Policy Principles Paper

A Framework for Certification and Operation of CO_2 Geological Storage Sites

The Issue

Widespread deployment of CO_2 Capture and Storage (CCS) will require standards and criteria to provide assurance of the long-term security of CO_2 Geological Storage (CGS). This paper describes several technical criteria that could be employed in a framework for certification and operation of CGS sites.

The oil and gas industry has over a century of experience of managing various high-pressure fluids in deep geological formations. This paper builds on that extensive knowledge base and outlines some high-level technical criteria that would be specifically applicable to CGS sites.

Background

Potential geological storage sites for CO_2 will not be found everywhere and will vary considerably in quality and capacity from one location to another. Some locations will prove to be outstanding in their ability to safely store large volumes of CO_2 while others will be poor choices. The knowledge base for site selection will vary considerably from region to region. Basins where oil and gas exploration has been active are likely to have both suitable sites and an extensive knowledge base that can be leveraged to predict storage performance with a high degree of confidence. Any CGS industry should build upon the existing knowledge and practices of the oil and gas industry. The UN IPCC Special Report on CO_2 Capture and Storage (SRCCS) states:

> "Available evidence suggests that, worldwide, it is likely that there is a technical potential of at least about 2,000 $GtCO_2$ (545 GtC) of storage capacity in geological formations. … There could be a much larger potential for geological storage in saline formations, but the upper limit estimates are uncertain due to lack of information and an agreed methodology. … The capacity of oil and gas reservoirs is better known. Technical storage capacity in coal beds is much smaller and less well known."

Early CGS projects will likely seek synergies with oil-fields that operate Enhanced Oil Recovery (EOR) projects or gas-fields operating Enhanced Gas Recovery (EGR) projects. Such sites are generally very well-characterized, but are operated to maximize cost-effective oil or gas recovery. These projects do not maximize the volumes of CO_2

Version 7: 16 July 2007

permanently stored in reservoirs, and there is no monitoring of the CO_2 after the project closes down.

Depleted gas fields are likely to provide excellent storage sites with minimal risk. Coal seams offer interesting opportunities, but issues about potential injection rates need to be addressed and resolved before large injection volumes are contemplated. While deep saline formations offer the most significant storage capacity for CO_2, in nearly all cases much less is known technically about the distribution of reservoir properties and seal for saline reservoirs than known about corresponding depleted oil and gas reservoirs in any given basin.

Large quantities of CO_2, natural gas, hydrogen sulfide and other fluids (including water and steam), have been safely injected into the subsurface for many years. In areas where this is done, regulations exist and are enforced to protect health, environment, and safety for the workers of the facilities and of the surrounding communities.[1] Many of the essential subsurface scientific and engineering principles used for developing those regulations can be adapted for large scale CGS. The SRCCS states:

> "With appropriate site selection based on available subsurface information, a monitoring programme to detect problems, a regulatory system and the appropriate use of remediation methods to stop or control CO_2 releases if they arise, the local health, safety and environment risks of geological storage would be comparable to the risks of current activities such as natural gas storage, EOR and deep underground disposal of acid gas."

Implications for Industry

Oil and gas companies have decades of experience safely injecting CO_2 and natural gas into geological formations in North America and Europe. In maturing oil fields, CO_2 is injected to enhance recovery of oil. In depleted gas fields, companies inject natural gas so that the gas can be stored to meet seasonal gas demand increases. Both types of operations are extensively regulated, from transport to injection and storage. In Canada, gas containing both CO_2 and hydrogen sulfide ("acid gas") has been injected safely for many years as well.

Site selection is paramount to the successful deployment of carbon capture and storage projects. The oil and gas industry has developed a wide array of techniques for reservoir and trap characterization and gas monitoring that can be applied to selection of CO_2 storage facilities. In reference to engineered systems for storage, the SRCCS states:

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[1] See CCP2 Principles Paper "Regulatory Treatment of CO2 and Impurities for CO2 Capture, Transport, and Storage Facilities."

