



Geologic Carbon Sequestration and Groundwater

What is geologic carbon sequestration and what does it mean to groundwater?

The disposal of carbon dioxide (CO₂) into the subsurface via well injection, also known as geologic carbon sequestration or carbon capture and storage (CCS), is one of a portfolio of technologies under consideration as a viable approach to mitigating greenhouse gas buildup. Recognizing that this option for carbon capture holds great promise, it is important to understand it also has the potential to endanger underground sources of drinking water if proper safeguards are not taken. The National Ground Water Association (NGWA), whose membership includes the country's eminent groundwater scientists, strongly encourages policymakers to include provisions in any future CCS programs that will help to protect and assess any potential effects on groundwater.

Why is geologic carbon sequestration needed?

CO₂ is a greenhouse gas which means that it contributes to global climate change, sometimes called global warming, so sequestering anthropogenic CO₂ from the atmosphere will help mitigate climate change [IPCC 2007].

How does geologic carbon sequestration work?

Instead of being released into the atmosphere, CO₂ generated at large industrial sources like ethanol plants, factories, or power plants is captured. Then the captured CO₂ is compressed into a dense, low-viscosity fluid and transported to a suitable location where it is injected into a deep geologic system to be permanently sequestered.

The geologic sequestration system, ideally, consists of four different geologic formations responsible for holding and keeping the CO₂ deep in the earth. These are a storage formation, a primary cap rock, a monitoring formation, and a secondary cap rock (Figure 1). The storage formation where the CO₂ is sequestered must have properties that allow the CO₂ to be injected and space for it to remain stored. It is important that the storage formation is not a mineral-bearing formation and is not an underground source of drinking water, also called a USDW. The primary cap rock is directly above the storage formation and its properties do not allow the CO₂ to pass through it, so the CO₂ remains trapped in the storage formation. The secondary cap rock must be above the primary cap rock and below the deepest source of drinking water. The secondary cap rock acts as a backup in case CO₂ gets through the primary cap rock. At some depth between the primary and secondary cap is the monitoring formation. The monitoring formation is used to detect and measure any potential leakage. If leakage does occur into the monitoring formation, the leakage will be contained beneath the secondary cap rock while the leak in the primary cap rock is mitigated.

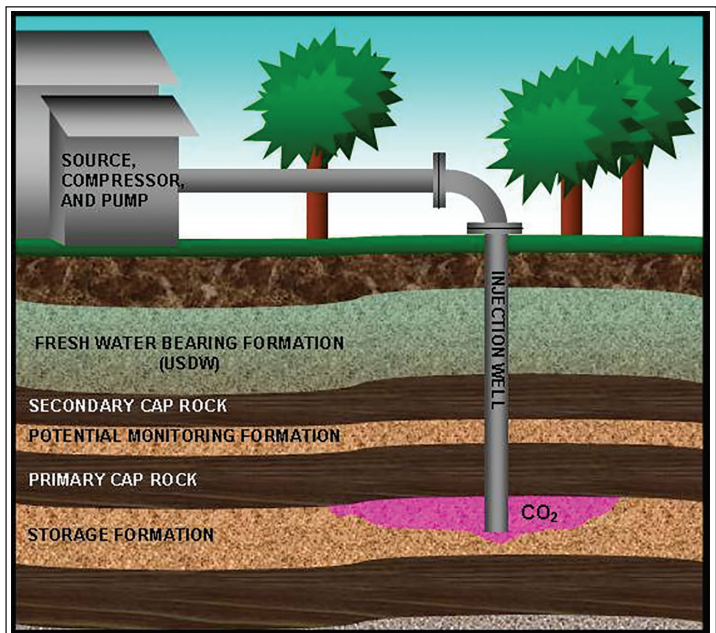


Figure 1. Geologic carbon sequestration showing the storage formation, cap rocks, and potential monitoring formation.

The Global Carbon Cycle

CO₂ is a naturally occurring gas that is important to many natural processes on earth. The exchange of CO₂ between different earth systems is called the carbon cycle (Figure 2). Since the start of the industrial revolution, large amounts of anthropogenic CO₂ have been released by human activities through a variety of industrial pro-

