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Abstract

This essay examines several legal, regulatory and organizational issues that need to be addressed to create an effective regulatory regime for carbon dioxide capture and storage ("CCS"). Legal, regulatory, and organizational issues will need to be resolved for the industrial organization of CO_2 transportation and storage, storage safety and integrity issues, and liability. Although there are some gaps in the current regulatory system as applied to CCS, we find that many of the currently identifiable issues have been successfully resolved in other contexts.

1. Introduction

Carbon dioxide capture and storage ("CCS") has emerged as a promising option among the portfolio of actions that may be taken to mitigate CO_2 emissions. Widespread deployment of CCS will require the resolution of a set of legal, regulatory, and organizational issues related to the industrial organization of CO_2 transportation and storage, storage safety and integrity issues, and liability. These areas are linked, with differences in liability standards and geology motivating reliance on pipelines for transportation of CO_2 as opposed to proximate storage. There are physical or historical regulatory analogs to almost all the legal, regulatory, and organizational issues of concern that arise here. Physical analogs are cases that are analogous in a physical sense to CCS, such as natural gas storage or enhanced oil recovery. Regulatory analogs may not necessarily address the same physical risks as CCS, but provide insight into the variety of policy templates that could be applied and the range of associated responses (Reiner and Herzog, 2004). In this essay, we explore the status of the current legal and regulatory framework that could govern CCS and identify what, if any, changes are needed to enable CCS deployment. Our analysis is restricted to the geological storage of CO_2 and, except where indicated, to the U.S. legal and regulatory system.

2. Industrial Organization: CO_2 Transportation and Storage

Much of the discussion of CO_2 transportation and storage has failed to articulate the likely industrial organization of these activities when they are undertaken at large scale. Indeed, the focus on one-off enhanced oil recovery ("EOR") projects is likely to provide an incomplete picture of what the industrial organization of these activities will look like at large scale in the future. By industrial organization, we refer to the ownership arrangements for pipelines and

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storage facilities, access and pricing policies that owners of transportation and storage facilities may be required to follow, the potential evolution of regulatory frameworks governing access and pricing, the application of the antitrust laws, and the mix of federal and state authority over both economic and safety aspects of transportation and storage facilities. The future CCS regulatory environment will depend on the industrial organization of the sector. An industrial organization where CO_2 is transported by a network of pipelines from multiple power plants capturing CO_2 to one or more storage sites will raise different regulatory and organizational issues from one where CO_2 pipelines and storage are a natural extension of an individual or proximate group of power plants where storage takes place very close to each facility. Most of the EOR experience involves private development of small individual point to point pipelines developed and owned by a single producer of CO_2 and supported by contracts between the producer and the owner of the facilities the buyers who use or store the CO_2. In a regime where many power plants are capturing CO_2, a more likely configuration will involve a networked system that is used by multiple power plants at different locations which are transporting CO_2 to one or more large storage sites. The historical analogies here are natural gas pipeline networks and oil pipeline networks. While such networks have traditionally been privately owned, industrial organizations may vary, involving both private and policy choices regarding the extent of vertical and horizontal integration. These pipeline networks have historically been subject to administrative regulation of transportation and storage prices (in the case of natural gas), access rules allowing third-parties to gain access to pipelines with natural monopoly attributes. The evolution of these industrial structures have also been influenced by the antitrust laws and antitrust sanctions resulting from abuses of dominant positions by pipeline owners. As with the natural gas and oil pipeline sectors, it is likely that it will be necessary to consider the administrative regulation of access to pipeline networks, price regulation of transportation and storage, and antitrust policy issues. The regulatory history of oil and natural gas pipelines and storage provides useful lessons for CCS.

Oil

There is a long history of antitrust policies regarding oil pipelines going back to John D. Rockefeller's Standard Oil Company in the late 19^{th} century. Antitrust doctrines related to "essential facilities," "foreclosure," and "refusals to deal" can be traced back to mergers, pricing, and access behavior that emerged during the early oil pipeline development period. At large scale, antitrust law will be potentially relevant to issues of CO_2 pipeline access, ownership structure, and pricing.

