Regulation of Carbon Sequestration:
Organization and Process

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January 2007

Draft; not for quotation

The technologies surrounding carbon capture and sequestration (CCS) are economically and politically important in the emerging debate over how to control emissions of greenhouse gases. They offer the potential to utilize coal, which is abundant and inexpensive worldwide, which could help lower the cost of slowing global climate change. And by keeping an abundant and politically well-connected fuel viable, CCS will help blunt and redirect the severe political opposition that big coal has mobilized against controlling carbon. These arguments are especially important in China, India and the United States—the three nations whose consent is essential to the practical success of any global warming policy and all depend heavily on coal.

This essay examines the regulatory dimension of CCS. My focus is on the grand strategy of regulation—its broad goals, progress and organization—rather than the important details and particulars. The purpose is to explore three essential aspects of a regulatory strategy:

- the regulation of demonstration-scale CCS projects, with the goal of gaining diverse information needed to steer further investments in R&D and also to preparing effective regulation of commercial-scale CCS. Concerning demonstration projects, the experience outside the realm of EOR-like injection programs, for there is already extensive experience with EOR and most of the relevant parts of the world already have EOR regulatory systems in place due to the oil and gas industry;
- transforming lessons learned during demonstration projects into a viable framework for the regulation of commercial operations;
- international coordination and rule-setting.

In discussing these issues, the paper is guided by three sobering lessons from the experience with regulation of nuclear power. First, the nuclear power experience underscores that there can be extremely large differences between the theoretical engineering potential of the technology—for CCS that potential is, indeed, inspiring—and its practical application in real markets. Many, perhaps most, highly regulated complex engineering projects fall short of their potential, and in the case of nuclear power to date the shortfall has been quite substantial. The design and implementation of regulation explains a large part of the shortfall. These lessons are being learned in nuclear power, of course. In the West there have been important innovations, over the last two decades, to create new more commercially-realistic systems for regulation of nuclear units. CCS will be stillborn, at least for a generation if not longer, if the regulatory environment is not designed with commercial realities in mind. Yet today, nearly all discussion focuses on the engineering potential of CCS and not on how that potential might be realized within real regulatory frameworks that operate at a commercial scale.

Second, the nuclear power industry has been a crucible for an influential tranche of sociological research on "normal accidents." Those studies argue that complex organizations are prone to fail and that "fixes" to make them "safer" yield higher levels of complexity that, in turn, amplifies the danger of cascading failures. As that field of study has progressed its conclusions have become more nuanced and less dismal. Organizational sociologists have identified the types of complex organizations that are prone to resilience and reliability and those likely to become brittle and unable to adapt. This conclusion suggests that when regulating CCS we must be attentive to the types of *organizations* that are likely to implement the technology—especially as the technology reaches commercial scale and is managed in a complex organizational environment rather than as an experimental boutique. It is not enough to answer the question "what kind of CCS regulation would be ideal?" by focusing on the technical attributes of the answer; we must also focus on the performance of the implementing organizations. For CCS, the organizational answers may be particularly important yet difficult to supply because CCS is unlikely to be run by stand-alone organizations focused on a single mission. Rather, CCS seems likely to be grafted on to existing organizations that operate electric power plants. The cultures of these types of organizations may be quite different. Indeed, for these organizational reasons alone it may prove difficult for most conventional power utilities—run by power engineers—to operate the complex chemical and subsurface activities that are typical of a CCS system.

Third, the nuclear power industry is famously a reminder of the risks of contagion. An accident or poor reputation that occurs anywhere worldwide in the industry will harm the prospects for use of the technology everywhere as a skittish public demands more onerous (or prohibitive) regulation. The risk of a catastrophe with CCS is much lower, of course, but some CCS risks are of the type that could lead to political contagion. These include, notably, the possibility of abrupt release of CO_2 due to faulting or other types of poor site selection and management, or operational problems such as failure of cement plugs in the high CO_2 environment. Even more minor leaks, whether prompt or slow, could generate a firestorm of reporting and speculation. These risks are not fanciful, even though they often leave engineers puzzled as to why local communities seem to "over-react" to modest risks. Underground gasification has run into trouble with neighboring communities who object to "setting the ground on fire." And LNG, despite a stellar safety record with no breaches of LNG tankers during four decades, suffers contagion from largely imaginary dangers.

