RCSP Water Working Group

Long-Term Protection of Freshwater Resources Following CO_2 Storage

Introduction

The subsurface geologic storage of carbon dioxide (CO_2) represents a primary option for achieving reduced greenhouse gas emissions to the atmosphere. Important to the successful commercial deployment of the geologic storage of CO_2 are 1) good site selection and 2) implementation of conventional as well as innovative monitoring methods, which will ensure that active carbon capture and storage (CCS) operations are performing properly and are protective of human health and the environment. Equally important to commercialization is the ability to provide assurances to the general public that impacts to human health and the environment will not occur sometime in the distant future.

This fact sheet identifies the primary physical and chemical mechanisms that are being relied upon to ensure the long-term containment of CO_2 in a storage reservoir following injection.

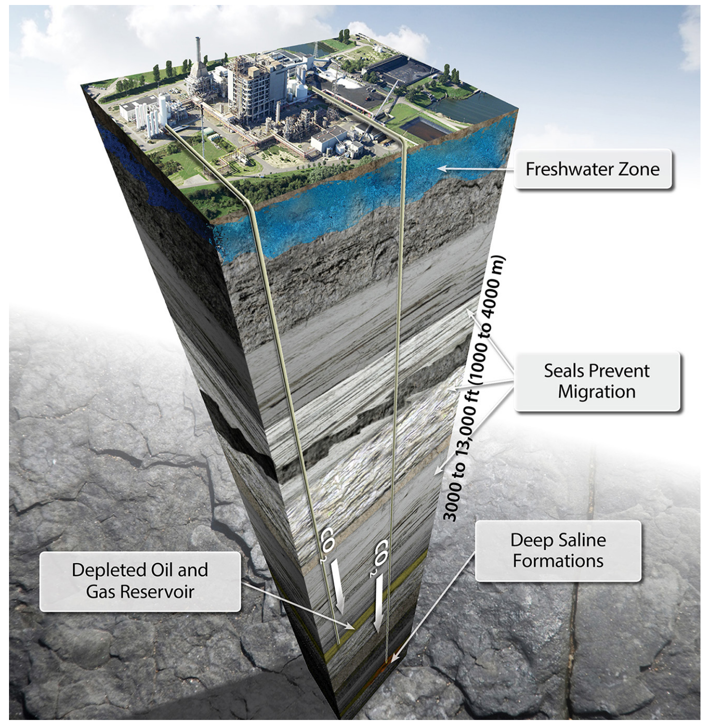

Figure 1. Geologic storage of CO_2 occurs deep below the surface and is separated from freshwater resources by thousands of feet of rock and impermeable barriers (modified from Peck and others, 2012).

Primary Mechanisms for the Subsurface Storage of CO_2

Target rock formations for geologic storage, such as depleted oil and gas reservoirs and deep saline formations, are much deeper than any usable groundwater and are separated from that groundwater by thick barriers of impervious rock (Figure 1). Generally, these formations have already proved their effectiveness in containing CO_2 by keeping highly salty saline water separate from usable groundwater for millions of years.

Following injection into the subsurface, several physical and chemical mechanisms actively store CO_2 and have the potential to ensure that the subsurface movement of CO_2 does not occur beyond the boundaries of the storage system. These "trapping mechanisms" include structural/stratigraphic, hydrodynamic, mineral, residual-phase, and solubility trapping. Each of these mechanisms is briefly described below.

Structural/Stratigraphic Trapping. In a structural/stratigraphic trap, CO_2 is physically trapped at the top of an anticline or in a tilted fault block. It is kept from further upward movement by the sealing rock (or cap rock).

Hydrodynamic Trapping. Hydrodynamic trapping results when the travel time of CO_2 in low-permeability storage aquifers is on the order of thousands to millions of years. Factors that have a substantial influence on the length of the migration pathway include 1) stratigraphic heterogeneities (e.g., siltstones, shales, and coals in the reservoir rock), 2) geochemical reactions, and 3) temperature.

Mineral Trapping. When dissolved CO_2 reacts with the reservoir rock, carbonate minerals can form and precipitate, trapping the CO_2 in stable chemical forms. The rate and extent of these reactions depend on the composition of the reservoir rock, the temperature and pressure of the reservoir, the chemical composition of the water, the water–rock contact area, and the rate of fluid flow through the rock. Mineral trapping is considered the most secure stage of CO_2 trapping.

Residual-Phase Trapping. When free-phase CO_2 migrates, it forms a plume. At the tail of this plume, the concentration of CO_2 decreases, and it becomes trapped in the pore spaces between the rock by capillary pressure from the water, which stops its movement. Over time, this residually trapped CO_2 can dissolve into the formation water, promoting even more secure mineral trapping.

Solubility (dissolution) Trapping. The solubility of CO_2 in water increases with increasing pressure and decreases with increasing temperature and increasing water salinity. As the dissolution of CO_2 in water takes place, the water becomes denser and begins to sink downward. This allows the CO_2 to become more dispersed in the water, and the amount of CO_2 dissolved in the water can increase, promoting even more secure mineral trapping.