As a result of the abuses by Standard Oil Company, Congress enacted regulation of interstate oil pipelines under the 1906 Hepburn Amendment to the Interstate Commerce Act ("ICA"). The Hepburn Act had several consequences for oil pipeline regulation: (1) the Interstate Commerce Commission ("ICC") was granted federal regulatory responsibility over interstate oil pipelines; (2) most interstate oil pipelines were declared to be common carriers; (3) shipment rates were required to be "just and reasonable"; and (4) shipments were required to be allocated on a nondiscriminatory basis (Birgisson and Lavarco, 2004; Hansen, 1983). However, several aspects of interstate oil pipelines were left unregulated, including the siting and construction of oil pipelines; abandonment or termination of service; and mergers, consolidations, and common control of oil pipeline assets (Coburn, 1982).

The ICC regulatory era over oil pipelines has been characterized as "benign neglect" (Coburn, 1982). Little was done to enforce federal regulatory authority, other than to establish general principles for the pipeline industry (Coburn, 1982). The regulatory efforts centered on valuation. Rates were initially fixed with respect to "fair value", and not on the basis of cost. It was not until 1940 that the ICC expressed an opinion on the reasonableness of rates, when it adopted a generic rate of return of 8% for the transportation of crude oil and 10% for the transportation of oil products (*Reduced Pipe Line Rates and Gathering Charges*, 1940). Rate issues were not considered again until the 1970s in the *Williams* and the Trans-Alaska Pipeline System cases. While the cases were being decided, the Department of Energy Organization Act of 1977 transferred responsibility for oil pipelines from the ICC to the U.S. Federal Energy Regulatory Commission ("FERC").

The FERC era has seen a similarly long and tortured history. As a result of D.C. Circuit criticism of the ICC valuation methodology (*Farmers Union Cent. Exch. v. FERC*, 1978), FERC retained the ICC valuation rate base, but adopted a new rate of return methodology (*Williams Pipe Line*, 1982). However, this methodology was rejected by the D.C. Circuit because FERC failed to provide a reasoned explanation for its departures from a cost-based approach (*Farmers Union Cent. Exch. v. FERC*, 1984). FERC issued a revised regulatory standard, which adopted a modified trended original cost ("TOC") methodology for oil pipelines, and provided for a "transition rate base" between the valuation rate base and the TOC rate base. FERC moved to a market-based rate alternative in the *Buckeye* proceeding of 1988. The rule, whose applicability has been broadened to all oil pipelines, established that "light handed regulation" (i.e. market-based rates) would apply where there was a lack of significant market power in the relevant markets (*Buckeye Pipe Line*, 1988). More recently, under direction from the Energy Policy Act of 1992, FERC developed a pricing index used to establish ceiling levels for oil pipeline transportation charges (Order No. 561, 1993).

Natural Gas

Federal regulation of interstate natural gas transportation was created to protect shippers and ultimately natural gas consumers from excessive transportation charges. The rationale for transportation price regulation was that natural gas pipelines where thought to have market power over gas transportation service (Breyer and MacAvoy, 1974). Intrastate transportation of natural gas is regulated on the state-level, while interstate transportation is federally regulated by the Federal Energy Regulatory Commission (FERC, formerly the Federal Power Commission). Under the federal Natural Gas Act of 1938 ("NGA"), the Federal Power Commission ("FPC") was granted regulatory authority over interstate natural gas pipelines. Like oil pipelines, regulatory authority over natural gas pipelines was transferred to FERC in 1977 when the FPC was renamed and reorganized as the FERC. The NGA requires that all rates, charges and terms of service be "just and reasonable" and not "unduly discriminatory or preferential". However, unlike oil pipelines, interstate natural gas pipelines are not treated as common carriers. Instead, a public utility regulatory approach was chosen. Transportation is only provided to shippers who enter into contracts with the pipeline operator.

