WORLD RESOURCES INSTITUTE

Workshop Summary

Addressing Long-term Liability of Carbon Dioxide Capture and Geological Sequestration

5 June 2007

Summary

The World Resources Institute convened this workshop on Tuesday, June 5th to explore issues around long-term liability of Carbon Capture and Sequestration (CCS) projects. Long-term liability is one of several important challenges that CCS faces. A key finding from the June 5 workshop is that long-term liability comprises both anticipated costs associated with the long term care of a storage facility and the potential for costs associated with unanticipated damages. Another key finding of the workshop is that there are important inter-relations among the different stages of a project (siting, operation, closure, and post-closure). These inter-relations are important both in terms of reducing the long-term risk of liability and in creating efficient and flexible financial mechanisms to mitigate long-term liability.

This workshop fits into the larger project WRI is conducting with representative stakeholders to begin addressing key CCS challenges. In particular, the larger project is developing guidelines that will help ensure public confidence in the technology, provide investor certainty, and clarify operational issues for project developers.

This workshop brought together 38 experts from the insurance, finance, research, energy, governmental and NGO communities (see Appendix B). The goal was to assess the need and options for sharing the long-term liability associated with CCS between the public and private sectors.

Long-term liability is an important issue from many perspectives. The public needs assurance that adequate care and funding will be in place to manage storage facilities long into the future, potentially long after the companies that operated storage facilities go out of business. Project developers, financiers, and insurers need to know the operational and regulatory requirements up front in order to manage costs and risks. There is a need for much greater clarity in this regard.

We covered the following sessions during the day (see Appendix A for the full agenda):

1. Scale and timing of CCS as a climate strategy
2. Potential risk and mitigation strategies for CCS
3. Barriers to long-term investment in CCS technology
4. Financial responsibility models
5. The role of the public sector
6. Elements of a potential framework for managing long-term liability

This discussion was a great success in that it brought together a diverse set of stakeholders, revealed a set of informational needs and identified a concrete set of steps towards making progress. That said, the discussion also illustrated that the group did not have a common language regarding risk and liability, nor did it have a common understanding of the potential risks associated with CCS. Rather than attempting to assess models for mitigating long-term liability, the group called for an interim step to develop a common vocabulary and more clearly articulate the potential risks from CCS. With this information in hand, the group plans to reconvene for a second workshop in the fall to review options for addressing long-term liability associated with the various potential risks from CCS.

Review of Discussions

Slides were used throughout the day except for the general discussions which took place in sessions numbered 3 and 5. These slides are available on the WRI site (http://carboncapture.wri.org) and are referenced in the notes below. The summaries below were prepared by the project team and not by the presenters. They include a recap of the important points from the presentations as well as a summary of the important points from the discussions.

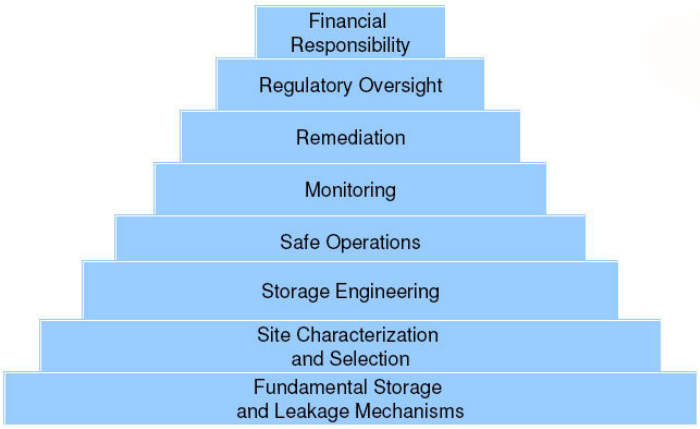
1. Dimensions of CCS – This presentation set the stage for the discussion with the following key points:

