A R T I C L E

The Limits of Liability in Promoting Safe Geologic Sequestration of CO_2

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Carbon capture and sequestration (CCS) is promoted by a broad range of prominent stakeholders who assert avoiding climate change will be impossible without it.[1] The importance attached to CCS is strongly associated with its scale. However, the advantage of the enormous scale of CCS is also a source of concern because it suggests that the risks are large as well.[2]

Beyond concerns about the high costs of capturing CO_2, two issues have dominated the debate: (1) the risks posed by leakage of CO_2 from sequestration sites, and (2) management of the long-term liabilities associated with them.[3] The CCS industry has reinforced fears by decrying the crippling effect that open-ended liability would have on CCS deployment,[4] a position some prominent academics and advocates have accepted and often amplified.[5] We will argue these fears are being fueled by misapprehensions about the risks posed by sequestration sites.

The scale involved in CCS and the indirect nature of the impacts will create unique challenges for effective regulation and novel factual settings for liability. However, the large scale of CO_2 sequestration is not entirely a negative, as large operations also offer economies of scale for regulation. And while impacts from releases could occur over vast areas, these impacts are well understood and relatively straightforward to mitigate, if not to prevent.[6] Put differently, the risks are remarkably small relative to the volume of CO_2 involved and the subsurface area covered by a typical sequestration site.

While the conventional belief among CCS advocates is that risks will decline rapidly in the decades after CO_2 injection ends,[7] new scientific studies demonstrate that geologic features such as faults and reservoir permeability, and human infrastructure such as abandoned wells, will create a mix of near- and long-term risks, some of which could persist for many decades.[8] The combination of risks with different temporal profiles will limit the role that liability can play. Economists have long recognized that market mechanisms are poorly suited to mitigate risks with long latency periods.[9] Essentially, if long-term liability offers only nominal deterrence, then the specter of moral hazard and CCS industry fears about open-ended liability that have received so much attention are groundless.

This article proceeds in four parts. Part I provides an overview of CCS, and analyzes the scientific work on the potential for releases of CO_2 and brine from sequestration reservoirs. Part II evaluates the comparative advantages of government regulation and common law liability and criti-

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1. According to the International Energy Agency (IEA), the annual costs of cutting global CO_2 emissions in half by 2050 would increase by 71% ($1.28 trillion per year) without CCS. Int'l Energy Agency, Energy Technology Analysis: CO_2 Capture and Storage: A Key Carbon Abatement Option 16 (2008) [hereinafter IEA], *available at* http://www.iea.org/textbase/nppdf/free/2008/CCS_2008.pdf. The IEA concludes, "CCS is therefore essential to the achievement of deep emission cuts." *Id.* at 15.
2. *See, e.g.*, Greenpeace Int'l, False Hope: Why Carbon Capture and Storage Won't Save the Climate 30–31 (2008), *available at* http://www.greenpeace.org/usa/en/media-center/reports/false-hope-why-carbon-capture/.
3. *See infra* Part I.A.
4. James A. Holtkamp, *Models Studied for Long-Term Liability Risks in CCS*, 24 Nat. Gas & Electricity 12, 12 (2008).
5. *See, e.g.*, David Hawkins et al., *Twelve Years After Sleipner: Moving CCS From Hype to Pipe*, 1 Energy Procedia 4403, 4407 (2009); Elizabeth J. Wilson et al., *Assessing a Liability Regime for Carbon Capture and Storage*, 1 Energy Procedia 4575, 4575 (2009).
6. *See infra* Part I.B.
7. *See, e.g.*, Envtl. Prot. Agency, EPA430-R-08-009, Technical Support Document: Vulnerability Evaluation Framework for Geologic Sequestration of Carbon Dioxide 44 (2008), *available at* http://www.epa.gov/climatechange/emissions/downloads/VEF-Technical_Document_072408.pdf.
8. *See* Frank B. Walton et al., *Geological Storage of CO_2: A Statistical Approach to Assessing Performance and Risk*, *in* Proceedings of 7th International Conference on Greenhouse Gas Control Technologies (E.S. Rubin et al. eds., 2004), *available at* http://www.granite.mb.ca/sheppard/GHGT7.pdf.
9. *See* Robert L. Rabin, *Environmental Liability and the Tort System*, 24 Hous. L. Rev. 27, 43 (1987).

