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CLIMATE CHANGE

CARBON SEQUESTRATION

The authors of this article say coal, given its abundance and cost, will continue to play a significant role in supporting the world economy. They say carbon capture and storage appears to be the most viable way to address coal's emissions of carbon dioxide. This article examines the challenges to commercial deployment of carbon capture and storage using geologic sequestration. The authors argue that carbon capture and storage will never become a reality without early federal investment in research and development, a uniform federal regulatory framework, and a framework to address the currently unknown and unquantifiable liabilities. The authors suggest one model to manage long-term liability is the liability cap established for the nuclear power industry under the Atomic Energy Damage Act, also known as the Price-Anderson Act of 1957. They say a similar framework that incorporates the peculiarities of carbon sequestration could address some of the questions concerning the long-term liabilities.

The Trouble With Angels: Carbon Capture and Storage Hurdles and Solutions

By Charles H. Haake and Karyn B. Marsh

Over the past 150 years, America has been powered primarily by coal, and coal continues to be a significant source of energy for the United States and the world. However, coal has fallen into environmental disfavor, one reason being its contribution to the emissions of carbon dioxide to the atmosphere. Continuing the use of coal while mitigating its contribution to greenhouse gas emissions will require the use of carbon capture and storage (CCS) utilizing geologic sequestration. Industry, however, has been slow to develop commercially viable CCS systems. Besides fiscal reasons,

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the private sector's inaction is likely due to the lack of a legal framework defining the relative rights, responsibilities, and liabilities of stakeholders.

Both states and the federal agencies have taken steps toward creating a regulatory framework for CCS, but as yet no uniform regulation is in place. Providing a uniform legal foundation that squarely addresses the liabilities associated with CCS is critical for its widespread implementation. There are several legislative models for risk management, but the one most analogous to the situation posed by CCS is the Atomic Energy Damages Act, or Price-Anderson Act of 1957.

This article will discuss the challenges of widespread commercial deployment of CCS, current efforts to provide a regulatory framework for CCS, and the suitability of a Price-Anderson Act mechanism for managing liabilities associated with CCS.

Climate Change Meets Carbon Sequestration

Global climate change is shaping up to be the defining environmental issue of the 21st century. Its cause has been attributed at least in part to the emission of greenhouse gases, namely carbon dioxide, from the burning of fossil fuels, such as natural gas, oil, and coal for the provision of energy.

The Obama administration and the leadership in Congress have signaled for some time that regulation and/or legislation to address global climate change is on the horizon. On March 31, 2009, for example, the Waxman-Markey discussion draft of the American Clean Energy and Security Act of 2009 was circulated. Like many of its predecessors, the bill establishes a cap-and-trade system for reducing greenhouse gas emissions and provides for innovations in energy efficiency and ''green'' technology. The act comprises four titles, the first of which addresses clean energy, including CCS.

As with any bill, the prospect of the American Clean Energy and Security Act passing in its current form is uncertain. The United States (along with China, India, and other nations) is heavily invested in coal for power generation. Coal makes up about 94 percent of the United States' fossil energy reserves.[1] Moreover, the United States has the world's largest coal reserve, accounting for 27 percent of the total.[2]

On account of coal's abundance it has become the fuel of choice in the United States: There are approximately 1,100 manufacturing plants using coal and 1,600 coal-fired power generation units operating in the United States.[3] Coal accounts for roughly 50 percent of electricity generation, 31 percent of all power generation, and billions of dollars in investment in the United States.[4]

The major problem with coal, however, is that it is one of the greatest contributors of greenhouse gases to the atmosphere. Although ceasing its use worldwide would certainly reduce carbon dioxide emissions, the rapid cessation of coal use would be both politically and economically impractical. Consequently, any effort to reduce carbon dioxide emissions through programs such as the cap-and-trade system proposed in the American Clean Energy and Security Act will require verifiable offsets for carbon like those potentially provided by CCS.

To enable the continued use of coal as an energy resource, researchers have been developing technologies for the capture of carbon dioxide, either before or after combustion of coal, and its subsequent storage or sequestration. With CCS, coal use can theoretically continue, while simultaneously achieving substantial reductions in carbon dioxide emissions.

