Opportunities for Carbon Capture and Geologic Storage

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Industrial carbon dioxide capture and geologic storage (CO_2 capture and storage, or CCS) is the subject of substantial research, development, and demonstration (RD&D) activity around the world because of its potential to significantly reduce the amount of CO_2 emitted to the atmosphere from industrial and energy-supply activities. These two economic sectors are the largest emitters of greenhouse gases, together accounting for about 45 percent of global anthropogenic emissions, according to the Intergovernmental Panel on Climate Change (IPCC, 2007).

Adding CCS to fossil-fuel power plants and other large industrial facilities—which can reduce a plant's CO_2 emissions by 80 percent or more—would enable these sectors to significantly reduce their "carbon footprint." However, not all of these large emitters will adopt CCS. The feasibility of adding CCS to existing plants depends on such considerations as adequate space for new equipment, access to safe geologic storage, and cost-effectiveness. Newer plants generally offer the most cost-effective opportunities for CCS conversion, and many coal-based plants currently being built in the United States are designed to later incorporate CCS, should regulations make it advantageous (or necessary) to do so.

The magnitude of the combined electric-power and industrial-sector CO_2 emissions means that developing and applying CCS to even a portion of this sector could impact overall efforts to stabilize and ultimately reduce CO_2 concentrations in the atmosphere. In fact, many analysts believe such an achievement will not be possible without widespread deployment of CCS. The challenge lies in making CCS available for broad commercial application by resolving current technical, economic, and legal/regulatory barriers.

CCS Consumes Energy

CO_2 is a nontoxic natural substance that is the primary product of combustion and other industrial and agricultural processes. Most technologies for separating it from other gases were developed for applications where separation was required commercially, such as in natural gas processing and urea fertilizer manufacturing. Some of these processes are now being modified for different operating pressures, gas-stream impurities, or gas-treatment volumes in order to capture CO_2 from fuel or exhaust gases at power plants, oil refineries, cement plants, and other large facilities.

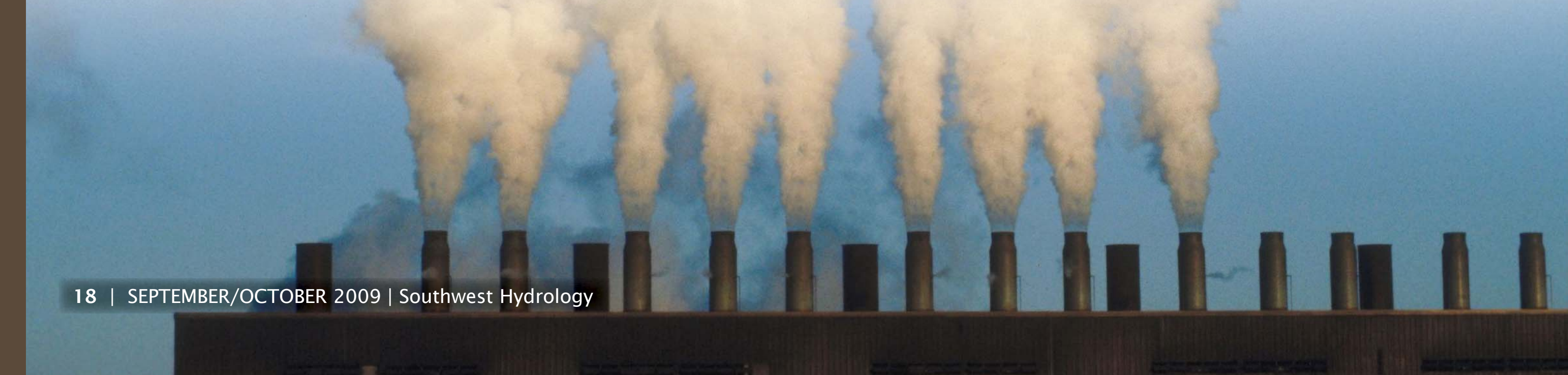
The separation processes currently use significant amounts of energy, and many CO_2 capture processes increase cooling-water requirements. Accordingly, much current RD&D is aimed at process improvements or alternatives that use less energy and cooling water, take up less space, and avoid the need for expensive construction materials or gas pretreatment systems.

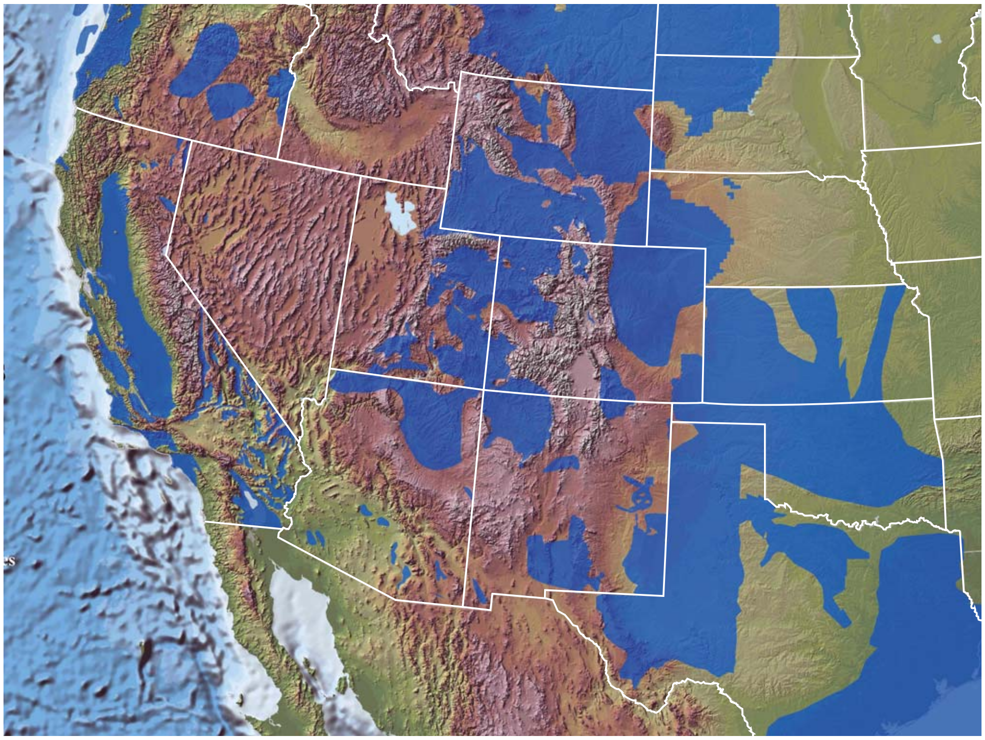
Once the CO_2 is separated, it must be compressed to a dense phase—a liquid-like state known as a supercritical fluid—to make underground storage and any intermediate pipeline transportation more efficient. Compressing CO_2 to dense-phase conditions also consumes energy, and often represents the second-largest CCS energy use after separation. Thus RD&D also is underway on more efficient CO_2 compression techniques.