cally analyzes current concerns about long-term liability and moral hazard. Part III examines the relative efficiencies of different doctrines of common law liability, finding support for negligence and strict liability, but noting the deterrence value of both doctrines will be limited to a subset of important near-term risks. These sections demonstrate that the current debate misdiagnoses the primary risks and overlooks operational factors simplifying application of common law liability. In Part IV we propose a hybrid legal framework combining a traditional regulatory regime with a two-tiered system of liability calibrated to objective site characteristics. This framework balances principles of economic efficiency and the realities of political viability.

I. Timing and Magnitude of the Risks Posed by Carbon Sequestration

The basic elements of CCS are straightforward. CO_2 is captured from the flue gas of an industrial source, compressed into a supercritical fluid for transportation to a sequestration site, and then injected into a deep brine reservoir for permanent disposal. Although the capture and compression of CO_2 are responsible for the bulk of the costs and many of the most challenging technological hurdles for CCS,[10] geologic sequestration of CO_2 has raised the most contentious legal and policy issues.

The massive volumes of CO_2 produced globally are more than matched by the available subsurface storage space in geologic reservoirs.[11] Recent estimates indicate that depleted oil and gas reservoirs could store 900 to 1200 billion metric tons of CO_2, while the capacity of deep saline reservoirs is conservatively projected to exceed 1000 Gigatons (Gt) of CO_2.[12] Given that annual global emissions of CO_2 are currently about 30 Gt,[13] the estimated capacity of deep brine reservoirs is sufficient to sequester the equivalent of thirty to forty years of total global CO_2 emissions or 75 to 125 years of the emissions from the power sector.[14] Despite the large reservoir capacities available, constraints on carbon-capture technologies, funding, and construction costs will limit the use of CCS to a fraction of its storage potential, making it viable as a bridge technology for substantially longer than these estimates suggest.[15]

A. Types of Risks

Like any complex engineering problem, CO_2 sequestration projects will not be risk-free. We will focus on the risks posed by releases of CO_2 and brine. The most significant form of environmental harm from such releases is predicted to be contamination of drinking water.[16] Little or no evidence exists that direct atmospheric releases of CO_2 could be a significant threat to humans.[17]

B. CO_2 Plumes and Brine Displacement in Sequestration Reservoirs

The risks associated with leakage of CO_2 and movement of brine into aquifers will not be identical in magnitude or timing. Leakage of CO_2 will not be dependent on the elevated pressures around an injection well, as the buoyancy of CO_2 is sufficiently high to drive it to the surface and to propel it laterally.[18] By contrast, because brine intrusion is driven by elevated pressure, the potential area of risk in the reservoir will continue to expand for many decades after CO_2 injection ceases as the pressure in the reservoir equilibrates.[19]

In a 2008 simulation study, researchers found that fifty years after the end of active CO_2 injection, the CO_2 plume would extend just three to five kilometers from the injection well, whereas the field of elevated pressure was projected to extend tens of kilometers from the well.[20] These results expose the heightened risks presented by releases of brine from sequestration reservoirs. They are more likely to be of longer duration than releases of CO_2, and the degree to which concerns about direct leakage of CO_2 have been overemphasized and should be reassessed.

