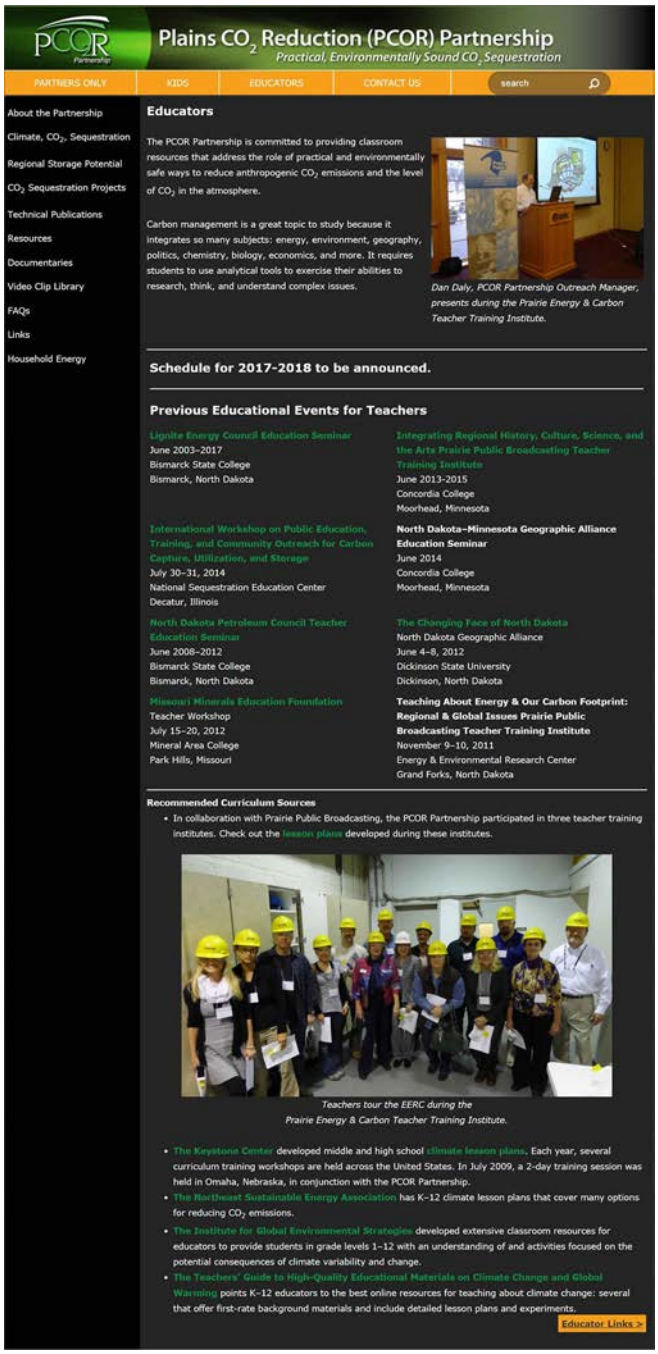


Figure 33. Updated Educators Web page.
Existing link: http://www.undeerc.org/PCOR/Educators/.

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_2 Sequestration Projects section; *The Bell Creek Story: CO_2 in Action* under the Documentaries section; and CO_2 EOR LCA Model under the Technical Publications section.