- Addressing climate change will require limiting greenhouse gas (GHG) emissions to the atmosphere to a finite level.
- The longer we wait to reduce emissions, the more we will have to do to "make up" for having waited.
- Large levels of reductions in GHG are expected to be necessary by the middle of this century and beyond. This will require fundamental changes to our energy system.
- Integrated assessment modeling of the global energy system suggests that no single technology (e.g., renewable energy, energy efficiency, nuclear energy, coal CCS) will be sufficient to achieve the reductions necessary. In fact, it suggests that all will be needed.
- CCS involves the capture and storage of the most common GHG, known as carbon dioxide or CO_2. CCS has the theoretical potential capacity to "fill the gap" or enable the world to make the reductions it needs in addition to those it achieves through other technologies, to meet the GHG reduction levels associated with the most commonly cited stabilization levels (450-750 ppm).
- The US is well endowed with potential storage capacity and an exercise to show the marginal cost of deploying CCS in the US for current large sources suggests that it could provide a cost-effective reduction option for large sources of CO_2 emissions.
- In order to achieve the lower stabilization concentration of 450 ppm, the integrated assessment modeling suggests that the efficient use of CCS in the US would represent several orders of magnitude increase in deployment over what we have today. This might include 100's of millions of tonnes being injected into the subsurface annually by 2050 whereas today the US injects only about 3 million tonnes annually.
- The group asked about the implications if this level of deployment was not achieved by mid-century. Although the modeling results were not prepared for the group, the response indicated that other studies and additional work by Battelle suggested that in the absence of achieving large scale deployment of CCS, other technologies would need to be used and the

predicted costs to reduce CO_2 or other GHG would rise dramatically. It was estimated that costs would more than double or would be worth more than tens of billions of dollars to the US economy.

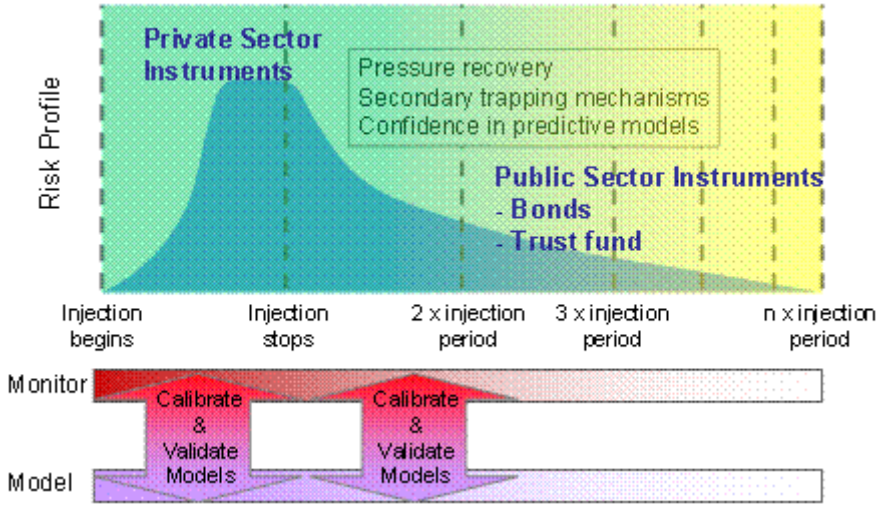
2. CCS Risks and Mitigation – This presentation covered three main topics: (a) the fundamentals of storage security (including physical analogs), (b) the environmental risks of geological storage, and (c) risk management and mitigation (including the storage security pyramid). It seemed that several participants did not have prior exposure to the information in this presentation and it stimulated significant discussion. In particular, the presentation included a conceptual risk profile (shown below) illustrating that the risk of leakage from the targeted reservoir diminishes over time as secondary trapping mechanisms came into effect. There was discussion about the ability of an operator to impact the risk profile through operational changes.

- CCS can take place in several types of geologic formations including depleted oil and gas fields, unmineable coal seams and saline (brine) formations. It's possible that other formations can be used as well, but there is less known about such formations.
- There are four ways that injected CO_2 is contained in the injection zone. The primary trapping mechanism is the overlying caprock. Secondary trapping mechanisms include CO_2 dissolving in brine, capillary trapping, and eventual "mineralization".
- IPCC experts agreed that for well-selected sites that are operated and monitored properly, there is a greater than 99% probability that CO_2 will remain in the selected storage reservoir for 1,000 years or more. An important caveat was noted that this figure was based on natural and industrial analogues and not specific modeling results. However, there is considerable evidence for this found in the natural and industrial analogs.
- The potential risks from CCS stem primarily from the unintended release of CO_2 (and also include potential industrial accidents conventionally associated with construction and drilling projects). Potential release pathways include well leakage (injection and abandoned wells), undetected faults, and excessive pressure buildup that can damage seals.
- An 8-tier "storage security pyramid" (shown below) was used to show the steps that could be taken to reduce the risk of CO_2 release.



