Overview of Geologic Sequestration

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Introduction

Geologic sequestration, a type of carbon dioxide (CO2) capture and storage (CCS) process, is a promising technology for stabilizing atmospheric greenhouse gas concentrations. Instead of releasing CO2 to the atmosphere, geologic sequestration involves separating and capturing CO2 from an industrial or energy-related source, transporting it to a storage location, and injecting it deep underground for long-term isolation from the atmosphere. Figure 1 below depicts the chain of activities involved in geologic sequestration: capture, transport and injection.

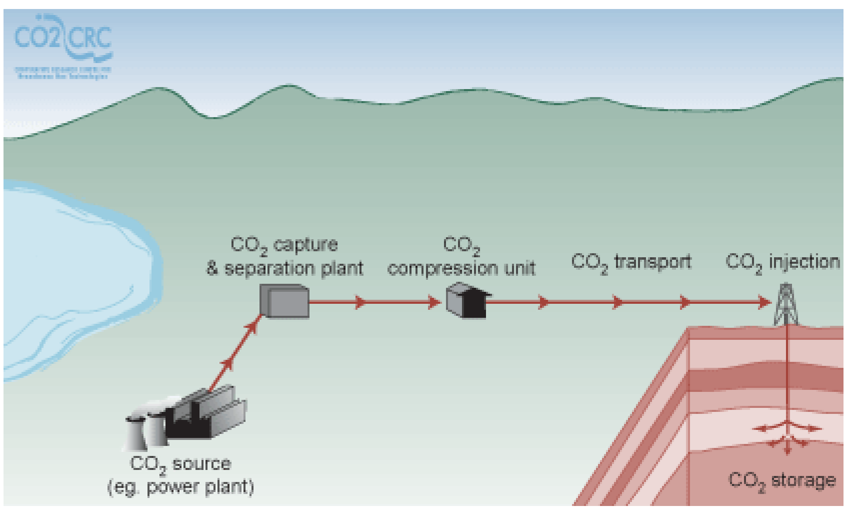

Figure 1: Geosequestration Four Main Steps. Figure courtesy: CO2CRC EXIT Disclaimer

Capture

The goal of CO2 capture is to produce a concentrated stream of CO2 that can be readily transported to a geologic sequestration site. Capture of CO2 can be applied to large stationary sources such as power plants, cement or ammonia production or natural gas processing. Several technologies, in different stages of development, exist for CO2 capture. Although these technologies are currently used in a limited number of facilities, research is still needed to improve the efficiency and cost.

Transport

After the CO_2 is captured from the source and compressed, it can be geologically sequestered on-site or transported to a separate injection site. CO_2 can be transported as a liquid in ships, road or rail tankers, but pipelines are the most efficient and cost-effective approach for transporting large volumes of CO_2. In the U.S., there is a network of CO_2 pipelines that supply CO_2 to oil and gas fields, where it is used to enhance oil recovery. The majority of the 40 Tg CO_2* transported in these pipelines today is produced from natural CO_2 reservoirs; however, the same pipelines can carry CO_2 captured from industrial facilities. In fact, a synfuels plant located in North Dakota (Dakota Gasification) has been transporting captured CO_2 via pipeline to a sequestration site hundreds of miles away in Canada since 2000.

* Tg = 10^9 kg = 10^6 metric tons = 1 million metric tons

Injection and Sequestration

Once a suitable geologic formation has been identified through detailed site characterization, CO_2 is injected into that formation at a high pressure and to depths generally greater than 2625 feet (800 meters). Below this depth, the pressurized CO_2 remains "supercritical" and behaves like a liquid. Supercritical CO_2 is denser and takes up less space. Once underground, the CO_2 occupies pore spaces in the surrounding rock, like water in a sponge. Saline water which already resides in the pore space will compress under pressure and/or move to allow room for the CO_2. Over time, the CO_2 also dissolves in water and chemical reactions between the dissolved CO_2 and rock can create solid carbonate minerals, more permanently trapping the CO_2.

Suitable geologic storage sites have a caprock, which is an overlying impermeable layer that prevents CO_2 from escaping back towards the surface. Target formations for sequestration include geologic formations, both on and off-shore, that can demonstrate their ability to retain CO_2 for very long periods of time. Well-suited formations include the following:

- Deep saline formations, rock units containing water with a high concentration of salts, are thought to have the largest storage capacity.
- Depleted oil and gas reservoirs are also targeted for CO_2 sequestration and have a history of retaining fluids and gases underground for geologic timescales. There is also more data available on these formations which may help characterize and better predict the long-term fate of injected CO_2.
- Unminable coal beds, which are either too thin or too deep to be mined economically, offer less storage capacity but they have the benefit of enhancing the production of methane, a valuable fuel source. Less is known about the efficacy of using these formations as targets for sequestration, but research is underway to evaluate them.