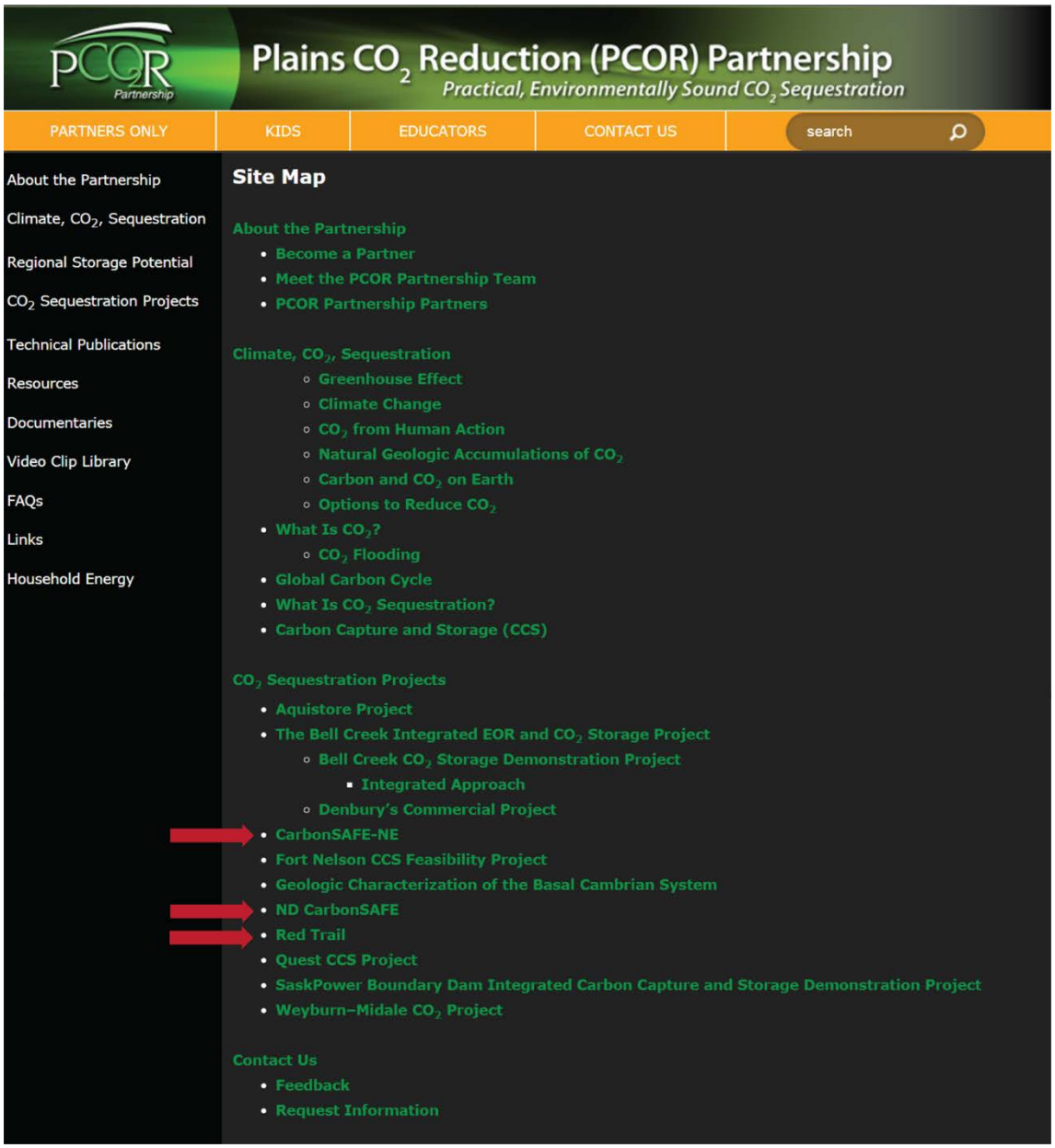


Figure 34. Updated Site Map page (continued).
Existing Link: undeerc.org/PCOR/SiteMap.aspx.

