

Scientists poke holes in carbon dioxide sequestration

Recent findings say earthquakes caused by CO₂ injection may cause bottled-up greenhouse gas to leak.

Newly published geophysical research and a committee of experts have cast doubts on whether carbon capture and storage (CCS) can play the major role that some scientists and coal producers had hoped for in mitigating climate change. A report released by the National Research Council (NRC) in mid-June warns that the injection of millions of tons of supercritical liquid carbon dioxide from fossil-fuel plants into deep geological formations is likely to create earthquakes that will fracture the surrounding impermeable rock and allow the greenhouse gas to work its way back toward the surface. Separately, Stanford University geophysicists Mark Zoback and Steven Gorelick write in a 26 June article in the *Proceedings of the National Academy of Sciences* that “there is a high probability that earthquakes will be triggered by injection of large volumes of CO₂ into the brittle rocks commonly found in continental interiors.” They argue that “large-scale CCS is a risky, and likely unsuccessful, strategy for significantly reducing greenhouse gas emissions.”

Colorado School of Mines geologist Murray Hitzman, who chaired the NRC committee that wrote *Induced Seismicity Potential in Energy Technologies*, told a 19 June hearing of the Senate Committee on Energy and Natural Resources that two factors, “net fluid balance” and the volume of the injected liquid, largely determine whether an earthquake will result when liquids are pumped into underground formations. According to the NRC report, oil and gas development projects that take into account the balance between fluid injected and fluid withdrawn produce significantly fewer seismic events than projects that ignore the fluid balance. In CCS, CO₂ is injected without any corresponding extraction of the brine that’s often present in the formation.

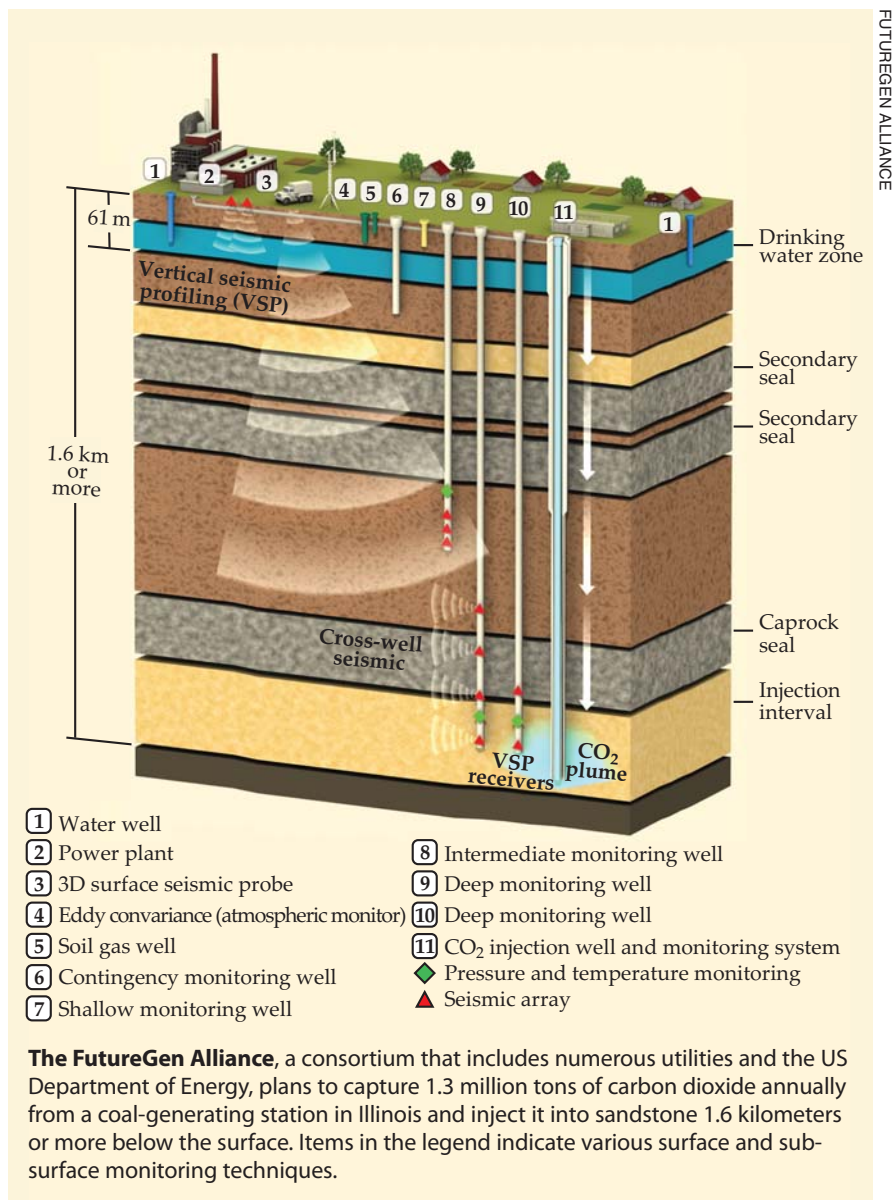
Zoback, who also appeared at the Senate committee hearing, said that for CCS to contribute significantly to mitigating climate change, about 3.5 billion metric tons worldwide would have to be sequestered annually. Right now, a few large-scale CCS operations, includ-

