Research Priorities for Sequestration of Carbon Dioxide In Deep Geological Formations

Testimony before the U.S. Senate Committee on Commerce, Science and Transportation
Subcommittee on Science, Technology and Innovation
Hearing on "Research Priorities for Safe and Efficient Carbon Sequestration Technologies"
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Oral Testimony

Good afternoon. Senator Kerry and members of the sub-committee, thank you for the opportunity to talk with you today. I am Sally Benson, a Professor at Stanford University and Executive Director of the Global Climate and Energy Project.

The Science Behind Safe and Effective Sequestration

The science behind carbon dioxide sequestration builds on concepts developed over a century in the oil and gas industry. Safe and secure sequestration can be achieved by injecting carbon dioxide into porous rocks and trapping it underneath thick and continuous fine-textured rocks or so-called "seals.[1]" Two mechanisms are responsible for trapping[2] and we know they are effective because these are the exact same mechanisms that are responsible for the existence of oil and gas reservoirs.

On this basis, it is straight forward to conclude that sequestration in oil and gas reservoirs is feasible. So what about the other types of formations that have been proposed for sequestration?

Saline aquifers are extremely important sequestration resources because they have the largest capacity and are located closer to more emission sources. The sealing mechanisms for saline aquifers are the same as for oil and gas reservoirs—but here we need scientific proof that the seals are sufficiently thick, have uniformly good sealing properties, and are not penetrated by active faults.

While, in principle, sequestration is straight forward—in practice there is a great deal of science and engineering that underpin safe and effective sequestration, for example:

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[1] Since the density of carbon dioxide is less than water, unimpeded, when injected underground, it would migrate back to the land surface. Therefore "seals" are needed to trap carbon dioxide underground.

[2] Two mechanisms are responsible for effective trapping by seals: extremely low permeability—which limits the rate of flow through the seals; and extremely high capillary entry pressure—which prevents any separate phase carbon dioxide from moving into the seal (IPCC Special Report on Carbon Dioxide Capture and Storage, 2005, Cambridge University Press).

seismic imaging for assessing and monitoring sequestration projects and computer simulation models to predict sequestration performance.

In addition, while there many reasons to conclude that sequestration is feasible—the question of scale cannot be ignored. Today there are three active sequestration projects[3]. To make a significant impact on emission reductions, thousands of projects will be needed—and each of the projects will be from 5 to 10 times larger than any of the existing projects. The potential for unforeseen consequences of large scale sequestration must be assessed and methods to avoid them developed.

Progress on Research and Development

World-wide, public and private research efforts continue to make steady progress on these issues. For example:

- Last summer, the Department of Energy funded an experiment to answer the question—what is the smallest leak that could be detected[4]? Field testing results proved that a number of existing and innovative techniques have the sensitivity needed for reliable monitoring.
- As another example, over the past several years, the Department of Energy has funded two pilot tests in Texas[5]. These tests demonstrated that the location of the plume could be tracked and modeled. The Regional Sequestration Partnerships will replicate these tests in different geological environments, providing valuable first-hand knowledge and experience for state and local regulators who will one day be called upon to oversee these projects.
- As a final example, the Global Climate and Energy Project[6] has developed new theoretical models to predict how quickly secondary trapping mechanisms[7] could

[3] The three existing sequestration projects are the Sleipner Project off-shore of Norway, the Weyburn Project in Saskatchewan, and the In Salah Project in Algeria. The Sleipner Project began in 1996 and sequesters 1 Mt/year of CO_2 in a saline aquifer. The Weyburn Project, which began in 2000, is a combined CO_2-EOR and sequestration project that injects about 2 Mt/yr into an oil reservoir. The In Salah Project began in 2004 and sequesters about 1 Mt/yr in a depleting gas reservoir. A fourth project, the Snohvit Project, is expected to begin injecting 0.7 Mt/yr into a saline aquifer under the Barents Sea in 2007.

[4] The Detection Verification Facility is collaboration between several Universities and National Laboratories led by Montana State University. The experiment showed that leakage of 100 kg/day over a 100 m long feature could be detected and quantified using flux accumulation chambers. A second experiment demonstrated that 300 kg/day could be detected and quantified by several methods

[5] The Frio Pilot Tests, led by the University of Texas at Austin, are a collaboration between University and National Laboratory scientists. The first test in 2003 injected about 1,600 tons of carbon dioxide. The second test in 2006 injected about 500 tons. Extremely valuable scientific results were gained from the small-scale pilot tests, including new methods for tracking migration of carbon dioxide movement in the surface, fundamental insights about multi-phase flow of carbon dioxide and brine, and geochemical interactions between carbon dioxide and the reservoir rocks.

