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Implementation of Aquifer Implementation
Report of the Aspen Breakout Group
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PROBLEM DEFINITION

We worked hard to define a problem that was conceptually as interesting as we could make it. We located ourselves in 2020-2030. We assumed that a carbon management regime was in place. We assumed a U.S. focus. We tried to imagine the kinds of issues people would be wrestling with as they attempted to implement a deep aquifer sequestration program.

Our focus was on the permitting process for aquifer disposal. We assumed the permitting process will focus on the potential for leakage. We note that leakage encompasses both leakage to surface aquifer drinking water supplies and leakage to the atmosphere.

PERMITTING FOR AQUIFER DISPOSAL

Our thinking became sharper when we separated two questions:

1. The science: Can a science understanding of leakage be achieved? A "scientific understanding" is one leading to consensus about "facts," "risks," and "uncertainties."

2. Interpretation of the science: Can a process be devised that permits effective discussion of the differing perspectives of various parties? For example, the risks will be viewed differently by various interests.

To be sure, the two questions cannot be completely decoupled. One reason Yucca Mountain is failing because a consensus about the science cannot be achieved. Sharply differing interpretations of the implications of the science are preventing convergent discussion of the science.

The Science.

It will not be easy to achieve a scientific understanding of aquifer leakage. It is nearly a mantra of geologists that "No two aquifers are the same."

Much can be learned from the extensive program of deep aquifer disposal of hazardous wastes, an EPA-administered program dating to the 1980s. It should be productive to return to sites where hazardous wastes have been injected to see where the wastes have gone. In the process, various modeling efforts that have supported the permitting of this activity would be validated. (Question: Is such post-hoc validation already going on?}

A specific challenge, prominent in aquifer disposal of hazardous wastes, takes the form of "artificial penetrations," wells drilled in the past, imperfectly plugged, and not identified in still available records.

Detection of leakage of carbon dioxide will be difficult, given the large background. There may be merit in adding a tracer to the carbon dioxide, at least during the phase of sequestration when confidence in the overall sequestration system is not fully developed. Chemical tracers, like sulfur hexafluoride, present the problem of differential permeability and differential below-ground chemistry. Stable-isotope tracers (a carbon-13/carbon-12 signature, for example) could be considered.

Research is needed addressed to the task of reducing the leakage resulting from a discovered leak. One should distinguish a leak discovered during injection from a leak discovered after injection is completed. A leak discovered during an injection process may be able to be managed by redirecting the injection.

Costs for aquifer sequestration may rise substantially if a large monitoring effort is required. Today, it is presumed that capture costs dominate disposal costs. Technology may lower capture costs, and public concern may raise disposal costs, to such an extent that disposal becomes more expensive than capture.

Failing to gain public confidence will be more costly than monitoring. Sampling strategies and rules allowing non-zero leakage will reduce costs over the long run.

Interpretation of the Science

Environmental justice is certain to be a concern, when sites for aquifer sequestration are selected.

Liability for mistakes and misbehaviors will need to be part of any system. Insurance will be part of any system. "Getting the incentives right" will be a challenge to policy design. Economic instruments need to be invented.

The permitting system could be based on several classes of permits, differing in the leakage rate that can be certified at a given level of confidence. The analogy is to classes of bonds (AAA, BB, etc.). A certain number of permits of each class would be issued, based on aggregate risk. Permits to use lower performance sites would be more expensive. There would be a lowest permissable grade of permit.

For specificity, one of us (Socolow) proposed that the lowest permissable condition might be a half-life of 300 years with 95% confidence.

Ethical issues surround our thinking about future generations. It is assumed in some world views, including the dominant world view of economics, that future generations will be richer and smarter. Within this world view, one can imagine that:

> Future generations will want to assess liability for mistakes and misbehaviors related to earlier sequestration efforts. Limits to the practicality of such activities will grow over time.
>
> Future generations will want to manage their climate. As a tool for doing so, they then may wish to retrieve the carbon dioxide from its sequestration sites.
>
> Future generations will still contain terrorists. It is important to note that carbon sequestration has no equivalent to the "plutonium mine" of nuclear waste disposal. (The plutonium in nuclear waste becomes more retrievable as time passes, because much of the surrounding radioactive waste decays away. Over time, it is argued, the plutonium becomes an attractive nuisance. Of course, over time it also becomes a more available energy resource for benign purposes.)

In other world views, future generations will not be richer or smarter. One can imagine that:

> Future generations have a lower level of scientific understanding. A Dark Age has intervened. They may be unable to measure leaks or understand their significance. It is important to note that it will be difficult for future generations of innocent savages to hurt themselves accidentally by accessing the deep aquifers in which carbon dioxide had been placed. This is different from the problem of inadvertently accessing a site of nuclear waste or hazardous waste disposal.

It is important to identify and discuss publicly the similarities and differences between carbon sequestration and nuclear and hazardous waste disposal.

If a broad consensus is achieved in favor of carbon management, there will be a need to institutionalize the role of skeptic, watchdog, advocate of future interests, so as to reduce the risk that inertia leads to smugness, conformity, and corner-cutting.

TIMING ISSUES RELATED TO INITIATING A PERMITTING PROCESS

There are at least three reasons why sequestration projects will be conducted even in the absence of a permitting process: There is science to be learned within an R&D framework; there is experience to be gained within an entrepreneurial framework; and there is good will to be gained within a corporate marketing framework.

Nonetheless, proceeding with the development of a permitting regime should not be delayed indefinitely. The process of developing a permitting regime will broaden public participation beyond what can be expected to be achieved within the three frameworks just cited.

It will be critical not to thwart on-going industrial activity, such as enhanced oil recovery and underground natural gas storage. **Recommendation:** A class of permits should be created specifically for activity that is already underway.