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LIABILITY AND FINANCIAL RESPONSIBILITY FRAMEWORKS FOR CARBON CAPTURE AND SEQUESTRATION

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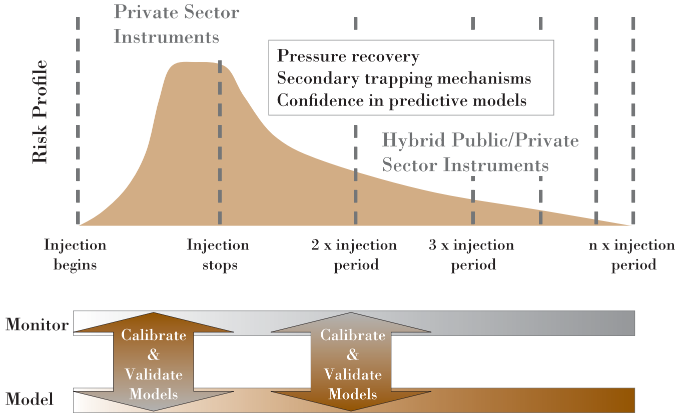
Conceptual Risk Profile for Sequestration



Source: Adapted from Sally Benson, Stanford University

INTRODUCTION

Carbon dioxide capture and sequestration (CCS) is an important option for reducing CO_2 emissions from human activities. There is growing interest in CCS as renewable energy and energy efficiency alone are unlikely to deliver the emission reductions necessary to stabilize atmospheric concentrations of greenhouse gases by mid-century.[1] CCS involves capturing CO_2 generated from fossil fuel combustion, transporting it and injecting it deep underground into geological reservoirs where it can remain sequestered indefinitely. This issue brief focuses on geological sequestration of CO_2 in deep saline formations and depleted oil and gas fields.

Although the technical and economic barriers to CCS have been well documented, relatively less attention has been paid to liability and the attendant financial responsibility associated with the siting and operation of CCS projects. This issue brief examines liability and financial responsibility frameworks potentially applicable to CCS projects by considering existing analogs and options for mitigating the near- and long-term risks of CCS technologies. It concludes that significant jurisdictional differences exist with respect to state liability and financial responsibility, which will likely influence the siting, construction and operation of CCS projects.

SUMMARY

This issue brief examines existing federal and state liability and financial responsibility frameworks that may be applicable for carbon dioxide capture and geological sequestration (CCS). Many of the potential risks involved with CCS have been successfully managed under existing state and federal regimes. However, the long time scales associated with CCS projects present unique risks that must be addressed before CCS technology can be widely deployed. Establishment of reliable risk profiles will help to create the appropriate financial responsibility framework to minimize and manage such risks. Significant jurisdictional differences in the existing state liability frameworks will likely influence the siting, construction and operation of CCS projects. Options to address these differences include establishing minimum standards for financial responsibility and/or an indemnity program.

CCS RISKS AND STATE-SPECIFIC JURISDICTIONAL DIFFERENCES IN LIABILITY

A CCS project entails the capture, transport, and geological sequestration of CO_2. This brief focuses solely on potential liabilities associated with the final sequestration stage which consists of four distinct phases, as shown in Figure 1: a) siting; b) operation (injection of CO_2); c) closure, plugging, and abandonment; and d) long-term post-closure care. Each phase bears a set of unique risks, as well as a range of potential li-

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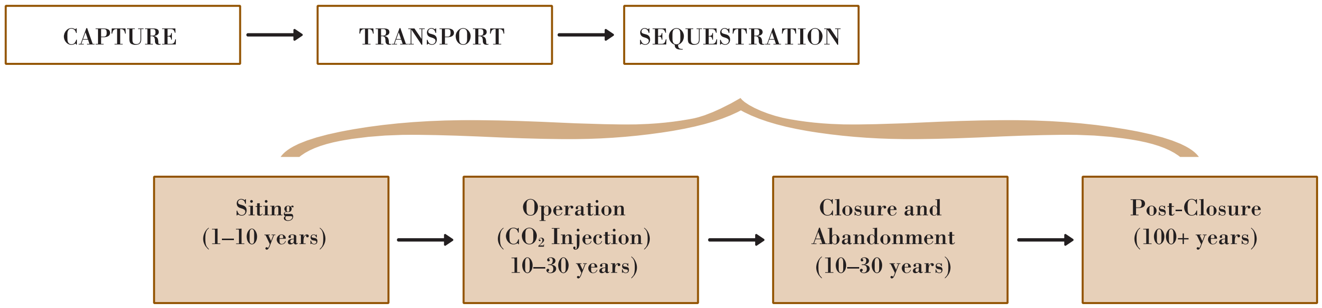
FIGURE 1 Geological Sequestration Project Life Cycle