The mention of CCS usually brings to mind geologic sequestration, which is the injection of carbon dioxide into a geologic formation at depths exceeding 2,500 feet, where it is hypothesized that the carbon dioxide remains in a supercritical state (liquid phase) and dissolves into the formation water, reacts with the geologic formation to form carbonate minerals, and/or is trapped by low-permeability deposits. This is a major component of CCS, but CCS also involves two other distinct steps: (1) separation and capture of carbon dioxide from liquefied coal pre-combustion or flue gas post-combustion and (2) transportation of the carbon dioxide from emissions sources to the sequestration site.

Technical Challenges

Although CCS has great potential to provide a bridge in the transition from a world dependent on fossil fuels to one powered by renewable, low-carbon energy resources, its widespread implementation is hampered by legal uncertainty and technological risks. Technologies for capturing and compressing carbon dioxide are currently available, but they have been tested only on a pilot scale; and although the results of these tests are promising, there are still technical challenges regarding efficiency. Specifically, if these technologies are scaled up to a standard 500-megawatt power plant, the energy required for the separation, purification, and compression of all carbon dioxide from the flue gas can range anywhere from 10 percent to 40 percent of the power station's capacity.[5] Full-scale demonstration plants, therefore, are needed to develop efficiency improvements to the carbon capture and compression processes.

Additionally, if the emission source is not near a site suitable for carbon sequestration, the supercritical carbon dioxide will have to be transported via high-pressure pipelines. One of the technical challenges with the pipelines is ensuring the safe transport of acidic carbon dioxide through corrosion-resistant pipes.

Finally, there are few geologic sequestration sites currently in existence, and thus little information regarding potential short- and long-term viability of geologic sequestration is available. For many years, the oil

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[1] *See* http://www.nma.org/statistics/fast_facts.asp.

[2] *See* General Accountability Office, GAO-08-1080 Report to the Chairman of the Select Committee on Energy Independence and Global Warming, House of Representatives: Climate Change, Federal Actions Will Greatly Affect the Viability of Carbon Capture and Storage as a Key Mitigation Option 7 (Sept. 2008).

[3] *See* Energy Information Administration, Existing Capacity by Energy Source, *available at* http://www.eia.doe.gov/cneaf/electricity/epa/epat2p2.html.

[4] *Id. See also* Chiara Trabucchi and Lindene Patton, *Storing Carbon: Options for Liability Risk Management, Financial Responsibility*, 173 World Climate Change Rep. (BNA) (Sept. 2, 2008).

[5] Juan Carlos Abanades et al., *Summary for Policymakers, in* IPCC Special Report on Carbon Dioxide Capture and Storage 4 (B. Metz et al. eds., 2005), *available at* http://arch.rivm.nl/env/int/ipcc/pages_media/SRCCS-final/SRCCS_WholeReport.pdf.

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industry has injected relatively small volumes of carbon dioxide into wells to obtain oil from depleted reservoirs, a method known as enhanced oil recovery. Natural gas has also been routinely injected into geologic formations for storage for several decades.

These analogs have provided some insight into the safety and efficacy of geologic sequestration. However, carbon dioxide injected for purposes of oil recovery generally is not intended to remain in an oil reservoir, and no post-injection monitoring is therefore performed at such sites. Some monitoring is performed at natural gas storage sites, but the monitoring technologies are designed for short-term storage.

Consequently, there are limited data concerning the four most pressing questions posed by CCS: (1) the ability of various geologic formations to sequester carbon dioxide indefinitely; (2) the availability of various geologic formations with the capacity to sequester the large volume of industrial carbon dioxide; (3) the impact of injected supercritical carbon dioxide on subsurface minerals, groundwater, surface water bodies, near-surface soils, and other natural resources should it manage to escape deeper formations; and, more critically, (4) the potential human health and safety impacts that could arise should fugitive carbon dioxide make it to the surface.[6] Without adequate monitoring data, it is very difficult to assess the risk of carbon dioxide migration and/or leakage from a geologic sequestration site over time.

The resolution of the technical issues related to carbon capture, transport, and storage will require substantial investment in research and development. As with any emerging technology, government funding for research and development early on spurs more rapid commercialization and private investment. CCS is no exception.

