MRCSP MIDWEST REGIONAL CARBON SEQUESTRATION PARTNERSHIP

MANAGING CLIMATE CHANGE AND SECURING A FUTURE FOR THE MIDWEST'S INDUSTRIAL

Geologic Sequestration of Carbon Dioxide

NETL NATIONAL ENERGY TECHNOLOGY LABORATORY

Geologic sequestration of carbon dioxide (CO_2) involves storage of the greenhouse gas in underground formations, after it has been captured from power plants or other large industrial facilities. It is an idea that is being pursued around the world in view of its potential to deliver significant reductions in CO_2 emissions. As part of a broader portfolio of technologies, geologic sequestration appears to be capable of playing an important role in stabilizing CO_2 concentrations in the atmosphere.

Much research is under way to determine how well CO_2 can be stored in various formations underground. This fact sheet provides a brief introduction to the topic and includes a set of additional resources at the end.

CO_2 can be separated and captured as a byproduct of fossil fuel, used for energy generation and numerous industrial processes. Currently a variety of technologies are in use or under development for separation and capture. For example, Integrated Gasification Combined Cycle (IGCC) technology converts fossil fuel, including coal, oil, natural gas, and biomass, into hydrogen gas and other components, including CO_2. This advanced technology facilitates CO_2 capture by creating a relatively pure and concentrated CO_2 stream. In addition, research is underway to develop technologies to capture CO_2 directly from the flue gases from combustion of coal, natural gas, and other fossil fuels. Once captured, CO_2 can possibly be compressed; transported via pipeline, similar to the way natural gas currently is transported; and, injected underground into a suitable storage area. A key focus of ongoing studies outside the Midwest Regional Carbon Sequestration Partnership (MRCSP) is reducing the high cost of separation, capture and transport.

Sequestration in geologic formations builds on a strong industry experience base. The primary types of geologic reservoirs for storing CO_2 underground under study are depleted oil and gas reservoirs, unmineable coal seams and deep saline formations. Many of these reservoirs have naturally stored crude oil, natural gas, brine and CO_2 over millions of years, and thus we know that they have at least the theoretical potential to store CO_2 from anthropogenic (man-made) sources. Many power plants and other large sources of CO_2 are located near geologic formations that are amenable to CO_2 storage. This proximity should reduce costs. Further, in many cases, injection of CO_2 into a geologic formation can enhance the recovery of hydrocarbons, providing value-added byproducts that can offset the cost of CO_2 capture and sequestration.

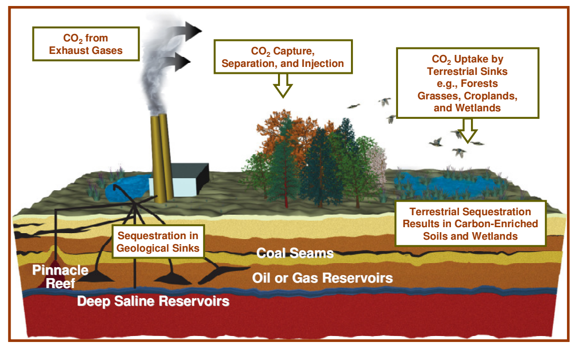
The U.S. Department of Energy's (USDOE) National Energy Technology Laboratory (NETL) is funding extensive research to understand the behavior of CO_2 when stored in geologic formations. For example, studies are being done to determine the extent to which CO_2 moves within the deep subsurface environment and the physical processes and chemical reactions within specific formation types that lead scientists to predict that once injected, CO_2 will remain in these formations permanently.

Near-term research efforts will focus on field testing of a variety of geologic storage options in order to ensure that geologic sequestration provides:

- Safe and permanent containment of CO_2
- Low environmental impact
- Low cost
- Conformity with national and international laws and regulations
- Public acceptability.

