BNA's

WORLD CLIMATE CHANGE REPORT

BNA Employee-Owned Since 1947

September 3, 2008 www.bna.com

CARBON SEQUESTRATION

The authors of this article say the technical complexity, economic impacts, social demand, and political challenges underpinning the deployment of carbon capture and storage technology to reduce greenhouse gas emissions from coal-fired electric power generation are daunting, but not unprecedented. In response to these challenges, the authors recommend the creation of a new 'federal government corporation' in combination with a suite of financial risk management mechanisms to ensure the deployment of carbon capture and storage technology in an efficient, safe, and environmentally balanced manner.

Storing Carbon: Options for Liability Risk Management, Financial Responsibility

BY CHIARA TRABUCCHI AND LINDENE PATTON

I. Executive Summary

Coal use and climate protection are on a collision course[1] and without rapid deployment of carbon capture and storage (CCS) systems, 2050 goals of emissions reductions likely will not be met. This article discusses options and offers recommendations for a financial[2] risk management mechanism designed to hedge risks arising from the operational, closure/post closure, and long–term stewardship phases of CCS systems, and specifically geologic sequestration.

CCS involves a series of processes designed to keep large quantities of carbon dioxide emissions from coal fired power plants and other industrial operations out of the atmosphere, thereby reducing the risks of climate change. However, CCS processes also create a suite of risks, including possible injury to private and public

[1] *See* Statement of congressional testimony of Michael Goo, climate legislative director for the Natural Resources Defense Council, to the House Committee on Energy and Commerce Subcommittee on Energy and Air Quality, July 10, 2008 (133 DEN A-6, 7/11/08).

[2] The scope of this article is limited to financial mechanisms. Although this paper does not specifically address physical risk management issues, it is important to note that physical risk management issues are an integral part of the design and underwriting criteria for financial management mechanisms. Specifically, an effective financial risk management system must ensure that developers, owners, and operators of CCS projects are incentivized to design and implement high quality physical risk management systems. By design, it is essential to assure that the financial risk management system manages solely prospective and fortuitous risks and does not encourage or effectuate the transfer of risks to a financial instrument, due to perverse financial incentives, that could be managed more effectively and efficiently by physical means.

Table 1. Recommended Financial Risk Management Framework for CCS

PART 1. CCS SAFETY BOARD ***Design Goal. Ensure siting/operating decisions that consider risk and minimize the potential for residual injury at the time of CCS site transfer.***	
Attributes ✔ Private/Public board, chartered as a federal government corporation. ✔ Comprises no less than nine members, including technical experts, government legal experts, private legal experts, financial experts, and state/federal regulators. ✔ Term limits of no less than six years.	***Charge*** ✔ Approve siting (''go'' v. ''no-go'' decisions) for CCS projects. ✔ Oversee design and management of CCS projects. ✔ Serve as arbiter for existing federal agencies authorized to address issues of technical safety, economic, climate, and ecological preservation related to CCS projects. ✔ Certify completion of key project milestones, e.g., site closure, post-closure. ✔ Accept eventual title to CCS sites, including attendant financial responsibility for long-term care. ✔ Maintain financial and administrative management authority over the CCS National Trust, including distribution of funds and the ability to use a percentage of collected funds to purchase risk transfer instruments, e.g., insurance/bonds.
PART 2. CCS NATIONAL TRUST ***Design Goal. Ensure availability of funds to pay for future (un)expected costs of long-term care and delimited compensatory damages.***	
Attributes ✔ Financed through a combination of: (a) initial authorizing funds, (b) a flat per unit fee on carbon dioxide sequestered during the operating life of the CCS facility, and/or (c) a transaction fee for carbon trades. ✔ Fee collection suspended when the trust reaches a maximum dollar threshold. ✔ Fee collection resumes when accumulation falls below a prescribed minimum threshold. ✔ Balance of funds mandated between a maximum (ceiling) and minimum (floor) financial threshold.	***Charge*** ✔ Address prospective risk, not known existing loss. ✔ Provide funds to pay for long-term care expenses associated with corrective action and compensatory damages resulting *after* the CCS facility is released from its post-closure obligations. ✔ Ensure trust balance and fund contributions map to the expected value of expenses/financial consequences likely to be incurred over the long term. ✔ Trust balance should be re-evaluated when actual site-specific monitoring data become available, but on no less frequently than every three years.
In addition to authorizing legislation for the CCSSB and the CCS National Trust, ADDITIONAL ENABLING LEGISLATION should:	
✔ **Establish Liability Provisions** ✔ **Identify Damages Thresholds** ✔ **Require Evidence of Financial Responsibility**	✔ **Provide for CCSSB Oversight Authority** ✔ **Allow for State Access to Funds in the CCS National Trust** ✔ **Address Miscellaneous Receipts Act Issues**

goods, which will continue beyond the operational life of the sequestration facility. It is likely that CCS projects will be sited near population centers, valuable subsurface resources, increasingly scarce sources of potable surface/groundwater, or protected or sensitive habitats. Proximity to one or more of these areas will create the potential for financial consequences, either in terms of corrective action or compensatory damages. Further, the CCS facility may face financial exposure under a carbon regime if CCS credits are used to meet carbon constraint standards and the sequestration site fails and the carbon dioxide leaks.

For these reasons, CCS-related risks present a unique set of consequences whereby neither traditional public, nor traditional private, nor a blend of traditional public and private risk management structures offer the perfect model for mitigating and managing such risks. With few exceptions, previously designed financial risk management mechanisms suffer from problems of fit, interplay and/or scalability—poor alignment (or fit) between the properties of the physical system, the financial characteristics of the associated risks, and the attributes of the institution regulating or managing the risk; lack of integration (or interplay) between and among existing laws, new laws and partnering institutions and the risks created by these new laws; and an inability to scale the financial mechanisms up or down in response to geopolitical, geographic, social, or environmental change.[3]

No financial risk management framework should inappropriately subsidize or otherwise provide economic advantage for CCS over future, as yet undeveloped or improved, technologies designed to make coal a cleaner source of power.

The technical complexity, economic impacts, social demand, and political challenges underpinning the de-

[3] Oran Young, *Environmental Governance: The Role of Institutions in Causing and Confronting Environmental Problems*, International Environmental Agreements: Politics, Law and Economics 3:377-393 (2003) Kluwer Academic Publishers (Netherlands).

ployment of CCS technology to reduce greenhouse gas emissions from coal-fired electric power generation are daunting, but not unprecedented. It is in response to these challenges that the authors recommend the creation of a new 'federal government corporation' in combination with a suite of financial risk management mechanisms designed to ensure the deployment of CCS in an economically efficient, safe, and environmentally-balanced manner.[4] Table 1 sets forth a high level summary of the recommended financial risk management framework. The components of the proposed structure are well grounded in financial theory, science, economics and current technological conditions; and appropriately weigh the complex interplay of existing laws and myriad federal authorities with a role to play in the advancement of CCS technology.

While existing institutions may argue that their authorities currently extend to certain (or all) aspects of the CCS project lifecycle, approaching prospective financial risk management of a new technology using tools designed for unrelated applications is highly likely to result in a bad fit[5] and unfortunate financial consequences. Lessons learned from Price-Andersen, the National Flood Insurance Program, the California wildfire management experience, and others suggest that specifically designed solutions that appropriately weigh issues of fit, interplay, and scalability are most likely to achieve public policy and financial goals.

In sum, the focus of this article is the development of a prospective risk management system, rather than a reactive risk assumption or allocation mechanism. The design of the proposed financial risk management framework for CCS considers lessons learned from past financial liability/indemnity models, many of which were established in reaction to immediate loss or damage. At this time, there is no 'loss' or 'damage' arising from CCS. The authors have the luxury of 20-20 hindsight with respect to past models, and therefore an unparalleled opportunity to design a framework that responsibly reduces risks from CCS operations and mitigates the attendant financial consequences on a thoughtful, proactive basis for future generations.

Basic Design for CCS Financial Risk Management

Financial risk management is predicated on the ability to forecast accurately the range of event-driven outcomes, recognize that forecasts can be, and sometimes are, wrong and weigh the consequences of being wrong. The most effectively designed financial risk management mechanism must respond to the changing nature of the subject facility's operations and in a manner consistent with the physical reality and evolution of risks over time. In the context of CCS, different risks are likely to present themselves at different stages during the facility's life-cycle, resulting in a range of consequences the financial materiality of which will depend on the site-specific characteristics and location of each CCS project. For these reasons, different phases of the CCS process will warrant different financial (risk) management mechanisms.

Further, financial mechanisms must be implemented by the institution with the best fit to effectuate the goal—the institution best situated to implement and enforce terms and conditions designed to incentivize sound operating behavior and assure funds are adequate and readily accessible to pay for the activities necessary to mitigate associated risks. The mechanism also must be designed in recognition of, and with an ability to, effectively interplay with the applicable legal schemes affecting the subject assets, natural resources and businesses within the regulated community. Essentially, jurisdiction, the nature of the harm, and the attendant financial consequences will interact to determine liability, compensability, and which (if any) party can transfer, release, or assume financial responsibility.

It is accepted generally that early movers will selectively site and operate CCS facilities in well-characterized, favorable zones. However, to achieve measurable gains against climate change over time, CCS will need to be deployed at a commercial scale that takes advantage of the range of existing geologic capacity[6]. Therefore, the design and application of financial risk management mechanisms for CCS must balance incentives that foster early deployment with the potential for adverse site selection due to moral hazard,[7] particularly as commercial-scale deployment evolves. For this reason, eventual financial risk management mechanisms for CCS must be sensitive to issues of scalability, including the range and magnitude of potential risks across varied industry sectors and geographic areas, the suitability of different financial mechanisms and cross border or cross-jurisdictional impacts involved.

While a multitude of public, private, and public-private financial risk management frameworks have been designed and implemented over the years in an attempt to manage environmentally related risks, none has successfully addressed the combined goal of assuring sufficient funds to pay for needed corrective action

[4] Congress has the authority to establish a federal government corporation pursuant to the Government Corporation Control Act, 31 U.S.C. 91. Congress has exercised this authority, and preceding authority, numerous times in history, including, but not limited to the creation of Millennium Challenge Corporation, Tennessee Valley Authority, and United States Enrichment Corporation. For a complete list of current government corporations, *see* 31 U.S.C. 91, Subtitle VI. For related information about complex energy security circumstances similar in some ways to the complex global security, trade, technical, scientific, and economic situation created by the attempts to adjust energy source supply such as coal fired power, *see* "The End of USEC's Golden Days," Oct. 5, 2007, for a discussion of related challenges created by issues involving nuclear material reprocessing and international trade involving United States Enrichment Corporation, available at http://www.stockinterview.com/News/10052007/End-USEC-Golden-Days.html.

[5] Here the term "fit" refers to the fit in the context expressed in Young, *supra* n. 3—that is, the fit and ability of the institution to execute the public policy goal.

[6] *See* Statement of congressional testimony of Michael Goo, climate legislative director for the Natural Resources Defense Council, to the House Committee on Energy and Commerce Subcommittee on Energy and Air Quality, July 10, 2008 (133 DEN A-6, 7/11/08).

[7] Moral hazard refers to the specific situation where the risks of an unplanned event increase, because the responsible party is (partially) insulated from being held fully liable for resulting harm. If CCS facilities are not held completely responsible for the consequences of their actions, arguably they will be less careful in their siting and operating decision. Therefore, the incentive to capture, transport, site/characterize, and inject carbon dioxide in an environmentally sound and protective manner may be diminished. The potential for risk increases because the chances of an unpredictable event occurring due to poor siting/operating decisions increases.

in perpetuity while addressing the potential for long-term, multimedia liability in a manner satisfactory to stakeholders. That said, a subset of financial management frameworks have proven to be (a) effective in their ability to foster operating decisions designed to substantially manage and mitigate risks, and (b) economically efficient in their application to pay for residual risks when they manifest.

It is in this context and in the reality of climate change that financial risk management options for CCS are assessed. Discussion of the mechanisms is made with an eye toward balancing the desire of stakeholders to reduce carbon dioxide emissions, while maintaining a safe, secure, reliable, and relatively inexpensive source of electric power.

The United States has a long history of legislating liability and financial risk management regimes, though these regimes tend to be limited in their ability to meet the combined goal of fit, interplay, and scalability. A subset of these regimes have been cited as appropriate models for the development of a long-term financial risk management framework for CCS. This article reviews these regimes; assesses the strengths, weaknesses, and lessons learned; and offers a suggested conceptual solution appropriate for CCS. In sum:

1. Appropriate analysis is needed to estimate the expected value of financial consequences that may arise from CCS sites.[8]

2. The financial risk management framework should align with the CCS project lifecycle, whereby the CCS facility remains financially responsible for consequences arising during the operational phase from capture through post-closure. Specifically, the operator should demonstrate the ability to manage such risks, technically and financially, using well tested first-party assurances based upon financial capacity or third party mechanisms, such as annually renewable insurance policies. However, because CCS is what the financial services sector calls a specialty or nonstandard risk, only a small part of the sector is equipped and qualified to analyze the risks and place capital at risk thereon. Thus, to assure sufficient participation and capital commitment for these risks from the financial services sector (through insurance, etc.) and the operating industry, a process similar to that followed with the advent of nuclear power risk management may be necessary, including antitrust waivers for participating parties.

3. With respect to siting, operational oversight, and long-term stewardship of CCS facilities, a private/public government (mixed ownership) corporation (CCS Safety Board or CCSSB) should be chartered and vested with the authority to oversee the siting, design, and management of CCS facilities.