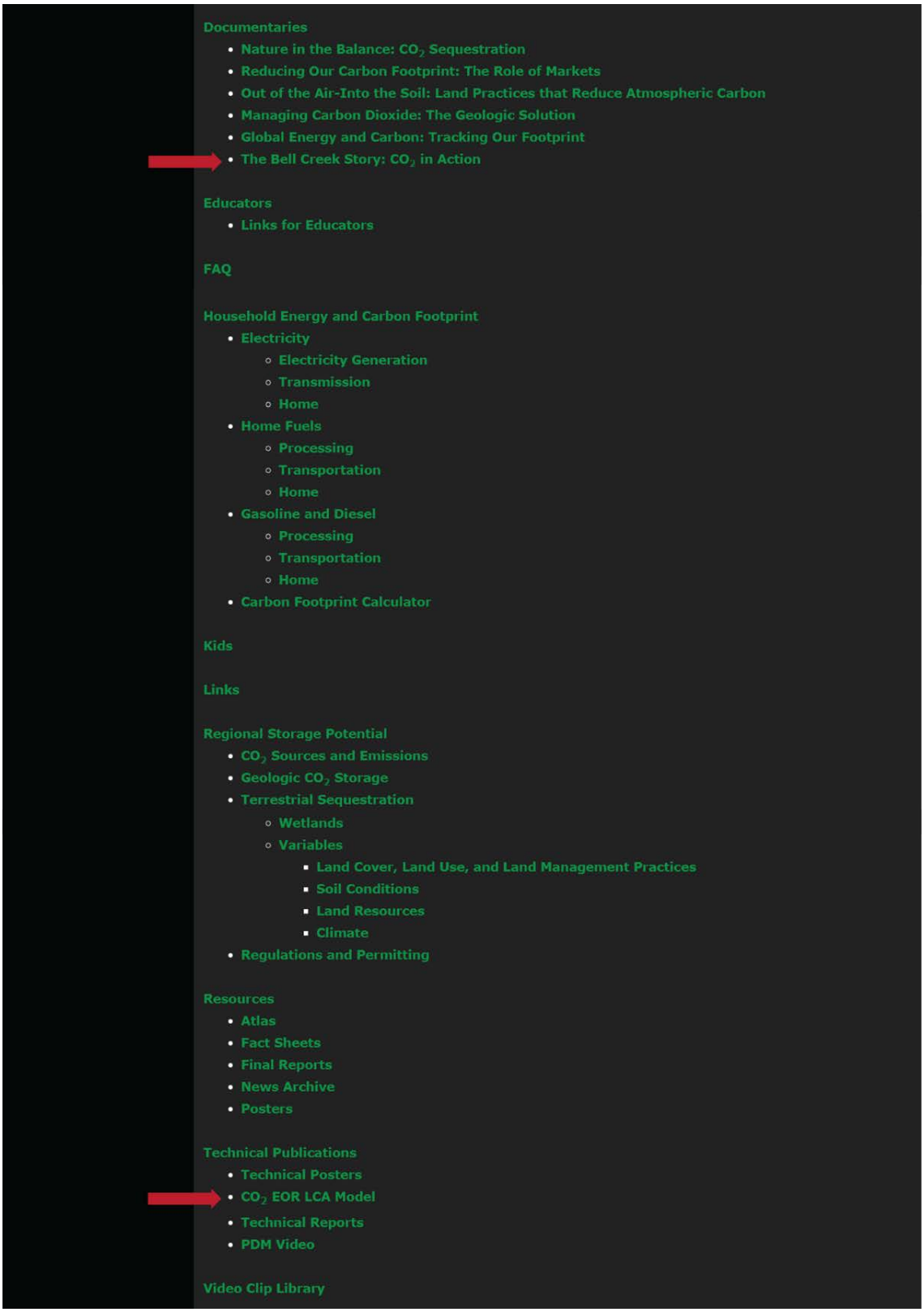


Figure 34. (continued) Updated Site Map page.
Existing Link: undeerc.org/PCOR/SiteMap.aspx.

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

What Is CO_2?

Carbon dioxide is a naturally occurring substance composed of one atom of carbon (C) and two atoms of oxygen (O_2). Its chemical formula is CO_2. CO_2 is gas under normal conditions.

Normal conditions are temperatures and pressures at or near the Earth's surface and in its atmosphere.

Like all substances, CO_2 can exist as solid, liquid, and gas. At temperatures below −78°C (−109°F), CO_2 condenses into a white solid called dry ice. Under normal conditions, dry ice vaporizes directly from a solid to CO_2 gas in a process called sublimation. Liquid CO_2 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_2 becomes a supercritical fluid. This occurs naturally at around 2500 feet below the Earth's surface.

CO_2 Exists Naturally

CO_2 occurs naturally in small amounts (about 0.04%) in the Earth's atmosphere.[1]

As a major greenhouse gas, CO_2 helps create and maintain the natural **greenhouse effect** that keeps our planet hospitable to life.

CO_2 is essential to plant life. Plants take in CO_2, 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_2 is formed again. This process is a key part of the **global carbon cycle**.

CO_2 is a by-product of our body's metabolism. Our lungs absorb oxygen from the air we breathe and exhale CO_2 as a waste product of cellular respiration.

CO_2 is produced naturally by processes deep in the earth. This CO_2 might be trapped in **natural underground geologic CO_2 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_2

CO_2 is added to soft drinks to make them bubbly.

Dry ice (frozen CO_2) is used to keep things cold.