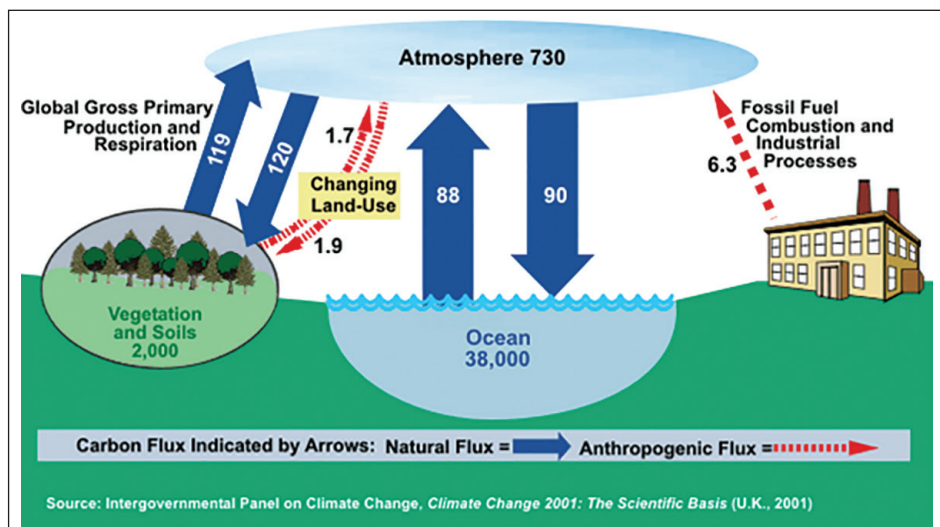


Figure 2. A diagram representing the earth's global carbon cycle, showing how carbon is partitioned and moves between different systems. Natural fluxes are shown with wide blue arrows and anthropogenic fluxes are shown with dashed red arrows. [Diagram from the Earth System Research Laboratory, ESRL 2007]

**Table 1: A summary of the carbon fluxes into and out of the atmosphere shown in Figure 2.
(1 metric tonne of carbon is equal to 3.66 metric tonnes of CO₂)**

	Carbon entering the atmosphere in billions of tonnes per year	Carbon leaving the atmosphere in billions of tonnes per year
Natural terrestrial carbon exchange	119	120
Changing land use	1.7	1.9
Exchange between the ocean and the atmosphere	88	90
Fossil fuel and industrial processes	6.3	0
Total	215	211.9

cesses. The effect of human activity on the carbon cycle can be seen by subtracting the total amount of carbon moving out of the atmosphere from the total amount of carbon moving into the atmosphere.

Subtracting the total amount of carbon leaving the atmosphere from the amount of carbon entering the atmosphere (215 – 211.9) shows that there is an extra 3.1 billion tonnes of carbon left in the atmosphere every year. This amount is equal to the measured rise in atmospheric CO₂ and it is this CO₂ that is “very likely” responsible for climate change [IPCC 2007].

What types of formations can be used for sequestration?

There are four types of formations being considered for sequestration. They are: deep saline formations, depleted oil and gas fields, unminable coal seams, and basalts. However, deep saline formations and depleted oil and gas-bearing formations potentially offer the most storage capacity and potential economic benefit.

Where can CO₂ be sequestered?

There is potential storage capacity throughout the United States, as is shown in Figure 3. In North America, it is estimated that the potential storage capacity is near 82 billion tonnes of CO₂ in depleted oil and gas reservoirs and between 919 and 3,378 billion tonnes of CO₂ in deep saline formations [NETL 2007]. Note: A tonne is a metric ton (1000 kg) which is equal to 1.10 short tons (2205 lbs).

What are the sources of anthropogenic CO₂ in the United States?

The U.S. annual energy-related emissions in 2006 were about 5.9 billion tonnes of CO₂ [U.S. Energy Information Agency]. The large sources of CO₂ in the United States are mostly energy-related and include natural gas and coal-fired power plants. Other large sources of CO₂ include ammonia plants, ethanol plants, and cement plants. Figure 4 shows the locations of sources in the United States that emit more than 100,000 tonnes of CO₂ per year.

What relevant experience is there with CO₂ injection?

The oil and natural gas industries regularly inject gas into the deep subsurface safely. CO₂ for enhanced oil recovery has been injected into the deep subsurface in the United States for over 30 years. Technologies to characterize and monitor the injection formation, cap rocks, and monitoring formation have already been developed for use in oilfield and geothermal applications and are adaptable for carbon sequestration. Although the volumes of gas that will be injected for sequestration will be much larger than those that are typically managed for subsurface injection, there have been two large (1 million tonnes of CO₂ per year) sequestration projects. One is the Sleipner project in the North Sea and the other is the Weyburn project in Saskatchewan, Canada. Both projects have been the focus of numerous scientific studies and have shown no detectable leakage. Additional research and large-scale pilot projects will assist in further developing the appropriate approaches and safe practices for long-term protection of human health and the environment.