In anticipation of impending carbon constraints, the power industry, the federal government, and even several states have committed funds for CCS technology development and deployment. For example, the Bush administration channeled $2.5 billion to the Department of Energy for the purpose of clean coal research and development. Part of this plan was the FutureGen Project, which was introduced by President Bush in 2003 pursuant to the National Energy Policy Act of May 2001.

FutureGen was an initiative to create a coal-fired power plant utilizing ''clean coal'' technology that would produce hydrogen and electricity and mitigate greenhouse gas emissions through carbon sequestration.[7] The project was a public/private enterprise with the Department of Energy funding 74 percent of the project. The department terminated its financial support of building a single demonstration plant based on cost concerns in June 2008, but the Obama administration is showing an interest in reviving the program.

Most of the climate change bills introduced in Congress over the last four years have made provisions for CCS. Section 114 of the American Clean Energy and Security Act provides for CCS by authorizing the establishment of a Carbon Storage Research Corporation that will fund CCS demonstration plants by assessing fees on utilities. Even more recently, the Senate approved language in the budget resolution for FY 2010 authorizing a deficit-neutral reserve fund for ''accelerated carbon capture and storage and advanced clean coal power generation research, development, demonstration, and deployment.''[8]

This strong interest by government in promoting CCS sends a clear signal to the private sector. One thing still lacking, however, is a well defined legal and regulatory structure for CCS projects. Given the technical and legal uncertainties that still surround CCS, private developers may be hesitant to take the risk of incurring undefined, material compliance costs and litigation risks that may be associated with such projects.

Current Efforts to Regulate CCS

Realizing the need for regulations to provide legal certainty, both states and the federal government are taking steps to address specific legal issues surrounding CCS. Washington state, for example, enacted a climate change statute in May 2007 that set forth emissions reduction targets for the state and established an emissions performance standard for power generators. Pursuant to this law, Washington state's Department of Ecology promulgated in June 2008 regulations defining performance standards for geologic sequestration sites and amending the rules for disposal via underground injection to include carbon dioxide injected for geologic sequestration.[9]

Other states, including California, Kansas, Massachusetts, Montana, New Mexico, North Dakota, Oklahoma, Pennsylvania, Texas, Utah, West Virginia, and Wyoming, have conducted studies on, passed legislation regarding, or proposed regulation of CCS. Kansas enacted legislation requiring the Kansas Corporation Commission to develop regulations for geologic sequestration sites, and draft rules have been proposed. Unfor-

[6] For example, those who are opposed to the use of CCS point to the potential for a sudden and calamitous release of carbon dioxide from its underground storage. In support of this concern, they cite the 1986 incident in Cameroon, Africa, where an eruption from volcanic Lake Nyos caused the largest known release of natural carbon dioxide that had saturated the lake's waters. Emily Rochon, et al., Greenpeace, FALSE HOPE: WHY CARBON CAPTURE AND STORAGE WON'T SAVE THE CLIMATE 7 (May 2008). The topography of the surrounding area was conducive to the accumulation of carbon dioxide at the surface, as opposed to its rapid dispersion into the atmosphere, and approximately 1,700 people and 3,500 livestock were asphyxiated. Mark Diesendorf, *Can Geosequestration Save the Coal Industry?*, *in* 9 TRANSFORMING POWER: ENERGY AS A SOCIAL PROJECT 223, 239 (John Byrne et al. eds., U. Del. Ctr. for Energy and Envtl. Policy 2006), *available at* http://www.sustainabilitycentre.com.au/CoalGeoseqChap.pdf. This example of a natural release owing to regional vulcanism may not be a good analog for sedimentary geologic sequestration sites, however. Sally Benson et al., *Ch. 5 Underground geological storage*, *in* IPCC SPECIAL REPORT ON CARBON DIOXIDE CAPTURE AND STORAGE 248–49 (B. Metz et al. eds., 2005), *available at* http://arch.rivm.nl/env/int/ipcc/pages_media/SRCCS-final/SRCCS_WholeReport.pdf.

[7] *See* Department of Energy Website on FutureGen and clean coal projects, *available at* http://fossil.energy.gov/programs/powersystems/futuregen/.

[8] Dean Scott, *Senate Paves Way for Carbon Capture Fund, Raises Bar for Passage of Cap-and-Trade*, 61 World Climate Change Rep. (BNA) (April 2, 2009).