"Observations from engineered and natural analogues as well as models suggest that the fraction retained in appropriately selected and managed geological reservoirs is very likely to exceed 99% over 100 years and is likely to exceed 99% over 1,000 years. For well-selected, designed and managed geological storage sites, the vast majority of the CO2 will gradually be immobilized by various trapping mechanisms and, in that case, could be retained for up to millions of years. Because of these mechanisms, storage could become more secure over longer timeframes."

The implication of this key finding of the SRCCS is clear: well selected, designed and managed geological storage sites are required for safe, long term storage. A basic framework of principles and criteria that builds on industry's knowledge and new lessons from current projects will be required for the successful deployment of CGS projects.

Recommended Principles for Certification and Operation

Summary

The overarching principle is that a site certification and operational framework can be practical From decades of oil and gas industry operational experience, an adequate level of knowledge of the subsurface chemistry, physics, and geology is already enabling the construction of analytical tools and computer simulations that allow the confident prediction of the performance of any CO_2 storage system in the subsurface. These tools are being adapted for local conditions, commensurate with perceived risks. Every site is different and should be evaluated on a site-specific basis by qualified experts from industry and government authorities.

Principle of Risk Mitigation

The CO_2 Capture Project recommends that CGS projects align with a principle of risk mitigation, which is described well in the SRCCS:

For geological storage, effective risk mitigation consists of four interrelated activities:

- Careful site selection, including performance and risk assessment and socio-economic and environmental factors;
- Monitoring to provide assurance that the storage project is performing as expected and to provide early warning in the event that it begins to leak;
- Effective regulatory oversight;
- Implementation of remediation measures to eliminate or limit the causes and impacts of leakage.

On the last point, the CCP believes that appropriate site selection should minimize the likelihood of the need for any remediation during the operational phase and at the time of site closure. At the same time, CCP recommends that project operators develop a plan for remediation measures early in the site certification phase of a project and continue to revise periodically such a plan based on experiences and data gathered during the operational phase and at the closure of the project. The plan and responsibility for remediation would be turned over to the government authority post-closure.

Framework for Certification and Operation of CO_2 geological storage

Four phases of CO_2 injection and storage can be defined. They are:

1. Site Certification (site appraisal and pre-injection certification)
2. Operation (site construction and injection operation)
3. Closure (post-injection and site decommissioning)
4. Post-Closure (post decommissioning – very long term)

1. Site Certification (short-term; project approval and investment)

The IPCC Inventory Guidelines (2006) on CCS offer national governments a proposed series of steps for estimating, verifying, and reporting CO_2 emissions from storage sites. For site evaluation, the Guidelines state:

> "Determine whether an adequate geological site characterization report has been produced for each storage site. The site characterization report should characterize and identify potential leakage pathways such as faults and pre-existing wells, and quantify the hydrogeological properties of the storage system, particularly with respect to CO_2 migration. The site characterization report should include sufficient data to represent such features in a geological model of the site and surrounding area. It should also include all the data necessary to create a corresponding numerical model of the site and surrounding area for input into an appropriate numerical reservoir simulator. Proper site selection and characterization can help build confidence that there will be minimal leakage, improve modeling capabilities and results, and ultimately reduce the level of monitoring needed."

The right to store CO_2 will have to be granted by the appropriate government authority. Site conditions should also be defined for turning over the site to the government authority. Therefore, before a storage project is approved, the government and the commercial entity will have to agree to the initial site conditions (i.e., the baseline) and operational limits, so that the site can be returned to the government at the end of the project. Initial site certification will require a site-specific risk assessment of numerous factors, including seal capacity and reservoir fluids pressure, their chemistry, etc. A data acquisition and analysis program will likely be required to bring all potential storage sites up to an appropriate level of risk of leakage.