FERC approval is also required for the construction or abandonment of any facilities used for interstate transportation of natural gas (Birgisson and Lavarco, 2004; Breyer and MacAvoy, 1974). This authority extends the LNG facilities as well. Less than a decade after its passage, the NGA was amended to give FERC eminent domain authority for the construction of natural gas pipelines in the public interest. Because natural gas storage is considered a necessary and integral part of the operation of gas pipelines, the NGA's eminent domain provisions have been deemed to apply to natural gas storage as well (*Columbia Gas Transmission Corp. v. An Exclusive Gas Storage Easement*, 1985; *Schneidewind v. ANR Pipeline Co.*, 1988).

In 1978, the Natural Gas Policy Act simplified the area rate approach to natural gas wellhead price regulation and provided for the gradual deregulation of the wellhead prices of natural gas. The Natural Gas Wellhead Decontrol Act of 1989 accelerated the deregulation of wellhead prices and this process was largely completed by 1992. FERC Orders 436, 500, and 636 issued between 1985 and 1993 transformed the industry by deregulating pipeline transportation under some conditions and allowing customers to buy gas directly (Reiner and Herzog, 2004).

The Energy Policy Act of 2005 permits FERC to authorize gas storage providers to charge market-based rates when the storage providers cannot (or do not) demonstrate that they lack market power. In Order 678, FERC allows storage providers to receive market-based rates for storage and storage-related services for new facilities if FERC determines that (1) market-based rates are in the public interest and necessary to encourage the construction of the storage capacity in the area needing storage services; and (2) customers are adequately protected (Order No. 678, 2006).

Preemption

It is very possible that as a CO_2 transportation and storage system grows, it could eventually be subject to preemption. By preemption, we mean the displacement of state law by federal law (Nelson, 2000).[3] Preemption is not uncommon, in fact many industries started out governed by state common law, only to be later preempted by federal law (Mashaw, Merrill and Shane, 2003). One example of preemption arises in the case of natural gas storage. FERC has authority over the siting of interstate natural gas pipelines and related storage facilities. Natural gas storage operators obtain a certificate of public convenience and necessity that allows them to acquire property rights to the storage formation by eminent domain if the rights are not able to be acquired voluntarily. Where a federal condemnation action is brought, the property owner may seek to sue or counter-sue the storage operator for trespass (McGrew, 2000). Some courts find that the property owner is preempted from bringing its state law trespass claim (*Columbia Gas Transmission Corp. v. An Exclusive Natural Storage Easement*, 1990; McGrew, 2000), while others find that the trespass claim may go forward (*Bowman v. Columbia Gas Transmission Corp.*, 1988; McGrew, 2000). Preemption is also relevant to the tortious liability issue, discussed later in this essay. Preemption of tortious liability would be caused by a federal remedial regime substituting or supplanting state common law claims. In short, if the scale of

[3] The courts have generally recognized three types of preemption: (i) express preemption (where a federal statute explicitly withdraws specified powers from states), (ii) "field" preemption (where a federal regulatory scheme is deemed so pervasive that it has invaded the field and state law enforcement is precluded), and (iii) conflict preemption (where federal law preempts state law with which it actually conflicts because compliance with both is a physical impossibility or because the state law stands as an obstacle to accomplishing and executing the full purposes and objectives of Congress) (Nelson, 2000). Note that most federal statutes do not address preemption directly, or even if they do, such as through the use of a saving clause, the language is often not specific enough to resolve the case at issue before the court (Mashaw, Merrill and Shane, 2003). A saving clause is a provision in a statute that "preserves state laws that would otherwise be displaced because they conflict with a substantive provision of the federal statute" (Dinh, 2000).

CCS grows to an extent such that it affects interstate commerce, regulatory authority may shift to the federal level.