<u>Demonstration Plants and Projects</u>

The goal with demonstration projects is to gather sufficient information to assess the feasibility of different technology paths for future investment and to make wider application of the technology feasible.

A regulatory environment must exist so that a range of demonstration plants can be built without undue regulatory barrier. Much attention is beginning to focus on the regulatory environment for underground sequestration, especially for non-EOR projects (for which a regulatory system is already in place in most relevant countries). Some kind of system must be in place so that underground experiments can occur and to assign mineral rights (or, perhaps, "anti-rights" since sequestration potential, such as pore space, is an exhaustible resource). Those are important questions, and other papers at this conference will look at those systems in more depth. Concerning sequestration in deep aquifers, for example, in the United States there is no immediately analogous situation that can guide regulators and thus perhaps the investor in a demonstration project will not know how to assure regulatory compliance, which almost certainly would make the project impossible to conduct since the effort would not pass any of the normal internal compliance reviews in modern corporations.

Gaining regulatory approval, though, is not just a matter of the subsurface. A larger challenge could be gaining credible approval from electricity regulators to build the plants at all. Demonstration plants will be built mainly, probably exclusively, by electric utilities that operate in regulated markets—either as privately owned and controlled through independent regulators (e.g., U.S. and some of continental Europe) or through the control that accrues through state ownerships (e.g., China). I will focus on regulated privately-owned utilities since they are located in the countries that are most likely to be interested in spending large amounts of money on CCS demonstration projects.

In principle, the status of a regulated firm should make it easier for firms to take risks with immature technologies because regulators can promise the utility that it will be made immune (fully or partially) from the commercial risk that arises from experimenting with a highly risky, capital-intensive technology. In practice, whether that actually transpires depends on the mandate of the regulator. Most regulators view their role as serving the public through assuring the least cost and most reliable electricity—a mission quite incompatible with building risky, expensive power plants. Even in those circumstances where regulators approve such plants, utilities have been wary about whether that regulatory approval is credible.

No matter what the regulators approve as "prudent"—which itself is likely to be narrow because regulators are mainly focused on cost and reliability for the near term—if the technology fails then the shareholders and firm managers will suffer a loss. In the United States, the most relevant precedent is from the large-scale investment in nuclear power plants, many of which proved to be much poorer financial investments than the utility anticipated when it made the original commitment. Despite assurances from regulators that plants would be allowed in the rate base and thus the actual risks from these investments would be small, the shareholders have been forced to pay a substantial fraction (usually more than half) of the lost value in cases where those investments have gone awry. The courts, including the U.S. Supreme Court, have consistently said that regulators are not required to honor previous commitments so long as they are not arbitrary and capricious when they change their minds—even though such reversals undermine the credibility of public institutions and make it harder for the future, as today with CCS, to encourage regulated utilities to invest in unproven technology.

This conservatism suggests a) that regulated utilities are likely to under-invest in risky technologies and b) that the range of demonstration projects actually built is likely to concentrate on a few technologies that can be benchmarked against each other (which makes regulatory review easier and less risky) and on technologies for which equipment vendors are willing to provide performance guarantees (which shifts the cost of error to other players, which is more attractive to a regulated firm even if it means paying more for the plant). For regulators, that will appear to be a prudent outcome. For society, however, that outcome is perhaps precisely the opposite of what is needed—a wider range of experiences so that utilities do not focus their orders for commercial plants on an excessively narrow range of experiences. Active efforts—perhaps with compensation guarantees to protect firms against regulatory delay and under-recovery, such as are now available for new nuclear plants—will be needed to ensure a diverse portfolio of experiences at the demonstration stage.

