GEOLOGIC CARBON SEQUESTRATION: BALANCING EFFICIENCY CONCERNS AND PUBLIC INTEREST IN PROPERTY RIGHTS ALLOCATIONS

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Commercial scale deployment of geologic carbon sequestration (GCS) requires a settled legal framework to justify extensive up-front capital investments. A key missing piece in the current legal environment is allocation of property rights—specifically ownership of the subsurface pore space for permanent sequestration of captured carbon dioxide. This Article seeks to begin untangling the various claims to pore space ownership based on the operational and geologic characteristics of the GCS activity (e.g., enhanced oil recovery, coal bed methane extraction, inaccessible coal seams, saline aquifer or basalt formation). Sequestration operations in each of these geologic zones implicate unique property rights issues. In some jurisdictions, state legislatures have attempted to simplify disputes (and appease constituents) by allocating pore space to the surface estate. Other legislative efforts, although unsuccessful, have sought to vest these rights in the state. Approaching pore space ownership from an economic theory rather than responding to political influences, however, provides a perspicacious basis to balance competing interests (e.g., surface estate owners, energy companies seeking GCS alternatives to alleviate impacts of prospective carbon taxing) to maximize efficient use of this resource. Accordingly, this Article identifies and analyzes the competing property rights issues embedded within GCS operations from an economic efficiency perspective and proposes a resolution that balances individual property rights with the public good arising from robust GCS development.

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INTRODUCTION

In February 2010, President Obama established the Interagency Task Force on Carbon Capture and Storage (CCS) and charged the group with developing a plan to overcome barriers to the cost-effective deployment of technologies to capture carbon dioxide (CO_2) emissions from anthropogenic sources and subsequent injection in geologic formations for permanent isolation from the atmosphere.[1] CCS refers to the process of separating CO_2 from industrial and energy related sources, converting the CO_2 to a supercritical fluid,[2] transporting the condensed substance (usually via pipeline) to a long-term storage site, and injecting the CO_2 into geologic formations for permanent sequestration.[3] Although most commonly considered in conjunction with electric power generation or other fossil-fuel intensive industrial activities,[4] the increased emphasis on life cycle greenhouse gas (GHG) emissions under the federal renewable fuel standard,[5] especially with respect to corn-based ethanol,[6] may present an additional opportunity to employ CCS technology and reduce the carbon footprint of biofuels.[7] For example, an experimental CCS facility in Decatur, Illinois, captures emissions from the fermentation process used in ethanol production and injects the CO_2 into a geologic formation over seven thousand feet below the surface for permanent sequestration in a saline aquifer.[8]

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1. Memorandum from President Barack Obama on a Comprehensive Federal Strategy on Carbon Capture and Storage, 75 Fed. Reg. 6087 (Feb. 5, 2010).

2. A supercritical state exists for a substance when it exhibits properties intermediate to those of gasses and liquids. For CO_2, this is obtained when its temperature is above 31.1 degrees Celsius and its pressure is above 73.8 bar. Federal Requirements Under the Underground Injection Control (UIC) Program for Carbon Dioxide (CO_2) Geologic Sequestration (GS) Wells, 73 Fed. Reg. 43,492, 43,493–94 (proposed July 25, 2008) (to be codified at 40 C.F.R. pts. 144, 146) [hereinafter EPA Proposed CCS Permit Rules].

3. INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC), IPCC SPECIAL REPORT ON CARBON DIOXIDE CAPTURE AND STORAGE 3 (2005) [hereinafter IPCC, SPECIAL REPORT ON CCS].

4. *See id.* tbl.SPM.1 (listing potential industrial activities suitable for CCS activity). Domestically, the FutureGen Industrial Alliance refers to a public-private partnership to design, build, and operate a coal-fired, zero emission electric power generation plant that captures and sequesters GHG emissions. *See* FUTUREGEN ALLIANCE, http://www.futuregenalliance.org (last visited Jan. 24, 2011).

5. Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program, 75 Fed. Reg. 14,670, 14,670 (Mar. 26, 2010) (to be codified at 40 C.F.R. pt. 80) (discussing need for the Environmental Protection Agency (EPA) to make life cycle GHG determinations for various biofuel production pathways).

6. *Id.* at 14,785–88 (outlining life cycle GHG emission for a natural gas-fired, dry mill, corn ethanol plant). *See generally* ILL. STATE GEOLOGICAL SURVEY, EVALUATION OF CO_2 CAPTURE OPTIONS FROM ETHANOL PLANTS (2006), http://www.sequestration.org/publish/phase2_capture_topical_rpt.pdf (technical report describing capital and operating costs for capturing CO_2 emissions from ethanol production facilities in Illinois).