4. The multimedia, cross jurisdictional nature of CCS technology results in diffuse authority spanning local, state, and federal agencies, including but not limited to the Department of Energy, Environmental Protection Agency, Department of the Interior, and Department of Transportation. The CCSSB should be vested with the authority to arbitrate permitting/operating issues spanning these myriad authorities, as well as be vested with the responsibility of instituting ''go'' or ''no-go'' decisions with respect to CCS projects, even if such decisions result after the CCS project is underway.

5. A trust fund (CCS National Trust), managed by the CCSSB, should be established to pay long-term care expenses and delimited compensatory damages resulting after the CCS facility is released from post-closure, but not for financial assurance during the revenue generating operating period.

6. Unless contributions to the trust map to the expected value of expenses/damages likely to be incurred over the long-term, there is little financial assurance that the balance of funds remaining at the time of site transfer will be appropriate to the long-term need for funds.

7. Consideration should be given to the liability and financial responsibility implications of industry pooling of sites based on geographic region, or site characteristics.

8. Consideration also should be given in determining the degree to which financial contributions to the trust release the CCS facility from legal liability.

These recommendations are not dissimilar to current provisions governing the Oil Spill Liability Trust Fund (OSLTF) and the National Pollution Funds Center (NPFC) mandated by the Oil Pollution Act of 1990,[9] or the Presidio Trust, established by Congress in 1996 as an independent management entity to preserve the Presidio's natural resources.[10] Further, the aforementioned recommendations could be extended and applied in a different country context, provided that local issues of fit, interplay, and scalability are considered adequately. China and India continue to expand their use of coal, further increasing the importance of establishing a well working CCS program in the United States. Ultimately, it may be necessary to export U.S. CCS technologies, risk management frameworks, and policies to other coal burning nations, including China.

II. Introduction—The Case for Cleaner Coal

A. Why Focus on Cleaner Coal?

A convergence of circumstances support and encourage the need to explore opportunities to reduce greenhouse gas emissions generated by the electric power generation industry. First, energy demands and economic efficiency support the use of all available natural resources, including the continued use of fossil fuel in combination with alternative, renewable fuel technologies.

Second, the sheer amount of coal reserves present in North America suggests that continued use of coal may be critical to energy security. Further, dependencies on coal for revenues and power generation are concen-

[8] Expected value should incorporate the probability of adverse events occurring. Expected financial consequences in a given year is calculated as the product of potential financial consequences multiplied by the annual probability of occurrence. Results for each year are summed over the relevant time period and discounted to generate an expected value of financial consequences.

[9] Oil Pollution Act, Pub. L. No. 101-380, Aug. 18, 1990, codified at 33 U.S.C. 2701 et seq.

[10] 16 U.S.C. 460bb Appendix (enacted as Title I of H.R. 4236, Pub. L. No. 104-333, 110 Stat. 4097, Nov. 12, 1996).

   ISSN 0000-0000

trated in specific regions of the United States, and across the globe. The resulting socio-economic and political tensions are such that eliminating the use of coal altogether is simply not a viable option. Notably, the United States has invested heavily in its fleet of coal-fired power plants: a total of 1,493 active coal-fired electric power plants were in operation in 2007[11], many of which have significant residual operational value. Ceasing operations and abandoning these plants would result in thousands of stranded assets, representing an inefficient use of billions of dollars in invested capital and placing tremendous strains on regional economies.

The volume of emissions attributable to coal-fired power plants is substantial.[12] To permit these facilities to continue operating without any means of effective emissions controls dooms global efforts to reduce anthropogenic carbon emissions and hinders society's attempts to avert continued and predicted worsening climactic change. On a global scale, the International Energy Agency forecasts that more than $5 trillion will be spent globally on new power plants in the next 25 years. This estimate includes 1,800 gigawatts of new coal plants that will increase the amount of coal power used by 50 percent over today's usage portfolio. Unless per plant emissions are reduced through technological advances, such as process changes or geologic sequestration, greenhouse gas emissions from coal fired power may increase by 50 percent, which will make the commitment to achieve a 50 percent reduction in greenhouse gas emissions agreed to by the United States during the meeting of the Group of Eight in Tokyo quite hard to achieve given the contribution of coal powered electricity to the United States' greenhouse gas footprint[13].

To preserve economic stability, ensure returns on invested capital, and address political resistance to the conversion to a low(er) carbon economy, a rational approach to manage carbon dioxide emissions from coal-fired power plants is essential. Specifically, to effectuate material reductions in greenhouse gas emissions and avoid stranded assets, the effective use of coal dictates commercial-scale deployment of CCS technology. The adoption of this technology also is critical to the economic future of states that mine coal and depend heavily upon electricity from coal fired facilities. Notably, the Intergovernmental Panel on Climate Change (IPCC) identified carbon capture and storage, and specifically geologic sequestration, as one of the more technically viable technologies to mitigate climate change.[14]

Additionally, to avoid unanticipated, unquantified intergenerational transfer of risk from CCS processes, development of a rational, disciplined approach to the design and implementation of a financial risk management framework that supports the continued use of coal-fired plants with new and emerging CCS technology is essential.

B. Impact, Global Dominance of Coal-Fired Power

The Earth's climate is changing. Evidence of this change exists in the increase in average global air and ocean temperatures, widespread melting of snow and ice, and rising global average sea levels.[15] Consider, the IPCC documents that annual emissions of carbon dioxide have grown by approximately 80 percent between 1970 and 2004. In 2005 alone, the atmospheric concentrations of carbon dioxide and methane exceeded the natural range over the last 650,000 years.[16] Leading scientists suggest that anthropogenic greenhouse gas emissions should be reduced by 50 to 85 percent below 2000 levels by 2050 to mitigate the risks of climate change.[17] Electric power generation is one of the major sources of anthropogenic carbon dioxide emissions, representing approximately 33 percent of U.S. carbon dioxide emissions.[18]

Coal-fired power accounts for approximately 50 percent of the electric power supply in the United States.[19] The Electric Power Research Institute (EPRI) has evaluated the future projected demands for electricity, including the capacity for expansion within the power industry, and has concluded that coal remains a substantial source of power for the next 100 years.[20] Specifically, according to the National Mining Association, coal represents nearly 95 percent of the United States' fossil energy reserves.[21] Based on recoverable coal reserves of approximately 275 billion tons, estimates suggest that the United States can supply enough energy at current recovery and usage rates to satisfy do-

[11] U.S. Energy Information Administration Electric Power Annual Report, Table 2.2, Existing Capacity by Energy Source, Oct. 22, 2007, available at http://www.eia.doe.gov/cneaf/electricity/epa/epat2p2.html.

[12] Revis James "The Full Portfolio," *Electric Perspectives*, EPRI (January/February 2008).

[13] The leaders of the Group of Eight industrialized countries agreed July 8, 2008, to seek a 50 percent reduction in greenhouse gas emissions worldwide at the U.N.-sponsored climate negotiations in 2009. The G-8 leaders did not commit to reducing their own emissions absent a global agreement (131 DEN A-1, 7/9/08).

[14] The process of geologic sequestration involves capturing carbon dioxide generated from fossil fuel combustion, injecting it deep underground and sequestering the carbon dioxide in geologic reservoirs indefinitely. Intergovernmental Panel on Climate Change, *Special Report on Carbon Dioxide Capture and Storage*, prepared by Working Group III of the Intergovernmental Panel on Climate Change (Metz, B.,O. Davidson, H. C. de Coninck, M. Loos, and L. A. Meyer (eds.) Cambridge University Press, 2005).

[15] *Climate Change 2007: Synthesis Report. An Assessment of the Intergovernmental Panel on Climate Change*, November 2007. It is not the authors' intention to endorse the IPCC report in this or any other footnote where it is cited, but to suggest that prudent businesses will take the data and predictions very seriously.

[16] *Id.*

[17] Reducing global carbon dioxide emissions by 50 to 85 percent below 2000 levels is expected to result in global average temperature increases between 2.0 and 2.4 degrees Celsius (or 3.6 to 4.3 degrees Fahrenheit). According to the IPCC Workgroup Group II, increases in global average temperature exceeding 1.5 to 2.5°C "are projected to [result in] major changes in ecosystem structure and function, species' ecological interactions and shifts in species' geographical ranges, with predominantly negative consequences for biodiversity and ecosystem goods and services, e.g. water and food supply." *Climate Change 2007: Synthesis Report. An Assessment of the Intergovernmental Panel on Climate Change*, November 2007.

[18] Revis James, "The Full Portfolio," *Electric Perspectives*, EPRI, January/February 2008. *See also*, Steven Specker, "Electricity Technology in a Carbon-Constrained Future," EPRI, February 2007.

[19] *Id.*

[20] *Id.*

[21] Available at http://www.nma.org/statistics/pub_fast_facts.asp.

mestic demands for 200 years.[22] The dominance of coal as an energy source is unquestionable, and it is not limited to the United States. At the current rate of production, global coal reserves are estimated to last for another 150 years.[23] Further, Chinese and Indian demands for electric power are expected to increase dramatically over the next 50 years; it is accepted generally that coal will power this expansion[24]

If the recommended anthropogenic greenhouse gas emissions reductions are to be achieved, a means for achieving these reductions from coal-fired power is essential. CCS offers a technologically viable option for achieving society's goal of cleaner coal.

C. Valuing and Pricing Low Carbon Power: How Willing is Society to Pay for Clean Coal?

In general, today's society is structured around a fossil fuel paradigm. Leading scientists attribute a significant amount of the worldwide increases in atmospheric greenhouse gas concentrations to the world's increasing use of and continued dependency on fossil fuels. Without significant public policy intervention this dependency is not likely to abate anytime soon.

Notably, the activities that emit the greatest amounts of greenhouse gases involve what developed economies have come to consider essential services—power, water, and transportation. To reduce greenhouse gas emissions without effecting a shift in energy consumption patterns, leading scientists assert that the underlying nature of the fuel that powers the base load energy supply for developed and emerging economies must change. In other words, a structural shift in how society generates energy is needed in order to consume more, but emit less. This structural shift comes at a price. Alternative fuels that emit less greenhouse gas (and carbon) all cost more than their fossil fuel (coal) counterpart.[25]

Nonetheless, for some the perceived value of green energy outweighs viable, cost-effective options resulting in clean coal.

As such, climate change is causing more than increased temperatures and rising sea levels. Climate change is forcing a shift in societal perceptions of what it means to pay for energy and other essential services. Beyond the simple tangible cost of electricity, natural gas, or oil, increasingly consumers are aware of the intangible cost of their energy decisions. Consumers are beginning to fully absorb the influence of product lifecycle and concomitant costs on the price they pay for fuel.

Society's willingness to pay for energy derived from fossil fuel combustion increasingly is impacted by the intangible environmental and ecological impacts of their consumption patterns. Essentially, consumers are beginning to add the cost of public good degradation into their cost of service calculus. The challenge is socially pricing that for which there is no economic substitute . . . the atmosphere that protects us and the air we breathe. The bottom line? Consumers in developed economies are weighing how their everyday choices contribute to a cleaner, greener world. These same consumers will be asked to place a value on their clean, green world, which begs the question—how much will they truly be willing to pay for clean coal?[26]

Ensuring the advancement and deployment of CCS on a scale large enough to reduce greenhouse gas emissions is simply not enough. The challenge will be to ensure the efficient, cost-effective, and sustainable deployment of CCS within the existing regulatory framework and societal structure. The market must confirm that CCS technology is financially viable. Utility rate payers must be willing to pay for carbon dioxide capture and sequestration in the form of increased prices and/or public policymakers must be willing to balance the costs of carbon dioxide capture and storage through a rational financial risk management framework.

Further, advocates of CCS, including developers and operators, must respond to public concerns regarding the short- and long-term environmental health and safety risks of CCS as a greenhouse gas mitigation strategy. This likely will be accomplished if, and only if, transparent analyses of risks and attendant valuation of financial consequences are communicated to the public. The suggested framework suggested herein is designed to engender this level of transparency. Society's willingness to substitute clean coal through CCS for other alternative fuels is predicated on whether it believes the upside benefits of CCS outweigh the potential downside risks.

D. Regulation of Essential Services Constrains Options

By their very nature, essential services are of great public interest. Essential services—power, water, and transportation—are the subject of significant policy debate and often are highly regulated at the federal and state levels. Regulations underpinning these services range from price controls, subsidies, and tax incentives to restrictive legal frameworks intended to protect human health, ensure safety, and mitigate adverse ecological impacts. Tension arises when legislative decisions that foster financial and economic stability fail to balance equal protection of human health and the environment or result in unequal risk sharing. For example, legislative actions that provide for broad-scale indemnity or other financial subsidy send a signal that it is appropriate for the private sector to bear less than the full price of risk for their actions. This tension is further exacerbated when the indemnity or subsidy involves valuation of a natural resource with public ownership and for which there is no economic substitute, such as the stability of the world's climate.

In such cases, policy choices underpinning legislative action can result in economically inefficient decisions that do not appropriately weigh financial market considerations with social welfare impacts. It may be that

[22] The Coal Based Generation Stakeholders Group, *A Vision for Achieving Ultra-Low Emissions from Coal-Fueled Electric Generation* (2005). *See also*, National Energy Technology Laboratory *Key Issues & Mandates Clean Power Generation—Market and Policy Drivers*,, available at http://www.netl.doe.gov/KeyIssues/clean_power2.html.

[23] World Energy Council, *2007 Survey of Energy Resources*.

[24] Netherlands Environmental Assessment Agency, *China Now No. 1 in CO2 emissions; USA in Second Position*, June 2008. Available at http://www.mnp.nl/en/publications/2008/GlobalCO2emissionsthrough2007.html.

[25] *Vattenfall's Climate Map 2030* (2007), available on the Web at .http://www.europarl.europa.eu/document/activities/cont/200803/20080305ATT22990/20080305ATT22990EN.pdf.