CO_2 is also used in fire extinguishers (CO_2 displaces the oxygen the fire needs to burn).

Every day, millions of tons of CO_2 are injected into underground geologic zones to help produce oil in a well-known industry practice called "**CO_2 flooding**" or enhanced oil recovery.

Is CO_2 a Pollutant?

CO_2 formed by human action is called **anthropogenic CO_2**. Plowing the land, making cement, and burning fossil fuels for energy all create anthropogenic CO_2, which adds carbon to the **global carbon cycle**. Between 1751 and 2013, approximately 1440 billion metric tons of CO_2 has been emitted to the atmosphere from these sources.[2] This is raising concerns about climate change.

The U.S. Environmental Protection Agency has ruled CO_2 a pollutant in order to be able to regulate anthropogenic CO_2 emissions from human activities under the Clean Air Act of 1970.

Energy, CO_2, and Our Carbon Footprint

References:

1. 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_2 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 (accessed June 16, 2016).

Last updated 6/9/2016

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What Is CO_2 Sequestration?

Sequestration means storage. Carbon or CO_2 sequestration means putting carbon into long-term storage.

There are two major types of CO_2 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_2 directly from the atmosphere. This relatively passive storage mechanism is important because it can be implemented immediately and begin to reduce atmospheric CO_2 levels soon.

Geologic Storage involves capturing anthropogenic CO_2 before it enters the atmosphere and injecting it into underground formations. Once CO_2 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_2.

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Terrestrial Sequestration

Terrestrial (or biologic) sequestration means using plants to capture CO_2 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_2 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.[1] 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.

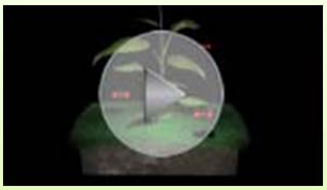
Mechanisms for Terrestrial Storage

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 [2,3]

Links:

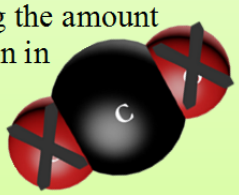
- **Sequestration Potential in Our Region**
- **Field Projects**



What is Terrestrial CO_2 Sequestration?

Carbon – *Not CO_2*

It is important to remember that terrestrial storage does not store CO_2 as a gas but stores the carbon portion of the CO_2. If the soil is disturbed and the soil carbon comes in contact with oxygen in the air, the exposed soil carbon can combine with O_2 to form CO_2 gas and reenter the atmosphere, reducing the amount of carbon in storage.



Sequestration Potential in the Prairies

Carbon Storage in the Landscape

References:

1. Paustian, K.H., and Cole, C.V., 1998, CO_2 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., 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_2 Reduction (PCOR) Partnership topical report for U.S. Department of Energy and multiclients, Grand Forks, North Dakota, Energy & Environmental Research Center, June.

Last updated 6/9/2016

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CCS Regulations and Permitting

Carbon capture and storage (CCS) projects are subject to regulation at the source of CO_2, 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_2. 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.

CCS Projects. In 2014, 136 CO_2 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_2 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.

Federal Regulations

- **United States** (34kb) pdf
- **Canada** (26kb) pdf

State and Provincial 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) https://energy.gov/sites/prod/files/nepapub/nepa_documents/RedDont/Req-NEPA.pdf	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) https://www.epa.gov/laws-regulations/summary-clean-water-act	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) https://www.epa.gov/laws-regulations/summary-clean-air-act	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) https://www.epa.gov/sdwa	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) https://www.fws.gov/laws/lawsdigest/ESACT.html	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) https://www.fws.gov/laws/lawsdigest/migtrea.html and the Bald Eagle Protection Act (BEPA, 1940) https://www.fws.gov/midwest/eagle/protect/laws.html	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) https://www.invasivespeciesinfo.gov/laws/execorder.shtml	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) http://laws-lois.justice.gc.ca/eng/acts/C-15.21/	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) http://laws-lois.justice.gc.ca/eng/acts/C-15.31/	The primary purpose of this act is to contribute to sustainable development through pollution prevention.
Transportation of Dangerous Goods Act (1992) http://laws-lois.justice.gc.ca/eng/acts/T-19.01/	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 *National Energy Board Act* or the *Oil and Gas Production and Conservation Act* or by the law of a province; or dangerous goods confined only by the permanent structure of a ship.
National Energy Board Act (1985) http://laws-lois.justice.gc.ca/eng/acts/N-7/	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) http://laws-lois.justice.gc.ca/eng/acts/F-14/	This act applies to fish habitat protection and pollution prevention as well as several other aspects of fishery regulation.
Canada Labour Code (1985) http://laws-lois.justice.gc.ca/eng/acts/L-2/	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_2 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_2 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.