abilities. The potential risks may be local, such as contamination of potable water supplies, or global, such as CO_2 releases to the atmosphere.

The IPCC Special Report on Carbon Capture and Storage estimates that more than 99 percent of injected CO_2 is "very likely" to remain sequestered for upwards of 100 years in a properly selected site (IPCC, 2005). Generally, injected CO_2 will be less dense than the subsurface waters found in the site's geologic formation, and will have a tendency to migrate upwards and laterally within the formation, making an effective trapping mechanism a key component of minimizing leakage. Once injection and closure is complete, risk should decrease over time as the site becomes more secure through geophysical and geochemical trapping mechanisms, including CO_2 capillary trapping within the porous rock, CO_2 dissolution in formation waters, and long-term mineralization.

Considering the changing magnitude and nature of risks over the life of a sequestration project—in other words establishing a "risk profile"—is critical for effective management. Any CCS regulatory framework will need to clearly delineate any responsible parties and address a management strategy for the long-lived liabilities, ensuring that risks are borne by those who share in the economic benefit of CCS technology.

The following sections provide more detail for each phase of the sequestration project lifecycle and related potential liabilities. Each project phase is associated with different risks, which are regulated differently across jurisdictions. Development of a sound regulatory program for CCS requires an understanding of the state-specific frameworks in order to identify the risks and liabilities that can be effectively managed at the state level and those which may be better managed at the federal level.

Phase 1: Siting

The establishment of large-scale sequestration reservoirs, with clearly defined property rights and liability arrangements, is essential for the successful deployment of CCS projects. Individual projects are likely to manage millions of tons of CO_2 annually. Injected CO_2 is likely to spread underground over a large subsurface area (10s to 100s of square miles), implicating pre-existing mineral rights,[2] water rights, and surface owner claims.

There are two types of liability issues that are particularly relevant to siting: (1) geophysical surface trespass, and (2) geophysical subsurface trespass. Geophysical surface trespass occurs when a trespassing party uses the surface to conduct seismic and other surface geophysical operations or when an operator uses portions of the surface for monitoring and verification activities (Anderson, 2004). For CCS projects, this implicates developers and operators that use geophysical operations to determine the suitability of a geological formation as part of the site characterization process and project operators monitoring the subsurface CCS plume. Geophysical subsurface trespass is caused by the underground migration of injected CO_2 into areas where property interests have not been acquired. In some jurisdictions, geophysical subsurface trespass liability could come from waves shot for 3-D seismic mapping and the information gathered, but for CO_2 associated trespass, the prospect of such liability is relevant to the siting phase of operations.

Both unitization (in oil and gas operations) and eminent domain (for underground natural gas storage) have been used in analogous subsurface injection contexts to address potential trespass concerns. Unitization, joining individual tracts into one common pool, has been used in the secondary oil recovery context to address the subsurface geophysical trespass concern. Most oil producing states have unitization laws that require a certain percentage (50-85 percent) of owners of the common oil pool to agree before unitization can occur, often requiring lengthy negotiations to secure necessary rights and reach agreement (OTA, 1978). However, some states – most notably Texas – do not have a compulsory unitization statute, meaning that unitization is solely on a voluntary basis.

Creation of underground natural gas storage fields are supported by the use of eminent domain—the inherent power of the state to expropriate private property for a public use—when public or private entities are unable to contract all necessary property rights by voluntary means. The use of eminent domain requires that a project provide a public benefit.