10. Sally M. Benson & Terry Surles, *Carbon Dioxide Capture and Storage: An Overview With Emphasis on Capture and Storage in Deep Geological Formations*, 94 Proc. IEEE 1795, 1802 (2006).
11. Franklin M. Orr Jr., *Onshore Geologic Storage of CO_2*, 325 Sci. 1656, 1656–57 (2009).
12. Benson & Surles, *supra* note 10, at 1796; *see also* Intergovernmental Panel on Climate Change, IPCC Special Report on Carbon Capture and Storage 211 (Bert Metz et al. eds., 2005), *available at* http://www.ipcc.ch/pdf/special-reports/srccs/srccs_wholereport.pdf; Int'l Energy Agency, *supra* note 1, at 106.
13. U.S. Energy Info. Admin., Int'l Energy Outlook 7 (2010).
14. *See* Int'l Energy Agency, CO_2 Emissions From Fuel Combustion: Highlights 9 (2010), *available at* http://www.iea.org/co2highlights/ co2highlights.pdf.
15. Intergovernmental Panel on Climate Change, *supra* note 12, at 33, 43–46.
16. *See* Ian J. Duncan et al., *Risk Assessment for Future CO_2 Sequestration Projects Based on CO_2 Enhanced Oil Recovery in the U.S.,* 1 Energy Procedia 2037, 2037–38 (2009).
17. *See, e.g.*, Karsten Pruess, *On CO_2 Fluid Flow and Heat Transfer Behavior in the Subsurface, Following Leakage From a Geologic Storage Reservoir*, 54 Envtl. Geology 1677, 1684 (2008).
18. Stefan Bachu, *CO_2 Storage in Geological Media: Role, Means, Status and Barriers to Deployment*, 34 Progress Energy & Combustion Sci. 254, 265 (2008).
19. *See* Johannes E. Kalunka et al., Effects of CO_2 Storage in Saline Aquifers on Ground Water Supplies 7–8 (2010) (prepared for Society of Petroleum Engineers International Conference on CO_2 Capture, Storage, and Utilization, New Orleans, Louisiana, Nov. 10–11, 2010), *available at* http://www.onepetro.org/mslib/servlet/onepetropreview?id=SPE-139665-MS&soc=SPE; Jens T. Birkholzer et al., *Large-Scale Impact of CO_2 Storage in Deep Saline Aquifers: A Sensitivity Study on Pressure Response in Stratified Systems*, 3 Int'l J. Greenhouse Gas Control 188-90 (2009).
20. Jean-Philippe Nicot, *Evaluation of Large-Scale CO_2 Storage on Fresh-Water Sections of Aquifers: An Example From the Texas Gulf Coast Basin*, 2 Int'l J. Greenhouse Gas Control 582, 589–90 (2008).

II. The Importance of *Ex Ante* Regulation and the Absence of Moral Hazard

While there is broad consensus that responsibility for carbon sequestration sites should ultimately be transferred to the federal government, questions have been raised about how and when this should occur.[21] Virtually all of the proposed policies are multilayered and tailored to specific stages in the lifecycle of a carbon sequestration site. Resolving the appropriate set of policy instruments for the final stage, long-term stewardship, has proven to be particularly contentious.

We will argue little or no tension exists between long-term liability and the environmentally sound development of carbon sequestration. Drawing on the technical details described above, it becomes clear that *ex ante* regulation is the single most important policy instrument for ensuring that latent impacts are factored into siting and operations decisions essential to the long-term safety of carbon sequestration sites.

A. Regulation Versus Common Law Liability

Steven Shavell, a leading economist writing in the area, was among the first to identify a set of governing criteria for tort liability and regulatory schemes. He identified four primary factors: (1) knowledge asymmetries between the private sector and regulatory agencies, (2) capital constraints of liable corporate defendants, (3) likelihood that suits will be brought against liable defendants, and (4) administrative costs of implementing regulatory programs versus litigating tort suits.[22]

The basic principle of Shavell's framework is simple: if a defendant's capacity to pay is less than the damages it could inflict, its capacity to pay will operate as a *de facto* cap on potential liability, and the incentive for due care created by tort liability will be inefficiently weak.[23] Essentially, the efficiency of *ex post* liability will decline the more potential liabilities exceed the capital reserves of a defendant.[24]