Source: Sally Benson, Stanford.

- Jumping to the top tier, financial responsibility (please see the slides for detailed information on each tier), the group was presented with a conceptual risk profile for CCS projects (shown below). The concept is that if storage projects do not demonstrate any problems during the operation stage, the risk of CO_2 release is expected to decrease as injection stops and the secondary trapping mechanisms take effect. However, the concept also shows that the risk will remain greater than zero for a long time in the future, suggesting that financial responsibility mechanisms may be needed to address long-lived, but low-probability risks. It was noted that this profile can be influenced by operational changes.



Source: Sally Benson, Stanford.

3. Barriers to Investment: This was an open discussion and covered a wide range of perceptions about the risks to investment. It led to a discussion about the nature of the business of storage and a call for a more precise articulation of the perceived risks. Some of the issues touched on and included the differences between long-term responsibility for measures such as ongoing MMV and well maintenance versus long-term liability for damages to human health and property through accidental future release of injected CO_2.

- It does not seem likely that investors will invest in CCS as a means of complying with existing climate change obligations, such as the Kyoto Protocol, because the timelines for compliance are so much shorter than the timelines for completing CCS projects. This means that most investors will be considering investment in CCS as it may pertain to compliance with potential post-Kyoto (or future US) requirements. Since none of those requirements are defined at this point, it may be the case that investor interest in learning about CCS will not be matched by hard investment until there is a stronger signal of future obligations.
- There is a disconnect between the typical investment horizon and the timelines associated with fully reducing the risk associated with CCS projects. If investors are going to be held responsible for the long-term risks of CCS, it will make those investments unattractive in

comparison to many other investments with shorter term payouts or more certain exit strategies.
- Likewise, investors will be interested in the transferability of the environmental benefit (carbon credit) associated with CCS.
- There is no such thing as perfect indemnification, especially in a litigious U.S. A concern was voiced that, if they looked hard enough, many lawyers could find a regulation or standard that the project developer did not meet completely.
- Demonstration projects are needed to start identifying and understanding the unknowns. For example, how much does it cost to plug an abandoned well? What will this cost in terms of business interruption? In terms of carbon lost? How far out into the future do project developers have to consider these?
- Regulatory uncertainty was identified as one of the biggest barriers.
- Differing opinions were offered about whether liability will be a major barrier.
    - One view: if the government is tasked with assuming long-term liability, they will be extremely cautious in allowing projects to move forward.
    - Another view: large firms can cover operational risks, but will want government to take over long-term monitoring and liability.

4. Financial Responsibility (FR) Models: This presentation outlined the rationale and some models for designing FR mechanisms. The rationales include properly incentivizing sound siting and operations practices, ensuring adequate funding to cover LT responsibilities and liabilities, and giving confidence to the public. At the heart of this presentation was the point that the nature of the risk needs to be well understood to design FR mechanisms and this point was the focus of discussion for the rest of the day. In addition, the insurance community pointed out the need for and the difficulty in adopting a flexible approach so that a FR mechanism can adapt to changes in scientific knowledge, technical capacity, and economic tools. Thus, the earlier conversation calling for a better definition of the risks was reiterated and it was refined to suggest distinguishing the interests of the public, investor groups and industry/carbon emitters.

This section of the discussion also included a brief presentation on the Zero Emission Technology Platform (ZEP) program in the EU. There were several important differences between the general approach to environmental regulation, litigation and ownership of pore space/mineral rights in the EU and the US, but nonetheless useful comparisons emerged in thinking about managing the long-term care of storage facilities.