Storage Capacity

With proper site selection and management, geologic sequestration could play a major role in reducing emissions of CO_2 EXIT Disclaimer (IPCC, 2005). Current assessments indicate that the storage capacity of these geologic formations is extremely large and widespread, with a significant proportion of storage opportunities in the U.S. In the U.S., an evaluation of CO_2 sources and potential storage sites suggests that 95% of the largest 500 point sources (i.e., power plants and other industrial facilities), accounting for 82% of annual CO_2 emissions, are within 50 miles of a candidate CO_2 reservoir. For more information on potential storage sites in the U.S., please see the 2006 GTSP report (PDF, 37 pp., 6.05 MB, About PDF) (GTSP, 2006).

Risk Management

There is limited experience with commercial-scale geologic sequestration today. However, closely related and well-established industrial experience and scientific knowledge can serve as the basis for appropriate risk management strategies. Key components of a risk management strategy include appropriate site selection based on thorough geologic characterization, a monitoring program to detect problems during or after injection, appropriate remediation methods if necessary and a regulatory system to protect human health and the environment. Please see the IPCC Special Report EXIT Disclaimer (IPCC, 2005).

Potential pathways exist for CO_2 to migrate from the target geologic formation to shallower zones or back to the atmosphere. These conduits for CO_2 leakage could be largely avoided through proper site characterization and selection. Pathways for CO_2 leakage include escape through the caprock (if it is compromised by high pressures or chemical degradation), an undetected or reactivated fault or an artificial penetration such as a poorly plugged abandoned well. In addition to careful site selection, a proper monitoring program can help ensure that CO_2 does not escape from the storage site. A monitoring system would detect movement of CO_2 into shallower formations and allow significant time to take corrective action in order to reduce potential impacts to human health and the environment.

Ground water could be affected both by CO_2 leaking directly into an aquifer and by saline ground water that enters an aquifer as a result of being displaced by injected CO_2. The risk of these impacts can be minimized through appropriate management strategies. Underground injection of CO_2 for the purpose of sequestration is regulated by the Underground Injection Control (UIC) Program under the Safe Drinking Water Act (SDWA). The UIC program ensures that injection activities are performed safely and do not endanger current or future sources of drinking water.

Existing and Planned Projects

Internationally, commercial-scale geologic sequestration (greater than 1 Tg CO_2 per year) is occurring or planned in various locations. Projects that are underway include the Weyburn CO_2 Flood Project (Canada), Sleipner (Norway), and In Salah (Algeria).

The Weyburn CO_2 Flood Project (PDF, 24 pp., 258 KB, About PDF) in Canada is the first international CO_2-enhanced oil recovery (EOR) project to be studied extensively. The CO_2 source is the Dakota Gasification plant near Great Plains, North Dakota. Unlike traditional EOR operations, the Weyburn operator will not use conventional end of projects techniques, which can release CO_2, but will maintain the site in order to test and monitor long-term sequestration.

Commercial-scale geologic CO_2 sequestration is also occurring at the Sleipner West EXIT Disclaimer field in the North Sea. Sleipner West is a natural gas/condensate field located about 500 miles off the coast of Norway. The CO_2 is compressed and injected via a single well into a 500 foot thick, saline formation located at a depth of about 2,000 feet below the seabed.

In 2004, a CO_2 capture and storage project was launched at the In Salah gas field EXIT Disclaimer, in the Algerian desert. Approximately 10% of the produced gas is made up of CO_2. Rather than venting the CO_2, a common practice on projects of this type, this project is compressing and injecting it 5900 feet deep into a lower level of the gas reservoir where the reservoir is filled with water. Around one million tons of CO_2 will be injected into the reservoir every year.

Additionally, commercial scale projects are planned throughout the world. More information can be found on international projects through the Carbon Sequestration Leadership Forum (CSLF) EXIT Disclaimer, an international climate change initiative focused on the development of improved cost-effective technologies for the separation and capture of CO_2 for its transport and long-term safe storage.

In the U.S., the Department of Energy (DOE) is the lead federal agency on research and development of geologic sequestration technologies. The Department of Energy's Fossil Energy program is developing a portfolio of technologies that can capture and permanently store greenhouse gases. As part of this portfolio, DOE and an industry alliance recently launched FutureGen, an initiative to complete the world's first near-zero emissions, coal-based power plant with sequestration by 2012. DOE is also sponsoring a number of small-scale CO_2 pilot projects designed to learn more about how CO_2 behaves in the sub-surface and answer practical technical questions on how to design and operate geologic sequestration projects.

References

- GTSP, 2006: Carbon Dioxide Capture and Geologic Storage: A Core Element of a A Global Energy Technology Strategy to Address Climate Change (PDF, 37 pp., 6.05 MB, About PDF). April 2006, JJ Dooley et al. Global Energy Technology Strategy Program (GSTP)
- IPCC, 2005: Special Report on Carbon Dioxide Capture and Storage, Special Report of the Intergovernmental Panel on Climate Change EXIT Disclaimer [Metz, Bert, Davidson, Ogunlade, de Coninck, Heleen, Loos, Manuela, and Meyer, Leo (Eds.)]. Cambridge University Press, The Edinburgh Building Shaftesbury Road, Cambridge CB2 2RU England