Phase 2: Operation (CO_2 Injection)

The second phase of sequestration involves injecting the captured CO_2 deep underground. There are four distinct risk areas that may yield liability including: (1) CO_2 leakage to the surface; (2) groundwater contamination; (3) hydrocarbon damage; and (4) geological hazards.

Ecological Risk from CO_2 Leakage to the Surface

Properly planned and operated CCS projects are extremely unlikely to threaten human life (Benson, 2002); nonetheless, siting requirements should ensure that nearby communities are protected from harm. The potential of slow releases of CO_2 to the surface raises concerns of risks to human health and environmental degradation (both degradation of the local environment and risks to the global climate from physical leakage to the atmosphere).

Recovery of damages resulting from CO_2 leakage will likely rely on established theories of nuisance and negligence. Precedents exist in both oil recovery and underground natural gas storage contexts. Similarly, for local environmental risks, there are established protocols for evaluating damage to cropland or forestry. Eventual liability and financial responsibility will depend on the perceived permanence of damages and the ability to establish a causal link between damage and the injected CO_2.

Groundwater Contamination

Damage to groundwater resources could potentially occur from CO_2 leakage into potable water supplies or displacement of saline water into drinking water, and is an important liability consideration for CCS projects. Groundwater law differs significantly from state to state. As shown in Table 1, all groundwater in California is the property of the state. In Texas, the "rule of capture" has historically allowed landowners to use any groundwater accessible from their lands.

Some of the causal chains of CO_2 damage to groundwater resources may be too attenuated to prove, such as the mobilization of metals and/or organic compounds, (due to CO_2 altering the pH of subsurface water) or groundwater displacement (large volumes of CO_2 forcing brine into fresh water formations). Nonetheless, in the interest of risk management, developers and operators of CCS technologies should consider options for mitigating the litigation (and subsequent financial) exposure resulting from potential damage to surrounding groundwater resources.

Hydrocarbon Damage

Some of the first-generation CCS projects are likely to be linked with enhanced oil and gas recovery operations which generally already have CO_2 injection infrastructure in place. Inadvertent damage to hydrocarbon resources due to the subsurface migration of injected CO_2 is a concern. Extensive regulatory and administrative regimes have been developed to protect oil and gas property rights and courts have generally upheld the interests of mineral estate owners. However, significant jurisdictional differences exist. As shown in Table 1, Texas and California have divergent jurisprudence with respect to secondary recovery of oil. The Texas judiciary has established a "rule of negative capture" that less valuable substances (i.e., water) can migrate through the subsurface and replace more valuable substances (i.e., oil) without incurred liability. Conversely, in California, the mineral estate owner whose hydrocarbons are drained by an adjacent secondary recovery operation is entitled to damages. It should be noted that the case law on hydrocarbon damage has focused exclusively on secondary recovery. As enhanced oil recovery operations are still relatively few and follow after secondary recovery operations, it is not surprising that a review of the case law found no such cases related specifically to enhanced oil and gas recovery, which shows the historically effective regulation of these risks.

Geological Hazards

A final source of potential liability is geological hazards, such as seismic events caused by changes in subsurface pressure due to CO_2 injection, a phenomenon known as induced seismicity. Studies have established this to be a low-level risk (IPCC, 2005). An additional geological hazard is ground heave (the upward movement of the surface), which could be a concern due to improper injection pressure regulation. In general, the risk of geological hazards can be addressed by underground

TABLE 1 Liability Considerations in California and Texas for Analogous Activities (Secondary Oil Recovery, Tertiary/Enhanced Oil Recovery, and Underground Natural Gas Storage)