- The discussion reiterated the need for and difficulty in allowing flexibility in FR mechanisms. Experience shows that it is often necessary to put FR mechanisms in place before projects can move forward, and that it is very difficult to make any changes in them once some project experience is gained and/or markets change.
- There were different views about whether we need to figure out all the LT liability solutions now. An effective framework must evolve with the technology and experience. It was suggested that this framework could perhaps be modified annually as we learn more about the risks and project performance.

- How FR is structured will impact larger companies very differently than smaller ones. For example, larger companies may be able to self insure whereas, smaller ones may not. Such a discrepancy could effectively preclude companies from engaging in CCS.
- A hybrid approach was discussed. In this model, different instruments and providers (private v. public) would provide financial assurance based on the phase of the project.
- Privately run risk pools have incentives to be operated efficiently and cost effectively. There are concerns that a publicly run program would not have these built-in incentives. In addition, publicly run pools are notoriously difficult to modify (e.g. RCRA).
- Perhaps the greatest need is to address the "break the bank" risks.
- It was again noted that it is imperative to determine who bears the financial risks, and when.
- Some participants voiced the opinion that the private sector could adequately deal with the risks, but would need the public sector to take over the long-term responsibility for monitoring.

5. The Appropriateness and Role for the Public in LT Liability Management Associated with Storage: This was a wide ranging discussion that highlighted several topics including (a) the appropriateness/precision of applying the term LT liability to the activities that might need to take place after closing or decommissioning a storage facility, (b) the nature of the concerns associated with the cost and/or uncertainty associated with those activities, (c) the need (both pros and cons) associated with any transfer of the responsibility for LT care to the public (either funded or unfunded, state or federal, and via creation of 3rd party institutions or other administrative options). This led to a reiterated call for an articulation of risk by stage, type and interested party.

- A well structured FR framework will encourage proper siting, operation, and closure—minimizing risks to all.
- There is a serious problem with the message that is being sent right now: "CCS is very safe, but we cannot move forward unless the public takes on the long-term risks for anything that might happen." This mixed message will undermine public acceptability. Public perception of CCS was identified as a potentially large challenge.
- One participant noted that life-cycle monitoring may not be that expensive, at perhaps $0.05-$0.10/ton. This cost is small compared to overall project costs.
- Concerns were raised about bureaucracy and inefficiency if the government was tasked to managing these sites after closure.
- One suggested criteria for transferring liability to the public was project performance.
- Some of the concerns of the private sector derive from the fact that this is a new technology. Demonstration projects are urgently needed to address a lack of knowledge, information, and experience.
- There was wide agreement on a strong need for defining and distinguishing risks, characterizing their timing and probability, identifying how to prioritize them, estimating their costs, and defining who should be responsible for what risks. Answers to these questions will determine the shape of the risk profile.

6. Potential Frameworks for LT Liability Management: This presentation compared some of the existing approaches to LT liability management being considered in various efforts to develop model CCS rules, support FutureGen and otherwise guide the early development of CCS. It attempted to draw common themes or framework elements to spur a discussion of what would be appropriate to include in a proposed framework. In many regards, this was a top-down approach to looking at long-term liability: it examined programs to determine how they addressed certain issues. The group called for more of a bottom-up approach that first identified the full suite of issues (risks) and then looked at ways to prioritize the risks and efficiently mitigate them. In the absence of having this analysis done, the group offered some reflections on the top-down analysis:

- Transferring LT responsibility to a public-private corporation was discussed. One reason that transfer to government or a public-private corporation is needed at some point is to ensure that the entity will be around to deal with any problems.
- There were some concerns that the term "liability" was being used by participants to mean different things. There is a difference between financial responsibility—liability for monitoring and post-closure management of the site—and liability for risk of something happening, such as injury to person or property. These are separate topics, and need to be clearly distinguished in future discussions.
- Concerns about lawsuits were voiced. Even lawsuits without merit could be very costly.
- There was discussion about the pros and cons of a one-size-fits all federal approach to liability versus a state-by-state approach. In a worst case scenario, unequal approaches across the states could result in a race to the bottom, creating perverse incentives for siting, operation, and closure.
- One suggested approach involved developing different models for liability based on risk profiles.