This conservatism embedded in the regulatory process may help explain why U.S. utilities appear to be giving disproportionate attention to "capture-ready" IGCC. That's despite the fact that "capture ready" is a misnomer, not least because it is the operation of the whole system (including capture) that really matters.[1] And that's despite the fact that there are many non-IGCC options that merit experiment at the demonstration scale. The mania for IGCC, perhaps, reflects that "capture-ready" IGCC units are perceived as the least costly option that qualifies for subsidies that have been proffered by federal and state governments; performance guarantees appear to be available for IGCC systems; and, firms and regulators that travel as a herd can benchmark performance against each other.

At the same time that it will be necessary to ensure that the regulatory complex does not produce an exceptionally narrow range of technological experiences it may also be important for each demonstration project to be regulated tightly—to ensure that an accident does not create the political contagion that will be harmful to the industry

[1] On a related point, utilities will perhaps try to segregate projects so that they control only the electric power operations while another enterprise runs the sequestration. This may be a wise organizational strategy, but it will not diminish any of the issues discussed here about extensive prudency review by electric regulators as the regulator will demand to know about performance of the whole system before they deem the investment "prudent." Atomizing plant operations in this way will also produce a special incentive for large and well-established firms to supply sequestration services since utility regulators, unfamiliar with the risks and operation of sequestration, will be especially wary of approving projects that would become financial disastrous if the firm that handled sequestration were to utilize poorly performing technologies or go bankrupt.

worldwide. It may also be necessary to require that the regulatory process supply particularly large amounts of information—on process, risks, experiments, etc.—so that the full range of experiences can be assessed. My impression is that this has been done especially well in the Weyburn field and that we should not automatically assume that demonstration scale projects will make such disclosures, especially if they arise in a commercially sensitive context.

Commercial Scale Operations

The line between "demonstration" and "commercial" operations is a fine one, for most complex technological systems involve a blend of established and novel technologies. I will consider the shift to "commercial" operations to have occurred when a) firms invest in CCS because it makes business sense on its own without subsidy, which means that b) a suite of technologies has been tested and proven for their technical and financial performance (and that performance includes benchmarks acceptable to utility regulators), and probably c) it is clear who will regulate each component of the CCS system.

The regulatory challenges are likely to shift at this point. During the demonstration stage there is a need to gather especially large amounts of information and to explore a wide range of ideas because there is a larger public benefit in exploring all avenues to the extent possible. At the commercial stage such an excessive gathering of information will be prohibitive for operators who will want to know the standards for compliance—whether technological or performance—and be left alone to run his business to the extent possible.

This shift from demonstration to commercial operation will require a shift in regulatory approach. This shift will occur in the regulation of above-surface plant operations as well as below surface sequestration. For simplicity, I will use some illustrations from the subsurface. During the demonstration phase, regulation is an extremely demanding activity since it is a boutique operation that is conducted by highly skilled professionals who can examine and ponder a wide array of information—on all the topics that dominate today's literature on sequestration risks such as faulting, failures of cement plugs, and scenarios for catastrophic releases. A different approach is likely when the technology is applied at commercial scale, for regulators will not have the information they need (nor on a sufficiently timely basis) to micro-manage field operations, and regulators will be staffed by line geologists who are interested in regularity and routine. Regulators will need to function much as regulatory commissions for oil and gas extraction—providing broad oversight for injection plans, forcing coordination (unitization) between different commercial players where needed, and overseeing the integrity of the organizations that, themselves, actually devise the details of injection plans and make operational decisions.[2]

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[2] There are important questions about *who* will regulate the subsurface (except for EOR operations, which surely will be regulated by the same bodies that control EOR). The best precedents are not clear, and some

Several tasks are essential to prepare the regulatory environment. First, with information from demonstration projects and from careful assessment of regulatory options, it will be essential to devise standard oversight plans and expectations for the *organizations* that will engage in CCS—standards for disclosure and audit, obligations to disclose additional information in case of unexpected behavior in reservoirs, etc. Running CCS operations may prove extremely complex, especially if CCS is integrated seamlessly into the operation of an already complex power plant. The analogies might be drawn from the organizations that regulate chemical plants, as well as from complex oil and gas fields.