	Issue	California	Texas
SITING-ASSOCIATED LIABILITY	Creating large and legal fields	Unitization statutes exist but are not universal; underground natural gas storage field establishment by contract and use of eminent domain	Unitization statutes exist but require 100% of interests to be in agreement (i.e. no compulsory unitization); underground natural gas storage field establishment by contract and use of eminent domain
	Geophysical surface trespass	No reported cases	Several reported cases
OPERATIONAL LIABILITY	Inadvertent damage to hydrocarbons	Mineral estate owner entitled to damages (secondary recovery)	"Rule of negative capture": mineral owner not entitled to damages where secondary recovery project properly authorized
	Damage to groundwater	Groundwater owned by the state, managed by groundwater councils; unclear how CCS would impact	Groundwater owned by property owner, but managed by the state; unclear how CCS would impact
	Damage to human health or environment	Precedent in courts	Precedent in courts
	Geological hazards	Injection pressures regulated, but no case law; experience with ground heave, subsidence with oil and gas and geothermal operations; seismically prone regions in state	Injection pressures regulated, but no case law; relatively stable geology
LONG-TERM ISSUES	Long-term responsibility	Needed: Clear delegation of responsibilities, time frames	

injection control regulations addressing injection pressure, but the large volumes of CO_2 to be injected and large-scale deployment warrant consideration of these risks.

Phases 3 and 4: Closure and Long-Term Post-Closure Stewardship

Carbon dioxide injected for CCS is expected to remain in the subsurface indefinitely. Liability and responsibility for post-closure stewardship is a concern, i.e., after injection has been completed and the well has been plugged and closed.

Post-closure liability differs in several fundamental ways from liability in the operational phase. In the event of an accident or damage after a well has been closed, there may be difficulty identifying responsible parties, delegating responsibilities for remediation, and apportioning damages given that corporations do not have lifetimes as long as the CCS stewardship period (hundreds of years). In addition, it is unclear who will remain responsible for long-term monitoring and verification of the sequestration site after closure is complete.

Prior to large-scale CCS deployment, it is necessary to clarify who will be responsible for long-term site care and for how long. The degree to which private parties remain responsible for long-term site management, or whether the government assumes a measure of responsibility, will directly influence the development of an adequate regulatory framework and investment in the technology. If the private sector may transfer responsibility to the public sector, the financial responsibility framework will need to ensure sufficient funds are available to maintain and manage the site over the long-term.

Table 2 summarizes the life-cycle phases of sequestration projects, including potential actions that could be taken to manage the associated liability.

TABLE 2 Potential Actions for Managing Liability

	Issue	Potential Action	Implications and Uncertainties
SITING-ASSOCIATED LIABILITY	Creating large and legal fields	Create mandatory mechanism for acquiring pore space and rights for injection	Requires demonstrating that CCS is a "public good"
	Geophysical surface trespass	Establish administrative rules for handling rights, responsibilities and damages for geophysical trespass	Depending on shape of statute, could discourage or encourage CCS development.
OPERATIONAL LIABILITY	Ecological risk from CO_2 leakage to the surface or near-surface	Better specify risk profile and establish remediation plan	Application of nuisance and negligence precedent. Establishing causal link between damage and injected CO_2.
	Groundwater contamination	Better specify actual risk profile by tests of in situ CO_2 impacts on potable groundwater quality and establish remediation procedures	Groundwater law varies by state. Causal links difficult to establish
	Hydrocarbon damage	No change needed given secondary recovery and EOR precedent	Established mechanisms for managing issue already exist
	Geological hazards	Regulate injection pressures, consider regional and basin scale effects	Difficulty of predicting or proving causal link to injection pressures and seismic activity
LONG-TERM ISSUES	Long-term responsibility	Delineate risk profile over time; evaluate liability management mechanisms	Cost, institutional structure, long-term stability.

PUBLIC POLICY IMPLICATIONS AND FINANCIAL RESPONSIBILITY

A crucial overlay to the set of CCS risks described above is the development of a financial responsibility framework that ensures developers and operators of CCS projects maintain the financial resources necessary to construct, operate, close and provide post-closure monitoring of their facilities in an environmentally sound manner. While property regimes are grounded at state jurisdictional levels, harmonization of financial responsibility requirements at the federal level may be necessary to facilitate commercial-scale deployment of CCS projects and provide adequate assurances for long-term risk management and stewardship.