Implications for CO_2

The differences between oil pipeline and natural gas pipeline regulation are significant. Both were intended to address market power concerns associated either with pipeline transportation per se or with the vertical integration between the production, marketing, storage and transportation of natural gas. However, oil pipelines evolved from a common carrier approach, while natural gas pipelines evolved from a public utility approach. Both approaches differ on the issue of market entry and exit. Entry and exit for oil pipelines is unregulated, while FERC approval is required for the construction and abandonment of natural gas pipelines.

CO_2 pipelines are not (yet) governed by regulatory regimes similar to those that have governed oil and natural gas pipelines during much of the 20th century. However, these regulatory institutions emerged only as the oil and gas industries matured and real or imagined market power problems were identified. In 1979, FERC determined that because the goal of the NGA was to protect consumers from "exploitation at the hands of natural gas companies", jurisdiction over CO_2 pipelines would "advance no goal or purpose" of the NGA (Cortez Pipeline, 1979). On the same facts, the ICC concluded that CO_2 was excluded from ICC jurisdiction when transported by pipeline (Cortez Pipeline, 1980; Cortez Pipeline, 1981). This is not unlike the early history of oil and natural gas pipelines as well as the interstate railroads which initially evolved without administrative regulation of prices and access rules. The growth of these sectors and the growing importance of transportation, abuses of market power, price discrimination and other issues, including conflicts between state and federal authorities led both to preemption by the federal government and administrative regulation. As the CO_2 transport and storage sector grows, similar issues of regulatory frameworks and the mix of federal and state jurisdiction are likely to have to be confronted, as has been the case for all network industries in the United States. The eventual economic regulatory development for CCS will need to consider the varying approaches taken for oil and natural gas, and the serious problems that their history experienced. One might draw similarities between CCS and natural gas because of its incorporation of storage within the same regime. There is much to learn from the natural gas regulatory experience which can help to allow any regulatory framework governing CO_2 transportation and storage to avoid past mistakes and incorporate recent experience with unbundling, open access rules, light handed price regulation, and increasing reliance on market-based prices and private contracting under the shadow of price regulation (Leitzinger and Colette, 2002; Finoff, Cramer and Shaffer, 2004).

3. Storage Issues

Common Law Ownership

The issue of common law property rights is implicated in two contexts: acquiring ownership of the geological formation into which the CO_2 will be injected, and ownership of the CO_2 after it has been injected into the geological formation.

The issue of ownership of the geological formation was first addressed in the mid-twentieth century for natural gas storage (*Central Kentucky Natural Gas v. Smallwood*, 1952;

Tate v. United Fuel Gas, 1952; Stamm, 1957; Scott, 1966; Creekmore and Harvey, 1967). The legislation governing this property right is broadly applicable to all subsurface contexts, not just natural gas storage. The determination of the ownership interest for the storage reservoir depends on whether the geological formation at issue is a mineral formation or a saline formation. For mineral formations, there are two property interests of significance: the mineral interest and the surface interest. The mineral interest comprises the right to explore and remove minerals from the land, while the surface interest consists of all other ownership. In most cases, the mineral interest will be severed from the surface interest, meaning that the mineral and surface interests are held by different owners. In situations of prior mineral severance, there is a split of authority regarding who owns the mineral formation once it has been depleted of minerals. The majority of states find that the owner of the surface interest owns the geological formation, while a minority of states find that the mineral interest owner retains the exclusive use of the subsurface space (de Figueiredo, 2007). However, even in states following the majority rule, there will likely be a transaction cost associated with acquiring the rights of the mineral interest owner who claims that the formation is not depleted of minerals and seeks compensation accordingly. The determination of interests in the case of the saline formation is virtually identical to the mineral formation case, the only difference being that the right to the groundwater must be acquired instead of the mineral interest. The rules governing groundwater appropriation vary by state and some states, particularly in the western United States, would prohibit the injection of CO_2 into any underground aquifer, regardless of salinity (Water Systems Council, 2003; de Figueiredo, 2007). The laws in those states would need to be amended if there was a desire to store CO_2 in deep saline formations.