ing one at a Norwegian gas well in the North Sea and another at a gas well in Algeria, are each storing around 1 million tons a year.

Site selection is paramount

The biggest CCS project to date has been taking in CO₂ at a rate of 2.8 million tons per year since 2000, but the CO₂ pumped there is used to help recover additional oil from the depleted

Weyburn and Midale oilfields in Canada. The CO₂ is produced and piped 320 km from a North Dakota coal gasification plant. In response to the Zoback–Gorelick article, Malcolm Wilson, CEO of the Petroleum Technology Research Centre, the nonprofit that manages Weyburn–Midale, asserted that no earthquakes, new faults, or fault reactivation had occurred following the injection of more than 21 million metric tons of CO₂. But Wilson acknowledged that carefully locating CCS storage sites is a “paramount” consideration.



Andy Chadwick, head of CO₂ storage research at the British Geological Survey, says that during CO₂ injection, pressures can be controlled to avoid fracturing the caprock. Tony Batchelor, president of the UK-based company GeoScience, agrees but notes that lower pressure means smaller storage capacities that could potentially drive up the cost of CCS. Several research groups are exploring the potential of active reservoir management to mitigate increases in reservoir pressure. That research aims to relieve pressure by extracting saline reservoir fluids displaced by CO₂ injection. Those fluids could be desalinated to provide clean water, says John Litynski, carbon storage technology manager at the US Department of Energy's National Energy Technology Laboratory.

Beginning in 2017 the FutureGen Alliance, a US-based industry-government consortium, plans to capture and store 1.3 million tons of CO₂ per year at a coal-burning power plant in Meredosia, Illinois. Lawrence Pacheco, a spokesman for the \$1.3 billion venture, says that at the injection site both the porosity of the sandstone formation nearly a mile below the surface and the caprock permeability are ideal for CO₂ storage. In addition to a

\$1 billion pledge to FutureGen, DOE is funding three industrial-scale CCS projects, including a plan to capture and store 4.5 million tons a year from a methanol refinery and another to sequester 1 million tons annually from ethanol production. Two of the three projects will use the CO₂ in enhanced oil recovery.

So far, so good

Since 2003 DOE has supported seven regional partnerships to develop the technology, equipment, and regulations needed for implementing large-scale CCS for differing North American geological formations. To date, no significant induced seismic events have been associated with any of the partnership storage projects, says Litynski.

David Borns, manager of the geotechnology and engineering department at Sandia National Laboratories, says that the Zoback-Gorelick article "raises a plausible scenario." But he and others say more data are needed.

That liquid injection or withdrawal could cause earthquakes has been known since the 1920s, according to the NRC report. The heightened public awareness of shale-gas production in the past several years has called attention to several quakes, many just large

enough to be felt, that occurred when fluids used in the hydraulic fracturing process—fracking—were injected into disposal wells in Ohio and Arkansas. Two earthquakes too small to be felt occurred during fracking at a site near Blackpool, UK, this year, causing UK regulators to shut the operation down.