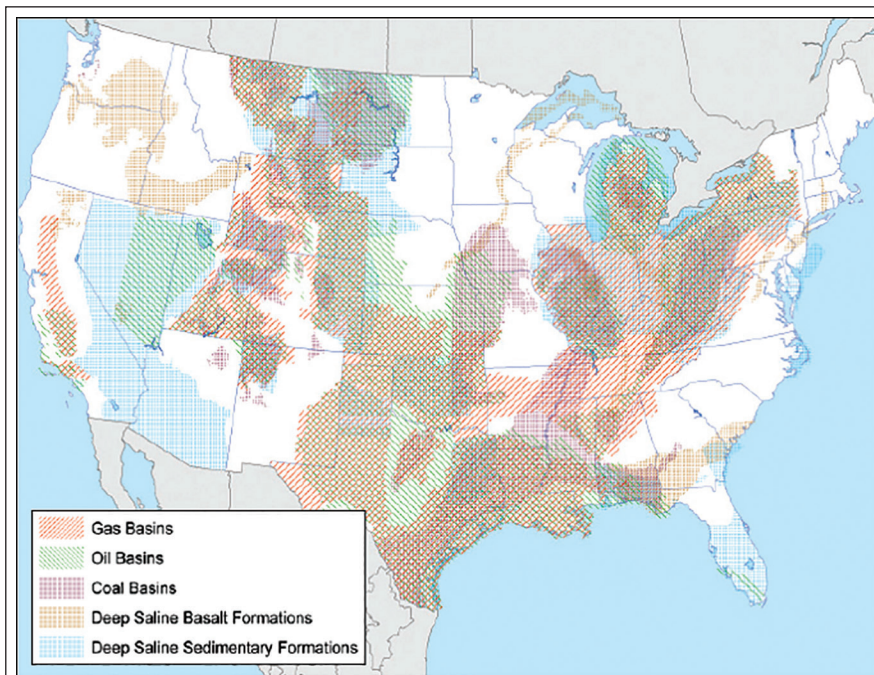


Figure 3. Potential CO₂ sequestration reservoirs in the United States.
Source: Dooley et al. 2006

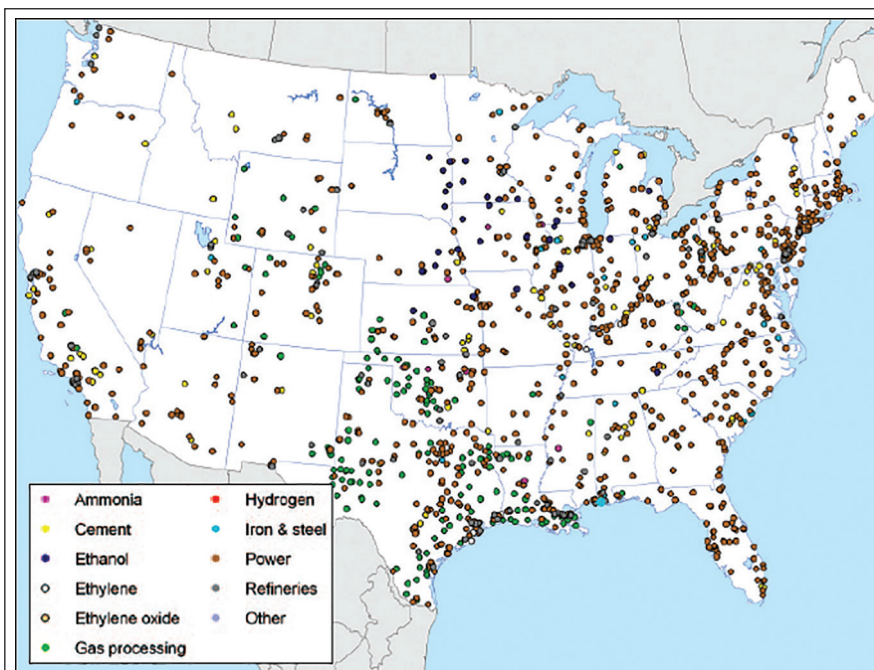


Figure 4. Sources in the United States that emit more than 100,000 tonnes of CO₂ per year. Source: Dooley et al. 2006

What are the potential issues and greatest concerns with geologic carbon sequestration?

The greatest concern with geologic carbon sequestration is the potential risk of leakage of CO₂ or existing saline formation fluids and brines into overlying formations that are underground sources of drinking water, caused by pressure created during injection or by the buoyant nature of CO₂ under typical sequestration conditions. The CO₂ or brine could act to change the chemistry of the underground source of drinking water, causing it to need extra

treatment before it can be used. Another concern is that the CO₂ might leak to the surface, causing a potential risk for exposure to humans or the environment. CO₂ is more dense than air, so if it leaks into a low area, like a ditch, and cannot mix with the atmosphere, it could build up to dangerous concentrations. At very high concentrations (above 80,000 parts per million in air [IVHHN]) CO₂ exposure can cause fatalities.

What are some of the potential advantages of geologic carbon sequestration?

Carbon sequestration is one of a portfolio of CO₂ emission mitigation technologies that will be used to reduce carbon emissions to the atmosphere. Unlike new technologies being developed or technologies that require time to build capacity, such as wind power, carbon sequestration can be implemented now at sources with high-purity CO₂ streams.

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