Financial Responsibility

Delineation of who is responsible for potential liabilities associated with CCS (and for how long) will influence the construction, operation and management of CCS projects. Most companies operate facilities that have finite physical lives. The nature of CCS suggests that management and monitoring of sequestered CO_2 might be necessary after the facility ceases operation. The long time scales associated with CCS require a clear regulatory framework that assigns responsibility for the entire lifetime of long-term sequestration projects.

To ensure accountability, developers and operators of sequestration projects must assume a measure of financial responsibility in order to guarantee the construction, operation, closure, and, to the degree appropriate, safe post-closure monitoring of their facilities. It is generally accepted that financial responsibility requirements serve as an inducement to firms to properly operate and maintain their facilities. In the case of CCS, the intent is to minimize the number of orphaned facilities, ensure proper long-term care, and mitigate any environmental risks from site releases.

At its core, financial responsibility is an issue of risk management. A well-established financial responsibility program will balance stakeholder interests and ensure the safe closure and responsible post-closure care and monitoring. Specifically, an effective financial responsibility framework will ensure that developers and operators maintain adequate financial resources to fulfill their near- and long-term obligations. Additionally, it will encourage competition and foster beneficial market impacts, including:

- **Targeted Capital Investment,** whereby firms are more likely to design, site and operate facilities that reduce the likelihood of injury to environmental/public health and minimize litigation risk.
- **Deterrence and Precaution,** whereby firms are more likely to undertake operating decisions that consider environmental (and remediation) costs.
- **Optimal Pricing and Consumption,** whereby firms are stimulated to appropriately internalize costs, minimizing excessive consumption of environmentally damaging goods.

A successful, well-structured financial responsibility framework will be based on a clearly defined risk profile that maps the changing magnitude and nature of risks over the life of a project, as shown in the figure on the front page. The CCS risk profile should address four key questions, including:

- What is the nature of the risk?
- What is the timing and probability of risk?
- How might the risk(s) be ranked or prioritized?
- Which risks bear managing, and by whom?

Relevant Analogs for CCS Financial Responsibility

Several analogs exist to address public, environmental risk. However, applicability to the CCS environment is not perfect, and not all analogs have been fully successful. Financial responsibility has an established history in federal and state programs, mapping to a breadth of statutory programs. The financial responsibility requirements underpinning four analogs are worthy of mention: (1) RCRA, (2) CERCLA, (3) Underground Natural Gas Storage, and (4) Federal Indemnity programs.

Analog 1. Resource Conservation and Recovery Act (RCRA)

One of the most comprehensive statutory requirements for financial responsibility exists under the Resource Conservation and Recovery Act (RCRA). Initially promulgated in 1982, the RCRA financial responsibility framework serves as the foundation for numerous other models, including Class I and Class II wells under the EPA Underground Injection Control program.

The RCRA financial responsibility framework presumes that risks and attendant costs are reasonably estimable and manageable either in the form of one-time costs (e.g., plugging/abandoning a well), or as on-going monitoring and maintenance costs. The RCRA regulations offer companies a suite of financial instruments that can be divided into two broad categories: (1) third-party instruments (e.g., trust funds, surety bonds, letters of credit, and insurance); and (2) self-insurance instruments (e.g., the corporate financial test, and the corporate guarantee). Self-insurance instruments are predicated on the firms' financial solvency; that is, with few exceptions, there is no third party guaranteeing payment. By design, the RCRA model creates an incentive for companies to effectively manage their day-to-day operations to mitigate future environmental risk, and thereby incur fewer costs when retiring their assets. RCRA requires owners and operators to set aside funds for eventual closure and post-closure care during the active, operating life of the facility. In so doing, the intent of the RCRA financial responsibility framework is to provide regulators (and the public) a hedge against corporate dissolution (or bankruptcy) and potential site abandonment.

There are several notable lessons to be learned from the RCRA closure/post-closure model. Prescriptive in design, the RCRA financial responsibility framework fails to account for advances in accounting and financial reporting standards. For example, accounting standards related to financial disclosure of environmental liabilities and the reporting of cash flow have evolved since the initial development of the RCRA framework. Moreover, the RCRA model is relatively inflexible and unable to shift with rapidly changing market environments, including evolution in risk management products.

