

## **Attributes of an Effective Regulatory Regime for CO<sub>2</sub> Geological Storage**

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### **Introduction**

Carbon sequestration is a generic term for fixing carbon on the earth, rather than in the atmosphere (where it is the main cause of global warming). There are several forms of carbon sequestration (including forestry, ocean storage and mineralization). This essay focuses on CO<sub>2</sub> Capture and geological Storage (CCS), which is a technology that could cost-effectively solve around a quarter of the global warming and ocean acidification problems.

The developed countries have used up the planet's carbon budget in achieving their high living standards. They therefore need to take the lead in solving the global warming problem. This essay focuses on North America, Europe and Australia, although ultimately, comprehensive frameworks will be required for CCS projects in developing countries.

Commercial entities cannot currently invest in CCS projects because they cannot answer the two basic questions required by any commercial venture:

1. Is it legal?
2. Can I get paid to do it?

This essay focuses on the first question, although the answer to question 2 – the commercial mechanism will have significant impact on the volume of CO<sub>2</sub> to be stored. Incentivising CO<sub>2</sub> stored will lead to larger volume of stored CO<sub>2</sub> than incentivising CO<sub>2</sub> avoided. The objective of any long-term CCS policy framework should be to maximize the volume of CO<sub>2</sub> avoided, while minimizing the volume of CO<sub>2</sub> stored.

CCS projects generally have three parts:

1. Capture
2. Transport
3. Storage

CO<sub>2</sub> Capture is a similar activity to existing fertilizer and chemical plants. The transportation of super-critical CO<sub>2</sub> in pipelines is similar to existing pipeline transportation of other fluids. Hence, CO<sub>2</sub> capture and transport will generally be regulated by existing frameworks (in some cases with limited modification). These are not addressed by this essay.

Geological storage of CO<sub>2</sub>, however is sufficiently different from existing activities that it raises new regulatory issues, for which there are few precedents. No region has a comprehensive regulatory framework governing CCS, but several processes are now under consideration. This essay explores attributes of a framework to regulate the geological storage of CO<sub>2</sub>. The primary purpose of a CO<sub>2</sub> storage regulatory framework would be to assure the public that the global benefits of CO<sub>2</sub> geological storage exceed the local environmental risks.

Every activity carries associated risks – cars crash and dams burst and yet people persist in driving to work and drinking water. The level of risk associated with an activity can be governed by the regulatory framework applied – the consequence of failure of a helicopter engine is far more serious than that of a car engine and hence the two operate under quite different environments and regulatory frameworks, with different levels of reliability.

### **Analogs for CO<sub>2</sub> Geological Storage**

Close analogs for CO<sub>2</sub> geological storage can be found in the oil and gas exploration and production industry, and particularly in the subset of natural gas storage. The technical limitations of natural gas storage as a precedent for CO<sub>2</sub> geological storage are generally:

1. Natural gas storage is generally shallower than CO<sub>2</sub> storage would be
2. The volumes of stored fluids are much smaller
3. Methane (natural gas) has quite different physical properties from CO<sub>2</sub>
4. Developers of natural gas storage projects want to seasonally reproduce their fluid, whereas developers of CO<sub>2</sub> storage projects want their fluid to be stored indefinitely

Natural gas storage generally carries higher local environmental risks than CO<sub>2</sub> storage, but the commercial value is also higher - natural gas is worth an order of magnitude more than CO<sub>2</sub> (>\$200/tonne compared to <\$20/tonne).

### **The Public Perception of (Global) Benefits and (Local Environmental) Risks**

The purpose of a CO<sub>2</sub> storage regulatory framework should be to assure the public that the global benefits exceed the local environmental risks. The concept of injecting and storing pressurised gas underground is not something people embrace without reason. Awareness, or familiarity, with not just CCS but the whole issue of climate change is an important factor in shaping public perceptions of CCS. As people gain familiarity with the various aspects of CCS (say drilling or injection), their comfort level with the technology increases. Likewise, when placed in the context of developing a portfolio response to climate change, public appreciation of the benefits of CCS increases. In contrast, the general response to CCS in the absence of a strong link to climate change is ambivalent.

Currently, awareness of climate change is minimal in many countries and familiarity with CCS is low or virtually non-existent. However, there are strong signs that awareness and concern about climate change are growing rapidly. Further, the implementation or announcement of industrial-scale CCS projects, combined with the increased discussion of CCS in the international climate community are all contributing to greater coverage of CCS in the media and consideration of the role of CCS in climate policy discussions.

Regardless of the assessed level of risk of an activity, regulatory frameworks are often driven by the public perception of risk. There are so few operational CCS projects in the world that the perception of local risks associated with catastrophic leakage of CO<sub>2</sub> from storage is immature, but very important to address. Research has shown that environmental groups and the general public tend to be most concerned about the local health and safety issues arising from CCS. In contrast, industry and the R&D community are less concerned because they have confidence that appropriate safeguards can be used to prevent adverse effects. Important observations relating to perceived risks include:

- a. In general, stakeholders seem comfortable with the notion that risk of catastrophic leak is relatively small, but it seems clear that such wholesale leakage would have very large negative impact on perceptions.