[9] Melissa Pollak and Elizabeth Wilson, *Regulating Geologic Sequestration in the United States: Early Rules Take Divergent Approaches*, 43 Envtl. Sci. & Tech. 3035 (March 30, 2009), *available at* http://pubs.acs.org/doi/pdfplus/10.1021/es803094f.

tunately, there are significant differences in the regulatory approaches among states even at this early stage.[10]

In July 2008, the U.S. Environmental Protection Agency proposed new rules under its Underground Injection Control (UIC) Program, established pursuant to the Safe Drinking Water Act of 1974. Under this program, EPA is proposing to create a new class of injection wells and set forth requirements for geologic site characterization to ensure proper location of geologic sequestration wells; construction and operation of such wells; site monitoring and tracking of injected carbon dioxide; post-injection site care and injection well closure; and financial assurance mechanisms.

EPA's proposed rules are a good start to providing some uniformity, but the UIC program may not be the ideal regulatory mechanism for regulating geologic sequestration. Although analogous, the UIC program primarily addresses the permanent disposal of hazardous wastes into deep injection wells, and its focus is on the protection of drinking water resources. The Safe Drinking Water Act of 1974 does not apply to natural gas storage and even though the UIC program covers enhanced oil recovery wells, states may supplant UIC regulations if they demonstrate that their regulatory programs meet the goals of the Safe Drinking Water Act. In contrast, the primary concern of geologic sequestration is mitigation of greenhouse gas emissions and prevention of leakage of sequestered carbon dioxide to the atmosphere.

This difference in objectives clearly plays out in the regulations, and a comparison between Washington state's geologic sequestration regulations and the proposed UIC regulations dramatically shows this divergence. For instance, the Washington state regulations expressly provide that the geologic sequestration site must contain 99 percent of the carbon dioxide for a minimum of 1,000 years,[11] whereas there is no such standard in the proposed UIC regulations. With regard to risk assessment, Washington regulations require quantification of all potential health and environmental impacts,[12] whereas the proposed UIC regulations require only that the impact to underground drinking water sources be considered.[13] With regard to monitoring, the Washington state regulations mandate that geologic sequestration sites maintain a system that can detect carbon dioxide leakage to the atmosphere such as through soil gas monitoring,[14] whereas the proposed UIC rules state only that the administrator may require such monitoring.[15]

Another problem with using the UIC to regulate geologic sequestration is the classification of carbon dioxide. EPA refused to classify carbon dioxide as a hazardous waste in the proposed regulations. Yet, it reserved the right to apply the Resource Conservation and Recovery Act to injected carbon dioxide containing hazardous impurities and to pursue damages under the Comprehensive Environmental Response, Compensation, and Liability Act (commonly referred to as Superfund), when hazardous substances are released as a result of carbon sequestration and impact aquifers or other natural resources.

The UIC program's purpose coupled with the rapid development of varying standards for geologic sequestration by the states does not lend itself to the most effective regulation of such projects. Instead, the best vehicle for uniform regulation of geologic sequestration that will allow more confident deployment of CCS nationwide is a federal framework established pursuant to comprehensive federal climate change legislation.

State Common Law

The states are ahead of the federal government in some respects because CCS substantially implicates state common law in the areas of property, torts, and contracts. For example, the construction of a carbon dioxide pipeline will require the acquisition of property rights to avoid liability for trespass and other torts. If several power plants utilize a network of pipelines leading to a single sequestration site, questions of pipeline and carbon dioxide ownership, transportation fees, easement, and property interests will all be raised, and if the pipeline network crosses state lines, the issues of choice of law and federal preemption will be also be implicated.

Likewise, surface and subsurface property rights are needed to establish a geologic sequestration site.[16] Many states recognize a property interest in the subsurface estate that is separate from the surface estate and have expressly provided in the context of natural gas storage that title to the subsurface pore space belongs to the owner of the surface estate.[17] Yet, differences do exist. A minority of states have found that the owner of the mineral interest retains title over the pore space even after removal of the minerals from the formation.

Ownership of the sequestered carbon dioxide itself also has not yet been tested. But the law governing the ownership of natural gas injected for temporary storage is fairly consistent—all jurisdictions hold that title is with the operator injecting the gas or the owner of the natural gas prior to injection into a geologic forma-

[10] For example, in addressing the long-term care of a geologic sequestration site, Kansas provided for transfer of responsibility to the state and established a fund for post-closure monitoring, while Washington state's legislation is silent on the issue.