Second, regulators will probably need to be highly reflective on their activities—engaging in regular regulatory assessment—to ensure that the regulatory system remains designed and applied in a way that assures safety as well as verifiability of injections for the purposes of emission accounting. Insofar as it is not yet clear how to devise a regulatory system that is appropriate to the task, nor even the regulatory organizations that should be tapped, it is likely that much learning by doing will be needed. Testing of regulatory systems during demonstration projects will help, but the shift from a boutique custom-regulation to a more regular and commercial system will require large adjustments. Demonstration projects are much more able to tolerate the ambiguity and higher transaction costs of boutique regulation, not least because such projects thrive on subsidies and special guarantees. Commercial projects, on the other hand, will be especially sensitive to regulatory uncertainties and ambiguities—especially those that could lead to plant shutdowns during the early years of commercial operation when the present financial value of unfettered operations is especially high.

There has been some attention to a possible third task: international coordination. It is unlikely that CCS projects will be politically or legally viable if they contravene international law. There have been some summaries of the potential legal precedents—notably the Law of the Sea, the London Dumping Convention, and the North Sea conventions, and in the latter case some legal experts have done some work focused especially on the issues of CCS. The conclusions are ambiguous because it is unclear if CO_2 is waste, and the answer to that critical question probably depends on whether the CO_2 is put to useful purpose (e.g., EOR) or not. Under the London Dumping Convention it is probably (but not necessarily) difficult to permit dumping in the open ocean, but injection under the sea bed might be acceptable. Injection by ship is harder to justify than injection by fixed pipe because the legal history of dumping conventions focused almost entirely on ship-based dumping activities.

Two lessons follow from the various tortured efforts to figure out the applicability of existing legal treaties. First, it is unlikely that the existing suite of international agreements offers an adequate framework for regulation of CCS, and trying to shoe-horn CCS into these treaties is probably a lot harder than simply creating a new treaty. CCS is unlike any problem that has been addressed in the canon of ocean disposal law. (I focus

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of the obvious precedents—such as the EPA-supervised subsurface injection program—are not encouraging (see the paper by Wilson et al. circulated in advance of this workshop).

on oceans because nearly all the on-shore disposal options involve transport and disposal entirely within a single country or are likely to occur within an existing bilateral framework, such as between the US and Canada for projects such as the Weyburn field in Canada that uses CO_2 produced in the United States.)

The second lesson is that efforts to create a treaty to regulate CCS are likely to end in disaster. Treaties are highly conservative legal instruments; they are effective in setting standards only when countries know that they can comply. It is not clear what rules should govern CCS. If rules are adopted by treaty they will surely need adjustment, which is often difficult once international rules—especially those that are set by treaty and thus legally binding—are firmly in place.

When treaty negotiators are forced to confront technologies and practices that offer possible risks with uncertain and distant benefits, the treaty process usually generates conservative outcomes that put a cloud over new technologies. This tendency is especially strong when the negotiations occur in the context of emotive concerns about environmental harm. Thus the London Dumping Convention has frustrated a broad array of seabed dumping technologies, including for nuclear waste—an area that is promising in theory yet barely attracts any funding today because of the difficulty of commercializing such technologies that would probably be deemed illegal under the Convention and other international laws. When the United Nations sponsored the negotiation of the Convention on Biological Diversity (CBD) the questions of genetically engineered crops were attached to those negotiations—mainly because they had become a hotbutton issue for the environmental community and for many European governments. The CBD's first protocol, on "biosafety," was intended to set rules for genetic engineering even though there was no established relationship between biosafety issues and the underlying purposes of the Convention, which were to promote protection of biological diversity and to spread a greater share of the benefits from innovations that used nature's biological diversity to developing countries. The presence of genetically engineered crops in the CBD is partially responsible for the cloud over the technology that appeared just at the stage when genetic engineering was ready for commercialization.