An important area of study for all types of underground storage is to develop measuring, monitoring and verification protocols. Needed protocols include the capability to 1) measure the amount of CO_2 stored at a specific sequestration site; 2) monitor the site for leaks or other storage integrity issues over time; and 3) ensure the stored CO_2 poses no threat to public health or the environment. In addition, each type of geologic reservoir system has its own unique characteristics as they relate to storing CO_2 and a resulting set of research priorities and opportunities. For example:

Oil and Gas Reservoirs. The U.S. is a world leader in enhanced oil recovery technology, using about 32 million tons of CO_2 per year for this purpose. In enhanced oil recovery a combination of CO_2 and water is pumped into depleted oil wells to re-pressurize wells and "push" additional oil toward production equipment. The Weyburn CO_2 enhanced recovery project in Saskatchewan uses about 1 million metric tons of CO_2 per year. Enhanced oil and gas recovery offers the highest near-term potential for storing CO_2, as well as an opportunity to sequester carbon at low cost, due to the revenues from recovered oil or gas. Currently, the scope is limited economically to point sources of CO_2 emissions that are near an oil or gas reservoir.



Source: Block diagram provided from the Plains CO_2 Reduction (PCOR) Partnership Regional Atlas (2005): Modified from Oak Ridge National Laboratory (2000). Original rendering by LeJean Hardin and Jamie Payne.

In an enhanced oil recovery application, the fate of the CO_2 that remains in the reservoir is well understood. In these applications, however, CO_2 was considered an added production expense and the amount left in the reservoir was minimized. DOE currently is supporting research on the long-term monitoring and verification of CO_2 storage as well as additional information such as the optimum combination of sequestration and enhanced oil recovery.

In addition to enhanced recovery operations, depleted oil and gas fields are natural reservoirs for storing CO_2. Depleted reservoirs can make attractive CO_2 sequestration targets since they have already proven their ability to contain oil, gas and water for millions of years and their geologic character is well defined by previous exploration efforts.

Unmineable Coal Beds. Coal beds in the subsurface typically contain large volumes of methane-rich natural gas. A high percentage of this gas is adsorbed naturally on to the surface of the coal. Currently, methods for recovering coal-bed methane involve depressurizing the reservoir by pumping water out of the coal, thus permitting those methane molecules adsorbed on the surface of the coal to be released as free gas. An alternative approach for methane recovery is to inject CO_2 into the coal bed. Experiments indicate that coal beds have an affinity to absorb approximately twice as many CO_2 molecules as compared to methane. Thus, the potential exists to displace and recover coal bed methane efficiently. CO_2 recovery of coal bed methane has been demonstrated in limited field tests; however, additional research is needed to understand and optimize the process.

Similar to the by-product value gained from enhanced oil recovery, the recovered methane provides a value-added revenue stream to the carbon sequestration process, creating a lower net-cost option. The DOE Office of Fossil Energy estimates that 90 percent of coal reserves in the U.S. are unmineable due to inadequate coal thickness, extreme depth or a lack of internal continuity of the coal bed. A substantial portion of these unmineable resources may be amenable to methane recovery from CO_2 injection.

Finally, many fossil-fired electricity generating stations (potential candidate sources of CO_2 for geologic sequestration) are located near to or in regions with substantial unmineable coal resources, reducing the extent of pipeline transportation of CO_2 required.

In the past few years, DOE has funded field experiments to thoroughly evaluate CO_2 injection into coal beds. Most notable of these are the Coal-Seq project in the San Juan Basin in New Mexico; and a seven-year project, including a five-year monitoring program, being conducted by CONSOL Energy in the northern panhandle of West Virginia.

Deep Saline Reservoirs. Deep saline reservoirs are saltwater formations located many thousands of feet below the earth's surface. These reservoirs have two important benefits as CO_2 storage options. First, the estimated carbon storage capacity of saline formations in the U.S. is very large, making them a viable long-term solution. And second, many existing large CO_2 point sources are within easy access of a saline formation injection point. As with all of these geologic formations, understanding how CO_2 moves within the formation and ensuring it stays there are key aspects of sequestration research.

