House Committee on Natural Resources

Hearing on
The Future of Fossil Fuels: Geological and Terrestrial Sequestration of Carbon Dioxide

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Mr. Chairman and members of the committee, thank you for the opportunity to appear before you today to discuss Carbon Dioxide (CO_2) geological sequestration. I have been involved with CO_2 capture and sequestration (CCS) for over 18 years. I started my first research project in CCS in 1989. In 1992-93, under Department of Energy (DOE) funding, I led a 2-year effort that produced the first comprehensive research needs assessment in the field (see DOE/ER-30194). More recently, I was a coordinating lead author on the Intergovernmental Panel on Climate Change (IPCC) Special Report on Carbon Dioxide Capture and Storage (see www.ipcc.ch), as well as one of 13 co-authors on the just released MIT report on The Future of Coal (see www.mit.edu/coal). I am also a US delegate to the Technical Group of the Carbon Sequestration Leadership Forum (see www.cslforum.org).

Just two weeks ago in the April 16 issue of Newsweek, this quote referring to climate change caught my attention: "If we cannot get a handle on the coal problem, nothing else matters." Similar sentiments motivated me and my colleagues at MIT to undertake our "Future of Coal Study". In that study, "we conclude that CO_2 capture and sequestration (CCS) is the critical enabling technology that would reduce CO_2 emissions significantly while also allowing coal to meet the world's pressing energy needs." While we conclude that CCS is a critical component of a portfolio of climate change mitigation options, we also recognize that CCS is not a silver bullet.

CCS has four major technical components in its life-cycle. First there is the capture of CO_2 at a large industrial source, such as a coal-fired power plant. By capture, it is meant isolating the CO_2 in relatively pure form (>90% by vol and typically >99%) and at high pressure (typically in the 1500-2500 psia range). Secondly, the CO_2 is transported from the capture site to the sequestration site, primarily by pipeline. Note that in many cases, the CO_2 capture site may be sitting on top of a sequestration site, so transport could be very minimal. Thirdly, the CO_2 is injected into the geological reservoir (usually at depths greater than 800 m). Finally, the injected CO_2 is monitored in the subsurface via a variety of techniques.

The cost of a CCS system has been estimated to add about 25% to the delivered price of electricity to the consumer. This price assumes that CCS systems are mature and operating at scale. Costs to first movers will be more. The majority of the costs are associated with the capture of CO_2. Over time, it is expected that costs will decrease as technological advances occur.

All components of a CCS system are in commercial operation today. There are several power plants in the US that capture CO_2 from a slip stream to sell into the commercial markets, such as carbonation of beverages. There exists over 2000 miles of CO_2 pipelines in the western US. We inject tens of millions of tons of CO_2 each year for Enhanced Oil Recovery at over 80 sites in the US. Finally, the monitoring tools used in oil and gas exploration are directly applicable to CCS operations.

What are lacking today are the demonstration of CCS as an integrated system and the demonstration of sequestration at scale in a variety of relevant geologies. The issue of scale is a critical point and the task ahead should not be underestimated. It will take considerable effort and investment. It should be noted that the world's current large sequestration projects operating today are all offshoots of commercial projects, with the science coming as an afterthought. We need sequestration demonstrations designed with scientific data collection as a primary goal to enable us to move on to the large-scale deployment phase.

For geological sequestration, the MIT Coal Study finds:

Current evidence indicates that it is scientifically feasible to store large quantities of CO_2 *in saline aquifers. In order to address outstanding technical issues that need to be resolved to confirm CCS as a major mitigation option, and to establish public confidence that large scale sequestration is practical and safe, it is urgent to undertake a number of large scale (on the order of 1 million tonnes/year injection) experimental projects in reservoirs that are instrumented, monitored, and analyzed to verify the practical reliability and implementation of sequestration. None of the current sequestration projects worldwide meets all of these criteria.*

The MIT Coal study makes five specific recommendations for sequestration:

1. The DOE should launch a program to develop and deploy large-scale sequestration demonstration projects. The program should consist of a minimum of three projects that would represent the range of US geology.

2. The US Geological Survey and the DOE should embark on a 3 year "bottom-up" analysis of US geological storage capacity assessments.

3. The DOE should accelerate its research program for CCS Science & Technology.

4. A regulatory capacity covering the injection of CO_2, accounting and crediting as part of a climate regime, and site closure and monitoring needs to be built.

5. The government needs to assume liability for the sequestered CO_2 once injection operations cease and the site is closed.

There is some urgency to start moving the sequestration demonstrations forward as quickly as possible. The urgency is related to the long lead times associated with developing energy technology. If we started on a well-funded and well-constructed demonstration phase today, within ten years we could then start deployment with commercial CCS plants going on-line. In other words, we need to start planting seeds immediately because of the long lead time required to bear the first fruit.