[11] Definition of "Permanent Sequestration," WASH. ADMIN. CODE § 173-407-110.

[12] WASH. ADMIN. CODE § 173-218-115(2)(l); *see also* WASH. ADMIN. CODE § 173-200-050(3)(a)(iii).

[13] Proposed UIC Reg. 146.84(c)–(e).

[14] WASH. ADMIN. CODE § 173-218-115(2)(i)–(k).

[15] Proposed UIC Reg. 146.90(h).

[16] In addition to traditional transfer mechanisms, unitization and eminent domain have been used to acquire the necessary rights for secondary oil and gas extraction operations. Unitization involves the joining of individual tracts into a single unit or pool. Some states mandate a certain percentage of owners of the oil agree to unitization before it can occur. Elizabeth Wilson et al., World Resource Institute (WRI) Issue Brief No. 3, *Liability and Financial Responsibility Frameworks for Carbon Capture and Sequestration* 2–3 (Dec. 2007). Natural gas storage operators can obtain from the Federal Energy Regulatory Commission a license allowing the use of eminent domain to acquire property rights to the subsurface if those rights cannot be obtained voluntarily. Mark A. de Figueiredo et al., *Regulating Carbon Dioxide Capture and Storage*, Center for Energy and Environmental Research 4 (April 2007) [referred to hereinafter as "de Figueiredo et al., April 2007"].

[17] de Figueiredo et al., April 2007 at 6. *See also* Darrick Eugene, VINSON & ELKINS CLIMATE CHANGE PROGRAM WHITE PAPER CARBON CAPTURE AND STORAGE AND FEDERAL LEGISLATIVE PROPOSALS 17 (December 2007).

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tion.[18] This is reasonable, given that natural gas is a commodity that has value. In the context of permanent sequestration of carbon dioxide, however, the determination may be different where the injected substance is more akin to waste than a valuable commodity and considerable liabilities attach to the ownership of the carbon dioxide.

The questions of title to the carbon dioxide and the subsurface estates are key to meeting the challenges of CCS because they ultimately will determine the rights and liabilities of all stakeholders. Limited by their authorizing statute, the Safe Water Drinking Act, the proposed federal UIC regulations cannot adequately address issues of liability, especially those relating to long-term stewardship of geologic sequestration sites. Some states are considering, or, in the case of Kansas and Illinois, have already enacted, laws transferring responsibility for geologic sequestration sites to the state after a certain amount of time and creating trusts for their long-term care. State models like these may be the best approach, so long as they are consistent.

Lingering Questions of Liability

The primary remaining legal obstacle to full commercial deployment of CCS is liability. There are several potential sources of liability associated with CCS operations: regulatory, tort, and contractual. Regulatory liability can involve the failure to operate CCS equipment and facilities in accordance with regulations and applicable permits. This liability can include cleanup costs under Superfund and other environmental laws if carbon dioxide is deemed to be a hazardous waste, pollutant, or contaminant, or induces the release of other contaminants into the groundwater or environment.

Tort liability based on the common law theories of trespass, nuisance, negligence, and strict liability would include personal injury and property and natural resource damages resulting from carbon dioxide releases. Contractual liability arises from carbon dioxide releases in violation of the contractual duty to transport or to sequester the carbon dioxide within certain performance standards.

Federal and state regulatory frameworks exist for oil and natural gas pipelines, and these can serve as models for the regulation of carbon dioxide pipeline networks. Industry also has been able to manage short-term, operational liabilities associated with enhanced oil recovery and natural gas storage pipelines through standard commercial insurance. The operational liabilities associated with CCS are expected to be handled similarly.[19]

One significant sticking point for CCS is the long-term liability associated with geologic sequestration.[20] Who will be held responsible for managing a geologic sequestration site after it has been closed and liable for any damages resulting from a post-closure release of carbon dioxide?

Data from pilot geologic sequestration projects and studies of enhanced oil recovery and natural gas storage sites suggest that the risk of carbon dioxide leakage actually decreases over time as the carbon dioxide reacts with the formation or becomes trapped by impermeable strata in the subsurface.[21] Yet, in spite of this encouraging information, the risk of carbon dioxide leakage is never eliminated. Earthquakes or anthropogenic activities on or near a geologic sequestration site can cause breaches. Moreover, if a geologic sequestration site is not well characterized before carbon dioxide injection starts, the long-term risks of leakage are substantially increased.