B. Implications for the Debate Over Long-Term Liability

With respect to carbon sequestration, the Achilles' heel of tort liability is latency, which will be a significant characteristic of the risks associated with CO_2 releases or brine. Only government regulation has the capacity to target risks with long latency periods.[25] Yet, regulators are also subject to temporal myopia and political pressures eroding their willingness or ability to promulgate regulations that adequately consider long-term risks.[26] In contrast to most private entities, countervailing pressures from powerful organizations and individuals committed to environmental protection exist within and outside government.[27] Accordingly, the government is institutionally better placed than the private sector to factor long-term risks into its decision-making processes.[28]

Neither fears about unbounded long-term liability nor concerns about limiting it should be impediments to the safe deployment of geologic carbon sequestration. Instead, concerns about ensuring carbon sequestration sites are selected and operated with due care ought to be focused on promulgating effective performance-based regulations.

III. The Appropriate Forms and Limited Role of Tort Liability

A. The Merits of Enhanced Tort Liability

Three supplementary tort doctrines—strict liability, proportional liability, and joint and several liability—have the potential to mitigate the challenges of establishing liability for harmful releases from sequestration sites. Strict liability eliminates the need to demonstrate negligence, proportional liability relaxes the standard for demonstrating causation under a theory of negligence, and joint and several liability makes defendants individually and collectively liable for the harms at issue regardless of their respective contributions. These doctrines increase both the likelihood that a plaintiff will prevail and the potential liability of defendants, and in so doing enhance the incentives for defendants to mitigate risks.

1. Subjecting Sequestration Sites to Enhanced Liability: Unilateral Harms

Subjecting sequestration sites to strict liability under circumstances of unilateral harm is economically efficient because site operators are the only parties capable of mitigating risks, and are thereby the lowest-cost risk avoiders.[29] Liability still has the potential to impact site-selection decisions.[30] Rough estimates of sequestration capacities in the United States suggest many high-quality sites will be available,[31] indicating liability can be used to encourage facility owners to locate sequestration sites in low-risk

21. Alexandra B. Klass & Elizabeth J. Wilson, *Climate Change and Carbon Sequestration: Assessing a Liability Regime for Long-Term Storage of Carbon Dioxide*, 58 Emory L.J. 103, 172–73 (2008); Chiara Trabucchi & Lindene Patton, *Storing Carbon: Options for Liability Risk Management, Financial Responsibility*, Bureau of Nat'l Affairs, Daily Envt'l Rep., Sept. 3, 2008, at 2-3, 14-15.
22. Steven Shavell, *Liability for Harm Versus Regulation of Safety*, 13 J. Legal Stud. 357, 359–64 (1984).
23. Donald G. Gifford, *The Peculiar Challenges Posed by Latent Diseases Resulting From Mass Products*, 64 Md. L. Rev. 613, 617 (2005); Shavell, *supra* note 22, at 360–61.
24. Shavell, *supra* note 22, at 360–61.
25. *See* Gifford, *supra* note 23, at 697; Rabin, *supra* note 9, at 4.
26. Robert M. Solow, *The Economics of Resources or the Resources of Economics*, 64 Am. Econ. Rev. 1, 12 (1974).
27. *See, e.g.*, Maureen L. Cropper et al., *The Determinants of Pesticide Regulation: A Statistical Analysis of EPA Decision Making*, 100 J. Pol. Econ. 175, 194–95 (1992).
28. *See, e.g.*, Clayton P. Gillette & James E. Krier, *Risks, Courts, and Agencies*, 138 U. Pa. L. Rev. 1027, 1039–42, 1067–70 (1990).
29. Steven Shavell, Economic Analysis of Accident Law 6–8 (1987).
30. *See* Richard A. Posner, Economic Analysis of Law 229 (8th ed. 2011).
31. Benson & Surles, *supra* note 10, at 1796; Orr, *supra* note 11, at 1656.

regions. If geologic sequestration of CO_2 is successful, cost-premiums will increase for higher-quality sites, but by that time scientists may have a better understanding of harmful releases and perhaps improved methods for mitigating them. Tort liability is therefore likely to be most effective during the earlier stages of CCS deployment.

