CCS

inFocus Carbon Capture & Storage

Is Geologic CO_2 Storage Safe?

There is scientific consensus, and growing evidence, that geologic storage has great potential for safely and permanently storing carbon dioxide (CO_2). Additional research is underway to acquire the data needed to completely validate CO_2 storage potential, capability, reliability, and safety.

Overview

The idea of injecting large quantities of CO_2 underground and having it stay there without leaking or causing environmental harm is a concern for some people unfamiliar with carbon capture and storage (CCS) technology. But there is a growing body of evidence that geologic storage is both safe and effective. Ongoing global research is helping scientists accumulate information needed to conclusively verify all operational and safety aspects of long-term CO_2 storage in depleted or declining oil and natural gas fields, saline reservoirs, unmineable coal seams, and other significant geologic formations. The goal is to scientifically confirm storage safety across the diversity and composition of storage sites, both necessary predecessors of large-scale commercial CCS deployment. CCS is widely considered a key component of a portfolio response strategy (including renewable and nuclear energy, and increased energy efficiencies) necessary for meeting ambitious worldwide atmospheric CO_2 reduction goals.

> **"The reason CO_2 storage works is simple: it uses the same natural trapping mechanisms which have already kept huge volumes of oil, gas, and carbon dioxide underground for millions of years."**
>
> European Technology Platform for Zero Emission Fossil Fuel Power Plants (ZEP)
>
> Did You Know?

Can CO_2 be securely stored in deep underground geologic formations?

Evidence, both natural and human-generated, strongly suggests the answer is a definitive "yes." The United Nations Intergovernmental Panel on Climate Change (IPCC) notes there are many natural geologic deposits of CO_2 trapped in rock formations underground: "**Underground accumulation of carbon dioxide (CO_2) is a widespread geological phenomenon, with natural trapping of CO_2 in underground reservoirs.**"[1] Natural trapping mechanisms, including pressure and physical and chemical characteristics of rock and geologic formations, have kept large volumes of not only CO_2, but also oil and natural gas deep underground for millions of years.

[1] United Nations Intergovernmental Panel on Climate Change (U.N. IPCC), "Special Report on Carbon Dioxide Capture and Storage: Chapter 5, Underground Geologic Storage," 2005, 5-4.

Additionally, the oil and gas industry has used CO_2 injection and storage for more than 40 years to recover oil from depleted or declining fields (known as "Enhanced Oil Recovery," or EOR). Currently in the United States (which accounts for 94 percent of worldwide CO_2-EOR oil production), more than 48 million tonnes (or 52.8 million short tons) per year of CO_2 are used for this purpose.[2]

Finally, there is the experience gained from demonstration projects around the world.

Eight Projects Actively Capturing and Storing CO_2

Project Name	Location	Started Storage (Year)	Tonnes Stored Annually*
Sleipner EOR	Norway	1996	1.0
Weyburn-Midale EOR	Canada	2000	2.7–3.2
In Salah Gas Storage EOR	Algeria	2004	1.2
Crust K12-B Test	Netherlands	2004	0.2
Zama (EOR)	Canada	2005	0.067
Snøhvit Field LNG and CO_2 Storage	Norway	2008	0.75
SECARB Cranfield EOR	United States	2009	1.0–1.5
Mountaineer CCS	United States	2009	0.1

*** Million Tonnes**

As of 2010, the three longest operating projects — Sleipner, Weyburn-Midale, and In Salah — had a cumulative total of 11 million, 18 million, and 3 million tonnes of CO_2 stored, respectively.

Three large-scale projects — Sleipner, Weyburn, and In Salah — have been injecting and successfully storing 1 million to 3 million tonnes of CO_2 annually for several years; five others have more recently begun operations; no adverse safety, health or environmental effects have resulted from any of these projects. Through these and other projects that are operating or will be soon, scientists are acquiring the data needed to completely validate the capacity and potential impact of geologic CCS. Continuing this research is vital to deploying the technology on a commercial basis. Based on the success encountered thus far, experts believe good site selection and characterization, proper CO_2 injection rates, appropriate monitoring, and safe operational and remedial practices will assure the long-term viability of CCS technology.