Under the proposed UIC regulations, EPA proposes to make industry financially responsible for carbon dioxide injection wells for 50 years after they are closed. This may not be realistic, however, given that geologic sequestration sites are expected to sequester carbon dioxide for hundreds of years and the life span of most private entities is not expected to be 50, much less hundreds of, years.

Beyond the 50-year period, EPA has offered no provisions to address the transfer of site responsibility. EPA's reluctance to promulgate such rules may be justified, nevertheless, because these issues are matters of state property, contract, and tort law. EPA promulgation of rules under the Safe Drinking Water Act may indeed be *ultra vires*, or beyond the agency's authority.

Section 112 of the American Clean Energy and Security Act of 2009 would amend section 813 of the Safe Drinking Water Act, requiring that EPA ''[take] into consideration all relevant statutory authorities,'' which would allow EPA greater leverage. Yet, even with this provision, federalism concerns may prevent EPA from effectively regulating long-term liability.

A federal statute specifically providing for long-term liability related to geologic sequestration sites appears to be necessary. The American Clean Energy and Security Act, however, goes no further than the UIC regulations in addressing this long-term liability. At best, section 111 mandates the preparation of a report to Congress identifying regulatory and legal barriers to CCS implementation and recommending additional rulemakings or legislation, while section 113 establishes a task force to study the legal framework for geologic sequestration sites with the specific objective of analyzing the adequacy of existing federal and state law to manage risk.

Liability Cap to Manage Long-Term Liabilities

EPA, state agencies, insurance industry representatives, legal commentators, public interest groups, and the regulated community have all made suggestions on the best approach to mitigating long-term liabilities associated with geologic sequestration sites. One of the most cited models is the liability cap established for the benefit of the nuclear power industry by the Atomic En-

[18] de Figueiredo et al., April 2007 at 6.

[19] *See* Trabucchi and Patton, *supra* note 4, at 9.

[20] *See* Craig A. Hart, *Advancing Carbon Sequestration Research in an Uncertain Legal and Regulatory Environment: A Study of Phase II of the DOE Regional Carbon Sequestration Partnerships Program*, Discussion Paper 2009-01, Energy Technology Innovation Policy research group, Belfer Center for Science and International Affairs, Harvard Kennedy School, January 7, 2009 (explaining that many geologic sequestration pilot projects sponsored by the Department of Energy have experienced delays or even cancellation because of the uncertainties over long-term liability), *available at* http://belfercenter.ksg.harvard.edu/files/2009_Hart_CCS_RDD_Legal_Barriers_rev.pdf.

[21] Trabucchi and Patton, *supra* note 4, at 11–12.

ergy Damages Act, popularly known as the Price-Anderson Act of 1957, 42 U.S.C. § 2210 *et seq*.

The situation with nuclear power plants in 1957 is analogous to CCS today. Like CCS, the nuclear power industry was in its infancy. The Price-Anderson Act was enacted to encourage investment in nuclear power generation by addressing the uncertain liabilities associated with nuclear facilities.

Price-Anderson establishes a framework in which the federal government partially indemnifies the nuclear industry against liability claims arising out of nuclear incidents, while ensuring compensation for injury to the public. It takes a tiered approach, requiring each nuclear facility to obtain primary insurance of $300 million from the private insurance sector and secondary insurance from a pool of over $10 billion, funded by the nuclear industry paying annual premiums of $15 million per plant and up to a maximum of $95.8 million per incident.[22]

If damages from an incident exceed both the primary and secondary insurance limits, the U.S. government will cover the remainder of damages over the primary and secondary insurance limits. Coverage includes liabilities associated with personal injury and property damage; incident response and evacuation costs; and the costs of investigation of and defense to claims. Price-Anderson also covers liability associated with the long-term management of nuclear waste and transfers responsibility to the U.S. Department of Energy.[23]