Last updated 4/28/2017

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CO_2 Sequestration Projects

Aquistore

Aquistore Project
Location: Southeastern Saskatchewan, Canada
CO_2 Injection: ~2300 tons (2100 tonnes) a day
This project stores CO_2 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^2 spanning the U.S. and Canadian border
This collaboration between Canadian and U.S. researchers found excellent potential for long-term CO_2 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_2 Injection: ~1.1 million tons (1 million tonnes) a year
This commercial project is setting a new standard for safely and efficiently using CO_2 for enhanced oil recovery with associated CO_2 storage.
Status: Active (as of September 2017)

Boundary Dam

The Boundary Dam Carbon Capture Project
Location: Estevan, Saskatchewan, Canada
CO_2 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_2 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_2
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_2 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_2 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_2
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_2 Injected: 90 tons (82 tonnes)
This small-scale test demonstrated that unminable lignite coal seams may act as permanent underground storage zones for CO_2.
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_2
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_2 Huff 'n' Puff Field Validation Test
Location: Northwestern North Dakota, United States
CO_2 Injected: 440 tons (400 tonnes)
This small-scale test demonstrated CO_2 huff 'n' puff for enhanced oil recovery and associated CO_2 storage for isolated wells in deep oil-bearing limestone rocks.
Status: Completed 2009

Quest

Quest CCS Project
Location: Fort Saskatchewan, Alberta, Canada
CO_2 Injection: 1.1 million tons (1 million tonnes) a year
CO_2 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_2
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_2 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_2 in prairie ecosystems as a means to mitigate anthropogenic CO_2 emissions.
Status: Completed 2009

Weyburn–Midale

Weyburn–Midale CO_2 Project
Location: Saskatchewan, Canada
CO_2 Injection: 2.2 million tons (2 million tonnes) a yearCO_2 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_2 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_2
This pre-feasibility study looking at large-scale stationary CO_2 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_2 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_2.
Status: Completed 2012