B. *The Appropriate Role of Tort Liability*

The timing of potential harms is central to the effectiveness of tort liability and turns on the nature of a release and the technical capacities to detect it. Subsurface monitoring can identify leakage from a sequestration reservoir long before impacts on risk receptors arise and before legally cognizable harms exist.[32] Moreover, extended periods of latency could foreclose avenues for altering site operation and limit options to near-surface remediation or natural attenuation. In any event, latency would also greatly diminish the deterrence value of tort liability.

1. The Net Effect of Imposing Enhanced Liability

The case for enhanced liability is strong but requires a nuanced understanding of the circumstances under which harmful leakage from a sequestration site is likely. We believe the most important factor favoring enhanced liability is the unilateral nature of the harms; site operators are the least-cost avoiders because only they have the capacity to prevent or mitigate harm. However, the practical value of enhanced liability cannot be assessed without considering the overlapping standards of conventional tort doctrines of nuisance and trespass.

The net benefits of the doctrines will clearly differ depending on whether a release involves CO_2 or brine. Harmful releases of CO_2 will be subject to strict liability under the doctrine of trespass irrespective of whether enhanced forms of liability are available because CO_2 plumes from different injection wells are unlikely to overlap. Subjecting these types of releases to enhanced liability is unlikely to have any effect. On the other hand, pressure-driven releases of brine will rarely entail a trespass, and where multiple parties are involved, the pressure effects driving a release will not be attributable to a single injector. This result suggests that accountability for such releases will typically be foreclosed absent enhanced liability.

2. Negligence Versus Strict Liability

A critical factor in deciding between negligence and strict liability is the likelihood that courts will establish an efficient level of due care. In general, to the extent determining the level of due care is technically complex and site-specific, strict liability will be favored over negligence or proportional liability.[33] We have already argued that the limits of geological data and the heterogeneity of site characteristics favor imposition of strict liability.[34] But these factors are most relevant to *ex ante* site selection, which differs in substance and information content from operational decisions.

Synthesizing our findings leads to the following conclusions. First, absent legislative intervention, releases of CO_2 will be subject to strict liability through trespass. Second, some form of enhanced liability should apply to releases of brine to overcome the indivisibility problems that could preclude plaintiffs from successfully bringing claims. Third, the deterrence value of liability will be limited to relatively near-term risks associated with releases through faults or abandoned wells. These findings reveal that the current debate over regulation of sites ignores the primary source of risk—brine intrusion—and misapprehends the legal issues in both the short and long term. In particular, the debate has overstated the potential role of tort liability as a policy instrument for promoting safe sequestration and the importance of liability in mitigating long-term risks.

This system would supplement a traditional *ex ante* regulatory regime, which is itself vulnerable to substantial informational gaps and asymmetries, by providing an added incentive for site owners to select higher-quality sequestration sites. We propose this hybrid approach both because it is normatively grounded on conservative economic principles and because it has political virtues that could mitigate industry opposition.

IV. A Two-Tiered System of Liability and Minimum Performance-Based Standards

Our hybrid policy framework for geologic sequestration of CO_2 exploits the complementary strengths of common law liability and traditional regulation. The framework uses enhanced liability in conjunction with regulatory standards and data: sites below a specified safety ranking would be subject to strict liability and possibly heightened regulatory requirements. This selective use of strict liability is designed to provide an incentive for site owners to select low-risk sequestration sites.

We believe that uncertainties about the technical, economic, and political viability of CCS are far more significant than the speculative concerns about long-term liability and alleged large-scale risks associated with CO_2 sequestration. However, the only way to begin the process of resolving these uncertainties about CCS viability is to construct full-scale CCS facilities. These efforts are being impeded by concerns about liability and risks to the environment and human health. Programs designed to promote deployment of CCS are unlikely to be successful without effective regulatory and liability policies, and ideally should be coordinated with them.

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32. R.A. Chadwick et al., *Review of Monitoring Issues and Technologies Associated With the Long-Term Underground Storage of Carbon Dioxide*, 313 Geologic Soc'y London 257, 271–74 (2009).