7. Erik G. Lindfeldt & Mats O. Westermark, *Biofuel Production with CCS as a Strategy for Creating a CO_2-Neutral Road Transport Sector*, 1 ENERGY PROCEDIA 4111 (2009) (discussing the ability to combine CCS with biofuel refining to minimize the carbon footprint of the transportation sector).

8. *See* Press Release, Archer Daniels Midland Co., ADM Receives $99.2 Million U.S. Department of Energy Grant for Second Carbon Sequestration Project (June 11, 2010), http://www.adm.com/Lists/PressRelease/Attachments/247/ADM%20Carbon%20Sequestration%20Release.pdf.

The Intergovernmental Panel on Climate Change (IPCC) previously identified geologic carbon sequestration as one of the key technologies available in the near term to reduce GHG emissions and mitigate climate change.[9] Several demonstration CCS projects exist in the United States, often with financial support from the U.S. Department of Energy.[10] Development of CCS beyond the experimental stage, however, requires removing several strategic barriers, one of which is the lack of a settled legal framework to justify the extensive capital investment necessary to deploy the technology on a commercial scale.[11] The Environmental Protection Agency (EPA), under authority of the Safe Drinking Water Act, is finalizing rules for permitting geologic carbon sequestration.[12] Establishment of the regulatory regime, however, is only part of the solution. There remains a pressing need to resolve the thicket of potential property rights claims to the geologic pore space in which to store the sequestered carbon dioxide.

Although several commentators have discussed, from a doctrinal perspective, potential legal regimes to justify the allocation of property rights in pore space and the redress of liability concerns,[13] they have, thus

9. IPCC, CLIMATE CHANGE 2007: MITIGATION OF CLIMATE CHANGE 256 (2007) [hereinafter IPCC, 2007 MITIGATION REPORT] (noting that fossil fuels comprise eighty percent of current world energy supply and adopting CCS technology as one of several potential solutions to GHG reductions); IPCC, CLIMATE CHANGE 2007: SYNTHESIS REPORT 60 (2007) [hereinafter IPCC, 2007 SYNTHESIS REPORT] (reporting that removal and storage of carbon dioxide from natural gas is a current technology and projecting commercialization of CCS for gas, biomass, and coal-fired electricity generation before 2030).

10. For a listing of CCS demonstration projects supported by the Department of Energy, see *Recovery Act: Carbon Capture and Sequestration from Industrial Sources*, U.S. DEP'T OF ENERGY, http://www3.fossil.energy.gov/recovery/projects/industrial_ccs.html (last updated Sept. 28, 2010).

11. As noted by the IPCC, cost estimates of a CCS system vary widely—from $6.6 to $131.3 per ton of CO_2 sequestered—and depend upon the emission source. IPCC, 2007 MITIGATION REPORT, *supra* note 9, at 287 tbl.4.5. A commercial scale CCS operation may sequester millions of tons per year and has an initial capital investment well over one billion dollars. *See* Paul Berrill, *Statoil Puts $3.7BN Price Tag on Norway's CCS Plant Plans*, RECHARGE (Feb. 11, 2009), http://www.rechargenews.com/business_area/finance/article171819.ece; Jerry R. Fish, CCS: Property Law and Liability Issues, Presentation to Cal. Carbon Capture and Storage Review Panel 26 (Apr. 22, 2010), http://www.climatechange.ca.gov/carbon_capture_review_panel/meetings/2010-04-22/presentations/CCS-Property_Law_and_Liability_Issues.pdf (noting multi-billion dollar cost of CCS facilities).

12. EPA Proposed CCS Permit Rules, *supra* note 2. As this Article went to press, the EPA published its final rule. *See* Federal Requirements Under the Underground Injection Control (UIC) Program for Carbon Dioxide (CO_2) Geologic Sequestration (GS) Wells, 75 Fed. Reg. 77,230 (Dec. 10, 2010) (to be codified at 40 C.F.R. pts. 124, 144, 145, 146, 147).

