Hearing on

Carbon Sequestration Technologies

Senate Committee on Commerce, Science, and Transportation
Science, Technology, and Innovation Subcommittee

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Mr. Chairman and members of the committee, thank you for the opportunity to appear before you today to discuss carbon sequestration technologies or more specifically, the sequestration of CO_2 into geologic formations. 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). For the past few years, I have also a US delegate to the Technical Group of the Carbon Sequestration Leadership Forum (see www.cslforum.org).

Coal is a critical fuel for the world. It supplies the majority of electricity at inexpensive prices in countries like the US, China, and India. However, coal also is responsible for about 40% of the world's CO_2 emissions. In the MIT Future of Coal 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."* So while we recognize that CCS is not a silver bullet, we do view it as a critical component in a portfolio of climate change mitigation options.

For geological sequestration, the MIT Coal Study finds: *"current evidence indicates that it is scientifically feasible to store large quantities of CO_2"* in geologic formations. This statement is based on actual field experience with CO_2 sequestration (e.g., Sleipner, Weyburn, In-Salah), other types of CO_2 injections (e.g., enhanced oil recovery, acid gas disposal), injection of other buoyant fluids (e.g., natural gas storage), and pilot tests (e.g., Frio Brine), as well as modeling and assessment studies. However, to scale up from what we refer to as the current megaton (i.e., millions of tons per year) scale to the required gigaton (i.e., billions of tons per year) scale is a major challenge and should not be underestimated. To move forward, we need to address the scientific and regulatory uncertainties associated with geologic storage at scale.

"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." Specifically, the MIT Coal Study recommends about ten sequestration demonstrations wordwide, with about three projects in the US to represent the range of US geology. 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 the next round of sequestration demonstrations designed with scientific data collection as a primary goal to enable us to start scaling up to the gigaton scale.

In addition to the demonstration program, other key recommendations from the coal study are:

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

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

- 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.

Summing up the situation, while geologic sequestration is scientifically feasible, it is not technologically or institutionally ready. If the recommendations given above are pursued aggressively, we should be able to achieve technological readiness in about 8-10 years. There is urgency to start moving the sequestration demonstrations forward as quickly as possible. The goal should be to achieve technological readiness by the time climate legislation creates market opportunities for CCS technologies. Unfortunately, we are not currently on that path.

The number one impediment to moving ahead is lack of funding. To achieve technological readiness for both capture and sequestration, the MIT Coal Study recommends about $1 billion/yr for the US CCS program. This is about 3-4 times the existing level of commitment for current R&D and demonstration programs. The current funding levels will require proposed demonstrations to cut corners, which can result in projects that demonstrate we can inject CO_2 into the ground (which we already know we can do), but will not advance the cause of technological readiness.

In summary, climate change will not be solved overnight. Rather, it will be a challenge mankind must address for at least the coming decades and possibly centuries. Even when policies to deal with the climate challenge are implemented, the inherent dynamics of both the energy and climate systems means that the benefits from our actions may take decades to appear. Therefore, while the debate on climate policy proceeds, it seems both prudent and relatively inexpensive to achieve technological readiness. We don't want to add further delays into the system by not having technological options available when needed. That is why there is urgency to get on the path to technological readiness now.

Thank you.

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.