[26] Lindene E. Patton, *Beyond Rising Sea Levels: The Importance of the Insurance Asset in the Process of Accelerating Delivery of New Technology to Market to Combat Climate Change*, European Business Review, May/June 2008.

   ISSN 0000-0000

society as a whole agrees that payment for a shared public good is appropriate. Such payment may occur in the form of base load portfolio standards, price supports, taxes, cap-and-trade, and/or loan guarantees. Unfortunately, some subsidies encourage the creation of legal structures that increase financial risk as a necessary condition of qualification for the subsidy. As such, selection of subsidy, including risk management and financial assurance mechanisms, must be done with great care, lest the wrong structure create additional or unexpected risk.

III. Design Considerations for Effective, Efficient Financial Risk Management Framework

To properly design financial risk management mechanisms for any activity, understanding the project lifecycle, the risks that may manifest at each stage of the lifecycle, the expected present value of financial consequences, and the subject legal environment is essential. Collectively, these components inform the need for financial assurance and influence the selection of financial mechanisms with the greatest likelihood of avoiding problems of fit, interplay, and scalability.

When considering the design of financial risk mechanisms, it is important to remember that most financial instruments are ''one-trick ponies'' designed with one goal—protecting private party rights, not managing public goods. For example, a common financial assurance mechanism, the letter of credit, represents a contract wherein a bank promises to pay a specified sum upon presentation of specified documents.[27] The bank predicates its decision to issue the letter of credit solely on the credit worthiness or ability-to-pay of the company purchasing the letter. Generally, the bank is indifferent to the physical or engineered system necessitating the financial assurance. If the contractual terms are met, the bank will pay.

Financial instruments are grounded in the certainty of contract law. Thus, it is critical to understand what events trigger the ability to call due the financial instrument and memorialize such events in a manner without ambiguity. While these objectives may appear to be common sense, designing financial mechanisms that realize these objectives is not a trivial exercise. The presumption is that traditional financial assurance instruments are designed to hedge the risk of an owner or operator defaulting on its financial obligations. However, relatively few financial assurance instruments are designed as ''promise to pay'' or financial guarantees.[28] The challenges of fit, interplay, and scalability become even more challenging when the events triggering the need for financial responsibility may not manifest for tens or hundreds of years, likely after the corporate actor ceases to exist.

In the world of CCS, the goal is to store carbon dioxide permanently. In service of this goal, stakeholders seek assurances that funds will be available to pay for the activities necessary to minimize the potential for releases of carbon dioxide post-injection and to detect problems before they adversely impact public welfare or the environment. In addition, significant public debate has centered on financial assurance for (un)foreseeable corrective action and compensation for damages resulting from the failure to store the carbon dioxide as planned. As described below, the consequences of failing to sequester carbon dioxide fully range from potentially impairing private rights to impairing public goods for which there is no economic substitute, the stability of our climate and the air we breathe. Where no private right is affected and no economic substitute readily available, the design of an effective, rational, financial risk management framework, be it public or private, is challenging.

If CCS is to be a vehicle for striking the political balance necessary to gain carbon dioxide emissions reductions, the financial risk management framework must be designed carefully and needs to comprise multiple single goal components. Only through a blend of financial mechanisms targeted to discrete phases of the CCS project lifecycle will society achieve its desired goals—protecting both private and public goods from harm and damage in the short and long term. No single financial mechanism or risk management technique can span the timing and range of potential financial consequences arising from CCS, which include the costs of closure, post-closure, and foreseeable corrective action, as well as potential compensatory damages resulting from carbon dioxide leakage post-injection.

A key first step in designing an effective financial risk management framework for CCS is defining the project lifecycle (technologies and their implementation), including the risks manifested by each phase of operation and possible consequences, both when the technologies perform as intended and in the event of operational exceedances. Risks/consequences arising from naturally-occurring events, including acts of God and other conditions of force majeure, also need to be considered as part of the design process.

Once the project lifecycle and attendant operational conditions are defined, consequences and associated damages to private and public parties and goods should be segregated according to the project's risk profile, including:

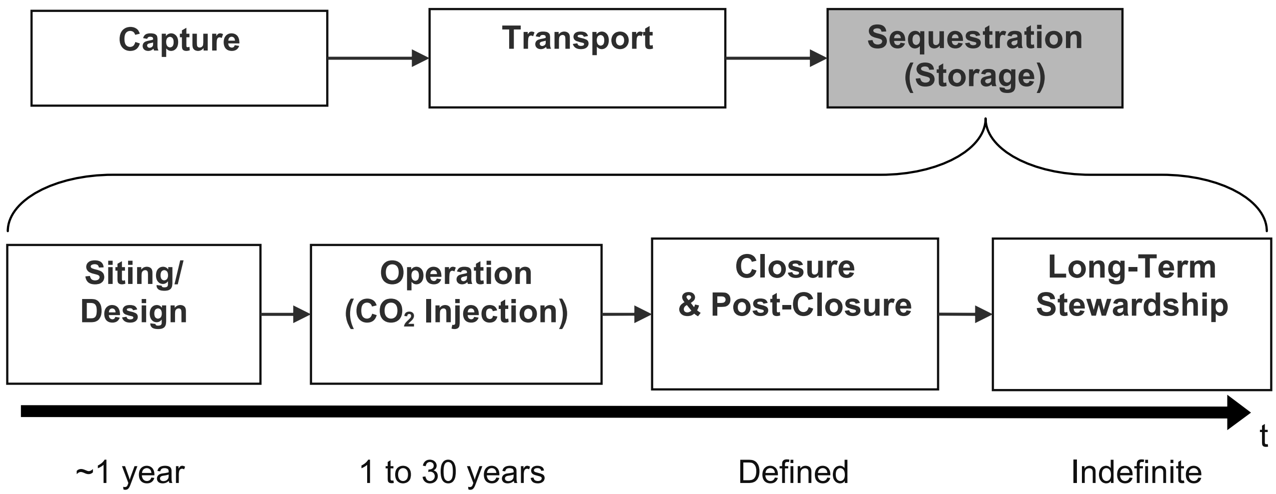
- time profile—when such events could occur,
- frequency profile—how often such events are expected to occur, and
- severity characteristics—the magnitude of damages that may result.

This mapping exercise, when adjusted in light of the applicable legal liability scheme, will reveal the likelihood and materiality of financial consequences by phase across the project lifecycle. These consequences underpin the pricing, and therefore face value, of the financial assurance instruments, including how much

[27] *Corp. Counsel's Guide to Letters of Credit* Section 1:2.

[28] While financial instruments generally are designed with a single goal, the practical application may yield widespread unintended behavioral consequences. Some of these consequential impacts may inure to the benefit of the public good of interest. For example, financial instruments may be void in the event such instruments are procured by fraud; minimizing fraud generally serves a public benefit. However, policymakers often seek to use a single financial instrument to attempt to incentivize both the directly affected behavior controlled by the instrument and the desired behavior involving public goods. Often, the use of a single instrument will fail to achieve both objectives for very practical realities involving politics. For additional insights into the issues inherent to traditional financial assurance instruments for the management of hazardous waste *see* Lindene E. Patton and James L. Joyce, *Hazardous Waste Financial Assurance: A Comparison of Third-Party Risk Management Mechanisms—Suggestions for Reform* (114 DEN B-1, 6/13/08).

Figure 1. CCS Project Lifecycle [29]



money will be needed, when, and for whom. Implicit in this analysis is a superior understanding of the existing laws that define responsibility and liability for intended or unintended damages arising out of operational activities. Because the legal liability scheme underpinning carbon emissions in the United States is in flux, this calculus has an additional uncertainty characteristic. Third-party risk transfer instruments may be able to assume some of this political/regulatory risk.

A. CCS Project Lifecycle, Associated Risks

A key component of ensuring the advancement and deployment of CCS on a scale large enough to reduce greenhouse gas emissions will be to frame the potential economic and ecological risks that exist, as well as any associated losses that may result from site-specific CCS projects. In so doing, rigorous and defensible valuation of near- and long-term financial consequences is possible. Markets by their very nature seek certainty. Identifying the residual risks on a prospective basis that are unique to CCS and can not be managed using existing physical risk management techniques, is essential to achieve market certainty. The key is determining whether the long-term residual risk tail for a particular CCS site will be skinny or fat.[29]

As illustrated in Figure 1, the CCS project lifecycle comprises three discrete phases, each of which lends the potential for risk and consequences. The public debate surrounding CCS has centered largely on the last phase, sequestration, due to the combination of (un-)foreseeable events that may arise post-injection and contribute to cross jurisdictional, multi-media liability. Nonetheless, design of a CCS financial risk management framework warrants discussion of the range of risks and impacts across all three phases.[30]

Phase 1: Risks at Point of Generation/Carbon Dioxide Capture Improper venting of carbon dioxide, leakage at the capture point, other technological failures causing additional property damage or bodily injury in addition to the carbon dioxide, or catastrophic weather events may result in supply chain interruptions or demand surges for energy. In general, these risks are standard property and casualty/pollution risks associated with an operating facility. Under existing financial risk management frameworks, these risks either are directly retained by the operator or are managed regularly with standard private third-party risk transfer mechanisms (e.g., bonds, insurance).

Under a legal regime with carbon constraints, the facility operator may face additional financial exposure, e.g., the required purchase of offsets, penalties/fines, if

[29] A ''skinny tail'' refers to a loss profile, whereby attendant risks have been mitigated and managed to the point where the loss profile visually presents as a tail along the x-axis that declines asymptotically in the out years. Although the possibility of a catastrophic loss remains, the likelihood or frequency of such an event becomes increasingly small over time due to sound risk management practices. For example, to allow construction only in non-flood plain areas, or to only allow building in flood plains using construction techniques designed to avoid damage (structural and otherwise) minimizes risk. Thus, when a flood occurs the likelihood of loss is lowered, but it is acknowledged that if a loss occurs it will be severe. Situations involving low frequency, catastrophic risks are well managed by a specialty approach to underwriting that requires highly protective risk management strategies, and tend to benefit significantly from pooling. By contrast, a ''fat tail'' manifests when risks of potentially great severity are not otherwise managed or mitigated resulting in potentially increased frequency and/or severity over time. The ''fat tail'' is characterized by moderate to high frequency catastrophic risks and no amount of pooling can spread the risk. Examples of such situations include knowingly building in flood plains, regularly permitting building in areas of high fire danger, and in the context of CCS, siting projects in sensitive environments or in unstable geologic structures. The challenge is to optimize the amount of risk management effort expended with the pooling technique to arrive at the optimally economically efficient risk management framework in the short and long term.

[30] Elizabeth J. Wilson, Mark A. De Figueiredo, Chiara Trabucchi, Kate Larson. *Liability and Financial Responsibility Frameworks for Carbon Capture and Sequestration*, World Resource Institute: WRI Issue Brief Carbon Capture and Sequestration, No. 3 (2007).

   ISSN 0000-0000

its allowances are exceeded. If such exceedances occur as the result of an insured property or casualty event, the business interruption coverage extensions on private insurance policies may be expanded to include compensatory damages or in-kind replacement obligations. Likewise, under certain situations, the entity may face adverse pre-treatment, treatment, or disposal costs if higher-than-expected impurities remain in the carbon dioxide stream making it unsuitable or unacceptable for CCS without further action.

Phase 2. Risks During Carbon Dioxide Transport. The potential for leaks during the transport of carbon dioxide from the point of generation (capture) to the sequestration (storage) site exists. Eventual transportation networks likely will travel through a combination of heavily populated areas, as well as potentially ecologically sensitive areas. Further, the corrosive nature of carbon dioxide when mixed with water under certain conditions such as colder climates may contribute to the risk of pipeline fractures. Such leaks may result in ecological, human health, and property-related consequences that may have substantial financial implications. Further, carbon constraints can add to the potential for first-party financial damages. Similar to the risks outlined above for carbon dioxide capture, these risks are standard property and casualty/pollution risks associated with an operating facility that either are directly retained by the operator or are regularly managed with standard private third-party risk transfer mechanisms (e.g., bonds, insurance).

Phase 3. Risks During Carbon Dioxide Sequestration. As illustrated in Figure 1, sequestration of carbon dioxide involves a series of four activities: (1) siting/design, (2) operation (carbon dioxide compression and injection), (3) closure/post-closure, and (4) long-term site stewardship. Notably, significant debate has focused on the timing of these activities, such as when one activity ends and the next activity begins. Not surprisingly, the majority of the discussion has centered on when post-closure ends and long-term site stewardship begins. It generally is accepted that the transition from post-closure to long-term site stewardship will involve demonstration of certain performance-based criteria by the CCS facility, with the eventual long-term management of minimal residual risk by a third-party entity. At issue remains the timing and nature of the demonstration, and the lack of a clear understanding of what a ''release'' from post-closure truly entails.

Financial certainty regarding the evolution of risk, consequences, and financial responsibility declines as the project moves through its natural lifecycle from siting to long-term stewardship. The fit, interplay, and scalability of various financial instruments shift in response to the evolution of the CCS project lifecycle. Further, the alignment of financial instruments between and among the various project phases will vary substantially based on site-specific and geopolitical characteristics. For this reason, the financial mechanisms underpinning an eventual financial risk management framework for CCS will need to be a blend or series of single goal instruments that address the unique fit, interplay, and scalability issues posed by each of the activities listed below.

1. Siting/Operation (Carbon Dioxide Compression, Injection)

The degree to which the long-term risk tail for CCS sites truly is minimal (or skinny) will depend on near-term decisions involving the siting and operation phases of the sequestration process. Further, the degree to which CCS facilities are incentivized to integrate risk management mitigation strategies as part of their siting and operational decisions will undoubtedly influence the site-specific long-term risk profile. If the operator has little or no financial risk resulting in a zero or low dollar price indicator with respect to the harm that could result from a poor siting selection or management decision, then the operator will not put sufficient resources toward this part of the process. Instead, they are likely to only put resources commensurate with the price indicator.