13. *See* TASK FORCE ON CARBON CAPTURE AND GEOLOGIC STORAGE, INTERSTATE OIL AND GAS COMPACT COMM'N, STORAGE OF CARBON DIOXIDE IN GEOLOGIC STRUCTURES: A LEGAL AND REGULATORY GUIDE FOR STATES AND PROVINCES 3 (2007) [hereinafter IOGCC REGULATORY GUIDE]; Owen L. Anderson, *Geologic CO_2 Sequestration: Who Owns the Pore Space?*, 9 WYO. L. REV. 97 (2009); 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 (2008); Alexandra B. Klass & Elizabeth J. Wilson, *Climate Change, Carbon Sequestration, and Property Rights*, 2010 U. ILL. L. REV. 363 (2010) [hereinafter Klass & Wilson, *Property Rights*]; Tracy J. Logan, Comment, *Carbon Down Under—Lessons from Australia: Two Recommendations for Clarifying Subsurface Property Rights to Facilitate Onshore Geologic Carbon Sequestration in the United States*, 11 SAN DIEGO INT'L L.J. 561 (2010); Philip M. Marston & Patricia A. Moore, *From EOR to CCS: The Evolving Legal and Regulatory Framework for Carbon Capture and Storage*, 29 ENERGY L.J. 421 (2008); Larry Nettles & Mary Conner, *Carbon Dioxide Sequestration—Transportation, Storage, and*

far, neglected to analyze the issue from an economic efficiency perspective. Also absent from current scholarship is a discussion of how a landowner presented with an easement for pore space to conduct carbon sequestration operations can begin to untangle the existing web of property rights (e.g., surface, coal, oil, and gas) allocated and distributed as a matter of state property law. This Article, through a case study of two CCS projects in Illinois, seeks to begin the untangling process.

Part I of this Article explores the economic theory of property rights developed by Professor Coase[14] and the anticommons concept described by Professor Heller.[15] In theory, establishment of a property right excludes others from unauthorized use of the resource and facilitates market-based transactions in the right to possess the resource. This enables market mechanisms to shift resource allocations toward an economically efficient distribution—in this case, use of pore space for geologic carbon sequestration. A necessary first step in determining potential claims to subsurface property rights for carbon sequestration is to characterize the CCS operation and accompanying pore space (e.g., enhanced oil recovery,[16] saline aquifer,[17] or basalt formation[18]). Each cate-

Other Infrastructure Issues, 4 TEX. J. OIL, GAS & ENERGY L. 27 (2008); Elizabeth J. Wilson & Mark A. de Figueiredo, *Geologic Carbon Dioxide Sequestration: An Analysis of Subsurface Property Law*, 36 ENVT'L L. REP. 10114 (2006).

14. *See* R.H. Coase, *The Federal Communications Commission*, 2 J.L. & ECON. 1 (1959) (arguing that the government can avoid regulation to obtain efficient outcomes so long as there are established property rights and the ability to exchange these rights via a market).

15. *See* Michael A. Heller, *The Tragedy of the Anticommons: Property in the Transition from Marx to Markets*, 111 HARV. L. REV. 621 (1998) (defining anticommons property and the potential for underutilization as a result of multiple owners exercising the right to exclude).

16. Enhanced oil recovery (EOR) refers generally to the process of injecting fluid (including compressed CO_2 in supercritical state) into an oil or gas reservoir to recover residual oil or gas. The injected fluid decreases the viscosity and/or displaces the remaining oil and gas, freeing it for recovery from the well site. *See* EPA Proposed CCS Permit Rules, *supra* note 2, at 43,493; *see also Enhanced Oil Recovery/CO_2 Injection*, U.S. DEP'T OF ENERGY, http://www.fossil.energy.gov/programs/oilgas/eor/ (last updated Jan. 13, 2011) (describing EOR technology and potential). CO_2 injected during the recovery process subsequently could be stored in the depleted oil or gas well and permanently sequestered from the atmosphere. *See Geologic Sequestration Research*, U.S. DEP'T OF ENERGY, http://www.fossil.energy.gov/programs/sequestration/geologic/index.html (last updated Aug. 23, 2010). For a map of the CO_2 storage potential in the Illinois Basin area from EOR, see *CO_2 Storage Potential for Illinois Basin Oil Fields*, MIDWEST GEOLOGICAL SEQUESTRATION CONSORTIUM (Dec. 2005), http://www.sequestration.org/publish/oil_co2_map_dec05.pdf.