Analog 2. Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)

The second analog is the CERCLA model. CERCLA is perhaps best recognized for the Superfund trust fund, which was established to address legacy liabilities associated with the clean-up of abandoned hazardous waste sites.[3]

A clear strength of the CERCLA model rests on its flexibility. Unlike RCRA, the CERCLA model allows for the use of hybrid financial instruments – a risk transfer instrument (insurance) with a financial guarantee (corporate financial test). It also allows for the use of tailored risk management products. Specifically, cost cap (or stop-loss) insurance evolved under CERCLA, and is designed to provide coverage for remediation cost overruns, where actual costs are greater than originally estimated.

However, the lack of prescribed regulations for CERCLA financial responsibility poses notable challenges. Without an established financial responsibility program, there is little hedge against corporate financial distress, contributing to abandoned sites and unfunded liabilities. In addition, the lack of self-implementing financial responsibility requirements under CERCLA has contributed to potential legacy liabilities for developers and operators acquiring abandoned sites.

Analog 3. Underground Natural Gas Storage

Underground natural gas storage has been cited as an appropriate physical analog to geological sequestration of CO_2. Financial responsibility requirements vary significantly from state to state; whereas a subset of states incorporate aspects of the RCRA financial responsibility framework, jurisdictional differences in other states contribute to divergent requirements (see Table 3).

Analog 4. Federal Indemnity (or Insurance) Programs

Also worthy of consideration are federally-backed indemnity programs. In general, indemnity programs are blended instruments designed to pool risk among those entities most likely to reap a shared benefit. Indemnity programs often are designed to encourage technological advancements where a public benefit accrues, but the long-tailed liabilities (or risk exposure) may be unknown.

Designed to mitigate the risk of catastrophic events with a low probability of occurrence, notable indemnity programs include the National Flood Insurance Program and the Price-Anderson Nuclear Industries Indemnity Act. Enacted in 1957, the Price-Anderson Act is one of the more familiar federal indemnity models. The Act establishes a no-fault insurance program designed to indemnify the nuclear industry against liability arising from accidental releases. The original objective of the program was to provide an economic incentive for the private development of nuclear energy, where the risks and potential damages were then unknown. The Act was intended to be temporary, and designed to subsidize the nuclear industry only until such time as it was able to provide sufficient data to demonstrate a clear risk profile and be able to obtain insurance through the private markets. However, since 1966, the Act has

TABLE 3 Comparison of Underground Natural Gas Financial Responsibility Frameworks

State	Financial Responsibility Framework
Colorado	Promulgated financial responsibility requirements addressing both the well and the storage reservoir. Established a blanket financial assurance requirement of $50,000 that can be negotiated upward by the Commission to ensure compliance with the state's requirements. Regulations are silent on the type and form of financial instruments used to demonstrate assurance.
Kansas	Promulgated prescriptive financial responsibility requirements that require the developer or operator to provide financial assurances for the closure of the facility and the plugging of any underground natural gas storage well. Developer must provide a written, detailed cost estimate addressing the closure of all underground storage wells and storage caverns. Developers are allowed to choose from a suite of financial instruments ranging from a financial guarantee or performance bond to self-insurance through a corporate financial test that is equivalent in nature to the RCRA Subtitle C financial test. Relies on a definition of underground natural gas storage facility that incorporates the acreage associated with the storage field within facility boundaries, as approved by the Secretary.
California, Michigan, Pennsylvania, and Texas	Promulgated requirements for financial assurance for underground natural gas storage. Financial assurances are required only for the construction and operation of the storage or injection well – there do not appear to be any financial responsibility requirements for the storage reservoir. The suite of acceptable financial instruments notably differs by state. For example, neither Pennsylvania nor Texas appear to allow self-insurance instruments (e.g., a financial test), and only Texas appears to allow the use of a fully-funded insurance policy. Conversely, California allows the use of cash or a surety bond, but the amount of financial assurance required depends on the number of injection wells, and the depth of each well.
Kentucky, Ohio, Louisiana, and Wyoming	Do not appear to maintain requirements for financial responsibility specific to underground natural gas storage – either for the injection well, or for the storage cavern/reservoir.

been extended numerous times – most recently through the Energy Policy Act of 2005.