If CCS is to have a meaningful impact in mitigating CO_2 emissions, large quantities of CO_2 will need to be stored over potentially large subsurface areas. Under current law, the right to use the subsurface would need to be acquired from every subsurface owner where the CO_2 plume migrates. If the CCS operator does not acquire all the necessary property rights, the operator faces potential liability for a geophysical subsurface trespass or for confusion of goods if the CO_2 intermixes with native substances. There will be transaction costs associated with acquiring all necessary subsurface property rights, as well as holdout problems from subsurface owners trying to extract the rents that accrue from the CCS project. The property rights issue has been addressed successfully by the oil industry through unitization (King, 1948; U.S. Office of Technology Assessment, 1978; Libecap and Smith, 1999) and by the natural gas storage industry, as discussed in the previous section, through the acquisition of subsurface easements by eminent domain (*Columbia Gas Transmission Corp. v. An Exclusive Gas Storage Easement*, 1985; *Schneidewind v. ANR Pipeline Co.*, 1988; McGrew, 2000; Smith, 2004). Analogous methods will likely need to be employed in the context of CO_2 storage.

Although the issue of ownership over injected CO_2 has not yet arisen in the courts, ownership over injected natural gas has been examined (*White v. New York State Natural Gas Co.*, 1960; *Lone Star Gas Co. v. J. W. Murchison*, 1962). One might expect that the holdings concerning natural gas storage will serve as precedent for future injected CO_2 property disputes. All states subscribe to the ownership theory of injected gas, namely that title to injected gas is not lost by injection into a geological formation for storage purposes. The injected gas remains the property of the original owner.

Underground Injection Control of CO_2

While there is no comprehensive legal and regulatory framework for CO_2 storage *per se*, the U.S. Environmental Protection Agency ("EPA") has a regulatory framework governing most types of underground injection, the Underground Injection Control ("UIC") Program. The UIC Program was created under the Safe Drinking Water Act of 1974 ("SDWA") and establishes requirements to assure that underground injection activities will not endanger drinking water sources. The UIC Program regulates underground injection under five different classes of injection wells, depending on the type of fluid being injected, the purpose for injection, and the subsurface location where the fluid is to remain. States are allowed to assume primary responsibility for implementing the UIC requirements in their borders as long as the state program is consistent with EPA regulations and has received EPA approval. Injection operators are required to provide financial assurance in case they cease operations, with the level of assurance a function of the estimated cost of plugging and abandoning the injection well. If there is a violation of a UIC permit, an enforcement action may be brought by the EPA Administrator or the applicable state agency (see 42 U.S.C. § 300h-2). Violators may be subject to administrative orders, civil penalties, and criminal penalties.

The SDWA has two special provisions related to the applicability of natural gas storage and EOR to the UIC Program. First, the SDWA exempts the underground injection of fluids which are used in connection with natural gas storage operations. According to legislative history of the exemption, Congress was persuaded that natural gas storage does not pose a threat to drinking water quality and natural gas storage operators have an economic incentive to prevent natural gas leakage (H.R. Rep No. 96-1348). Second, the SDWA authorizes any state to assume primary responsibility for controlling underground injection related to oil and gas recovery and production by demonstrating that its program meets the requirements of the SDWA and represents an "effective" program. This is in contrast to other types of underground injection, which must meet minimum EPA requirements.