But what happens if a CO_2 leak occurs?

Potential geologic storage sites will need to be carefully selected and managed so as to minimize any chance of CO_2 leakage. Given the complexity of most geologic reservoirs and the potentially huge volumes of CO_2 that may be injected, the possibility of some leakage over time may never be completely eliminated. But scientists expect the reservoir characterization process (using geologic and engineering data to quantify a potential storage area's characteristics) will rule out geologic formations that do not have adequate caprocks or other geologic seals, are intersected by faults or fractures that might be pathways for escaping CO_2, or are in areas prone to earthquake or volcanic activity. Additionally, measuring, monitoring, and verification programs will be used to plot the migration of injected CO_2 over time to detect potential reservoir leakage.

[2] National Energy Technology Laboratory, "Carbon Sequestration Through Enhanced Oil Recovery," http://www.netl.doe.gov/publications/factsheets/program/Prog053.pdf, April 2008, 2.

The geological formations that would be used to store CO_2 are porous rock (not open underground caverns), making massive releases extremely unlikely. In fact, because the CO_2 becomes trapped in the tiny pores of rocks, any leakage through the geological layers would be extremely slow, allowing plenty of time for it to be detected and dealt with. Any such leak would not raise local CO_2 concentrations much above normal atmospheric levels.[3]

Higher concentration leaks could come from man-made wells and are likely to diffuse quickly. In addition, the oil and gas industry already has 50 years of experience in monitoring wells and keeping them secure. Storage sites will not, of course, be located in volcanic areas.

Should movement of CO_2 from the storage reservoir occur during or after injection, methods are generally available to fix the leak. Most of these methods have long been used to fix leaks from other types of wells (used for natural gas storage and liquid waste disposal). These techniques can also be used for CO_2, with the advantage that unlike those other materials, CO_2 is not explosive, flammable, or toxic. It is reasonable to expect that these techniques would work for CO_2. Because it has not been necessary to fix leaks at existing geologic storage projects, they have not yet been used for this purpose.

> **"... evidence from natural systems demonstrates that reservoir seals exist that are able to confine CO_2 for millions of years and longer."**
>
> United Nations Intergovernmental Panel on Climate Change, "Special Report on Carbon Dioxide Capture and Storage," 5-61.
>
> Did You Know?

Can stored CO_2 explode?

CO_2 does not burn or explode; in fact, it is a flame retardant commonly used in extinguishers. CO_2 is only problematic at very high concentrations in closed settings.

Although it is a major greenhouse gas, CO_2 is also a fundamental and essential part of nature. Plants need it to grow, while animals and humans exhale it. It also leaks naturally from volcanoes and geysers.

Can injecting CO_2 underground cause earthquakes?

CO_2 storage operations are designed to avoid inducing earthquakes. A detailed survey takes place to identify any potential leakage pathways (including seismic faults) before a CO_2 storage site is selected — if these are discovered, then the site will not be selected for CO_2 injection.

During injection, scientists and engineers can ensure that the pressure of the CO_2 does not exceed the strength of the rock by limiting injection rates and volumes, thereby avoiding over-pressurization of the reservoir.

Additionally, CO_2 storage sites have demonstrated the ability to retain injected carbon dioxide even if a natural earthquake occurs nearby. In October 2004, a major earthquake measuring 6.8 on the Richter scale occurred 12 miles from the injection site of a CO_2 geologic storage site at Nagaoka, Japan. This project stored CO_2 in a saline formation nearly a mile deep. Injection activities were halted immediately after the earthquake, but were resumed shortly thereafter. The storage formation was monitored before, during, and after the earthquake and no leakage has ever been detected.[4] Further evidence that earthquakes would not cause leaks is that a large number of producing oil and gas fields in California are near seismically active faults. They have virtually the same trapping mechanisms as CCS and earthquakes over many years have not caused them to leak.