- b. There will likely be significant public concerns about the indirect effects of CCS, such as reduced property values from proximity to storage areas.
- c. Even those risks with a very low probability of occurrence can have significant influence on public perceptions and need to be taken seriously.

### **Adequacy of Regulatory Frameworks to Address Risks**

No region has an adequate regulatory framework in place to govern CCS. In several regions existing environmental rules governing drilling, injection and gas transportation are being used to regulate aspects of CCS, but there are no comprehensive rules for long-term storage. In several countries there are processes underway to develop these regulations. It will be critical that these regulatory development processes consider the broader set of perspectives related to CCS rather than focusing more narrowly on just the technical issues. Such regulatory development processes need to be consultative and they should be linked to supporting policy development.

### **Regulatory Subsidiarity**

The competence to regulate geologically stored CO<sub>2</sub> currently exists at a national or a State level, either with hydrocarbon extraction regulator (the IOGCC in the US or the DTI in the UK), or with the terrestrial waste disposal regulator (the EPA in the US or DEFRA in the UK). Such competence is devolved from supra-national bodies (such as the European Union or the United Nations), following the principle of subsidiarity. The purpose of a CCS regulatory framework should therefore be to guide the conversation between a nation/landowner and a commercial entity wishing to develop a geological storage project. Because Mother Nature made geology different around the globe, no two CO<sub>2</sub> storage sites will be the same and permitting requirements for CO<sub>2</sub> storage will have to be a site-specific conversation between a regulator and a project developer. Oil and gas (and natural gas storage) projects are permitted in this way.

### **The Regulatory Framework for Oil and Gas Activities**

Existing legislation for petroleum activities provides regulatory frameworks for the exploitation of oil and gas resources, transport of oil and gas produced, and operation and decommissioning of oil and gas fields. Many of the issues that need to be considered for CCS activities are therefore already regulated, particularly so for those CCS operations involving enhanced hydrocarbon recovery. The development of new regulations is likely to be required to address certain novel aspects of CCS, for example for storage of CO<sub>2</sub> in deep saline formations (for which there are presently no legislative provisions). However, here too the existing principles contained in current petroleum legislation could provide a useful starting point. The process for authority assessment of CO<sub>2</sub> licence applications, and the technological and environmental scrutiny that a licence application will undergo, will be specific to this activity. Adopting the principles of petroleum legislation in this way will enable governments and industry to build on the positive experience of a longstanding and efficient regulatory framework.

### **An Outline Regulatory Framework for CO<sub>2</sub> Geological Storage**

The IPCC Special Report on CO<sub>2</sub> Capture and Storage states that “the proportion of CO<sub>2</sub> retained in appropriately selected and managed sites is.....likely to exceed 99% over 1000 years”. Therefore the focus of a regulatory regime should be on the appropriate selection and management of geological storage sites. Subsequent monitoring will depend on the assessed risk of leakage from individual sites and should be developed on a site-specific basis by agreement with the national regulator. Well characterised sites (such as oil and gas fields - that have proven traps) will require less monitoring than poorly characterised sites (such as deep saline formations). Specific issues to be considered in the regulatory framework are set out below in chronological order in the life of a CO<sub>2</sub> storage site (with indicative time-periods):

#### **1. Site Certification (short-term, indicative - years 0-5)**

The right to store CO<sub>2</sub> will have to be granted by the State and should define site conditions upon return to the State. Therefore, before a storage project is approved, the State and the commercial entity will have to agree on the initial site conditions (baseline) and operational limits, so that the site can be returned to the State at the end of the project. Initial site certification will require a site-specific risk assessment, based on seal capacity and reservoir fluids (pressure, 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.

#### **2. Operation (mid-term, indicative - years 6-39)**

Depending on the quality of the site and the assessed risk of leakage, operational requirements will include the need to meter and limit the pressure, temperature, flow-rate and composition of the CO<sub>2</sub>, the need to comply with local regulations on the use of CO<sub>2</sub> 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 to the modeling predictions.

Each site's monitoring program should adopt monitoring activities that are consistent with the site characterization leakage risk assessment and modeling results. In general the monitoring program should include provisions for (i) Background fluxes of CO<sub>2</sub>; (ii) Continuous measurement of the mass of CO<sub>2</sub> injected at each well throughout the injection period; (iii) Monitoring to determine any CO<sub>2</sub> emissions from the injection system; (iv) Monitoring to determine CO<sub>2</sub> produced back to 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. Pre-Closure (mid-term - indicative year 40)**

Once CO<sub>2</sub> injection has ceased, 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) and ownership and liabilities will revert to the State.

Before storage operations commence, a clear and predictable framework is needed to regulate how liability will be transferred from the operator to the State at the cessation 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 some clarity at time of project investment. At the point of liability transfer industry should be held harmless from liabilities, except in the case of negligence. 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 Pre-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 (long term - indicative years 40-1,000)**

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 modelling versus performance results during operation. A well-characterised site that has achieved its performance goals should require no long-term monitoring, whilst a poorly characterised site whose performance did not match modelling expectations will require long-term monitoring and possibly remediation/mitigation obligations. A competent regulator should decide on appropriate site-specific obligations within those two extremes.