In March 2007, the EPA announced that it recommended using an experimental well category ("Class V") for permitting pilot CCS projects (U.S. Environmental Protection Agency, 2007). The Class V status relieves the operator from complying with the minimum requirements of the class into which the injection well would ordinarily fall. For small existing pilot projects such as Frio Brine or Mountaineer which inject perhaps hundreds or thousands of tons of CO_2 per year this situation is probably acceptable since the goals are clearly experimental and potential commercial benefits are minimal at best. By contrast, permitting commercial CCS projects that might inject perhaps a million tons of CO_2 per year on such an *ad hoc* basis in the long-term is probably not advisable. Absent an overarching CO_2 control regime that regulates all aspects of CO_2 including storage or amending the SDWA so that CO_2 is exempted in the same manner as natural gas, the EPA will need to create a new sub-classification or an entirely new classification for CO_2 injection wells. Although there is precedent in the creation of sub-classifications, the EPA has not created a new classification in the history of the UIC Program. Nonetheless, there is nothing in the SDWA that would prevent the EPA from doing so. Regardless of whether a sub-classification or new classification approach is chosen, there are several criteria that will need to be considered: specification of CCS site selection criteria, an area of review that would take into account the subsurface aerial extent of migration, injection well design standards that would minimize degradation of the well from the acidic CO_2 injectate, financial assurance for abandoning the site, post-injection monitoring criteria, and measures for halting CO_2 injection and remediation of the site in the event that loss of containment poses a risk to health, safety, or the environment.

International Law

While onshore storage of CO_2 has received significant attention in the United States and Canada, offshore storage is being closely examined in Europe, especially in conjunction with oil and gas production. CO_2 could also be injected into a geological formation which extends beneath both the onshore and offshore, as has been proposed in Australia. Offshore storage could be favorable where there is a lack of onshore geological capacity, where there is already offshore infrastructure that could easily be adapted for CO_2 storage, or where offshore hydrocarbon recovery is already taking place.

Although CCS conducted onshore would generally be governed by national law, CCS conducted offshore would be impacted by international law. Its legality will depend on global and regional marine agreements, such as the United Nations Convention on the Law of the Sea ("UNCLOS"), Convention on the Prevention of Marine Pollution by Dumping of Wastes and other Matter of 1972 ("London Convention"), Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and other Matter of 1996 ("London Protocol"), and regional conventions such as the Convention for the Protection of the Marine Environment of the North-East Atlantic ("OSPAR Convention").

UNCLOS would defer to the London Convention and London Protocol for CCS activities. The London Convention establishes a legal regime for the dumping of wastes or other matter at sea and has eighty-one parties to the Convention. The London Protocol is a separate agreement that modernizes and updates the London Convention. The London Protocol went into force in 2006, and twenty-eight states have acceded to the London Protocol. States can be a party to the London Convention, the London Protocol, or both. The United States is a party to the London Convention, but not the London Protocol.

The geological storage of CO_2 would appear to be acceptable under the London Convention because the London Convention only governs the disposal of wastes or other matter "at sea". Because geological storage involves the injection of CO_2 into the sub-seabed and not into the water column, it is not the disposal of wastes or other matter at sea. The London Protocol, in contrast, does govern the storage of wastes or other matter in the seabed. Under the London Protocol, wastes may only be disposed of if they are listed on a white list of approved wastes, which until recently, did not include CO_2. In November 2006, the London Protocol was amended to include "CO_2 streams from CO_2 capture processes" on the list of approved wastes (IMO, 2006). The amendments, which entered into force on February 10, 2007, state that "carbon dioxide streams may only be considered for dumping if disposal is into a sub-seabed geological formation; they consist overwhelmingly of carbon dioxide (they may contain incidental associated substances derived from the source material and the capture and sequestration processes used); and no wastes or other matter are added for the purpose of disposing of those wastes or other matter". Even with the amendment, there remain ambiguities on the application of the London Protocol to CCS, such as what it means for a stream to consist "overwhelmingly" of CO_2 or what it means to contain "incidental" associated substances. A technical group will prepare guidance on the meaning of the provisions, to be reviewed at the Second Meeting of Contracting Parties to the London Protocol in November 2007.