Under the Act, accident liability for the nuclear industry is capped at a present value of $7 billion (approximately $10 billion in nominal terms as of 2006). Essentially, a risk-pooling program, the program comprises three tiers:

- **Tier 1** (individual financing) requires the individual nuclear plant to obtain primary insurance coverage up to a mandated level (as of 2005, $300 million per plant).
- **Tier 2** (collective financing) requires that each company contribute up to a statutory cap of $95.8 million in the event of a nuclear accident. Actual payments made by each company in the event of an accident are capped at approximately $15 million per year until claims are met, or the maximum individual liability has been reached.
- **Tier 3** (federal financing) requires the federal government to backstop the remaining balance owed to claimants through the general treasury, once the individual and collective caps are reached.

To date, the Price-Anderson fund is largely untested. To put the value of the fund (approximately $10 billion) in perspective, consider recent claims made under the National Flood Insurance Program established in 1968. As of October 2005, estimated borrowings from the U.S. Treasury to backstop the Program from losses associated with Hurricanes Katrina and Rita were estimated to be as much as $30 billion, 15 times greater than the $2 billion in premium payments collected by the program during 2004 (Hartwig, 2005).

A long-lived, risk-pooling framework may be appropriate to manage risks associated with accidental release or catastrophic events with a relatively low probability of occurring. However, if not crafted carefully and priced accurately, a federally-backed indemnity program can inappropriately shift the burden of long-tailed liabilities to the public. Arbitrary limits on liability and fixed fee structures may result in inadequate collection of funds, resulting in significant financial exposure both for the institutions providing insurance coverage and the public.

Financial Responsibility Implications for CCS Technologies

An effective CCS program requires a liability and financial responsibility framework that is self-implementing, transparent, and which integrates lessons learned from past frameworks. Understanding the evolution of the risk profile and the attendant costs associated with mitigating each stage of risk are essential to assess the utility of, and appropriately price, various financial instruments for purposes of financial responsibility.

Notably, an effective financial responsibility framework will establish requirements that:

1. Ensure funds are adequate, if and when needed;
2. Ensure funds are readily accessible;
3. Establish minimum standards for financial institutions securing funds (or underwriting risk);
4. Ensure continuity of financial responsibility, if and when sites are transferred;
5. Not impose excessive barriers to projects that have public benefits.

Prioritizing and ranking relevant risks over the post-closure period, identifying the subset of risks that require management, and identifying the parties, be they private or public, who will bear responsibility for managing each risk is essential to mitigate liability and to ensure continued financial responsibility.

A relatively clear understanding of the risk profile exists for the site characterization, injection and closure phases of sequestration projects. These activities are not unlike current activities required for RCRA, enhanced oil and gas recovery or underground natural gas storage. Risk transfer or finite risk instruments (e.g., insurance or compulsory bonding), where the developer or operator obtains an insurance policy or posts a financial guarantee, may be an effective approach to address moral hazard for contractual and regulatory liability associated with the development and early-stage implementation of CCS technology.

Policy Options

A financial responsibility framework that is accurately priced will reflect the true nature of the risk profile and ensure that risks are borne by those who share in the benefit of CCS technologies. The siting and operational stages of a CCS project are relatively well understood. Existing financial responsibility models may be adequate to hedge the risks associated with these phases of the CCS project. However, a need remains for ongoing research and analysis into the post-injection risk profile. The outgrowth of this research and analysis will influence which of several options is best suited to ensure long-term financial responsibility under the CCS regime. Two possible options are summarized below.[4]

Federal Indemnity

Precedent exists to remove economic impediments and stimulate private development of new technology that results in a shared public benefit through federal indemnity of future liability. Such programs often rely on risk pooling to ensure the public receives compensation in the event of a release. Depending on the design of the program, compensation may result from releases that are accidental or catastrophic in nature. In the CCS context, the use of an indemnity program might be limited to a discrete set of pilot projects designed to test the parameters and scope of CCS technology, and be limited only to discrete risks or those associated only with the post-injection phase. The design of an indemnity program for CCS projects should clearly articulate limits of liability and be accurately priced – the public should not be asked to unnecessarily subsidize private development and implementation of CCS technologies indefinitely.