17. A saline aquifer is comprised of "[d]eep and geographically extensive sedimentary rock layers saturated with waters or brines that have a high total dissolved solids (TDS) content (i.e., over 10,000 mg/L TDS)." EPA Proposed CCS Permit Rules, *supra* note 2, at 43,494. Dissolved minerals in saline formations could react with injected CO_2 to form solid carbonates, ensuring permanent sequestration from the atmosphere. Carbonate-forming reactions, although increasing permanence, also have the potential to plug the geologic formation in the immediate vicinity of the injection well, thereby hindering additional CO_2 sequestration. *See Carbon Sequestration*, NAT'L ENERGY TECH. LAB., http://www.netl.doe.gov/technologies/carbon_seq/core_rd/storage.html (last visited Jan. 24, 2011). Because many saline aquifers are at considerable depth, the earth ambient pressure and temperature will preserve the supercritical fluid nature of CO_2. *See* Marston & Moore, *supra* note 13, at 439. For a map of the CO_2 storage potential in saline aquifers in the Illinois Basin area, see *CO_2 Storage Potential for the Mt. Simon and St. Peter Sandstones in the Illinois Basin*, MIDWEST GEOLOGICAL SEQUESTRATION CONSORTIUM (Dec. 2005), http://www.sequestration.org/publish/saline_co2_map_dec05.pdf (map of sequestration potential).

gory of pore space implicates unique property rights issues that both CCS operators and landowners must navigate before proceeding with an agreement for sequestration activities. The lack of defined property rights, high transaction costs, and imperfect information within the context of geologic carbon sequestration, however, predict an inability of a purely market-based system to efficiently order pore space usage. Rather, these conditions may lead to what Professor Heller describes as a "tragedy of the anticommons" in which too many holders of property rights result in the underutilization of a resource.[19] Due to the unique, overlapping nature of subsurface property rights and novel use of these previously inaccessible geographic strata, the initial allocation of pore space ownership is a critical gap in current legal regimes and some form of government intervention may be required to facilitate a functioning market in pore space for geologic carbon sequestration.

In three states—Wyoming, Montana, and North Dakota—legislatures have attempted to simplify property rights issues by allocating pore space to the surface estate owner.[20] These efforts undoubtedly fill a critical gap in current legal regimes, but may not be a preferred option. Part II briefly describes the implications of these legislative initiatives and unresolved issues. Part III explores CCS operations in Illinois—one of the most desirable locations for CCS due to favorable subsurface geologic formations and proximity to GHG intensive industries.[21] The divergent approaches adopted by two CCS operations to secure rights in pore space further illustrate the current legal confusion confronting this nascent industry in states without settled property rights regimes and why legislative action may be a necessary precursor to attracting the capital investment required for further development of a commercial CCS industry.

If a property right is an essential element for the development of the industry, must it be a privately held right vested in either the surface or mineral estate?[22] Most commentators to date start with the assumption

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18. "Basalt formations are geologic formations of solidified lava. Basalt formations have a unique chemical makeup that could potentially convert all of the injected CO_2 to a solid mineral form, thus isolating it from the atmosphere permanently." *Carbon Sequestration*, *supra* note 17; *see also* B. Peter McGrail et al., *Potential for Carbon Dioxide Sequestration in Flood Basalts*, 111 J. GEOPHYSICAL RES. B12201 (2006) (generally describing sequestration models for basalt formations).

19. Heller, *supra* note 15, at 668.

20. *See infra* Part II (discussing the statutory regimes in the three states).

21. "The ideal geologic formation for CO_2 sequestration offers large storage capacity per unit of reservoir volume, with a caprock that prohibits vertical migration of CO_2." *Screening Criteria for Geologic CO_2 Sequestration*, MIDWEST GEOLOGICAL SEQUESTRATION CONSORTIUM, http://www.sequestration.org/sc_abstract.htm (last visited Jan. 24, 2011); *see also Screening Criteria for Geologic CO_2 Sequestration: Stratigraphic Column for the Illinois Basin Showing Vertically Stacked Reservoirs*, MIDWEST GEOLOGICAL SEQUESTRATION CONSORTIUM, http://www.sequestration.org/sc_strat.htm (last visited Jan. 24, 2011) (indicating graphically the alternating caprock and potential pore space areas for geologic carbon sequestration in the Illinois Basin).

22. The concept of a mineral estate is an admittedly vague, constantly changing term. *See* OWEN L. ANDERSON ET AL., HEMINGWAY OIL AND GAS LAW AND TAXATION 1–2 (4th ed. 2004). Within the context of this Article, the term "mineral estate" refers to a general subsurface property interest in a

that one of these two estates in land also has rights to pore space for geologic sequestration.[23] Part IV steps back and explores this assumption. If, as many claim, CCS is a critical component of mitigating global climate change and due to the market's failure to internalize the costs of GHG emissions—does responsibility now fall on the government to implement policies to reduce GHG emissions and mitigate climate change? If so, should the government allocate this heretofore undifferentiated and unused subsurface property right to the private sector or reserve this to the government in trust for the public? Despite our propensity to allocate all property rights to the private sector,[24] legislatures remain free to create or abolish nonvested rights.[25] Subsurface interests in pore space not associated with hydrocarbon recovery is a nonvested right. As discussed below, the concept of government ownership of new property interests is not without precedent, as one only needs to look to the government's reservation of property rights accompanying other new technologies such as the airspace above the surface estate for air travel or government control of radio frequencies. Property rights in pore space, especially in deep saline aquifers or basalt formations, may be another candidate for initial public ownership with subsequent allocation to the private sector (whether as a free public good or market based) in a manner designed to achieve policy priorities at the lowest cost to society.