4. Liability

The liability issue for CCS can be framed in terms of operational liability and post-injection liability. Operational liability includes the health, safety, and environmental risks associated with CO_2 capture, transport, and injection. Such risks have been successfully managed for decades in the context of EOR (Heinrich, Herzog and Reiner, 2004). Post-injection liability of CCS describes the liability related to the storage of CO_2 after it has been injected into a geological formation. Firms engaging in CCS face a potential post-injection liability exposure if the stored CO_2 is not fully contained by the geological formation. Post-injection liability presents a unique set of challenges because of the scale of projected CO_2 storage activities, the hundreds of years over which the risks may manifest themselves, and the uncertainties of the geophysical system.

Tortious Liability

One type of post-injection liability relevant to CCS is the tortious liability associated with damage to health, safety and the environment. Because of the long time frames expected for CO_2 to be stored in the subsurface, it is possible that the risks may manifest themselves after injection operations have ceased. This is mitigated by geophysical or geochemical trapping mechanisms that allow the containment of stored CO_2 to become safer over time (IPCC, 2005). Probably the most likely mechanism for loss of containment would be via abandoned wells. Although injection wells abandoned using proper procedures would likely contain the stored CO_2 effectively, CO_2 could escape through injection wells that have been poorly completed. CO_2 could also escape through the pores of low-permeability caprock, openings in the caprock, or migration via faults. Currently identifiable sources of tortious liability include induced seismicity, groundwater contamination, harm to human health and the environment, and property interests. While these risks are non-trivial, they have been successfully managed in other subsurface injection contexts, such as acid gas injection, natural gas storage, and EOR (de Figueiredo, 2007).

Fundamental decisions will need to be made on (1) who is responsible for the long-term management of the CO_2 storage site and (2) who will pay if damages are incurred. With respect to long-term management of the site, a regime could be developed under the UIC Program where government plays a supervisory role in the short-term and a more active role in the long-term. As a condition for receiving a CO_2 injection permit, the operator could be required to conduct post-injection monitoring and would be allowed to hand-over responsibility of the site to the government after a certain amount of time and upon a showing of containment of the stored CO_2 (de Figueiredo, 2007).

Both the private sector and public sector have developed a number of regulatory tools for financing large-scale, long-term tortious liabilities of the sort expected for CCS. Some exemplary and creative uses of these instruments can be found in regulatory analogs that are outside of the traditional subsurface injection context (de Figueiredo, 2007).

One approach is to use private liability insurance or private contractual mechanisms. Liability insurance operates by transferring risk from risk-averse parties to risk-preferring parties, combining individual risks into a pool, and charging premiums to reflect the level of risk posed by the insured (Abraham, 1988). There is precedent for using liability insurance in the environmental realm, but insurance contracts have temporal limitations and insurance markets will face challenges in setting premiums that predictably estimate the social costs of the risks imposed (Abraham, 1988). Private contractual techniques allocate risk among parties. One contractual mechanism, indemnification, has been mentioned in several legislative and project proposals for CCS.[4] An indemnity is a contract where one party agrees to cover the liability of another party given a certain factual development, such as a court judgment resulting in financial loss to the indemnified party (Garner, 2004). An indemnity does not necessarily address the long-term nature of the problem, but it may be an adequate strategy in the near-term and where injected volumes are relatively small.

Second, government could create an immunity cap through legislation, where the operator would be financially responsible for all liability beneath the cap, but would not be financially responsible for any payments above the cap. A variation on the liability cap is a liability exemption, where the cap is set at zero and the party would be completely immune from liability. The immunity cap mechanism is used by the Price-Anderson Act, which governs liability for nuclear power plants in the United States. Under Price-Anderson, each nuclear facility must have primary insurance in the amount of $300 million per facility and secondary insurance in the amount of $15 million per plant per year, up to $95.8 million per incident. Operators are not liable for losses above the cap. In the approximately fifty years that Price-Anderson has been in force, liability has never exceeded the primary insurance amount.

