Models of carbon storage get real

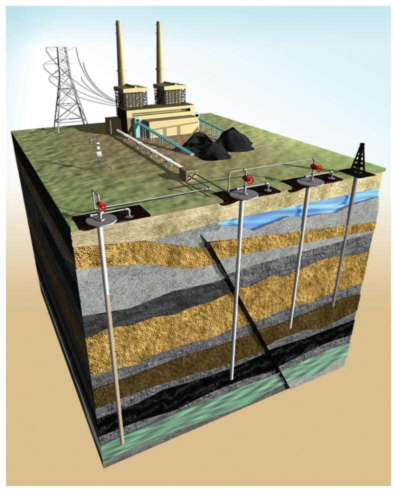
A handful of expert groups are creating increasingly sophisticated computer models to determine where—and how well—CO_2 can be stored underground. Efforts to store CO_2 this way are part of a race to develop new technologies to avert catastrophic climate change.

Two new modeling studies published in *ES&T* (DOI 10.1021/es801135v; 10.1021/es800403w) chip away at the challenge of simulating long-term CO_2 storage. The first examines the leakage of stored CO_2 from abandoned oil wells, and the other attempts to holistically simulate the capture, injection, and storage of CO_2 to help scientists and decision makers quickly evaluate the costs and leakage risks of potential storage sites. Also in *ES&T*, Vyacheslav Romanov proposes the use of coal mines as CO_2 storage sites in his Feature article.

Both papers simulate carbon capture and storage (CCS) projects, which aim to capture CO_2 from point sources such as power plants and store it underground, primarily in aquifers and sedimentary deposits found worldwide. Pilot CCS projects are under way now in Germany, Norway, Canada, Algeria, and the U.S.

The first paper, from an international team led by Jan Nordbotten of the University of Bergen (Norway) and Princeton University, finds that abandoned wells have created a kind of Swiss cheese pattern of holes across the North American landscape through which some CO_2 can escape. The wells are particularly common in places like Texas and Alberta (Canada), which have a long history of oil exploration.

"Basically, you can think of CO_2 leaking from an aquifer as being like people going into an elevator," Nordbotten says. Aquifers are layered like different floors in a building, he says, "and for each aquifer that this well passes through on the way up to the surface, some CO_2 will enter the aquifer and some will continue along the well." Undersea storage sites would avoid the "Swiss cheese problem", but piping CO_2 into the ocean is more expensive than piping it into aquifers, he notes.



ANTHONY MANCINO/LANL

Small pilot projects are already capturing and storing carbon belowground. A larger-scale system for capturing and storing CO_2 produced by a coal-fired power plant is illustrated above.

The second study, by researchers at the Los Alamos National Laboratory (LANL) and National Energy Technology Laboratory, describes a model called CO_2-PENS. "This is an entire system-level approach, from injection at the surface to leakage, costs, and risk analysis," says Philip Stauffer, who led the study.

Stauffer and his team evaluated two sample sites, one shallow and one deep, to test their model. They found, contrary to their expectations, that carbon storage was more economical at the deeper site, despite higher pipeline costs. In the colder, shallower site, CO_2 behaves like a thick liquid, and more wells are needed to inject the same amount. In the deeper site, "it's like honey—as you heat it, it gets much more fluid," Stauffer says. In addition, greater pressure deep underground means that CO_2 can be injected at higher pressures without dangerously stressing underground faults and fractures.

The work is part of a U.S. Department of Energy (DOE) program for determining geological sequestration risks. DOE is planning a program with seven sites around the country, called Regional Carbon Sequestration Partnerships, that will inject more than 1 million tons of CO_2 into the ground.

Both models take a simplified approach rather than making detailed process calculations, says Rainer Helmig, who heads the hydrosystem modeling department at the University of Stuttgart (Germany). "That is a [scientifically] conservative concept, and it is straightforward and relatively simple and really fast," he adds.

Helmig and his department colleague Holger Class, who specializes in CO_2 sequestration modeling, are working on a project called CO_2SINK. So far, they have injected about 60,000 tons of CO_2 into a small geological reservoir in Germany.

Researchers say models and small pilot studies can help predict the risks of larger-scale tests before they are launched, but neither provides a crystal ball. "We may need to do some larger tests in order to learn from them," Stauffer says. "And although enhanced oil recovery has provided valuable data on subsurface injection of CO_2, the high volumes required for CCS will doubtless require new methods and understanding."

Hamdi Tchelepi, a modeler at Stanford University, notes another limiting factor. "When it comes to storing CO_2, it's not obvious how much investment one will have at hand to collect good characterizations of geological formations. So the uncertainty associated with CO_2 sequestration may well be much wider with respect to the uncertainty in developing an oil reserve."

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