If an industrial facility with CO_2 capture does not overlie a geologic formation suitable for long-term storage, the compressed CO_2 must be transported to an injection wellhead via pipeline. CO_2 pipeline technology is mature; several thousand miles of pipelines have operated safely for decades to supply CO_2 for enhanced oil recovery. In the Southwest, the industrial facilities generating the largest amounts of CO_2 tend to align well with geology suitable for storage, so costs associated with pipeline runs are not likely to be prohibitive. The energy use for transporting supercritical CO_2 is relatively small.

CO_2 injection technology is also mature, given decades of commercial application for enhanced oil recovery. Injection wells are similar to oil and gas wells, and are drilled and completed using the same types of rigs and construction methods. Cements and other downhole materials may be specially selected to withstand the mildly acidic conditions that can be produced by CO_2 storage in aqueous environments. As with pipeline transport, the energy use associated with injecting CO_2 already compressed to dense-phase conditions is relatively small.

The U.S. Department of Energy (DOE, 2009) estimates that the sum of all energy uses for CCS application to existing coal-fired power plants could equal 20 to 30 percent of the plant's energy output without CCS. Because this represents both a significant portion of CCS costs and a large new energy demand, DOE has established RD&D programs aimed at reducing CCS energy requirements for coal power applications to about 10 percent of the plant's output without CCS, halving the energy use of today's systems.





Deep saline formations (shown in dark blue) are prevalent throughout much of the Southwest and offer the largest potential CO_2 storage capacity (from NETL, 2008).

Where Will It Go?

DOE's regional carbon sequestration research teams have estimated a potential geologic CO_2 storage "resource" of roughly 3,500 billion metric tons in the United States and portions of Canada (NETL, 2008). This figure is derived from estimates of available pore space ranging from 1 to 4 percent in deep (>3,000 feet) sedimentary basins believed to contain high-salinity water (>10,000 parts per million total dissolved solids) in closed reservoirs or with regional confining layers of shale or other low-permeability rock (see map, above). The estimate also includes storage opportunities in depleted hydrocarbon reservoirs and deep, unmineable coal seams. This storage resource corresponds to over 1,100 years of the current rate of CO_2 emissions from the area's point sources (NETL, 2008). Although some fraction will prove uneconomical for development, in general, storage space will not be the limiting factor to CCS deployment.

RD&D efforts are concentrated on developing and refining computer models to predict, and monitoring techniques to detect, the subsurface location and behavior of CO_2 over time. The physical and chemical mechanisms by which CO_2 is immobilized and stabilized in the subsurface include structural trapping, residual or pore space trapping, dissolution/solubility trapping, mineralization, and in the case of storage in coal seams, surface adsorption. Standard practices in oil and gas production often can be adapted to CO_2 monitoring. To protect freshwater resources, shallower monitoring wells are typically used to warn of encroachment by saline waters from the CO_2 injection zone.

Integration and overall scale-up of CCS processes is another critical step to commercialization. Together, three of the world's largest long-term CO_2 storage projects—the Weyburn-Midale CO_2 Monitoring Project in Saskatchewan, Canada, the Sleipner Saline Aquifer CO_2 Storage project in the North Sea, and the In Salah Project in Algeria—currently inject an amount equal to about one-fourth of the annual CO_2 emissions of the single largest coal-fired power plant in the Southwest.

Experience from more large-scale projects will be needed before undertaking widespread commercial deployment, and small-scale injection tests will help characterize commercially suitable CO_2 storage sites in areas without a long history of oil and gas production.

Research in the Southwest

The Southwest is home to two DOE Regional Carbon Sequestration Partnerships, each guided by three main goals: 1) characterizing the West's CO_2 storage resource base; 2) drilling test wells to confirm the stratigraphy and rock and fluid properties of promising sedimentary strata; and 3) validating CO_2 storage capability, groundwater protection, and monitoring techniques through CO_2 injection tests. The West Coast Regional Carbon Sequestration Partnership will soon drill a CO_2 injection test well near Arizona Public Service Company's Cholla power plant in northeastern Arizona near Holbrook (see page 28). The Southwest Regional Carbon Sequestration Partnership (SWP) has ongoing CO_2 injection and monitoring projects in New Mexico, Utah, and Texas. ■

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