[3] European Technology Platform for Zero Emission Fossil Fuel Power Plants, "Frequently Asked Questions," n.d., http://www.zeroemissionsplatform.eu/faq.html/carbon-dioxide-capture-and-storage.

[4] Hiroshi Yamagata, Japan Ministry of Economy, Trade, and Industry, "Carbon Capture and Storage Activities in Japan," n.d., http://www.cslforum.org/publications/documents/Japan_CCS.pdf, 4.

carbon sequestration leadership forum

Can geologic CO_2 storage cause groundwater contamination?

To date, no known contamination of groundwater has occurred from the capture and geologic storage of CO_2.[5] Storage sites must be properly selected/designed, fully characterized, and appropriately monitored. If a site was to be improperly characterized or designed and leakage occurred that was not subsequently controlled, then CO_2 could migrate toward the surface.

CO_2 injection will be much deeper (more than a mile underground) than usable sources of groundwater and will generally be contained by one or more layers of thick, impermeable caprock.

CO_2 injection is proposed for deep saline formations containing water, but this water is unusable because of its high salt and mineral content. Given proper site selection and operation, the risks to usable water supplies would be extremely small. In the unlikely event that CO_2 would migrate upward toward shallower groundwater, seismic monitoring, groundwater analysis, and chemical tracers can detect any CO_2 that migrates upward into groundwater reservoirs and evaluate its effect on water quality.

"On the surface, air and soil sampling can be used to detect potential CO_2 leakage while changes deep underground can be monitored by detecting sound (seismic), electromagnetic, gravity, or density changes within the rock formations."

World Coal Institute, "IEA Greenhouse Gas R&D Programme," 4.

Did You Know?

What is at risk if CO_2 leaks?

CO_2 is not toxic, flammable, or explosive (like methane or propane gas, for example), but if allowed to accumulate in enclosed spaces at high concentrations, CO_2 could displace oxygen and cause unconsciousness or asphyxiation. The chances of such high concentrations forming during CO_2 injection for carbon storage are remote, assuming the reservoir is well characterized.

The effects of CO_2 on terrestrial ecosystems are well known as there are many places worldwide where CO_2 seeps naturally to the surface before harmlessly dispersing in the air. We also know that soils commonly contain high concentrations of natural CO_2 produced by the respiration of soil organisms and many soil animals are tolerant of CO_2 levels in the 10–15 percent range. The effects on other animals and humans are also well known — man has been living in high CO_2 flux areas (e.g., near volcanoes) since prehistoric times.

How would leaks be detected?

Before a CO_2 storage site is chosen, a detailed survey takes place to identify any potential leakage pathways and assess the storage integrity of the site. Only sites with a high level of integrity are selected for CO_2 storage. In the United States, Europe, and other parts of the world, underground gas storage (natural gas and hydrogen) has an excellent safety record, with sophisticated monitoring techniques that are easily adaptable to CCS.

Surface air and soil sampling can be used to detect potential CO_2 leakage, while underground changes can be monitored by detecting sound, electromagnetic, gravity, or density changes (see World Coal Institute reference in box above).

[5] Sally M. Benson, "Carbon Dioxide Capture and Storage: Assessment of Risks from Storage of Carbon Dioxide in Deep Underground Geological Formations," 2 April 2006, 22.

The risk of leakage through man-made wells is expected to be minimal because they can easily be monitored and fixed, and closed, if necessary.

Sources for Additional Information

- United Nations Intergovernmental Panel on Climate Change, http://www.ipcc.ch/
- International Energy Agency, http://www.iea.org/
- World Coal Institute, http://www.worldcoal.org/
- The World Bank, http://www.worldbank.org/
- European Zero Emissions Platform, http://www.zeroemissionsplatform.eu/

Other inFocus Factsheets:

- Why Carbon Capture and Storage?
- CO_2 Capture — Does it Work?
- Underground CO_2 Storage: A Reality?
- CO_2 Transportation — Is It Safe and Reliable?
- 10 Facts About CCS