The NRC report, requested by Congress in 2010, identifies only two instances, one each in the US and UK, where an earthquake strong enough to be felt was directly induced by fracking. There are an estimated 35 000 shale-gas extraction wells in the US alone. Eight other temblors—magnitude 2 or greater—analyzed by the committee were said to be caused by the injection of wastes from oil and gas production, including used fracking fluids, at a few of the 30 000 wastewater disposal wells in the US.

Layers of protection

The microseismic events that occur during fracking each release on average about the same amount of energy as a gallon of milk falling off a kitchen counter, Zoback told the Senate committee. That's because fracking affects only a limited volume of rock, typically several hundred cubic meters, and the

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pressurization typically lasts for only a few hours. By contrast, the injection of large volumes of CO₂ over many years will steadily build pressure in the reservoir, according to the NRC committee and Zoback.

But a breach in the sealing cap doesn't necessarily mean that the CO₂ will return to the biosphere, Litynski says. "Subsurface geology is very heterogeneous, and potential storage sites typically have multiple sealing units . . . above the primary seal, providing additional protection against fluid migration."

Ruben Juanes, associate professor of energy studies at MIT, believes that seismicity, though an important consideration, does not represent the death knell for geologic sequestration. "While I

agree that these risks are serious, I disagree with the authors' claim that they will likely render CCS unsuccessful," he says. The quakes attributed to fluid injection have been at magnitudes below the damage threshold, Juanes notes. The evidence presented by Zoback and Gorelick is anecdotal and "does not justify the conclusion that moderate-size earthquakes will threaten the seal integrity to the point of rendering CCS unsuccessful. In particular, [Zoback and Gorelick] support this sweeping statement with a reference to some lab experiments, rather than field experiments, on granitic rocks, which would never be used as a host rock for CCS."

In the big picture, seismicity pales in comparison to cost as an impediment to the adoption of CCS, says Rachel Clee-

tus, a climate economist with the Union of Concerned Scientists. "Honestly, the challenges to CCS are so significant on the economic front that this is just going to be one more thing that makes people question the risk of going down that path versus other options that are readily available and much less risky, such as wind and solar," she says.

"The difficulty is that carbon isn't priced in a meaningful way," adds GeoScience's Batchelor. "Until carbon has a price, it bears down on the renewables, and it bears down on CCS. And the US, UK, and most European governments are not going to put their industries at a competitive disadvantage by saying we insist you do [CCS] and double the price of power on a unilateral basis."

David Kramer

Germany differentiates its universities

Winners and losers in a bid for money and prestige say the process has helped universities plan for the future. Many also see the heightened competition as good for research.

The big surprise in the second and final round of Germany's Excellence Initiative, which aims to propel a few of the country's universities into the international top tier, was that three of the big winners from the first round lost their "elite" status. Results were released on 15 June.

Jaws dropped with the news that the Karlsruhe Institute of Technology (KIT)—

formed beginning in 2006 under the Excellence Initiative in a pioneering merger of the University of Karlsruhe, funded by the state of Baden-Württemberg, and a federally funded research center of the Helmholtz Association—failed in its renewal bid. The Universities of Göttingen and Freiburg are also licking their wounds. In a surprise to some, the University of Bremen, a small campus, won

its bid with a research cluster of excellence—a collaboration, often across departments or institutions, intended to become a leader in a particular area of research—in marine environmental studies and a graduate school in social sciences. And joining the ranks of excellence are two universities from the former East Germany: the Humboldt University of Berlin and the University of Technology Dresden.

German researchers like to say that it takes a fortune and a few hundred years to create a university like Harvard

HUMBOLDT UNIVERSITY OF BERLIN



A historical machine test bed (left) is now a cafeteria at Humboldt University of Berlin, a big winner in the final round of Germany's Excellence Initiative. The university's physics department is at the back right, and an administrative and teaching center is at the left. Graduate students (below) display a research satellite they built at the University of Technology Dresden. The two universities are the only ones from the former East Germany to win "elite" status.



KARSTEN ECKOLD, UNIVERSITY OF TECHNOLOGY DRESDEN