The way in which CO_2 is injected and flows through the storage reservoir, together with the time the CO_2 remains in storage, determines the relative proportion of the above trapping mechanisms that occur in a storage system over time (Figure 2). In turn, the movement of CO_2 in the reservoir depends on the geologic structure of the reservoir and the composition of the storage rocks and formation waters.

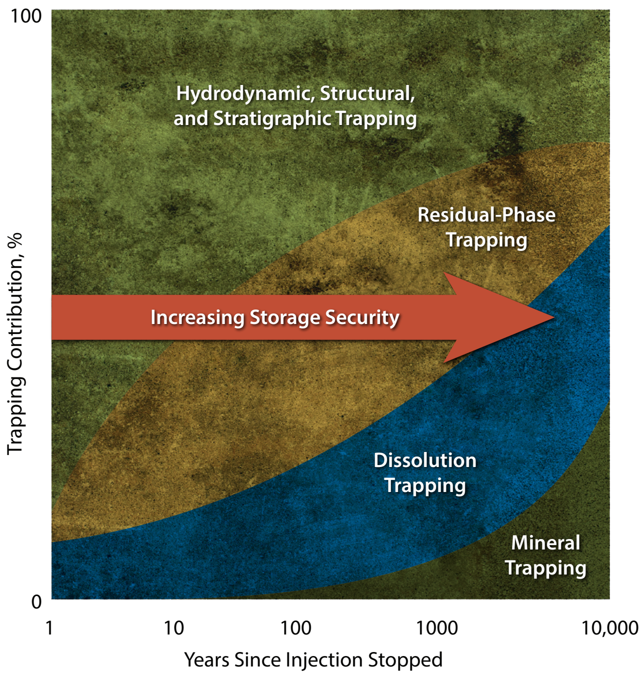

Figure 2. The relative impact of trapping mechanisms over increasing timescales (modified from Intergovernmental Panel on Climate Change, 2005).

Additional Information

DOE Regional Carbon Sequestration Partnership Program: http://energy.gov/fe/science-innovation/carbon-capture-and-storage-research/regional-partnerships.

National Risk Assessment Partnership: http://esd.lbl.gov/research/programs/gcs/projects/nrap.

Long-Term Protection Through Proactive Research Programs

The U.S. Department of Energy (DOE) is proactively conducting fundamental and applied research to quantify the security of freshwater resources during subsurface CO_2 injection over a project's life cycle (including operational injection phase and site closure). This research is focused on developing a complete understanding of the trapping/storage mechanisms discussed here and incorporating this understanding into mathematical models capable of predicting subsurface conditions over hundreds of years. These models, such as the ones being developed by the National Risk Assessment Partnership in combination with the Regional Carbon Sequestration Partnerships (RCSPs), will support the development of risk assessment for geologic storage sites over time.

Furthermore, these efforts will be combined with the results of other research initiatives to define "best practices" that can be applied at the preinjection, active, and postclosure stages of CO_2 geologic storage operations. Before injection, protective actions emphasize proper site selection and the presence and thickness of impermeable cap rocks. Proper site selection includes analysis of factors such as pore space volume, injectivity, and formation porosity and permeability, to name a few. The selection of potential sites for CO_2 injection also excludes areas with groundwater containing less than 10,000 milligrams per liter of dissolved solids, since these sources of groundwater are considered protected freshwater by the U.S. Environmental Protection Agency. Research into appropriate preinjection steps is complemented by research that investigates the real-time monitoring of the surface, near-surface, and subsurface environments during active operations to assess system performance and ensure the protection of water resources. This will help ensure the protection of freshwater resources, as well as compliance with the evolving regulatory framework during and following the widespread deployment of geologic storage of CO_2.

References

Intergovernmental Panel on Climate Change, 2005, IPCC special report on carbon dioxide capture and storage: Prepared by Working Group III of the Intergovernmental Panel on Climate Change, Metz, B., Davidson, O., de Coninck, H.C., Loos, M., and Meyer, L.A., eds., Cambridge, United Kingdom, Cambridge University Press, 442 p.

Peck, W., Buckley, T., Battle, E., Grove, M., Riske, J., Gorecki, C., Steadman, E., and Harju, J, 2012, Plains CO_2 Reduction (PCOR) Partnership atlas (4th ed.): Grand Forks, North Dakota, Energy & Environmental Research Center, 124 p.

The Water Working Group (WWG) consists of members from all of the RCSPs who serve as a team of experts representing government, academia, and industry. The goal of the WWG is to address stakeholder concerns regarding emerging carbon capture and storage technology and its potential interactions with local and regional water resources. The WWG is organized by the Plains CO_2 Reduction (PCOR) Partnership, which is a group of public and private sector stakeholders working together to better understand the technical and economic feasibility of storing CO_2 emissions from stationary sources in the central interior of North America. The PCOR Partnership is led by the Energy & Environmental Research Center at the University of North Dakota and is one of seven regional partnerships under DOE's National Energy Technology Laboratory (NETL) RCSP initiative. To learn more, contact:

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Visit the PCOR Partnership Web site at www.undeerc.org/PCOR. New members are welcome.

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