33. *See supra* Part III.A.1.
34. *See supra* Part III.A.1.

A. The Current Legal Environment: Federal Versus State Regulation

None of the existing federal laws, on its own, provides a comprehensive regulatory framework for carbon sequestration. EPA currently regulates sequestration of CO_2 through its UIC program, designed to regulate traditional threats to ground and surface water from toxic contaminants.[35] EPA's authority to regulate underground injection under the Safe Drinking Water Act (SDWA) is limited to setting minimum standards[36] and does not provide any incentives for companies to go beyond the minimum.

On balance we believe the current regime of minimum performance-based standards under the SDWA should be retained. The critical importance of site selection to mitigating potential risks underscores the need for establishing a consistent set of minimum standards across the country. Consistent standards will help ensure that sites are selected for their merits rather than the regulatory environment.

Minimum federal standards alone will not ensure that the best sites are selected; instead, they will only exclude higher-risk sites from being developed. Tiered tort liability has the capacity to augment federal standards by providing an added incentive for operators to select high-quality sites. While a tiered framework could be implemented through a regulatory regime, this approach would entail broader federal preemption of state regulations and would be subject to the limitations of a pure regulatory approach. It would also require legislative action extending the existing regulatory system under the SDWA, which is likely to provoke strong opposition in Congress.[37]

Our hybrid regime is less intrusive, although it would also require new legislation to establish a program for ranking sites and rules governing liability for releases from them. This hybrid approach has three primary virtues over a pure regulatory regime: First, the ranking system is a form of information-based regulation that is backed up by the incentives provided by common law liability, and avoids the trappings of "command and control" regulation likely to inspire the strongest opposition from regulatory critics. Second, our approach minimizes federal preemption of state programs.[38] Third, the imposition of enhanced liability on lower-ranked sequestration sites is supported by principles of economic efficiency and mitigated by the modest magnitude of the risks and liabilities at stake.

We have found tort liability will be limited to playing only a supplementary role to traditional performance-based regulations. We have outlined how liability could be effectively leveraged in this secondary role; namely, to provide additional incentives for selection of low-risk sequestration sites.

B. Creating Complementary Regulatory and Liability Regimes

Similar to other commentators, we believe that regulation of sequestration sites should be structured around the different stages of site operations (active operation and injection of CO_2, site closure, a ten to thirty year period of post-closure monitoring and oversight, and finally long-term stewardship). We also agree that when a site transitions to long-term stewardship, it should be transferred to a government entity that will have sole responsibility for the sequestration site, including all liabilities.

Our approach differs from other proposals in two primary respects: First, it promotes selection of the safest sequestration sites and places less reliance on site monitoring and oversight by federal regulators. Second, our framework integrates a formal regulatory regime and common law liability through a comprehensive system of mapping and ranking potential sequestration sites. This ranking would be conducted by a federal agency and used to determine whether a site will be subject to strict liability.

We believe a rough ranking of sequestration sites would be neither technically demanding nor cost-prohibitive.[39] The limited risk assessments needed to support such a ranking would amount to a small fraction of the cost of a full site characterization.[40] Equally importantly, the ranking would be based on data that are quite accurate and straightforward to interpret.[41]

This informational approach draws on a hierarchical permitting system recently proposed by Jean-Philippe Nicot and Ian Duncan.[42] Under their scheme, a government agency would map, characterize, and rank deep brine reservoirs that are candidates for geologic sequestration of CO_2.[43] Rather than linking this assessment to liability, Nicot and Duncan adopt a pure regulatory approach tying permitting requirements to the rank of each site, and suggesting regional-level permits could be developed under