Significant scientific research and analysis have been done on the risks associated with carbon dioxide injection and storage. Notable financial and economic damage risk pathways include, but are not necessarily limited to: (1) induced seismic activity, (2) surface/subsurface trespass, (3) groundwater contamination, (4) property damage resulting from geologic exploration, or ground heave, (5) asset infringement, where the value of an existing surface owner's oil, gas, or storage rights is diminished, (6) bodily injury and/or property or ecological damage resulting from catastrophic (acute, high quantity) release, and/or (7) bodily injury and/or property or ecological damage resulting from chronic low volume releases.

As with the capture and transportation phases, the outlined risks attendant to the compression/injection and storage phases of the operations are similar to standard property and casualty/pollution risks associated with an operating fossil fuel or chemical facility. The exception with respect to CCS projects involves the underground nature of the containment zone—all monitoring techniques are necessarily indirect. Consequently, it is more difficult to devise a means by which the facility can monitor and evaluate operational conditions and the continued integrity of the containment zone. Because CCS is what the financial services sector would call a specialty risk, only a small part of the sector would be equipped and qualified to analyze the risks and place capital thereon. Thus, to assure sufficient participation and capital commitment from the financial services sector (through insurance, etc.) and the operating industry for these risks, a process similar to that followed with the advent of nuclear power risk management, including antitrust waivers for participating parties, may be necessary.

2. Closure/Post-Closure

The characteristics of carbon dioxide injection and storage are not dissimilar to those associated with enhanced oil recovery and natural gas storage facilities. Prevailing scientific thinking is that the activities associated with well plugging and abandonment (closure), as well as post-closure monitoring for CCS are likely to be the same as those for enhanced oil recovery. However, there is an inherent difference between traditional enhanced oil recovery activities and CCS. Where enhanced oil recovery is focused on the extraction of a natural resource, the objective of CCS is the permanent storage of a buoyant substance. Appreciably, enhanced oil recovery activities involve the injection of carbon dioxide as an extraction technique. However, to achieve the anthropogenic greenhouse gas reductions necessary to halt climactic change, exponentially greater volumes of carbon dioxide will need to be injected and stored than those used in support of enhanced oil recovery activities.

Further, the time horizon for CCS projects is substantially longer than those traditionally associated with enhanced oil recovery projects. For this reason, it is likely that closure and post-closure activities planned in the short-term will need to be revisited when closure and post-closure at CCS sites actually occur 10, 20, or 50 years from now.

While the array of risks likely to manifest during the closure and post-closure periods are largely the same as those likely to manifest during carbon dioxide injection/operation, there is the added risk of changing science. Society's understanding of what it means to store carbon dioxide in perpetuity will evolve. For this reason, there is added uncertainty under this phase of the CCS project lifecycle than under previous phases. For example, there may be the discovery of some previously unanticipated condition 10, 20 or 50 years from now that must be addressed (e.g., corrective action issues) but was not contemplated at the time financial assurances were provided.

Finally, the design of a financial risk management mechanism for the closure/post-closure phase presumes an ability to estimate the future expected value of financial consequences that may arise. Financing risk associated with the appropriate use of discount rates also warrants consideration.

3. Long-Term Site Stewardship

In addition to the risks identified above under carbon capture, transport and operation, legal liability may result from the failure of the owner, operator, or developer of the CCS site to permanently sequester carbon dioxide. However, unlike the initial phases of the CCS project lifecycle, the risks of carbon leakage during the post-injection phase are expected to diminish over time.[31] This shift in the CCS risk profile presents a notable contrast to the expected accrual of risk in the near term during the compression/injection phase. The presumption is that at the time injection operations cease, the CCS facility is likely to be at its maximum risk condition.

B. Defining and Valuing Consequences

The development of a financial risk management framework for CCS must be informed by the potential timing and expected materiality of financial consequences that may arise at CCS sites. Although the process for estimating financial consequences is conceptually straightforward, doing so in practice for CCS poses notable challenges.

Specifically, the lack of real, readily accessible, non-private monitoring data can make it difficult to confirm the magnitude, duration and/or areas that may be exposed to a carbon dioxide release. Further, the characteristically buoyant nature of carbon dioxide, and its potential to travel far afield from the initial injection point, will make it difficult to trace carbon dioxide leaks back to their source. For both of these reasons, the monetary value of potential losses associated with carbon dioxide leakage can be difficult to measure, particularly when addressing nonmarket impacts, such as injuries to endangered species or ecological resources.

These impacts also can extend well into the future adding yet another layer of complexity—the extent and duration of related impacts in future years. Losses which will not manifest for years typically are calculated using a discount rate to bring them to present value. However, as noted above, the use of a discount rate introduces an additional layer of financing risk, due to the difficulty in selecting a discount rate today that appropriately characterizes the long-term risk profile of, as yet unconstructed, CCS sites.

Nonetheless, methods for characterizing and valuing financial consequences have evolved in a variety of contexts that are applicable to CCS sites. At a minimum, appropriate consideration in the context of CCS should be given to four categories of impacts, all of which involve a combination of public and private goods.

1. ***Human Health & Welfare Impacts.*** Leakage potentially could result in concentrations of carbon dioxide or other residual impurities in the carbon dioxide stream sufficient to cause morbidity or mortality. Specific damages that may result include reductions in the quantity or quality of recreational activities in affected areas, adverse impacts to commercially exploitable resources (e.g., forests, croplands, mineral reserves, oil/gas reservoirs), and/or restrictions to land use or subsurface activities. Additional losses could include claims for business interruption, asset infringement and diminution in property value through loss or damage.

2. ***Ecological Impacts.*** Leakage at any point during the CCS project lifecycle, and physical disturbances specifically during operations, can impact ecological receptors adversely, resulting in the need for response actions to remove or reduce threats to the surrounding ecology. In some cases, actions may be needed to return affected biota or habitats to expected conditions "but for" the event, i.e., baseline condition. In other situations, the impacts may be so severe and the present ecology so degraded, that a restoration project elsewhere is required to offset the present situation.

3. ***Atmospheric Releases.*** Leakage can reduce the climate benefits of capturing carbon dioxide, decreasing the overall effectiveness of CCS as a climate change mitigation strategy and reversing any accrued public benefit with respect to reducing emissions. Further, unanticipated atmospheric releases may result in the need for CCS facilities to purchase carbon offsets in an amount sufficient to match any increases in atmospheric carbon dioxide caused by leakage. Some valuation may be made with respect to legal liabilities established in a common law context. However, an actual value would require that the common law recognize that release of carbon dioxide into the atmosphere is in

[31] Notably, per the IPCC, "Observations from engineered and natural analogues as well as models suggest that the fraction retained in appropriately selected and managed geological reservoirs is very likely to exceed 99% over 100 years and is likely to exceed 99% over 1,000 years. . . .Similar fractions retained are likely for even longer periods of time, as the risk of leakage is expected to decrease over time as other mechanisms provide additional trapping." Intergovernmental Panel on Climate Change, *Special Report on Carbon Dioxide Capture and Storage* (2005).

fact a damage which is compensable. Further, actual monetary damages will not exist until the law, common or statutory, recognizes a value to the degradation of the atmosphere, a public good. In other words, in the absence of a carbon cap or some other legal mechanism to define and attribute value to the release of carbon dioxide to the atmosphere, valuation of a release is problematic and highly uncertain, ranging from zero dollars to potentially orders of magnitude higher numbers.

4. ***Impacts to Water Resources.*** CCS also may adversely impact water resources, including potable drinking water, groundwater and/or surfacewater. Particularly, water resources are at risk if the carbon dioxide stream escapes the system, if brine or other fluids are displaced as a result of pressure changes from carbon dioxide injection, and/or if contamination occurs due to residual impurities in the carbon dioxide stream. Financial consequences arise from the impaired and/or precluded use of water resources. In some states, water markets are well established and provide a ready means for valuing the impairment or loss of water resources.

The outlined impacts span the CCS project lifecycle, and generally result in numerous potential claimants and causes of action. Specifically, the CCS facility may face expenses associated with corrective action and/or compensatory damages resulting from nuisance, trespass, negligence, or other torts related to any single or combination of impacts. Further, statutory liability involving existing environmental legislation, such as the Safe Drinking Water Act, Clean Water Act, Clean Air Act, Resource Conservation and Recovery Act, and Endangered Species Act, as well as local statutes, also may give rise to material financial exposure in the form of remediation expenses and possible damages. Finally, jurisdiction, nature of the harm, and attendant damages will interact to determine liability, compensability, and which (if any) party can transfer, assume, or release the CCS facility from liability.

C. The CCS Risk Profile

The risk profile for CCS has been the subject of much debate. Modeled data suggest that for sites that are well-selected, designed, operated, and monitored, in excess of 99 percent of injected carbon dioxide is very likely (probability between 90 percent and 99 percent) to remain sequestered for more than 100 years.[32]

The risks and losses potentially associated with the activities underpinning the CCS process are distinct in their profiles: e.g., some are low frequency and catastrophic in nature, while others are recurring and of modest severity. Further, some manifestation of risk resulting in harm or injury to private and public goods is likely in the short to medium term, that is, from the point in time operation begins to when the CCS facility is able to make a performance demonstration of reasonable long-term containment of the carbon dioxide. The absolute length of time that correlates to 'short to medium term' is site-specific, and likely will vary from one year to 50 years to hundreds of years after the facility stops its injection activities.

Figure 2 represents the risk profile curve that has been cited repeatedly as the eventual risk profile for CCS. When considering risk management options and an eventual financial risk management framework, it is important to consider that the profile captured in Figure 2 is that of a well-sited, characterized, operated, and managed site—a site with significant confidence in predictive modeling, likely injection pressure, and secondary trapping.

The shape of this curve and magnitude of risks over time will assuredly vary across CCS sites. In fact, each CCS project will be affected by unique geologic attributes, the spatial area, and the attributes of key receptors in the vicinity of the site. The degree to which the CCS facility is able to take precautions during site characterization, operation, and eventual site closure will influence the degree and probability of forecasted risks occurring. For example, certain industry sectors may present greater or lesser risks, reflecting their effectiveness at removing impurities from their carbon dioxide stream.

Further, early movers likely will look to site CCS projects in well characterized zones with the most favorable characteristics[33]. Doing so represents an economically efficient, or rational, business decision. The likely outcome will be that later actors will be left with less attractive geologic options. Perhaps by that time, new technologies will have created additional risk management options for carbon dioxide generated by coal-fired power plants, or power in general. However, if no better solutions present in the intervening period, late market entrants may need to perform more advanced pre-treatment activities to obtain acceptable risk profiles that meet established permitting and underwriting criteria. Insurance and other third-party risk management tools used to underwrite financial assurance will send price signals with respect to the risk differential between well-sited and poorly-sited CCS projects.

It is important to note that at some risk levels, pricing can not and should not cover the risk differential between types of sites. Instead, physical, i.e., engineering and operating, solutions will be the most efficient means of risk control. In such cases, the CCS site likely will be denied coverage by third-party providers, and public policy makers/regulators should resist the temptation to indemnify the CCS operator or waive compliance. In the absence of listening to and heeding signals from well-qualified parties who decline to put capital at risk for CCS operations due to their assessment that the risk is too great or uncontrolled, the uncontrolled risk would be unaccounted for in the financial markets. Therefore, the risk would transfer to the public and proffer a competitive disadvantage to environmentally superior operations. For these reasons, the eventual financial risk management framework for CCS must balance financial, economic, and regulatory incentives that foster early deployment of the technology against the potential for adverse and increasingly risky site selection as commercial-scale deployment evolves.

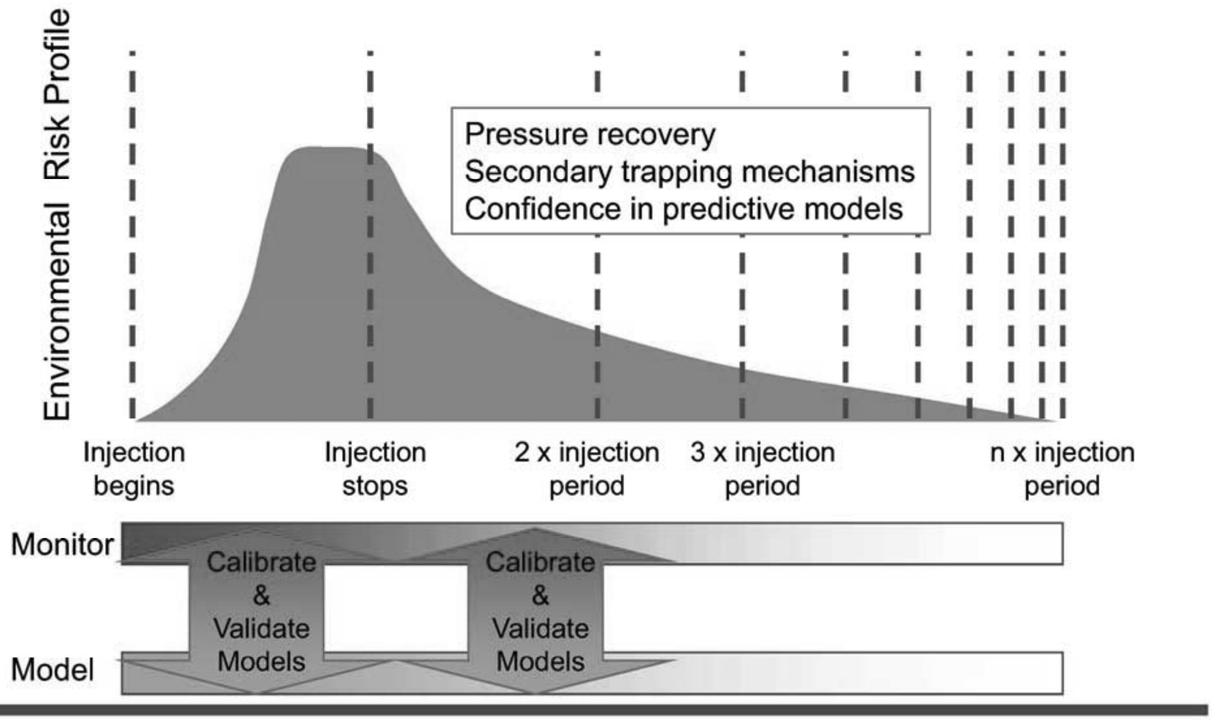
The blend of financial mechanisms underpinning the financial risk management framework for CCS should

---

[32] Intergovernmental Panel on Climate Change, *Special Report on Carbon Dioxide Capture and Storage*, prepared by Working Group III of the Intergovernmental Panel on Climate Change (Metz, B.,O. Davidson, H. C. de Coninck, M. Loos, and L. A. Meyer (eds.) Cambridge University Press, 2005).