[6] The Global Climate and Energy Project at Stanford University funded by ExxonMobil, GE, Toyota and Schlumberger, performs fundamental breakthrough research to develop a wide range of low-carbon and carbon-free energy supply technologies—including carbon sequestration. http://gcep.stanford.edu/.

[7] Secondary trapping mechanisms include dissolutions of CO_2 in brine, capillary trapping and mineralization (IPCC Special Report on Carbon Dioxide Chapter and Storage, Cambridge University Press, 2005).

permanently immobilize carbon dioxide—thus further reducing the potential for leakage.

There is also an urgent need for demonstration projects—at a scale commensurate with the 5 to 10 million tons per year of carbon dioxide emitted from large coal-fired power plant. Plans are underway for at number of publicly[8] and privately[9] funded demonstration projects—and it is important they get started now. Without definitive results from these and even larger scale tests, policy makers, investors and society will not have the confidence to proceed with widespread deployment of CCS.

Barriers to Implementing Geological Storage

As interest in sequestration has grown, so too has the concern about long term stewardship and liability. Who will be responsible for long term monitoring? Who will pay to remediate a site if it starts to leak 100 years from now? The prospects of long term stewardship and long term financial responsibility make investors nervous—and if not addressed, will create a barrier to widespread deployment. In part, answers to these questions are legal and institutional in nature. However, scientific research has a large role to play in bounding the probability of unforeseen events and providing a scientific framework for addressing these issues.

In particular, naturally occurring secondary trapping mechanisms such as converting the carbon dioxide into solid minerals can provide additional storage security—and these processes become more effective as time passes. Fundamental research is needed quantify the potential and timeframe for completely reducing the risk of leakage and for learning how accelerate these processes if needed. Long term stewardship and financial responsibility are much less daunting if the risk of unforeseen events can be shown to predictably decrease with time.

Gaps in Public and Private Research Activities

Now, coming to your final question—are there gaps in public and private research activities? Certainly, growth in federal support for sequestration research has been impressive over the past decade—increasing from nearly nothing ten years ago to over $100 M in 2007. Industrial support is also growing. But, while growing interest and support is encouraging, at the current pace of progress, convincing answers about safety and effectiveness may not be available for more than a decade. Accelerating the pace of progress requires commitment to a parallel development pathway, simultaneously

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[8] Federally funded project include FutureGen and 3 recently announced sequestration projects carried out by the Plains Carbon Dioxide Reduction Partnership; Southeast Regional Carbon Sequestration Partnership; and Southwest Regional Partnership for Carbon Sequestration. All will conduct large volume tests for the storage of one million tons of carbon dioxide (CO_2) in deep saline reservoirs.

[9] Announcements for privately funded mid-to-large scale projects in the U.S. have been made by a number of companies. Examples include the BP Carson project and AEP's projects in West Virginia and Oklahoma. All of these are in the planning stage.

- building a strong fundamental scientific program[10];
- providing sufficient financial resources for the pilot projects in order to learn as much as possible from them; and
- expediting full-scale demonstration projects.

In closing, carbon sequestration is a promising and necessary technology. Thank you very much for the opportunity to discuss this important topic with you.

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[10] DOE's Office of Science conducted a workshop in research opportunities in the geosciences related to sequestration (Basic Research Needs for Geosciences: Facilitating 21st Century Energy Systems, http://www.sc.doe.gov/bes/reports/files/GEO_rpt.pdf). Five priorities for improving our understanding of multiphase flow were identified:

- New approaches are needed to accurately predict migration of multiple fluid phases in environments that are highly heterogeneous, from the pore scale to the basin scale—over large spatial scales and long time frames.
- Methods to quantify and predict rates of geochemical reactions between multi-phase, multi-component fluids and minerals are needed to understand how quickly dissolution and mineralization will occur.
- Fundamental scientific understanding of basin-scale geomechanical processes is needed to predict shallow crustal deformation and basin scale brine displacement caused by large and rapid anthropogenic perturbations such as injection or extraction of multiphase fluids in the subsurface.
- A new multi-disciplinary approach is needed to assess the multi-phase flow properties of membrane seals, faults and fractures—in order to determine whether or not a geological reservoir has an adequate seal.
- Dynamic field-scale imaging is needed to test and validate multiphase flow models.