If designed carefully with the peculiarities of CCS in mind, a Price-Anderson-type model could work well for geologic sequestration sites. As with nuclear power plants, the probability of a catastrophic release from a geologic sequestration site is low. But should such a release occur, the damages could be prohibitively high, though not as high as a nuclear incident. A fee could be charged for every ton of carbon captured and sequestered, and these fees would be deposited into a dedicated trust that would cover long-term care for and damage claims associated with geologic sequestration sites. Moreover, a single fund for pooling of risk associated with these sites is superior to multiple state funds, which may not sufficiently spread risk and may not be adequately capitalized to cover actual damages incurred above insurance coverage limits.[24]

One challenge in devising a Price-Anderson-type scheme for CCS would be the determination of fees on sequestered carbon to provide adequate funding of a trust fund. Another challenge would be setting sufficient damage thresholds given the risks, when there are few data regarding long-term liabilities. Finally, given the fact that carbon dioxide is meant to be sequestered for hundreds of years, the designers of the program would have to consider whether it would have a sunset provision similar to those found in Price-Anderson and other similar federal programs that have legislatively determined termination dates.

The major downside of a liability cap for geologic sequestration sites, however, is the stigma that comes with them. Liability caps are generally associated only with activities having catastrophic risk such as nuclear power generation plants and waste disposal facilities.[25] Using Price-Anderson as a model for geologic sequestration sites could raise concern among the public, even though the Price-Anderson governmental indemnity has not been used. All nuclear power plant claims, including those related to the 1979 accident at Three Mile Island, thus far have been paid by primary insurance, and the Department of Energy has spent a relatively small amount ($98 million) for its obligations with regard to nuclear waste.

Nevertheless, the public has not looked favorably on the Department of Energy's proposal to dispose of high-level radioactive waste at Yucca Mountain in Nevada, which is also covered by Price-Anderson. Characterization of the Yucca Mountain site started in 1978; yet, 30 years and $13.5 billion later, the facility has not opened, and the current plan is to scrap the project altogether.[26] The difficulty in establishing just one disposal site for nuclear waste, albeit a highly hazardous waste, does not bode well for the development of potentially hundreds of geologic sequestration sites across the country, especially if those sites are proposed in areas densely populated with inhabitants and/or industry.

Additionally, some may be concerned that a liability cap that relieves owners and operators of CCS facilities of all liability past a certain amount could create a moral hazard, disincentivizing operators from making decisions that are sufficiently protective of the environment and human health and safety. In other words, operators might be tempted to select less than optimal sites for geologic sequestration; perform inadequate site characterization; or install minimal site monitoring systems.[27] Having regulations in place for the proper site characterization, monitoring, and operation of a geologic sequestration site, however, would help reduce this temptation.

Conclusion

Given its abundance and cost, coal will continue to play a significant role in supporting the world economy. Addressing the concerns about coal's contribution to emissions of carbon dioxide to the atmosphere will require some method for reducing or eliminating these emissions, and carbon capture and storage appears to be the most viable solution. Yet, CCS will never become a reality without federal government support through early investment in research and development, a uniform federal regulatory framework, and a framework for addressing the currently unknown and unquantifiable liabilities.

One model to manage long-term liability is the liability cap established for the nuclear power industry under the Atomic Energy Damage Act, also known as the Price-Anderson Act of 1957. That law established a framework in which the federal government partially

[22] 42 U.S.C. § 2210(b)(1).
[23] Trabucchi and Patton, *supra* note 4, at 18.
[24] Pollak and Wilson, *supra* note 9, at F.

[25] Mark A. de Figueiredo et al., *Framing the Long-Term In Situ Liability Issue for Geologic Carbon Storage in the United States*, 10 MITIGATION AND ADAPTATION STRATEGIES FOR GLOBAL CHANGE 647, 652 (2005), *available at* http://sequestration.mit.edu/pdf/Framing_the_Long-Term_Liability_Issue.pdf.
[26] *Official: No Nuke Waste at Yucca Mountain*, CBS News, March 5, 2009, *available at* http://www.cbsnews.com/stories/2009/03/05/national/main4847330.shtml.
[27] Trabucchi and Patton, *supra* note 4, at 19.

indemnified the nuclear industry against liability claims that may arise from a potential nuclear incident. A similar framework that incorporates the peculiarities of CCS could encourage investment in carbon capture and geologic sequestration by addressing some of the questions concerning the long-term liabilities associated with CCS, much as Price-Anderson did with nuclear power facilities.

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