[33] Sally Benson, *Carbon Dioxide Capture and Storage: Research Pathways, Progress and Potential*, GCEP Annual Symposium, October 2007.

Figure 2. Risk Profile Curve for CCS Sites[32]



send clear price signals as the risk selection becomes more adverse to assure that if alternate technological options for carbon dioxide emission mitigation present over time, CCS continues to be evaluated in the proper economic context. No financial risk management framework should inappropriately subsidize or otherwise provide economic advantage for CCS over future, as yet undeveloped or improved, technologies designed to make coal a cleaner source of power.

In sum, as shown in Figure 3, risks at CCS sites are believed to accumulate during the operational phase, and decline as sites move from closure to post-closure to eventual long-term care. Prevailing scientific opinion expects the tail of the risk profile will diminish, becoming increasingly skinny with time. The good news is that the likelihood that the risk of some events occurring that result in an unexpected release of carbon dioxide more than 10 years after termination of injection will become increasingly remote due to geochemistry conditions. Risks of other events, such as seismic or tectonic events, should remain constant over time.

A rational financial risk management structure will anticipate the potential for the occurrence of an unexpected catastrophic event. Just because the tail is skinny does not mean that the risk is eliminated. The ''skinny tail'' simply means that the likelihood of the catastrophic risk has been minimized, and therefore the amount of capital that must be allocated for the occurrence of such an event, if many risks are pooled together, is reduced. Without pooling, managing the availability of funds for that unlikely, low frequency event is not provided for, and the default result is an intergenerational risk and loss transfer.

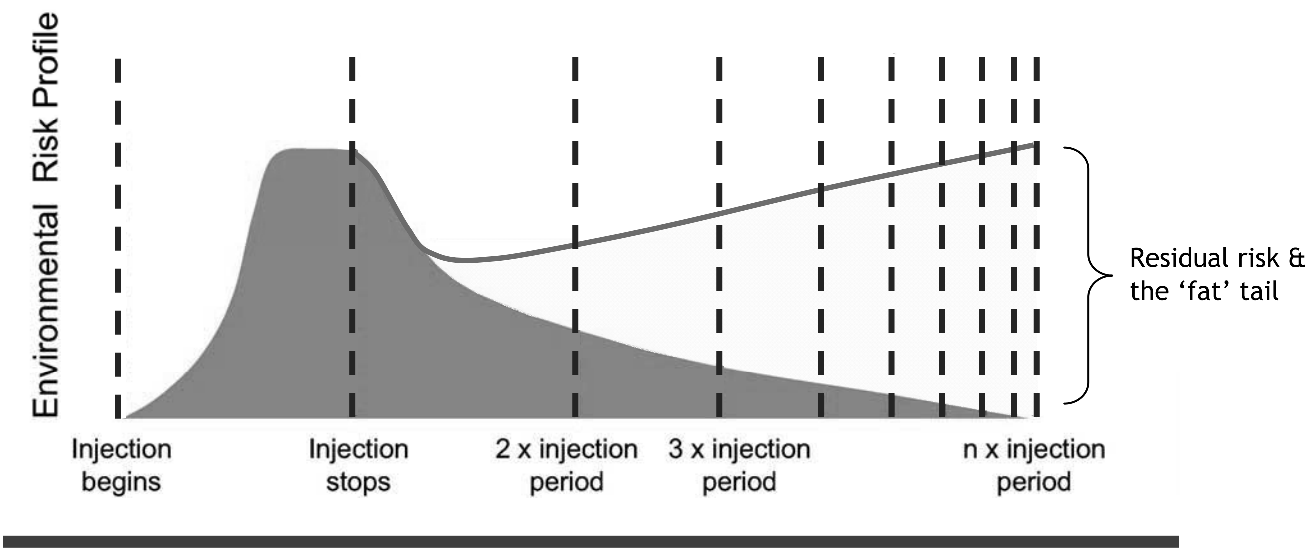
By design, a rational risk management solution, including the attendant financial management mechanisms, must be structured to avoid the ''fat tail,'' the nonzero probability that the risk profile does not diminish with time or, under a worst case scenario, increases with time. Designing a permitting and regulatory system that inadvertently, albeit through a well-intentioned attempt to accelerate deployment of carbon emission abatement technology, creates a fat residual risk tail when implemented would be an unmitigated economic disaster. An effective structure will address who should be responsible for the unexpected ''fat tail'' prior to project inception and design that portion of the financial risk management tool accordingly, e.g., to disincentivize the approval of poor sites that leave ''fat tails'' and a greater likelihood of large or catastrophic loss.

Finally, it is important to recognize that the potential for immediate and measurable harm from CCS does not necessarily correlate with the magnitude of releases. Relatively large releases could cause no immediate, measurable damages to private property or persons, leaving the damage calculation to focus solely on release of stored carbon dioxide back to the atmosphere—e.g., damages to the public good.[34] Conversely, comparatively small releases in sensitive loca-

[34] The ability to value the damage to this public good will be completely dependent upon the subject legal framework affecting the value of such a release, whether that is a cap-and-trade based valuation system or something driven by a common law tort system which develops a theory for valuation of same, or both. The less certain the legal scheme defining this liability, the more difficult this valuation will be.

   ISSN 0000-0000

Figure 3. A Different Risk Profile for CCS Sites



tions may cause significant harm, and result in material financial consequences and/or long-term care expenses to remediate natural resources. Such locations may include those near the basements of buildings, close to surfacewater, groundwater or other valuable mineral or biological resources, including potentially endangered species.

D. Site-Specific Risk Drivers

The timing, magnitude, and array of harm or injury that may result from CCS processes, as well as the characterization of long-term risks will differ by site, depending on the specific geologic characteristics of the site, the nature and volume of the carbon dioxide stream injected therein, and the resultant geochemical reactions that occur as the supercritical gas seeks chemical equilibrium with its new environment. For example, carbon dioxide streams resulting from technologies that separate the carbon dioxide pre-combustion will differ from those resulting from post-combustion technologies.

Further, site-specific geologic attributes including cap rock characteristics, mineral makeup, natural and artificial faults, fractures, abandoned wells tectonic activity, etc., will affect whether, when, and the degree to which certain risks manifest. Individually and collectively, these attributes contribute to the risk exposure profile of an individual site. Some of these characteristics may change over time, and the risks associated with each component risk may increase, decrease, or remain static over time. As such, each CCS site will necessitate a technical and site-specific risk analysis that appropriately considers site vulnerability with performance-based endpoints for each assessment, rather than prescriptive 'one-size-fits-all' evaluation criteria.

Human activity and natural events can introduce additional risks at any point during the CCS project lifecycle. Therefore, risk analysis must include operational risk mitigation actions, including operations and maintenance activities, institutional controls, and the like, as part of the overall risk analysis. Appreciably, design and operational factors that can be directly managed by the site developer (e.g., well siting, construction, and monitoring) will mitigate the potential for risk and minimize the occurrence for harm or injury, and attendant financial consequences. Such actions and related design criteria necessarily will impact the magnitude of required financial risk management mechanisms.

IV. A Rational Approach to Risk Management

Nearly all industries operate facilities with finite physical lives. At the center of the public debate regarding CCS is the risk that developers, owners, and operators of CCS projects will be unable to pay for the costs of closure, post-closure, corrective action, and/or long-term care, and that such costs will be borne by the public in the event of bankruptcy, corporate dissolution, or site abandonment. By virtue of requiring CCS operators to bear the cost of safely operating and closing their facilities, these companies will have a financial incentive to site, design, and operate facilities in a manner that will reduce the likelihood of environmental risks from site releases, thereby minimizing harm and attendant damages to public and private goods.

An integrated, effective financial responsibility program will provide a menu of financial instruments to CCS operators that ensure funds are adequate if and when needed, and readily accessible to pay for site operational, closure, post-closure, and corrective activities, both now and in the future. An integrated solution will blend the strengths of both private and public risk management approaches.

A. Financial Responsibility. The Influence of Markets

Given the risk characteristics and attendant risk profile associated with CCS, which party is best suited to bear which risks, and at what point in time?

The answer to this question requires a short discussion of financial markets and the pricing of risk. In general, the risks which present themselves across the CCS project lifecycle are not dissimilar to those created by the collection, transportation, and injection of fossil fuels and other chemicals. Further, possible risk mitigation or management strategies are not dissimilar to those available for such fossil fuels and other chemical operations. To date, from a financial risk management perspective, society has determined that risks of this nature can be managed satisfactorily by relying on market forces to demand adequate third-party instruments through insurance, bonds, etc. or adequate capitalization. As an implicit requirement, firms seeking investment capital to finance a viable business venture must demonstrate the ability to assume and manage proper first- and third-party risks, and thereby meet the investors' desire to preserve their investment value. Where such operations are publicly financed and attendant risk exposure subsidized, no such assertion can be made.

Essentially, public financing distorts or eliminates the impact of market forces in determining what is or is not a rational, risk-neutral business venture. As such, public financing requirements must include additional risk management requirements, such as mandatory purchase of third-party instruments or self insurance, to have the same risk profile result that would emerge with privately financed projects. The consequence of not requiring this additional financial risk management structure on publicly financed projects is intergenerational transfer of risk. Although, in fairness, intergenerational benefits also may transfer, the key question should focus on whether the costs and benefits are in parity.

Certain parts of the financial markets are expert at absorbing different components of risk. Depending on the time horizon over which the risks, and attendant financial consequences, are likely to manifest, capital markets will impute varying risk premia—the expected rate of return for a given investment above the return on a risk-free investment. Further, the markets will undertake a variety of risk control techniques to reduce the amount of inherent risk in their financing decision. Through a combination of risk avoidance, risk transfer, loss prevention, and loss reduction, market participants will hedge the chance that their invested capital will drop in value. Depending on their role in the financial markets, participants will offer short-, medium-, or long-term capital. In general, the shorter the term of the capital investment, the greater the market segment's tolerance for risk.

Because coal-fired power plants are long-lived assets, financing CCS ventures requires investors with a long-term capital horizon. Typically, investors of this sort have a very low risk tolerance for the unexpected, unquantifiable, or for that which may be quantified but without great precision. As such, this segment of the financial markets tend to seek risk-sharing opportunities with other market segments demonstrating a higher risk tolerance. In so doing, the institutional investor is best able to diversify its investment portfolio and hedge its overall risk exposure.

Under traditional debt financing, lenders and bond issuers typically require the range of property, casualty and environmental risk to be bounded, quantified, and accounted for in the business model—either directly as an expense, or indirectly through the purchase of a third-party financial mechanism, e.g., insurance, that will cover losses in the event the risk should manifest.

B. Potential Approach. A Recommended Framework

Numerous public- and private-sector frameworks exist to manage risk and mitigate liability. However, with few exceptions, the existing frameworks pro-actively manage liability only for operational phases of risk. Few financial provisions are made in these frameworks for post-operational latent defect discovery or disposal liability. As such, simply extending the current business and legislative models to CCS without paying due diligence to the unique risks that present themselves with new technologies will result in gaps in coverage. These gaps may include, but are not necessarily limited to, liability for risks that manifest after the active operations of the facilities and the associated cash flows have terminated.

If not managed effectively, such gaps will place the public, and potentially interested private actors, at financial risk and may result in an intergenerational transfer of risk. As a result, in response to the eventual implementation of a carbon regime, the private sector will need to revisit aspects of their risk management portfolios. In all likelihood, state and federal authorities will need to similarly revisit aspects of their legislative and regulatory frameworks to best manage the economic, environmental, and social impacts that will result from commercial-scale CCS deployment.

Specifically, uncertainties regarding the short, medium, and long-term nature of CCS projects, including legal and financial ramifications have been cited as posing impediments to full-scale deployment of CCS technology.[35] CCS assumes that carbon dioxide will be stored for a period of time that transcends the life expectancy of humans living today and the typical business life cycle of many corporate endeavors. As a result, many CCS operators likely will seek to transfer legal and financial liability for their long-term site responsibilities. These responsibilities range from financial consequences resulting from carbon dioxide migration from the point of capture through sequestration to future expenditures associated with the cost of long-term care and monitoring, measuring, and verification. Yet, in the same breath, CCS operators also cite reports that affirm the long-term safety and security of sequestered carbon dioxide, calling into question the need for indemnity.