Hybrid Approach

Until the nature and probability of the long-term risks are better defined, geological sequestration of CO_2 may lend itself to a hybrid financial responsibility framework. A hybrid framework would use different mechanisms to best fit each phase of the project and the nature of the risk profile. For example, a hybrid framework might include the use of pre-existing financial responsibility mechanisms during the siting and operational phases; then, once wells are plugged and post-closure monitoring begins, the site would transition to a federally-backed indemnity structure. The transfer of responsibility from private operators to the public could be either performance-based (for example, when reservoir pressure reaches a certain level) or prescriptive (for example, after 10, 20 or 30 years). Under a performance-based standard, an additional stricture could be added that requires the developer and/or operator to re-assume financial responsibility (and attendant liability) in the event the site fails to maintain prescribed standards at set monitoring points over time. Regardless, the eventual regulatory regime for CCS must be adaptive to new information from the initial pilot projects and evolve with the advent of commercial-scale deployment of CCS.

CONCLUSION

If CCS is to play an important role in reducing emissions of greenhouse gases, it will need to be widely deployed. This will require resolution of liability and financial responsibility considerations throughout the entire lifecycle of CCS projects. An integral step in developing an effective regulatory and financial responsibility framework is understanding the evolution of the risk profile and the cost of remediation measures associated with CCS. Without a clearly defined risk profile – one which articulates the degree and probability of risks – financial institutions may be reticent to develop products that appropriately manage the risk of environmental exposure. Initial large-scale pilot CCS projects are essential to develop this institutional knowledge. *Ex ante* regulation, as opposed to *ex post* litigation, can provide a more certain approach to mitigate CCS risks, foster incentives for private investment, and enhance public confidence in CCS technology. The eventual regulatory regime for CCS should be adaptive to new information as it becomes available and evolve with the advent of commercial-scale deployment of CCS.

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For more information about this or other Carbon Capture and Sequestration issue briefs, please contact John Venezia. Ph: 202.729-7715. E-mail: jvenezia@wri.org.

NOTES

1. For a discussion of various strategies to reduce global CO_2 emissions, see, e.g., Pacala, S. and R. Socolow (2004) Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies. *Science* 305: 968-972.
2. Including fugacious minerals, such as oil and natural gas.
3. In 1995, the taxing authority expired and has not been reauthorized. Since 1996, the balance of funds in the Superfund trust fund has decreased significantly — from an estimated $2 billion in fiscal year 1995 to less than $370 million in fiscal year 2002 — the Superfund program relies increasingly on appropriations from the general fund to offset shortfalls in funding.
4. The WRI CCS stakeholder project is currently working to develop a set of recommendations for a liability framework to manage the long-term risks of geological sequestration.

About WRI

The World Resources Institute is an environmental think tank that goes beyond research to create practical ways to protect the Earth and improve people's lives. Our mission is to move human society to live in ways that protect Earth's environment for current and future generations.

Our program meets global challenges by using knowledge to catalyze public and private action:

- To reverse damage to ecosystems. We protect the capacity of ecosystems to sustain life and prosperity.
- To expand participation in environmental decisions. We collaborate with partners worldwide to increase people's access to information and influence over decisions about natural resources.
- To avert dangerous climate change. We promote public and private action to ensure a safe climate and sound world economy.
- To increase prosperity while improving the environment. We challenge the private sector to grow by improving environmental and community wellbeing.

In all of our policy research and work with institutions, WRI tries to build bridges between ideas and actions, meshing the insights of scientific research, economic and institutional analyses, and practical experience with the need for open and participatory decision-making.

For more information, visit WRI's website at http://www.wri.org.

This is the third in a series of WRI policy briefs on CO_2 capture and sequestration. These briefs are part of a larger project WRI is leading with diverse stakeholders to develop and build consensus on guidelines for CCS deployment. More information on this project is available at http://carboncapture.wri.org.

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