Next Steps

There are two next steps planned to complete this discussion:

1. Develop a risk log to identify a common vocabulary and complete set of risks associated with the various stages of CCS. There are several papers and significant other work related to CCS risk assessment. The risk log proposed here will attempt to draw from those and also to contemplate a broad group of stakeholders including project developers, the public, and investors. Once complete, we will initiate an iterative process to solicit input from a working group of participants in the meeting and additional outside experts. Using conventional approaches to risk assessment, the goal is to develop a prioritized ranking of risks and an understanding of their interrelations and options for mitigation.

2. Convene a second workshop in early fall to review the risk log and options for most efficiently managing the risks. The purpose of this review is to develop recommendations suitable for addressing planned pilot and research projects in the short term and also to offer suggestions for approaches to be used over the long term in addressing commercial deployment.

Appendix A

Agenda for CCS Long-Term Liability Workshop

8:00 - 8:30 **Overview:** Frame the discussion, and give a charge to the group (Jeffrey Logan, WRI; Sarah Wade, AJW, Inc.)

8:30 – 9:15 **Scale and Timing of CCS if it is Deployed as a Climate Strategy?** (Jim Dooley, Joint Global Change Research Institute)

9:15 – 10:15 **What is the Potential Liability from CCS and Options to Mitigate?** (Sally Benson, Executive Director of GCEP, Stanford)

10:15 – 11:00 **Barriers to long term investment in CCS technology** (Group Discussion) Representatives from the oil/gas industry, electric industry, investment community and financial community kick-off group discussion

11:15 – 12:30 **Options for Financial Mitigation of LT Risks from Storage** (Chiara Trabucchi, Industrial Economics; Lindene Patton, Zurich; Keith Harsham, BP)

12:30 – 1:30 **Lunch and informal discussion**

1:30 – 2:15 **What is the appropriate role and timing for the public sector to share the long-term storage risk of CCS with the private sector?** (Group Discussion)

2:15 – 3:45 **Elements of a Potential Framework for Managing LT Liability** (Sarah Wade, AJW, Inc.) Presentation of matrix and group discussion

3:45 – 4:00 **Wrap up – next steps in the process**

Appendix B

Participant List for CCS Long-Term Liability Workshop

Vicki Arroyo
Pew Center on Global Climate Change

Adrienne Atwell
SwissRe

Julia Bailey Dulan
Southern Company

Sally Benson
Stanford University

Robert Bradley
World Resources Institute

Kipp Coddington
Alston and Bird

Jack Cogen
Natsource, LLC

Jim Dooley
Joint Global Change Research Institute

Matt Elkington
Marsh Europe S.A.

Ivan Gaydarov
Occidental Petroleum Corporation

Tim Grant
National Energy Technology Laboratory

Dr. Keith Harsham
Bp Alternative Energy International Ltd

Elliott Heide
Occidental Petroleum Corporation

Anhar Karimjee
Environmental Protection Agency (EPA)

Asteghik Khajetoorians
BP

Sarah Ladislaw
Center for Strategic and International Studies

Melissa Lauderdale
Edison Electric Institute

Susan Macey
Indiana Office of Utility Consumer Couselor

Granville Martin
JP Morgan Chase and Co

Gary Meggs
Southern Company

Mike Mudd
FutureGen Alliance

Larry Myer
California Energy Commission

Kyung-Ah Park
Goldman Sachs

Lindene Patton
Zurich (North American) Insurance Company

George Peridas
Natural Resource Defense Council

Darlene Radcliffe
Duke Energy

David Reisinger
AIG Global Marine and Energy

Sierra Salmon
AIG

John Steelman
Natural Resource Defense Council

Frank Tierney
AEGIS

Chiara Trabucchi
Industrial Economics, Incorporated

Robert F. Van Voorhees

Bryan Cave L.L.P.

John Venezia
World Resources Institute

Preeti Verma
World Resources Institute

Sarah Wade
AJW, Inc.

Richard Wagner
AIG Insurance Company

Mark Webster
Duke Energy

Fred Wellington
World Resources Institute

Elizabeth Wilson
University of Minnesota