NETL has initiated a number of field tests to study the behavior of CO_2 after it is injected into a formation. NETL also seeks to characterize potential sites to ensure their suitability of the geology (earth and rock structures). Factors to confirm include:

- The impermeability of the rock (cap rock) above the proposed storage area to prevent CO_2 from gradually moving upwards in the formation. For example, the presence of a thick shale without interconnected cracks would indicate an effective cap (shales have a texture that does not permit fluids or gases to move through them)

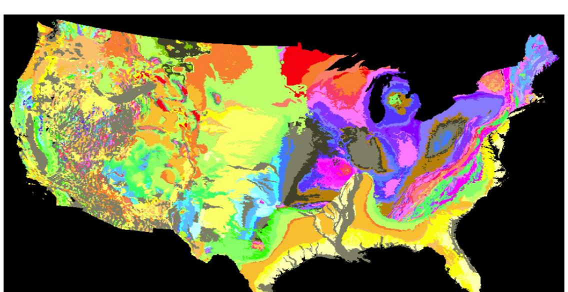
- The storage capacity of the rock formation, i.e., whether it can hold enough CO_2 to be worth the cost of injection

- The distribution of the CO_2 in the reservoir and the chemical reactions that occur between the CO_2 and the reservoir rock and fluids

- A lack of faults in the area of injection operation that would avoid migration of fluids.

MRCSP Research

The Midwest Regional Carbon Sequestration Partnership (MRCSP) is one of seven regional partnerships established by the USDOE to research and develop carbon sequestration technologies for possible deployment in the future as one option for mitigating climate change. The research is being conducted in three incremental phases. In Phase I, from 2003-2005, the MRCSP identified regional sources of carbon dioxide emissions and storage opportunities. The research was led by the Ohio Division



Source: Schruben, P.G., R.E. Arndt, and W.J. Bawiec, 1997, Geology of the Conterminous United States at 1:250,000 scale ---A Digital Representation of the 1974 P.B. King and H.M. Beikman Map: U.S. Geological Survey Digital Data Series DDS-11, release 2.

of Geological Survey, working with staff at the State Geological Surveys of Indiana, Kentucky, Maryland, Pennsylvania, and West Virginia and the Department of Geosciences at Western Michigan University. The results of this research are available on this website (see Phase I report). The research did not include New York or New Jersey which were not members of the MRCSP during Phase I. Data will be added in the future. During Phase II, a four-year program which began in 2005 and is ongoing, the MRCSP began implementing three small-scale, field validation tests in Michigan, Ohio and Kentucky. Concurrently in 2008, the MRCSP began Phase III of the research program. This third research phase will involve a large-scale geologic field test. The test is scheduled to occur over a ten-year period and will inject a larger amount of carbon dioxide for a longer period of time.

In addition to conducting specific site tests, the MRCSP aims to characterize and quantify the overall sequestration potential of the geological formations underlying our region (shown above). For more information about this map, please see: http://geo-nsdi.er.usgs.gov/metadata/digital-data/11/metadata.faq.html.

Please see the following web sites:

1. The DOE/NETL web site at: http://www.netl.doe.gov/technologies/carbon_seq/index.html. The site includes a wide variety of information, including links to newsletters, journals, papers, news reports, a video and program plans. For a comprehensive overview of current activities and plans, link to the *Carbon Sequestration Technology Roadmap and Program Plan*.

2. The DOE/NETL ATLAS available on the DOE/NETL web site reference shelf at: http://www.netl.doe.gov/technologies/carbon_seq/refshelf/refshelf.html. See also, the web site of the MIDCARB research consortium (Midcontinent Interactive Digital Carbon Atlas and Relational DataBase) which presents the results of its research evaluating the capacity for geologic sequestration in the member States Illinois, Indiana, Kansas, Kentucky and Ohio at: http://www.MIDCARB.org.

3. The International Energy Agency's web site at: www.ieagreen.org.uk/ and companion site focusing on carbon capture and storage at: http://www.co2captureandstorage.info/.

4. The Intergovernmental Panel on Climate Change: http://www.ipcc.ch/.

For More Information

For more information about carbon sequestration and the MRCSP and its activities see www.mrcsp.org. If you have questions or comments, contact Dave Ball, Project Manager at Balld@battelle.org (614-424-4901) orTraci Rodosta, the USDOE Project Manager at Traci.Rodosta@NETL.DOE.GOV.