To date, the public dialogue surrounding CCS has focused on who will bear financial responsibility for long-term care and site stewardship, including potential damage claims and long-term remediation expenses. Interestingly, the dialogue has failed to place similar emphasis on the need to manage financial risks during the design and operational parts of the facility life cycle, despite the fact that the risk management systems put in place during these initial phases of the life of the facility assuredly will bound and determine the residual risk profile of the long term stewardship obligations. To mitigate long-term tail risk, it is essential that the operational risk management system demand, and financially support proper siting, immediate corrective action, and early shut down of highly risky facilities; and in so doing, avoid continued operation of any facility that poses

---

[35] Elizabeth J., Wilson, Mark A. De Figueiredo, Chiara Trabucchi, Kate Larson, *Liability and Financial Responsibility Frameworks for Carbon Capture and Sequestration*, World Resource Institute: WRI Issue Brief Carbon Capture and Sequestration, No. 3 (2007).

  CCR ISSN 0000-0000

Figure 4. Financial Risk Management Options

Financial Responsibility Mechanisms	CCS Project Phases		
	Operation (Carbon Dioxide Injection)	Closure & Post-Closure	Long-Term Stewardship (after prescribed post-closure)
1. Third-Party Instruments (Trust Funds, LOCs, Insurance, Bonds)	✓	✓	✓
2. Self-Insurance (Financial Test, Corporate Guarantee)	✓	✓	X
3. Private/Public Frameworks ▶ Insurance Models ▶ Trust/Compensation Funds	X	X	✓

excessive risk because of institutional inertia or political tension. To mitigate this risk, the creation of a legislatively authorized, funded, and empowered private/public board is recommended, chartered as a federal government corporation and charged with a variety of responsibilities. The board's focus should be overseeing the siting of CCS projects and serving as an arbitrator between existing federal agencies authorized to address issues of technical safety, economic, climate, and ecological preservation.

Essentially, an effective financial risk management framework will assure funds are available to pay for the necessary activity to:

- Minimize potential releases of the carbon dioxide stream from the geologic zone over the short, medium and long-term from the time of proper design and siting through post operations and confirmed stabilization; and
- Ensure sufficient monitoring, measuring, and verification values so as to detect problems before they adversely impact public welfare or the environment.

An important challenge, however, rests with the concept of corrective action for conditions discovered during the operation, or as a result of latent defects which manifest only after the operation of the facility has terminated. The dialogue has failed to address the extent to which damages will be redressed, by whom, and up to what limit after the operations of the facility are complete – which could be 50 or more years after initial carbon dioxide injection. This challenge is further exacerbated by the fact that, in the CCS context, liability issues span both federal and state jurisdiction in the United States—the nature of the harm and attendant damages will interact to determine liability, compensability, and which (if any) party can transfer, release, or assume liability. Moreover, the nature of CCS results in numerous potential claimants and causes of action, including nuisance, trespass, negligence and existing statutory liabilities. Finally, risk and economic exposures resulting from contractual and potential carbon market caps—the possible required purchase of offsets—add yet another layer of complexity to an already difficult situation.

All of the above listed items create issues of fit, interplay and scalability when attempting to devise an appropriate financial risk management solution for CCS.[36] In evaluating financial risk management mechanisms for CCS, one must consider the fit of the institution (or risk management tool) for achieving the sequestration without collateral damage, the effect of interplay with existing laws, and the awesome challenges created by the volume and scale of the carbon dioxide deposits, as well as the potential for financial consequences to span geographic jurisdictions and legal regimes.

1. It's About the Lifecycle. Conceptualizing the Components of a Rational Financial Risk Management Framework

The financial risk management framework should align with the CCS project lifecycle, whereby the CCS facility remains financially responsible for consequences arising during the operational phase.

As illustrated in Figure 4, financial and third-party instruments exist to appropriately manage and hedge risks that manifest during the operational phases, such as self-insurance predicated on the financial strength of the CCS facility and third-party instruments. These financial mechanisms are well suited to manage risks that present themselves when the CCS facility is active and best able to leverage funds to finance the mechanisms. The multiple single goal components of these traditional financial mechanisms address the near-term need for financial assurance, and offer CCS operators flexibility in managing their risk portfolio.[37] In addition, the costs associated with closure, post-closure, and foreseeable corrective action tend to be reasonably estimable on an annual basis, and therefore quantifiable during the operational phase.

However, careful consideration and appropriate analysis is needed when estimating the expected value of these financial consequences.[38] The magnitude and

[36] It is important to note that these same challenges present in Europe and Asia, but with different institutional, cultural, economic, and sovereign constructs and paradigms.

[37] While financial instruments generally are designed with a single goal, the practical application may yield widespread unintended behavioral consequences. Some of these consequential impacts may inure to the benefit of the public good of interest. For additional insights into the issues inherent to traditional financial assurance instruments for the management of hazardous waste refer to Lindene E. Patton and James L. Joyce, *Hazardous Waste Financial Assurance: A Comparison of Third-Party Risk Management Mechanisms—Suggestions for Reform* (114 DEN B-1, 6/13/08).

[38] Expected value should incorporate the probability of adverse events occurring. Expected financial consequences in a given year is calculated as the product of potential financial consequences multiplied by the annual probability of occur-

likelihood of financial consequences—in terms of the costs of closure, post-closure, and foreseeable corrective action, as well as potential compensatory damages resulting from carbon dioxide leakage during operations—will have significant implications on the design and application of a financial risk management framework for CCS facilities. Moreover, the appropriate pricing of the financial mechanisms is dependent on accurate cost estimation. No financial assurance instrument, no matter how robust, can overcome the fundamental problem posed by inadequate or improper cost estimation.[39] For this reason, consideration should be given now to the range of expected values, and not as an afterthought when the financial risk management framework is applied.

Issues arise when attempting to map this traditional financial assurance structure to the long-term stewardship phase of the CCS lifecycle. Given the long time horizon, and the likelihood that the CCS operator will not be a viable corporate entity 50 to 100 years after carbon dioxide injection has ended, the same financial mechanisms that underpin the operational phases are ill-suited to address long-term financial consequences. For this reason, a three-part solution to managing the long-term consequences of CCS sites is recommended.

Part 1: Carbon Capture and Storage Safety Board

It is in this context that the authors recommend the development of a private/public board (CCS Safety Board or CCSSB). The CCSSB should be authorized legislatively as a 'federal government corporation,' chartered and vested with the authority to oversee the siting, design, and management of CCS facilities and be comprised of no less than nine members,[40] including technical experts, government legal experts, private legal experts, financial experts (institutional investors, insurance), and state/federal regulators, with set term limits of no less than six years.

Specifically, the board should be charged with performing a minimum of four critical functions: (1) oversee siting of CCS facilities, including the right and responsibility to suspend or close poorly performing or excessively risky sites,[41] including risks related to financial assurance; (2) mediate operational/permitting disputes; (3) certify completion of key project milestones, e.g. closure/post-closure; and (4) accept eventual title to CCS sites, including attendant financial responsibility for long-term care. By virtue of this authority, the CCSSB is incentivized to foster siting and operating decisions that consider risk and minimize the potential for residual injury at the time of site transfer, because in the absence of doing so, financial responsibility for corrective action and compensatory damages rests with the board.

Part 2: A National Trust for Prospective Risk

A national trust fund (CCS National Trust) also should be established to pay long-term care expenses and delimited compensatory damages resulting after the CCS facility is released from its post-closure obligations. The CCSSB should be vested with management authority over the trust.

Financing of the trust should be based on a combination of: (a) initial authorizing funds, (b) a flat per unit fee on carbon sequestered during the operating life of the CCS facility[42], and/or (c) a transaction fee for carbon trades similar to the Securities and Exchange Commission surcharge currently in effect for stock transactions. Fee collection is suspended when the trust reaches a maximum dollar threshold, and resumes when accumulation falls below a prescribed minimum threshold. The balance of funds should be mandated between a maximum and minimum financial threshold that appropriately integrates the expected value of financial consequences that may arise from CCS sites.

Part 3: Additional Enabling Legislation

In addition to authorizing legislation for the CCSSB and the CCS National Trust, additional enabling legislation should establish:

- Liability provisions, whereby the CCS facility remains liable for all damages and remediation activities during the operational phase, and cost recoveries are deposited into the trust;
- Damage thresholds, whereby responsible parties are responsible for consequences up to a dollar threshold per occurrence plus remediation costs;
- Evidence of financial responsibility for the operating life of the facility, in an amount sufficient to compensate for maximum probable loss expected from the facility operations, including low frequency, catastrophic risks, using either corporate financial test, corporate guarantee, and/or third-party instruments;
- Evidence of financial responsibility, whereby each CCS facility is required to maintain evidence of financial assurance during the operational phase equal to the expected value of closure, post-closure, foreseeable corrective action, and the net present value of long-term site monitoring;
- Oversight authority for the enforcement of operational/permitting disputes, whereby the board is vested with the responsibility of instituting 'go' or 'no-go' decisions with respect to CCS

rence. Results for each year are summed over the relevant time period and discounted to generate an expected estimate of financial consequences.

[39] Lindene E. Patton and James L. Joyce, *Hazardous Waste Financial Assurance: A Comparison of Third-Party Risk Management Mechanisms—Suggestions for Reform* (114 DEN B-1, 6/13/08).

[40] For governance reasons, the number of members selected must be uneven.

[41] ''Go'' or ''No-Go'' decisions may be warranted, even if the consequence of suspending or requiring closure of the project is the temporary release of carbon dioxide back to the atmosphere—if continued sequestration endangers groundwater or another natural resources. An independent, third-party entity, such as the CCSSB, is best suited to avoid the political drivers of such decisions; carefully assess available scientific, technical, and economic data; and weigh the adverse private/public consequences of continued CCS sequestration against the consequences of reversing gains in greenhouse gas emissions reductions.

[42] Basic financial and business theory suggests that any fee-based structure essentially results in a pass through of the fee to consumers in the form of increased prices. To the degree such price pass throughs are warranted in the context of CCS deployment, enabling legislation likely will be necessary to allow for adjustments in rate allocations to account for the increased expense of delivering power. However, such pass throughs must be constructed carefully to avoid sending a zero dollar price signal to the operators about affected risks.

   ISSN 0000-0000

projects, even if such decisions result after the CCS project is underway;

- Financing provisions requiring that the CCS facility, at the time of site transfer, deposit into the trust a one-time, lump sum payment equal to the net present value of the expected cost of long-term site monitoring commensurate with actual site-specific monitoring data collected during the operational phase;

- State access to funds up to a dollar threshold per occurrence for monitoring, mitigation and/or immediate remediation costs incurred during response efforts involving a CCS site only where the CCS facility has been released from its closure/post closure obligations; and

- Provisions that overcome issues associated with the Miscellaneous Receipts Act, whereby the Board receives initial authorizing funds and is vested with the authority to collect funds and generate revenues, as well as invest the balance of funds in a diversified investment portfolio, with the expectation of becoming financially self-sustaining by a set date.

- A means by which the CCSSB is able to use a percentage of collected funds to purchase bonds or insurance for potential cost overruns associated with long-term site care and/or address fortuitous residual risks remaining at the time of CCS site transfer to the extent such is possible and economically feasible at the time of the transfer.

Further, unless contributions to the trust map to the expected value of expenses/damages likely to be incurred over the long-term, there is little financial assurance that the balance of funds remaining at the time of site transfer will be appropriate to the long-term need for funds. That is, there is no *a priori* reason to believe that the amount of funds remaining in the trust at the time of site transfer will be equal to the actual amount of funds needed for long-term care. Given the lack of real monitoring data, the trust likely will be under- or over-funded for initial CCS projects, potentially resulting in an inefficient use of economic resources. For this reason, the trust balance should be re-evaluated when actual site-specific monitoring data become available, but no less frequently than every three years.

The Importance of Pooling

Finally, consideration should be given to the liability and financial responsibility implications of industry pooling of sites based on geographic region, or site characteristics. Consideration also should be given in determining the degree to which financial contributions to the trust release the CCS facility from legal liability. Specifically, questions remain with respect to whether release/transfer of liability should be limited to (a) specific categories of harm, damages, and/or expenses, or (b) when a maximum dollar threshold has been achieved.

A Prospective Trust: Familiar and Tailored to CCS

These recommendations are not dissimilar to current provisions governing the Oil Spill Liability Trust Fund (OSLTF) and the National Pollution Funds Center (NPFC) mandated by the Oil Pollution Act of 1990,[43] or the Presidio Trust, established by Congress in 1996 as an independent management entity to preserve the Presidio's natural resources.[44] Further, the aforementioned recommendations could be extended and applied in a different country context, provided that local issues of fit, interplay, and scalability are considered adequately.

2. Existing Risk Management Frameworks and Lessons Learned

Numerous liability and financial risk management models have been instituted at the federal level to address a broad range of risks involving myriad private and public goods and in service of a variety of private and public actors—from cultural assets, art and artifacts, biohazards, environmental hazards, qualified anti-terrorism technology, nuclear power, floods, pesticide use, avian flu, oil spills, and livestock protection to name a few.[45] Existing federal models range from the obscure to the common. Most reflect a reaction to an unanticipated risk occurrence with material financial consequences, such the Commercial Space Launch Act following the Challenger disaster, or the Support Anti-terrorism by Fostering Effective Technologies Act of 2002 following the events of Sept. 11, 2001.

Despite the narrowly focused objectives of many of these frameworks, a review of the strengths, weaknesses, and lessons learned prove useful in evaluating approaches to address how best to manage the residual long-term risk and attendant financial consequences of CCS sites.

In general, these programs involve a blend of instruments designed to pool potential risk across private, public, or a mix of private/public actors. By design, and depending on the situation, these programs release affected parties from financial responsibility for financial consequences after a certain point in time, after a certain financial threshold has been reached, or for categories of harm or injury. In general, the programs involve a hybrid of public- and private-sector financing instruments.