35. Federal Requirements Under the Underground Injection Control (UIC) Program for Carbon Dioxide, 75 Fed. Reg. 77235 (Dec. 10, 2010) (to be codified at 40 C.F.R. pt. 124).
36. *Id.* at 77241.
37. *See, e.g.*, John M. Broder, *House Republicans Take E.P.A. Chief to Task*, N.Y. Times, Feb. 10, 2011, at A16; Paul Krugman, Op-Ed, *Party of Pollution*, N.Y. Times, Oct. 21, 2011, at A35.
38. Similar kinds of limited preemption of state common law are not unprecedented. For example, the 1986 SARA amendment to CERCLA added provisions that dictate the trigger date for statutes of limitations for certain common-law actions. 42 U.S.C. §9658 (2006).
39. *See* Curtis M. Oldenburg, *Screening and Ranking Framework for Geologic CO_2 Storage Site Selection on the Basis of Health, Safety, and Environmental Risk*, 54 Envtl. Geology 1687, 1693 (2008); Yingqui Zhang et al., *Probability Estimation of CO_2 Leakage Through Faults at Geologic Carbon Sequestration Sites*, 1 Energy Procedia 41, 42 (2009).
40. *See generally* J.G. Kaldi & C.M. Gibson-Poole, Coop. Research Ctr. for Greenhouse Gas Tech., Storage Capacity Estimation, Site Selection and Characterization for CO_2 Storage Projects 19–21 (2008), *available at* http://www.co2crc.com.au/dls/pubs/08-1001_final.pdf.
41. *See, e.g.*, Curtis M. Oldenburg et al., Risk Assessment Framework for Geologic Carbon Sequestration Sites 10 (2010), *available at* http://escholarship.org/uc/item/8297g3k2; Lisa Bacanskas et al., *Toward Practical Application of the Vulnerability Evaluation Framework for Geological Sequestration of Carbon Dioxide*, 1 Energy Procedia 2565, 2566 (2009).
42. Philippe Nicot & Ian J. Duncan, *Science-Based Permitting of Geological Sequestration of CO_2 in Brine Reservoirs in the U.S.*, 11 Envt'l Sci. & Pol'y 14, 21 (2008).
43. *Id.* at 17–18.

which site-specific permits be fast-tracked.[44] Consistent with our approach, their framework emphasizes passive geological safety characteristics and is intended to complement EPA's minimum performance-based standards.[45]

Two factors are critical to assessing the relative virtues of regulation versus liability: the latency of environmental harms and the information asymmetries between the private sector and the government. The greater the latency of leakage from carbon sequestration sites, the stronger the case for a pure regulatory regime and the less effective traditional common law liability. In opposition to this factor, the greater the information asymmetries between the private sector and the government, the more a liability regime is favored.

While significant uncertainties remain, scientific modeling has shown the latency for leakage of CO_2 is likely to last for many decades after injection, whereas releases of brine could arise within a decade.[46] If these projections prove accurate, the effectiveness of common law liability is likely to turn on the near-term risks associated with brine releases. In general, lower-ranked sites will be more likely to leak early than highly ranked sites. As such, these characteristics would enhance the relative deterrence value of a liability regime for lower-quality sites.

Information asymmetries will nevertheless persist with a federal site-ranking program. More detailed and new site information will become available only during the active CO_2 injection phase of a sequestration site.[47] While government regulations will require site operators to disclose at least some of this information, EPA's capacity to monitor operations and emerging reservoir data will be limited by resources and time. Consequently, information asymmetries could increase as operations at sequestration sites evolve and site operators gain direct experience.

The countervailing effects of latency and information asymmetries suggest three possible legal frameworks for the period spanning site selection, operation, and active post-closure. To the extent that latency is dominant, and thus liability largely ineffective, the Nicot-Duncan regulatory regime would be favored. Under this scheme, sites with lower scores could be subject to more stringent regulatory review and higher permitting fees, CO_2 mitigation credits could be discounted (if a U.S. market were established), or there could be some combination of both mechanisms.[48] If information asymmetries were dominant and latency minimal, a pure liability regime incorporating a system of strict liability for all sites would be favored.

By using strict liability to promote selection of higher quality sequestration sites but making selection contingent on well-established criteria for site quality, the hybrid approach has the potential to mitigate industry opposition without sacrificing safety or efficiency. This approach is viable because a surplus of high-quality sites will exist for the next several decades, and it will be most effective during the early stages of CCS deployment when knowledge is still being gained about the risks and reliability of sequestration sites. As the quality of information increases and the surplus of sites falls, we expect that the balance between regulation and liability will shift as more refined regulations become possible.