A better solution than a new treaty would be a regulators' forum where national regulators could discuss their experiences and develop plans for making regulation more effective in the future. There are many such forums such as the *Codex Alimentarius* Commission (a forum for food safety regulators, organized by the FAO and WHO, at which regulators, based on their experiences in their home markets, negotiate coordinated regulations through a consensus-building process that eventually leads to more widespread application of the most effective rules), forums of central bankers, electricity regulators (in the US through NARUC and now also in Europe), and so on.

For CCS, the goals of such a forum would be: 1) diffusing information about regulations that work; 2) organizing that information so that regulators in the wide array of relevant areas, notably electricity and subsurface, can forge a useful cooperation; and 3) training programs and other activities that could ensure high levels of regulatory competence wherever the technologies are applied worldwide. Just as with banking and so many other areas modern activity marked by the danger of contagion, such a forum could help reduce the risk of dangerous CCS projects by making all regulatory systems more capable.[3]

The same logic leads to the need for a forum for the operators of CCS activities, akin to the INPO activities for nuclear plants. Because these operators will be drawn mainly from petroleum engineering, the Society of Petroleum Engineers is perhaps the most competent institution for convening them on a regular basis.

The process of regulatory assessment and learning might, in time, generate a canon of rules and standards that might be usefully written into international law, such as through a treaty or through widespread practice. In most other areas of international cooperation, however, such technical standards have much greater effect if they are left nonbinding and thus flexible. The effectiveness of transnational regulatory coordination arises, usually, not because of the legal status of the process but because the content of the coordination becomes embedded into the regulatory institutions and into the best practices that guide commercial operators. The experience with the *Codex Alimentarius* Commission is sobering. The Commission had high influence for many decades when it was organized as a voluntary body. In 1995 its rules took on a more binding character when they became the benchmark for resolving food safety disputes under the WTO. Ever since, a larger fraction of the Commission's proposed rules are put to a vote, efforts to coordinate new rules in complex or contentious areas have stalled, and the role of the body as a flexible regulators' forum has eroded.

Conclusions

I close by emphasizing a few key points that could help guide the *process* of establishing a sound regulatory strategy for CCS.

First, there is a special need for a wide portfolio of experiences during the demonstration stage of CCS. Just as there is perhaps excessive attention to IGCC without adequate focus on rival approaches in power generation, sequestration could suffer from a similar herd mentality. Active policy efforts will be needed to offset this tendency toward narrowness. The processes that govern regulated utilities will exacerbate this tendency to narrowness. This diversity is essential to ensure that a wide portfolio of technologies are put to the test, that the fullest information is gathered and disseminated, and that a wide range of possible regulatory systems and approaches is tested.

Second, it is likely that there will be large differences between the demonstration and commercial stages of CCS. During demonstration, the goal for regulators is to gain a wide array of information to assess the appropriateness of different regulatory models.

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[3] There are many ways that this could be organized. One strategy could combine the OECD (for its expertise on economic regulation and coordination) with the academies of sciences (which can mobilize the expertise needed to evaluate the appropriateness of regulatory frameworks for the subsurface). My impression is that subsurface regulators are not, already, well organized.

That process will yield boutique information with high transaction costs. For the technology to be viable commercial, it will be essential to transform that information and process into regulatory procedures that are not excessively onerous for commercial operations. Almost certainly, that commercial approach will require the setting of performance standards and organizational procedures so that the regulatory system does not create crushing uncertainties and ambiguities.

Third, efforts should be made to avoid the instinct, especially strong in international environmental circles, to address regulatory problems through international treaties. A treaty in this area, at the current stage where the best regulatory strategies are unknown, would be either so broad as to be useless or so uncertain and restraining in its application that it would cloud the viability of commercial application that the technology would be hobbled. Instead of a treaty, two forums—one for regulators and the other for CCS operators—could better promote the necessary coordination and diffusion of information.