In addition to the IPCC Inventory Guidelines (2006), national guidelines are emerging on how to evaluate potential sites. In the United States, the Environmental Protection Agency (EPA) issued final guidelines, March 2007, for evaluating storage sites of pilot projects proposed under the US Department of Energy's Regional Carbon Sequestration Partnerships. In the Underground Injection Program draft guidance #83, the EPA states:

> "The appropriateness of injection sites selected for pilot CO2 injection will depend on the goals of the project. Possible experimental goals may include testing the effectiveness of various geologic formations in receiving or trapping CO2 (e.g., short-term and long-term relations between trapping mechanisms, structural and stratigraphic considerations, and formation impacts such as solubility and mineralization); failure scenario testing; or testing or validating the accuracy of models in certain geologic conditions. In general, to prevent endangerment of [underground sources of drinking water], an adequate receiving and confining system for a CO2 injection site should consist of:
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> - A receiving zone of sufficient depth,4 areal extent, thickness, porosity, and permeability;
> - A trapping mechanism that is free of major non-sealing faults;
> - A confining system of sufficient regional thickness and competency; and
> - A secondary containment system which could include buffer aquifers and/or thick, impermeable confining rock layers."
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> On the last point, the CCP agrees and further recommends that the storage project proponent assess the proposed storage site as part of a regional containment system. While the IPCC and the US EPA guidelines may not be used ultimately for large scale storage projects, the concepts embodied in these criteria can serve as the basis for discussions between government authorities and the project proponent on more detailed assessments and certification of individual storage sites.

2. Operation (CO_2 injection; duration could vary from a few years to decades)

Depending on the quality of the site and the assessed risk of leakage, operational requirements will include the need to meter the pressure, regulate the flow-rate and define the composition of the CO_2, the need to comply with local regulations on the use of CO_2 resistant construction materials in wells, cement plugs and surface facilities, and the need to adhere to a monitoring regime that will include updates to, and validation of, the reservoir modeling. Performance results will be reported periodically to the regulator. As in hydrocarbon operations, the regulator may require intervention if the performance measurements are significantly different from the modeling predictions.

Each site's monitoring program should adopt monitoring activities that are consistent with the determinations made during the site characterization phase on leakage risk assessment and suitable to compare with modeling results. In general the monitoring program should include provisions for:

- Background fluxes of CO_2
- Continuous measurement of the mass of CO_2 injected at each well throughout the injection period
- Monitoring to determine any CO_2 emissions from the injection system
- Monitoring to determine the volume of CO_2 produced back to the surface in conjunction with an associated EOR scheme or concurrent production operations.

Changes to an agreed monitoring program could be made, subject to case-by-case agreement between the regulator and the operator, as technology for monitoring and risk assessment improves and experience is gained from a portfolio of early projects.

3. Closure (CO_2 injection ceases; duration of this phase may vary)

Once CO2 injection ceases, the operator can apply for a closure certificate based on the initial site certification obligations and the monitored performance of the site during operation. Once this certificate has been agreed, the operator can remove the infrastructure (and associated intervention capability). Ownership and all liabilities should revert to the appropriate government authority.

Before storage operations commences, a clear and predictable framework is needed to regulate how liability will be transferred from the operator to the government at the cessation of operations. For example, the authority responsible for issuing the permit for closure should outline the criteria or performance requirements that would trigger cessation of liabilities for the site operator. Such criteria would need to be in accordance with clear requirements set out in the regulations in order to give a degree of clarity at the time of project investment. At the point of liability transfer industry should be held harmless from all liabilities, At minimum, in common law regimes, the government should indemnify the project operator against all liabilities from permitting authority and third-parties. The liabilities regime will also need to address the re-use of previously closed (abandoned) oil or gas reservoirs. The risk of inheriting liabilities connected with previous use as a hydrocarbon reservoir could deter many operators from re-opening these for CCS use.

This closure period should be as short as possible because during this period, the operator will continue to incur infrastructure operating expenses, but have no source of revenue.

4. Post-Closure (monitoring may not be required; duration may vary)

Post-closure requirements should be determined on the basis of site-specific risk assessments, accounting for risks identified during the original and the subsequent pre-closure site certification and on modeling versus performance results during operation. A well-characterized site that has achieved its performance goals should require no long-term monitoring, while a poorly characterized site whose performance did not match modeling expectations will require long-term monitoring and possibly remediation/mitigation obligations. The project proponent and the government authority will need to negotiate and agree to appropriate site-specific obligations within those two extremes.

Taken together, the general principles and the outlined elements of a proposed framework in this paper can form the basis for developing detailed elements that would be required for further discussion with government authorities on site selection, operation, and risk mitigation of a CO_2 injection and storage project.