Third, government could develop an administrative compensation fund, where CCS operators make payments into a fund and the fund pool is used to compensate parties for damages. The types of compensable events would be pre-determined by the authorizing legislation or regulation and ultimate compensation judgments would be made during an administrative proceeding (Abraham, 1987; de Figueiredo, 2007). There are a number of ways that such a fund could be structured, such as through a purely private burden-sharing program, or a fund which is launched, managed, and/or even co-funded with the government.

One might expect that several strategies will be combined to address the tortious liability issue for CCS. The mechanisms will also need to account for jurisdictional differences if CO_2 leakage occurs across state or national borders. For a more thorough summary of CO_2 storage tortious liability, see de Figueiredo (2007).

Contractual Liability

The second type of liability relates to the effects of leakage on future climate change (Herzog, Caldeira and Reilly, 2003). Contracts to store CO_2 will likely be associated with certain standards of performance, sometimes referred to as an acceptable rate of leakage. If leakage from the reservoir exceeds the standard of performance, there will be liability associated

[4] FutureGen Industrial Alliance, *Final Request for Proposals* p. 44 (March 7, 2006) ("The offeror agrees to take title to the injected CO_2 and indemnify the FutureGen Industrial Alliance and its members from any potential liability associated with the CO_2."); Texas House Bill 149 (passed May 15, 2006) ("The University of Texas System … may enter into a lease … for the use of lands owned or controlled by the system … for permanent storage of carbon dioxide captured by a [FutureGen] project, provided that such lease adequately indemnifies the system against liability for personal or property damage…"); Illinois House Bill 5825 (filed with the clerk August 22, 2006; first reading November 1, 2006) ("If a civil proceeding is commenced against an operator arising from the escape or migration of injected carbon dioxide, then the Attorney General shall, upon timely and appropriate notice by the operator, appear on behalf of the operator and defend the action. … [U]nless the court or jury finds that the action was intentional, willful, or wanton misconduct, the State shall indemnify the operator for any damages awarded and court costs and attorneys' fees assessed as part of any final and unreversed judgment or shall pay the judgment.").

with covering the contract. There are three ways that the contractual liability could play out. The first way would be a "seller beware" approach, where the CO_2 storage operator would be required to cover the contract by storing an additional quantity of CO_2 equivalent to the amount of CO_2 that leaked from the reservoir or purchasing additional credits on the market. Variations on the seller beware approach include a mechanism where the CO_2 storage operator acquires insurance or puts up a bond to assure the integrity of the credits. A second liability approach would be "buyer beware", where the purchaser of the credits would be required to acquire additional credits on the market equivalent to the amount of CO_2 that leaked from the formation. The buyer beware approach is not a preferred strategy in the case of CCS because of the associated moral hazard problems. Finally, a discounting approach could be used. Instead of imposing liability *ex post* (i.e., after leakage has occurred), the discounting approach assumes a future rate of leakage and imposes a penalty on the credits at the time of exchange. The choice between the seller beware and discounting approach will depend on the feasibility of monitoring CO_2 leakage at a resolution necessary to ensure the integrity of the climate regime.

5. Conclusions

In summary, we propose three guidelines in developing future CCS regulations.

1. **Be cognizant of precedent:** Most of the identifiable issues of concern have been addressed in other contexts. We need to understand and learn from this experience to avoid some of the missteps and shortfalls of past efforts.
2. **Be flexible in applying precedent:** It is important not to be too deterministic about precedent. Future regimes will be informed by precedent, but there are multiple approaches to these issues and there may be the need for experimentation or creative integration of solutions. We encourage the use of integrated analysis, namely combining legal and technical analyses and considering interaction effects across what are normally treated as separate regulatory domains.
3. **Be accommodating to new information:** Since CCS is still in its infancy, there are a number of technical and regulatory uncertainties. As we gain experience in the field, regulatory policies implemented today should be able to adapt as new information about the risks and benefits of CCS emerges and the sector matures.

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