Each statutory model is unique in the range of risks covered, the range of entities receiving indemnity, the degree of financial indemnity provided, and whether or not the indemnity transfers with asset or site transfers.

Price-Anderson Nuclear Industries Indemnity Act

Enacted in 1957 as an amendment to the Atomic Energy Act of 1954, the Price-Anderson Nuclear Industries Indemnity Act (Price-Anderson) is one of the more familiar federal indemnity models. Price-Anderson was intended to encourage the development of nuclear power, by partially indemnifying the nuclear industry in the event of a catastrophic nuclear event. The act also was intended to protect the public in the event of a nuclear incident by ensuring prompt and equitable compensation for victims of a nuclear incident.

Essentially, Price-Anderson establishes a multi-tiered, risk-pooling program to indemnify the nuclear

[43] Oil Pollution Act, Pub. L. No. 101-380, Aug. 18, 1990, codified at 33 U.S.C. 2701 et seq.

[44] 16 U.S.C. § 460bb appendix (enacted as Title I of H.R. 4236, Pub. L. No. 104-333, 110 Stat. 4097, on Nov. 12, 1996)

[45] Dollar estimates included in the following section are as represented by the source document, and have not been inflated to current year dollars. Further, subsequent legislative action may have amended referenced values.

industry against liability arising out of, or in connection with, licensed activities.[46] The act provides no-fault insurance to benefit the public in the event of a nuclear power plant accident that the NRC deems to be an ''extraordinary nuclear occurrence.'' However, this structure involved operator, third party, and governmental capital.

The act establishes three financing or coverage tiers for licensed nuclear facilities with a rated capacity of 100,000 electrical kilowatts or more:[47]

- (Tier 1) **Individual Financing**. Primary financial coverage equal to the maximum amount of liability insurance available from private sources. Demonstrations can be in the form private insurance, self-insurance, or other proof of individual financial responsibility.

- (Tier 2) **Collective (Industry) Financing – the Nuclear Pools (and Mutuals)**. Private liability insurance available under an industry retrospective rating plan. This insurance is to be used when public liability claims exceed the level of primary financial protection from private sources. Premiums and claims are capped by statute.

- (Tier 3) **Federal Financing**. Licensees are indemnified from public liability arising from nuclear incidents after the individual and collective caps are reached.

Under this three-tiered coverage system, licensed facilities are required to finance both individual liability insurance and industry-pooled liability insurance. In the event of a nuclear occurrence, the act designates that the licensee first draw down its individual insurance to pay for private claims. If the value of the claims exceeds the amount available from their individual insurance, the licensee may access funds in the industry-pooled insurance to pay the balance of claims. In the event that the private claims against a licensee exceed the amounts available in both individual and pooled insurance, the NRC is charged with assessing the cause and extent of residual (unpaid) damages—to determine whether public liability exceeds the liability limits available in the primary and secondary tiers. If so, then Congress is vested with the authority to ''take whatever action'' it determines necessary to compensate the public for all resulting public liability claims.[48]

Currently, under Section 2210(b)(1), the act caps the standard deferred premium charged at a maximum dollar amount of $95.8 million, and not more than a set threshold of $15 million in any given year.[49] If claims for an incident exceed the available premiums from both the private and pooled insurance, the NRC has the authority under Price-Anderson to indemnify the licensee from remaining liability in connection with the occurrence.

Currently, all 104 operating nuclear facilities in the United States must be licensed by the NRC.[50] To obtain and retain licensing, the facility must submit proof of coverage for primary and secondary insurance. Price-Anderson also covers all Department of Energy (DOE) facilities, including their licensees and contractors.[51] In addition, DOE is required to provide indemnification up to the statutory limit in any contracts that carry the risk of a nuclear incident.[52]

Intended to be temporary in nature, to foster development of nuclear power as a new and emerging technology, Price-Anderson has been repeatedly reauthorized. Most recently, as part of the Energy Policy Act of 2005, Congress extended Price-Anderson for an additional 20 years (until 2025), and under Section 2210(d) increased the required coverage under the second-level insurance tier (from $63 million to $95.8 million).[53]

To date, Price-Anderson is largely untested. All claims made have been covered through the individual financing (Tier 1) level. Specifically, from the enactment of Price-Anderson in 1957 through December 1997, approximately $131 million has been paid in settlement of private claims and litigation costs.[54] Approximately $70 million of the $131 million was paid for claims resulting from the 1979 accident at Three Mile Island.[55] In addition, DOE has paid approximately $98 million in claims covered under Price-Anderson, arising from qualified activities at their facilities.

Notably, Price-Anderson attempted to create an express financial risk management system for the long-term stewardship of nuclear waste through a combination of fee collection and a transfer of responsibility for siting, transport, and long-term waste care to DOE. However, after decades of litigation, the United States remains without a meaningful storage mechanism for spent nuclear fuel.

The lesson to be learned from Price-Anderson is that private/public tiered risk management systems can work, but only when planned and properly financed in advance. However, to the extent that a financial risk management system transfers liability from the facility operator to other public or private actors in a manner that defers the specifics of long-term siting and cost management to some future, undefined date, implementation of the framework is fraught with problems and becomes largely ineffective and economically inefficient.

National Flood Insurance Act

The National Flood Insurance Act (NFIA) was enacted in 1968 as an insurance alternative to disaster assistance. The act serves two main purposes: (1) to compensate floodplain occupants for flood damage; and (2) to shift a measure of the financial burden from flood

[46] The Atomic Energy Commission (AEC) originally managed the implementation of the Act. The Energy Reorganization Act of 1974 abolished the commission and created the Nuclear Regulatory Commission (NRC); thereby transferring the authority of the AEC to the NRC. Energy Reorganization Act of 1974, Pub. L. No. 93-438, Sections 104, 201 and 202.

[47] 42 U.S.C. 2210(b)(1).

[48] 42 U.S.C. 2201(e)(2).

[49] 42 U.S.C. 2210(b)(1).

[50] 42 U.S.C. 2131. Number of licensed operating nuclear facilities obtained from the NRC.

[51] U.S. Department of Energy, ''Report to Congress on the Price-Anderson Act,'' March 18, 1999. *See also* 42 U.S.C. 2210(d).

[52] *Id.*

[53] Energy Policy Act of 2005, 42 U.S.C. 15801 et seq., Title VI, Subtitle A: Price Anderson Amendments Act of 2005, 42 U.S.C. 2011 et seq.

[54] U.S. Nuclear Regulatory Commission, ''NRC's 1998 Report to Congress on the Price-Anderson Act,'' July 2, 1998.

[55] *Id.*

   ISSN 0000-0000

losses away from the federal government. The objective of NFIA is to:

- More effectively indemnify[56] individuals for flood losses through insurance,
- Reduce future flood damages through state and community floodplain management regulations, and
- Reduce federal expenditures for disaster assistance and flood control.[57]

The Federal Emergency Management Agency (FEMA) administers the National Flood Insurance Program (NFIP), which was created to manage the implementation of NFIA. Under NFIP, flood insurance is provided to property owners in participating communities in exchange for state and community floodplain management regulations that reduce potential future flood damages.

Under NFIP, insurers establish a pool to provide flood insurance coverage to eligible property owners. The pool is designed so that insurers are able to assume a proportion of financial responsibility for payment of claims. In specific cases, the federal government subsidizes insurance premiums. The NFIP is designed to pay for flood insurance claims from funds paid through premiums rather than from tax revenues. Under NFIP, the insurance sector receives an expense allowance. Premium income in excess of the allowance is remitted to the federal government.

Funding for NFIP is through the National Flood Insurance Fund, established by the U.S. Treasury in 1968, when the statute was enacted. Premiums collected are deposited into the fund and losses, as well as administrative costs, are paid from the fund. The program has the authority to borrow funds from the U.S. Treasury to cover fund shortfalls. However, borrowed funds must be repaid with interest. Liability for damages is capped by the statute.[58]

Specifically, NFIA stipulates insurance companies must participate in a pool to provide flood insurance coverage and enables payment of claims for losses under the NFIP.[59] Further, under specific sections of the act, NFIP is limited in the amount of funds it can issue for any given event. Finally, coverage based on chargeable premiums is capped for residential properties and small businesses.

The National Flood Insurance Reform Act of 1994 reauthorized NFIA and instituted several notable changes, including increases to the amount of flood insurance that can be purchased.[60] Notably, the 1994 amendment established the Flood Mitigation Assistance grant program to assist states and communities in developing mitigation plans and implement measures to reduce future flood damages to structures.

In 2004, the Flood Insurance Reform Act was promulgated to reduce losses to properties for which repetitive flood insurance claim payments have been made.[61] As a result of the substantial increase in claims following Hurricanes Katrina and Rita in 2005, temporary permission to increase FEMA's borrowing authority from $1.5 billion to $20.8 billion was granted by Congress in March 2006.[62]

Since its inception, NFIP has made several payments for flood damage claims, primarily resulting from hurricanes and tropical storms. Through August 2005, NFIP has paid approximately $14.6 billion in losses that otherwise would have been financed through disaster assistance or absorbed by individual homeowners.[63] In response to claims made resulting from Hurricanes Katrina and Rita, NFIP has paid approximately $16.2 billion, equating to more than 170,000 claims.[64] FEMA estimates that when all claims are settled, total paid claims will total more than $20 billion, which is nearly 15 times greater than the $2 billion in premium payments collected by the program during 2004—the year prior to the hurricane event.[65]

Lessons learned from NFIP, as evidenced by the disparity between premiums collected and losses paid, suggest that the proffered system fails to effectively control for the manifestation of a "fat tail." This unintended consequence generally arises because the system does not effectively control siting decisions with sufficient detail— particularly when such decisions involve the politically unpalatable displacement of private citizens located in known flood zones. Zoning decisions and building permits are issued locally by institutions who do not pay the costs for flood damages. In fact the same problem is now manifesting in California with respect to fire fighting costs.[66] In the context of CCS, some parties are proposing the use of eminent domain to acquire the necessary subsurface rights to sequester carbon in technically safe and appropriate locations, which would pose similar challenges as those experienced with the administration of NFIP. Further, a rational, effective financial risk management framework for CCS will ensure that the parties who are charged with making siting decisions are the same parties responsible for managing and/or assuming eventual long-term liabilities. In so doing, the framework is best able to avoid the manifestation of a residual fat risk tail, because the decisions required to avoid the "fat tail" and better assure a "skinny tail" are politically unpalatable.

[56] Indemnity refers to the obligation to make good any loss or damage that another party has incurred, or may incur at some point in the future. Indemnity also refers to the right that a party suffering a loss or damage is entitled to claim.

[57] 42 U.S.C. 4001(a) and (c).

[58] 42 U.S.C. 4016 and 4017.

[59] National Flood Insurance Act of 1968, 42 U.S.C. 4051 (a).

[60] National Flood Insurance Reform Act of 1994, Pub. L. No. 103-325, Section 573.

[61] Bunning-Bereuter-Blumenauer Flood Insurance Reform Act of 2004, Pub. L. No. 108-264.

[62] Government Accountability Office, "National Flood Insurance Program: New Processes Aided Hurricane Katrina Claims Handling, But FEMA's Oversight Should Be Improved," GAO-07-169, December 2006.

[63] *Id.*

[64] Government Accountability Office, "National Flood Insurance Program: Greater Transparency and Oversight of Wind and Flood Damage Determinations are Needed," GAO-08-28, December 2007.

[65] Government Accountability Office, "National Flood Insurance Program: New Processes Aided Hurricane Katrina Claims Handling, But FEMA's Oversight Should Be Improved," GAO-07-169, December 2006.

[66] "Development is approved at the local level, and local governments then bear little fiscal consequence if the state is responsible for the firefighting . . .Says Ms. Kehoe (D-Senator Calif.): 'Local land use approval for . . .development. . .should be tied to the future cost of firefighting. . .' "California Ponders Who Should Pay Firefighting Bill," Wall Street Journal, July 9, 2008, p. A3.

Trans-Alaska Pipeline Authorization Act of 1973

Enacted in 1973, the Trans-Alaska Pipeline Authorization Act (TAPAA) was administered by the Department of Interior's Bureau of Land Management.[67] In 1990, TAPAA was largely superseded by the Oil Pollution Act of 1990. Nonetheless, aspects of TAPAA warrant discussion in the context of designing a long-term financial risk management model for CCS.

By design, the intent of TAPAA was to facilitate delivery of North Slope oil to domestic markets through the construction of the trans-Alaska oil pipeline. Under certain circumstances, TAPAA provided indemnity to the holder of the pipeline right-of-way for damages in connection with, or resulting from, activities along the pipeline right-of-way.

The act also established the Trans-Alaska Pipeline Liability Fund (TAPLF), a nonprofit corporation administered by the holders of the right-of-way. Under TAPLF Section 204(c), the vessel owner/operator was held strictly liable for an initial dollar threshold of claims and then remained liable for claims in excess of this threshold when the damages involved were caused by owner/operator negligence, up to a maximum dollar threshold, as capped by Congress.[68]

The TAPLF was financed through a fee of 5 cents per barrel of transported TAPS oil, paid by the owner of the oil. The permittee or right-of-way holder received the fee from the owner, and transferred it to a dedicated-TAPLF account. Fee collection was suspended when the maximum dollar threshold, on a per-owner basis, had been accumulated. Collection resumed when the accumulation fell below a prescribed minimum threshold. The provisions of TAPLF applied only to vessels engaged in transportation between the terminal facilities of the pipeline and ports under the jurisdiction of the United States.[69]

Under the act, the holder of the right-of-way was held strictly liable to all damaged parties, unless it could demonstrate the damages were caused solely by: (1) An act of war, or (2) negligence on the part of the United States, other government entity or the damaged party.[70] Liability for allowable claims was determined in proportion to ownership interest in the right-of-way. Similar to Price-Anderson, TAPAA provided for strict liability payments up to a specified limit. Unlike Price-Anderson, however, TAPAA allowed the limit to be waived when negligence was involved— injured parties could sue for damages exceeding the limit established by the act, if they were able to prove negligence on the part of the operator. Essentially, TAPAA did not limit the rights of injured parties to pursue damages from potentially liable parties.[71]

[67] Government Accountability Office, ''Trans-Alaska Pipeline: Regulators Have Not Ensured That Government Requirements Are Being Met,'' Report to the Chairman, Subcommittee on Water, Power, and Offshore Energy Resources, Committee on Interior and Insular Affairs, House of Representatives, July 1991.