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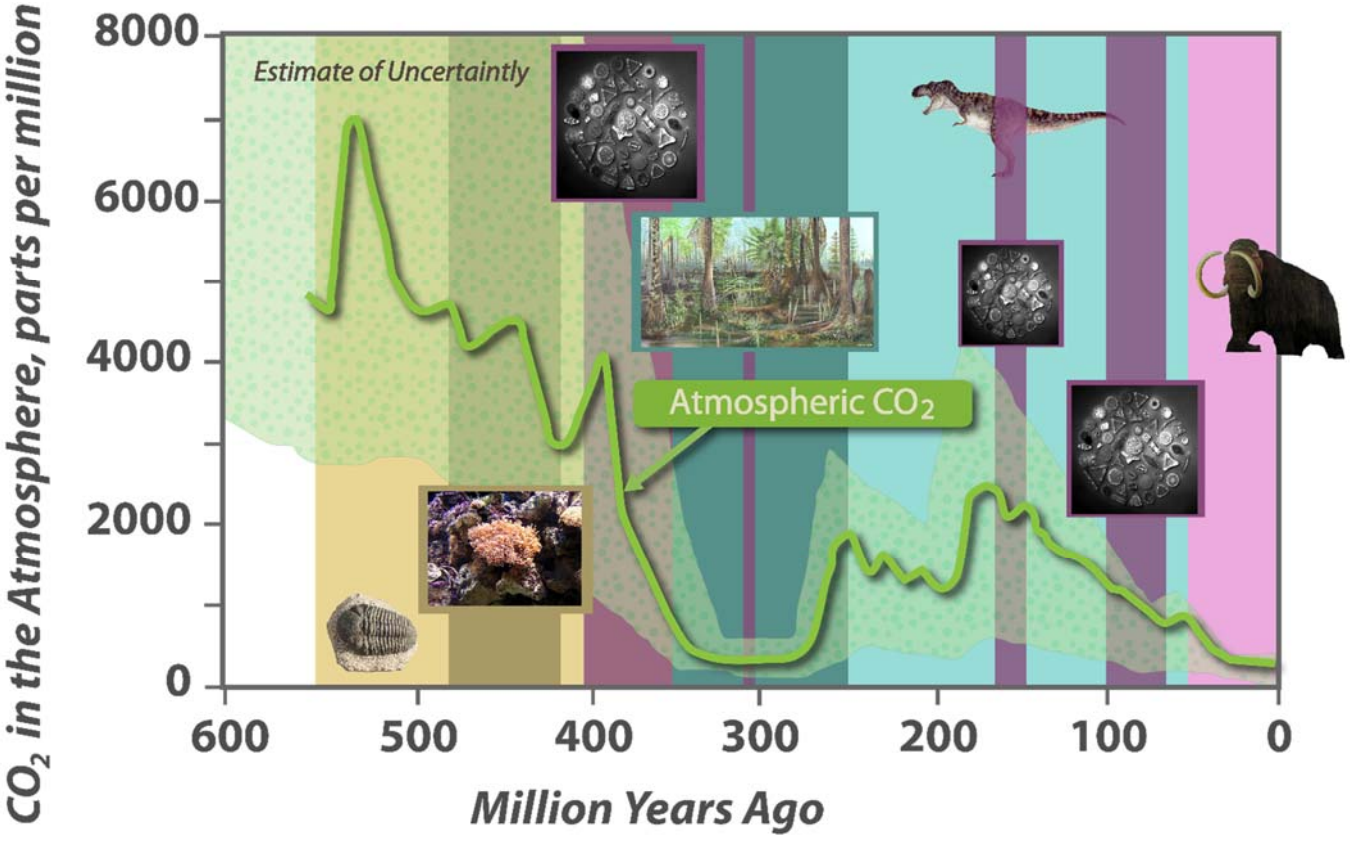
Plains CO_2 Reduction (PCOR) Partnership
Practical, Environmentally Sound CO_2 Sequestration

Carbon and CO_2 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.

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

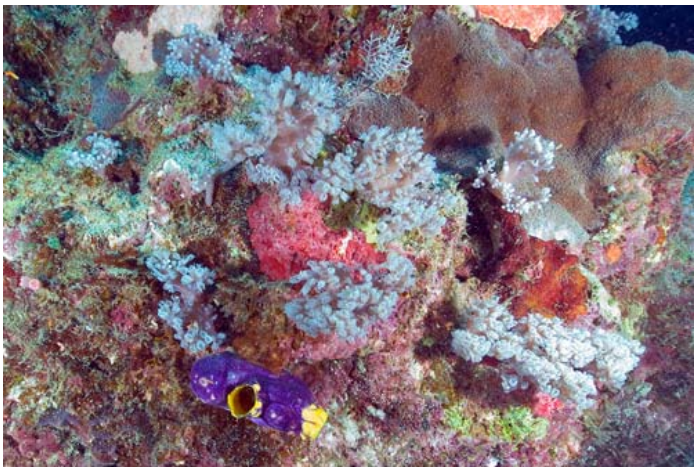
Scientists tell us that Earth started out about 4.5 billion years ago as a ball of hot gases. About 3.5 billion years ago, Earth was cool enough to have a solid crust as well as a primitive atmosphere. At the same time, carbon dioxide was being formed deep in the earth by geologic processes, and this CO_2 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_2 in the atmosphere. As biological production exploded over the last billion years, much of that atmospheric CO_2 was absorbed by plants and animals and buried in ocean sediments.



Estimated atmospheric CO_2 concentrations over the most recent 600 million years (up to 1950). Modified from earthguide.ucsd.edu.

CO_2 Sequestered in Limestone

According to scientists, the atmosphere of half a billion years ago contained about **20 times** the CO_2 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_2 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_2 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_2 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

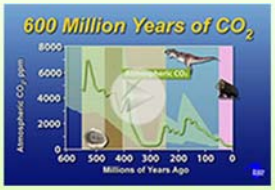
CO_2 Sequestered in Oil and Gas

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_2 Returns to the Atmosphere

Scientists tell us that the amount of CO_2 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_2 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_2 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_2 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.[1]



Atmospheric CO_2 Prehistoric to Modern

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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