Unfortunately, the situation today regarding sequestration demonstration projects are that they are underfunded and do not meet the criteria I outlined above. Instead, the proposed projects are being driven to inject CO_2 into the ground as soon as possible. We do not need to demonstrate we can inject CO_2 into the ground – we are already doing that. Instead, we need demonstrations with full monitoring, integrated where possible, to lay the groundwork for large-scale deployment.

In Summary, I would like to end with the central message of the MIT Coal Study:

The demonstration of technical, economic, and institutional features of carbon capture and sequestration at commercial scale coal combustion and conversion plants, will (1) give policymakers and the public confidence that a practical carbon mitigation control option exists, (2) shorten the deployment time and reduce the cost for carbon capture and sequestration should a carbon emission control policy be adopted, and (3) maintain opportunities for the lowest cost and most widely available energy form to be used to meet the world's pressing energy needs in an environmentally acceptable manner.

For more details on these topics, please see the MIT Coal Study at www.mit.edu/coal. Chapter 4 deals with the topic of geological sequestration. Below are the introduction and recommendations of that chapter.

Introduction:

Carbon sequestration is the long term isolation of carbon dioxide from the atmosphere through physical, chemical, biological, or engineered processes. The largest potential reservoirs for storing carbon are the deep oceans and geological reservoirs in the earth's upper crust. This chapter focuses on geological sequestration because it appears to be the most promising large-scale approach for the 2050 timeframe. It does not discuss ocean or terrestrial sequestration.

In order to achieve substantial GHG reductions, geological storage needs to be deployed at a large scale. For example, 1 Gt C/yr (3.6 Gt CO_2/yr) abatement, requires carbon capture and storage (CCS) from 600 large pulverized coal plants (~1000 MW each) or 3600 injection projects at the scale of Statoil's Sleipner project. At present, global carbon emissions from coal approximate 2.5 Gt C. However, given reasonable economic and demand growth projections in a business-as-usual context, global coal emissions could account for 9 Gt C by 2050. These volumes highlight the need to develop rapidly an understanding of typical crustal response to such large projects, and the magnitude of the effort prompts certain concerns regarding implementation, efficiency, and risk of the enterprise.

The key questions of subsurface engineering and surface safety associated with carbon sequestration are:

Subsurface issues:

- Is there enough capacity to store CO_2 where needed?
- Do we understand storage mechanisms well enough?
- Could we establish a process to certify injection sites with our current level of understanding?
- Once injected, can we monitor and verify the movement of subsurface CO_2?

Near surface issues:

- How might the siting of new coal plants be influenced by the distribution of storage sites?
- What is the probability of CO_2 escaping from injection sites? What are the attendant risks? Can we detect leakage if it occurs?
- Will surface leakage negate or reduce the benefits of CCS?

Importantly, there do not appear to be unresolvable open technical issues underlying these questions. Of equal importance, the hurdles to answering these technical questions well appear manageable and surmountable. As such, it appears that geological carbon sequestration is likely to be safe, effective, and competitive with many other options on an economic basis. This chapter explains the technical basis for these statements, and makes recommendations about ways of achieving early resolution of these broad concerns.

Recommendations:

Our overall judgment is that the prospect for geological CO_2 sequestration is excellent. We base this judgment on 30 years of injection experience and the ability of the earth's crust to trap CO_2. That said, there remain substantial open issues about large-scale deployment of carbon sequestration. Our recommendations aim to address the largest and most important of these issues. Our recommendations call for action by the U.S. government; however, many of these recommendations are appropriate for OECD and developing nations who anticipate the use CCS.

1. The US Geological Survey and the DOE, and should embark of a 3 year "bottom-up" analysis of US geological storage capacity assessments. This effort might be modeled after the GEODISC effort in Australia.

2. The DOE should launch a program to develop and deploy large-scale sequestration demonstration projects. The program should consist of a minimum of three projects that would represent the range of US geology and industrial emissions with the following characteristics:
    - Injection of the order of 1 million tons CO_2/year for a minimum of 5 years.
    - Intensive site characterization with forward simulation, and baseline monitoring
    - Monitoring MMV arrays to measure the full complement of relevant parameters. The data from this monitoring should be fully integrated and analyzed.

3. The DOE should accelerate its research program for CCS S&T. The program should begin by developing simulation platforms capable of rendering coupled models for hydrodynamic, geological, geochemical, and geomechanical processes. The

geomechanical response to CO_2 injection and determination or risk probability-density functions should also be addressed.

4. A regulatory capacity covering the injection of CO_2, accounting and crediting as part of a climate regime, and site closure and monitoring needs to be built. Two possible paths should be considered — evolution from the existing EPA UIC program or a separate program that covers all the regulatory aspects of CO_2 sequestration.

5. The government needs to assume liability for the sequestered CO_2 once injection operations cease and the site is closed. The transfer of liability would be contingent on the site meeting a set of regulatory criteria (see recommendation 4 above) and the operators paying into an insurance pool to cover potential damages from any future CO_2 leakage.