[68] An Act to Amend Section 28 of the Mineral Leasing Act of 1920, and to Authorize a Trans-Alaska Oil Pipeline, and for other purposes, Pub. L. No. 93-153, Nov. 16, 1973, Section 204(c).

[69] *Id*.

[70] 43 U.S.C. 1653(a)(1).

[71] Dan R. Anderson, *Limits on Liability: The Price-Anderson Act versus Other Laws The Journal of Risk and Insurance*, Vol. 45, No. 4 (1978).

On March 24, 1989, the *Exxon Valdez* ran aground on Bligh Reef in Prince William Sound and spilled thousands of barrels of oil. In response to events surrounding the *Exxon Valdez* spill, Congress amended TAPAA through the Oil Pollution Act of 1990 (OPA). Specifically, Congress instituted a temporary amendment, 43 U.S.C. Section 1653(c), establishing additional provisions related to the liability for discharges of oil loaded at terminal facilities and the payment of claims by TAPLF.

Under the amendment, TAPLF was required to pay damage claims if the owner or operator refused to do so. The amendment authorized the fund to recover prejudgment interest, costs, reasonable attorney's fees, and at the discretion of the court, penalties for any action brought by the fund against an owner or operator to recover costs incurred by the fund.[72]

Intended to be temporary in nature, OPA instituted provisions stipulating that the amendments to TAPAA applied only to claims arising from incidents occurring before the date of enactment of OPA. They were designed specifically to address the consequences of the *Exxon Valdez* spill.

Lessons learned from the TAPLF suggest that maximum probable loss estimates should be revisited with frequency as new, technically important data become available. In so doing, society is able to avoid establishing artificial funding or liability caps that are below or above the likely loss amounts, given the characteristics and reality of the operations indemnified.

Oil Pollution Act of 1990

In response to rising public concern following the *Exxon Valdez* incident, the Oil Pollution Act (OPA) was signed into law in August 1990. Essentially, OPA encompassed and expanded the provisions of TAPAA. Specifically, OPA authorized use of the national Oil Spill Liability Trust Fund (OSLTF) established in 1986. The fund is managed by the National Pollution Funds Center (NPFC), an independent unit reporting directly to the Coast Guard Chief of Staff.[73]

In 2005, the Energy Policy Act increased the borrowing limit of the fund to $2.7 billion.[74] The balance of OSLTF is mandated between $2 billion and $2.7 billion.[75]

There are three main sources of financing for the OSTLF, including:[76]

- Barrel tax (5 cents per barrel), collected on petroleum produced in or imported to the United States. The tax expired in 1994, but was reauthorized by

[72] Oil Pollution Act, Pub. L. No. 101-380, Aug. 18, 1990, Section 8102. On June 25, 2008, the U.S. Supreme Court overturned the punitive damages award of $2.5 billion against Exxon for the 1989 oil spill in Alaska's Prince William Sound. The U.S. Supreme court ruled that, ''as a matter of maritime common law,'' the punitive damages award was excessive, and should be limited to an amount equal to compensatory damages, or $507.5 million in this case. *Exxon Shipping Co. v. Baker*, 128 S. Ct. 2605, 66 ERC 1545 (2008). *See also* (123 DEN A-1, 6/26/08).

[73] Department of Homeland Security, United States Coast Guard, *Report on Implementation of the Oil Pollution Act of 1990*, (2005).

[74] Energy Policy Act of 2005, Pub. L. No. 109-58, Aug. 8, 2005, Section 1361

[75] *Id.*

[76] Department of Homeland Security, United States Coast Guard, *Report on Implementation of the Oil Pollution Act of 1990* (2005).

   ISSN 0000-0000

Section 1361 of the Energy Policy Act of 2005. Collection of fees is suspended when a pre-set maximum dollar threshold in the fund has been accumulated. Collection resumes when the accumulation falls below a set minimum threshold.[77]

- Transfers from other existing pollution funds, including $335 million transferred from TAPLF collected between 1995 and 2000. No additional funds remain in TAPLF to be transferred to OSLTF.
- Interest on OSLTF principal from the U.S. Treasury investments.
- Cost recoveries from responsible parties.

In addition, OPA established the following provisions:

- **Liability Provisions**. The owner or operator of a vessel or a facility from which oil has been discharged is liable for damages and removal costs.[78]
- **Damage Thresholds**. Under the Section 2704(a) of the act, tank vessels larger than 3,000 gross tons are capped at $1,200 per gross ton or $10 million, whichever is greater. Responsible parties at onshore facilities and deepwater ports are liable for up to a pre-set dollar value per spill. The federal government has the authority to adjust, by regulation, the liability limit established for onshore facilities. Holders of leases or permits for offshore facilities also are liable for up to a pre-set value per spill, plus removal costs.[79]
- **Evidence of Financial Responsibility**. Offshore facilities are required to maintain evidence of financial responsibility of up to an absolute dollar value.[80] Vessels and deepwater ports must provide evidence of financial responsibility up to the maximum applicable liability amount.[81] Claims for removal costs and damages may be asserted directly against the guarantor providing evidence of financial responsibility.

Finally, OPA provided states with the authority to enforce, on the navigable waters of the state, requirements for evidence of financial responsibility. In addition, states are provided access to federal funds (up to $250,000 per incident) for immediate removal, mitigation, or prevention of a discharge. The states also can be reimbursed by the OSLTF for removal and monitoring costs incurred during oil spill response and cleanup efforts.[82]

Lessons learned from the OPA and OSLTF structure include, but are not limited to, the importance of the continuation of any funding for any and all applicable financial risk management mechanisms. This is particularly important if the structure is designed to compensate for liabilities and losses caused during the operational life of any covered facility or for any activity that must continue throughout the entire lifecycle of the facility or operation. Artificial sunset provisions that are not connected to an evaluation of risk can leave financial risk management tools unfunded or underfunded, and thus eliminate the assurance that funds will be available in the timing and amounts necessary to meet their intended purpose.

C. Conclusion

A long-lived, private/public financial risk management framework that relies solely on risk-transfer instruments, such as insurance, may be appropriate to manage certain catastrophic risks and financial consequences, particularly with respect to relatively low-probability, high-damage scenarios.

The limitations of this model lie in the fact that, by design, existing federal models—Price-Anderson and NFIA—are intended only to compensate for damages. These models do not easily address the companion need to finance long-term care activities after the owner or operator has been released from its post-closure responsibilities. In other words, these types of liability frameworks generally are designed to compensate for damages after the fact, not for the carrying costs of monitoring, measuring, or verification, or for costs of minimum activities over time to ensure site security before the fact. In addition, if not crafted carefully and priced accurately, a federally-backed indemnity program, such as the Price-Anderson and NFIP models, inappropriately may shift the burden of future liabilities to the insurance sector or other third-party institution in the near-term, and the general public in the long-term.

Further, arbitrary limits on liability that do not map to the evolution of the long-term risk profile of CCS sites—from early movers to commercial-scale deployment—may result in inadequate coverage, resulting in substantial financial exposure for the institutions backstopping claims made against the program.[83] This is particularly so if commercial-scale deployment results in the adverse selection of sites with increasingly risky profiles due to moral hazard.

As such, a revolving fund may be most appropriate to address certain ‘‘skinny tail’’ liabilities. The advantage of compensation funds, or a national trust, rests with the assurance that funds are dedicated for an intended purpose. Similar to TAPLF and OSTLF, contributions to the fund can span numerous funding sources, and thereby appropriately share the burden across private- and public-sector stakeholders. In addition, the financing of the fund can be designed such that collection of fees is suspended when a prescribed maximum dollar threshold in the fund has been accumulated, and collection of fees can resume when the accumulation falls below a minimum set threshold.

However, there are several notable considerations when considering the design of an effective trust framework. First, which entity (state or federal, public or private) will assume responsibility for managing and disbursing moneys invested in the fund? Second, to what degree will financial contributions to the fund release the owner or operator of a CCS from legal liability? Will release or transfer of liability be limited to specific categories of harm, damages and/or expenses, or at the time a maximum dollar threshold has been achieved? Third, who will determine the value of the fund, and how will it be determined?

[77] Energy Policy Act of 2005, Pub. L. No. 109-58, Aug. 8, 2005, Section 1361.
[78] 33 U.S.C. 2702(a).
[79] *Id.*
[80] 33 U.S.C. 2716(c)(1)(C).
[81] 33 U.S.C. 2716(a) and 2716(c)(2).
[82] 33 U.S.C. 2712(d)(1).

[83] Elizabeth J. Wilson, Mark A. De Figueiredo, Chiara Trabucchi, Kate Larson, *Liability and Financial Responsibility Frameworks for Carbon Capture and Sequestration*, World Resource Institute: WRI Issue Brief Carbon Capture and Sequestration, No. 3 (2007).

Federal agencies currently do not have the authority to collect, manage, and disburse dedicated funds. Legislation establishing a dedicated trust fund for CCS activities will be necessary.

State jurisdiction for CCS sites that span containment zones crossing state boundaries will pose unique problems with respect to the transfer of a CCS site at the state level, as well as the right and ability of multiple states to access the fund. For this reason, a national trust that is managed by an independent third-party—the CCSSB is recommended. In addition, consideration should be given to whether the trust should establish sublimits by site (based on contributions, perhaps) and/or by state, and if so, what will be the basis for establishing such sublimits?

Unless priced accurately, the amount of money remaining in a compensation fund, or national trust, after the CCS operator has been released from its post-closure responsibilities, may not be equal to the actual amount of funds needed to cover expenses and potential damages resulting post-injection. There is no *a priori* reason to believe that residual fund balances from financial responsibility instruments used during the operational phases of the CCS project lifecycle will appropriately match the need for funds over the long-term. In fact, to combine the financial assurance instruments between the phases would reintroduce issues of fit, interplay, and scalability.

To ensure adequate resources at the time of site transfer, the compensation fund or national trust should be re-evaluated, and 'trued up' based on a clearly defined long-term risk profile, developed from actual site-specific monitoring data—one that articulates the degree and probability of long-term risk at the site.

Finally, if contributions to the trust on a per-owner or per-operator basis do not map to the actual risk profile and the expected value of damages/expenses likely to be incurred over the long-term at each CCS site, there is little assurance that the balance of funds remaining at the time of transfer will be appropriate to the long-term need for funds. Further, there is little assurance that high quality, low risk operations will be favored over high risk, low quality operations, unless the mechanism sends price signals which accurately reflect risk. In other words, the fund likely will be either under- or over-funded, potentially resulting in an inefficient use of economic resources. Moreover, and perhaps most importantly, is the issue of moral hazard: Does this type of structure inherently provide site developers with a free pass?

By definition, fee-based trusts and compensation funds lend themselves to situations where the site developer believes it has paid first dollar for relief. As such, there is little or no incentive to make economically efficient, environmentally sound operating decisions. The soundness of the CCS operator's decisions during the initial siting and operational phases will assuredly influence the probability of long-term risks manifesting, and the attendant materiality of financial consequences. If not held completely financially and legally responsible for future, long-term damages, will the CCS operator be less careful in their siting and operating decisions? Only time will truly tell.

A financial risk management system, as described in this article, can be designed to mitigate the potential for the fat residual risk tail through the retention of financial responsibility with the operator in ways that create an appropriate fit, given the economic system and associated institutions—i.e., corporate, private-public—in which the technology must be deployed. Via the creation of the CCSSB and attendant operational financial requirements, the financial risk management framework for CCS should cover properly the risk management needs of the operation, closure, and post-closure phases of the facility lifecycle through the adoption of established financial assurance requirements. It also must provide for long term care—after demonstration of performance-based endpoints—through a properly created, funded and dedicated revolving fund administered by the CCSSB.

The goal should be to create a framework today that can address society's stated preference for short and mid-term needs to reduce carbon dioxide emissions from coal-fired power plants, without the unintended consequence of numerous stranded assets that contribute to the inefficient use of invested capital and unnecessary strains on regional economies. Further, the sheer amount of coal reserves present in the United States suggests that the continued use of coal may be critical to energy security. However, an equally important objective is incentivizing the lowest risk deployment of CCS technology as economically as possible, while leaving room for technological and risk reduction improvements and simultaneously protecting against the reasonable worst case scenario—climactic change and continued ecological degradation.

***About the Authors**: This article was written by Chiara Trabucchi and Lindene E. Patton. Trabucchi is a Principal with Industrial Economics. Patton is the Chief Climate Product Officer for Zurich Financial Services. The views presented here are the personal views of the authors and do not necessarily reflect the views of any other person or entity.* *The authors would like to thank Scott Anderson, Brendan Beck, Anhar Karimjee, Tom Kerr, Doug Koplow, Christine Lee, Andrew Paterson, George Peridas, Frank Tierney, and Sarah Wade for their insights and willingness to brainstorm about the options available to address the challenging policy and technical issues associated with the long-term care of CCS sites.*