C. *Early-Stage Carbon Sequestration Projects*

The urgency surrounding mitigation of CO_2 emissions places a premium on facilitating rapid development of CCS. The need for additional incentives to encourage early entrants is significant, but the primary barriers to CCS deployment are the large upfront economic costs and remaining technological uncertainties, particularly with respect to capturing CO_2. Addressing them will require creative use of public-private partnerships, tax incentives, and direct subsidies, each of which has been incorporated into prior climate change bills in Congress, most notably the Waxman-Markey bill.[49] Tort liability is directed at negative externalities, whereas the primary barriers to deployment of CCS involve unrelated technological uncertainties that will not be affected by a liability cap.

The complementary roles that regulation and tort liability can play are of particular importance to geologic carbon sequestration. Overcoming public fears surrounding carbon sequestration will require concerted efforts by the industry, government, and non-governmental organizations to promote operational transparency and public understanding.

Transparency can be compelled through regulations or liability suits.[50] Tort liability also creates disincentives for companies to collect information that could be used against them in a lawsuit.[51] Ensuring regulations and tort liability are harmonized to promote transparency will be important because the industry will possess detailed site information that will not be available to state and federal agencies.[52] Reporting requirements applying to all CO_2 emissions ought to ensure that most of the relevant information is public, but it will be imperative that sequestration-site-specific reporting requirements are in place and rigorously enforced to ensure that regulations keep up with evolving sequestration technologies and knowledge.[53]

44. *Id.* at 18–19.
45. *Id.*
46. *See supra* Part I.B.
47. Chadwick, *supra* note 32, at 272–73.
48. Nicot & Duncan, *supra* note 42, at 18.
49. American Clean Energy and Security Act of 2009, H.R. 2454, 111th Cong. (2009) (as passed by the House of Representatives on June 26, 2009).
50. Thomas O. McGarity, *The Complementary Roles of Common Law Courts and Federal Agencies in Producing and Using Policy-Relevant Scientific Information*, 37 Envtl. L. 1027, 1029 (2007); Wendy E. Wagner, *When All Else Fails: Regulating Risky Products Through Tort Litigation*, 95 Geo. L.J. 693, 695–97 (2007).
51. *See, e.g.*, Wagner, *supra* note 50, at 697–98.
52. Tracey R. Lewis, *Protecting the Environment When Costs and Benefits Are Privately Known*, 27 Rand J. Econ. 819, 826–31 (1996).
53. Robert V. Percival, *Responding to Environmental Risk: A Pluralistic Perspective*, 14 Pace Envtl. L. Rev. 513, 528 (1997).

V. Conclusions

This Article challenges several misconceptions about the risks associated with geologic sequestration of CO_2 and the significance of open-ended legal liability. We have shown that the current debate is overly focused on the risks associated with CO_2 leakage and insufficiently attentive to the primary source of risk—releases of brine into drinking water aquifers. As a general rule, releases of brine are much more likely and are projected to occur much earlier in the lifecycle of a sequestration site than releases of CO_2.

Understanding the nature of these risks, particularly their modest impacts and relative simplicity, ought to diffuse the controversy over legal liability for CCS. As we have demonstrated, loss of incentives provided by long-term liability is ultimately of negligible importance. Nevertheless, near-term liability can play a meaningful role, albeit a limited one, if it is directed primarily at risks associated with releases of brine.

Our analysis also reveals principles of economic efficiency support imposing either strict liability or negligence, although a stronger case exists for strict liability. We advocate a two-tiered system of liability based on two distinct classes of decisions—site selection and operational judgments—operating in parallel with minimum federal performance standards. This tiered hybrid approach leverages public and private information to enhance efficiency; however, we ultimately advocate this approach to mitigate problems with low political viability that would be associated with an effort to impose strict liability on owners or operators of sequestration sites.