GLOBAL CCS INSTITUTE

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GEOLOGICAL CO_2 STORAGE

Storing carbon dioxide (CO_2) underground is not a new or emerging technology – it is an existing reality on an industrial scale. In fact, there are geological systems that naturally contain CO_2 and many others throughout the world that experts have determined can retain centuries worth of injected CO_2. This will help abate climate change by removing and keeping this greenhouse gas out of the atmosphere.

How does geological storage of CO_2 work?

Geological storage involves injecting CO_2 captured from industrial processes into rock formations deep underground that have the capacity for large volumes of the greenhouse gas and containment characteristics that will not allow it to leak. This way, the CO_2 is permanently isolated from the atmosphere.

The following geologic characteristics are typically associated with effective storage sites:

- the storage formations have enough voids, or pores, in the rock to allow the injection of CO_2;

Image source: PCOR Partnership Staff, 2011, Plains CO_2 Reduction (PCOR) Partnership atlas (4th ed.): Grand Forks, North Dakota, Energy & Environmental Research Center [in preparation].

- the pores in the rock are connected well enough, a feature called 'permeability', so that the CO_2 can move and spread out within the formation, providing the capacity to accept the needed amount of CO_2; and
- the formation has an extensive cap or barrier at the top to contain the CO_2 for hundreds to thousands of years, and longer.

Fortunately, there are many locations around the world that have formations with these characteristics, and most of these are found in vast geological features called 'sedimentary basins'. Almost all oil and gas production is associated with sedimentary basins, and the types of geologic formations that trap oil and gas (and also naturally occurring CO_2) include sandstones, limestones and dolomites that are similar to those that make good CO_2 storage reservoirs. It is the natural geologic characteristics that resulted in oil and gas being trapped for millions of years before they were discovered that make secure geologic storage of CO_2 such a viable option for greenhouse gas mitigation.

How is CO_2 injected underground and why does it stay there?

Once captured, the CO_2 is compressed into a fluid almost as dense as water (known as a 'supercritical state'), and then pumped down through a well into a porous geological formation, as described above.
The pores in underground formations are initially filled with a fluid, either oil, gas, or much more commonly, very salty water. Although CO_2 can be injected into oil reservoirs to help with oil recovery, most future large-scale CO_2 injection projects will target a saline water-bearing formation for storage as they are more common and can have enormous capacity. In general, depths greater than 800 metres are desired to keep the CO_2 in the compressed, or dense, state.

Because the CO_2 is initially slightly more buoyant than water, a portion will migrate to the top of the formation, where it becomes trapped beneath the impermeable caprock that acts as a seal. And in most natural systems there are numerous thick barriers between the reservoir and the surface.

Some of the CO_2 will start to dissolve slowly into the saline water becoming effectively trapped indefinitely, whereas another portion of CO_2 can become residually trapped in tiny pore spaces. The ultimate trapping process involves dissolved CO_2 reacting with the reservoir rocks to form a mineral, much like snails or clams use calcium and carbon from seawater to form their hard shells. Depending on the reservoir minerals present this process can be relatively quick or very slow, but it effectively transforms the CO_2 into a solid mineral.

Is underground storage of CO_2 safe?

Three industrial-scale storage projects – injecting up to two million tonnes of CO_2 annually into saline formations – have been operating for many years, along with other smaller projects actively capturing and storing CO_2.

These industrial-level experiences are complemented by numerous research-scale CCS projects, intergovernmental and industry partnerships, research programs, and stakeholder networks. No adverse safety, health, or environmental effects have ever been documented from any of these operations.

How do we know that it works?

There are decades of operational experience from projects that are very similar to CCS, including underground CO_2 injection for enhanced oil recovery (EOR) and the use of technologies analogous to CCS, such as acid gas (a combination of hydrogen sulphide and CO_2) injection, and natural gas storage.

The oil and natural gas industries have more than 40 years' experience injecting CO_2 into geologic reservoirs to increase oil production. This process is a type of EOR and uses the properties of CO_2 to mix with the oil to move it out of the reservoir more effectively. In most operations, the CO_2 is recycled and will remain in the reservoir indefinitely at the end of the life of the oil field. These sites have been injecting many millions of tonnes of CO_2 safely into the subsurface for decades. The success of these projects and the increasing number of research demonstrations provides considerable confidence in the potential to store large quantities of CO_2 underground – safely, securely and for very long periods.

How much CO_2 can be stored underground?

The United Nations Intergovernmental Panel on Climate Change (IPCC) estimates the world's potential capacity at two trillion tonnes, although there could be a 'much larger potential' (UN IPCC, 'Special Report on Carbon Dioxide Capture and Storage: Summary for Policymakers', 2005).

A number of regions around the world – the United States, Canada, China, South Africa, Europe and Australia – are doing significant amounts of work on characterising potential storage sites.

A 2010 report prepared by the United States Department of Energy has documented more than 3,500 billion tonnes of CO_2 storage potential in oil and gas reservoirs, coal seams, and saline formations across the United States and Canada alone.

That means there are centuries worth of CO_2 geological storage for the region.

A European Union project estimates the CO_2 storage capacity in oil and gas fields, in and around the North Sea alone, at 37 billion tonnes, which would enable this region to inject CO_2 for several decades once the fields are depleted (European Union Fifth Framework Programme for Research and Development, 'Geological Storage of CO_2 from Combustion of Fossil Fuels', November 2004).

The Sleipner project, located some 240 kilometres off the coast of Norway in the North Sea, is storing more than 2,700 tonnes of CO_2 per day, injected nearly 800 metres below the seabed.

Over the lifetime of the project, more than 20 million tonnes of CO_2 are expected to be injected into the saline formation.

Monitoring surveys of the injected CO_2 indicate that over the past 15 years, the gas has spread out over nearly ten square kilometres underground, without moving upwards or out of the storage reservoir.

Long-term simulations also suggest that over hundreds to thousands of years the CO_2 will eventually dissolve in the saline water, becoming heavier and less likely to migrate away from the reservoir.

For more information on CO_2 storage:

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