I. A COASIAN APPROACH TO PORE SPACE OWNERSHIP

Although most commonly known for his seminal work with respect to property rights and liability in *The Problem of Social Cost*,[26] Professor Coase's earlier article, *The Federal Communications Commission*,[27] which served as the basis for his later, more famous article,[28] provides an analogous theoretical framework from which to approach allocation of property rights in pore space for geologic carbon sequestration.

In *The Federal Communications Commission*, Coase describes the chaotic state of the use of radio frequencies prior to the passage of the Radio Act of 1927 and subsequent amendment by the Communications

commodity resource (e.g., coal, oil, gases, and metallic substances) and the right of reasonable use of the surface estate to extract the resource.

23. *See infra* Part I.A (discussing prior scholarship regarding subsurface ownership rights).

24. *See* RICHARD A. POSNER, ECONOMIC ANALYSIS OF LAW 33 (6th ed. 2003); *see also* ERIC T. FREYFOGLE, *The Lure of Privatization*, *in* THE LAND WE SHARE: PRIVATE PROPERTY AND THE COMMON GOOD 157, 161 (2003) (criticizing a default rule of privatization of commons as best environmental policy).

25. Silver v. Silver, 280 U.S. 117, 122 (1929) ("[T]he Constitution does not forbid the creation of new rights, or the abolition of old ones recognized by the common law, to attain a permissible legislative object."); Spear T Ranch, Inc. v. Knaub, 691 N.W.2d 116, 133 (Neb. 2005) ("The Legislature is free to create and abolish rights as long as no vested right is disturbed."); Rosenberg v. Town of N. Bergen, 293 A.2d 662, 667 (N.J. 1972) ("The Legislature is entirely at liberty to create new rights or abolish old ones as long as no vested right is disturbed.").

26. R.H. Coase, *The Problem of Social Cost*, 3 J.L. & ECON. 1 (1960).

27. Coase, *supra* note 14.

28. Coase, *supra* note 26, at 1 n.1.

Act of 1934.[29] Justice Frankfurter, writing for the Court in *National Broadcasting Co. v. United States*, noted that the eventual governmental control via regulation of the radio frequencies was as vital to the development of the broadcasting industry "as traffic control was to the development of the automobile."[30] The inference from Justice Frankfurter's comment is that some form of government regulation was essential to maximize utilization of this new technology within the context of a constrained resource (i.e., a limited number of interference-free radio frequencies in a given area is similar to the limited number of cars that can enter an intersection without a collision or gridlock).

Coase disagreed, noting that almost all resources used in an economic system (e.g., land, labor, and capital, in addition to radio frequencies) have limited quantities, but are not subject to government allocation.[31] Rather, a price mechanism can, and should, allocate resources in an economically efficient manner without the need for government oversight.[32] The problem with overlapping use of radio frequencies that led to the Radio Act, according to Coase, was not an inherent problem in the form of the resource,[33] but rather stemmed from the absence of an enforceable property right in the radio frequencies that would exclude unfettered use by nonowners.[34]

> A private-enterprise system cannot function properly unless property rights are created in resources, and, when this is done, someone wishing to use a resource has to pay the owner to obtain it. Chaos disappears; and so does the government except that a legal system to define property rights and to arbitrate disputes is, of course, necessary.[35]

More than eighty years after passage of the 1927 Act, and more than fifty years after Coase's writings on this topic, the developing CCS industry faces a similar chaotic atmosphere with respect to ownership of subsurface pore space for geological sequestration activities. Interestingly, Coase discussed one example of subsurface property ownership—a newly discovered cave.[36] Does the cave belong to the person who discovered it, the person on whose land is the entrance to the cave, or the per-

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29. Coase, *supra* note 14, at 2–6 (describing the turmoil in the use of radio frequencies and the repeated calls by several organizations to establish government control and the eventual passage of the Radio Act of 1927, Pub. L. No. 69-632, 44 Stat. 1162, and its eventual amendment by the Communications Act of 1934, Pub. L. No. 73-416, 48 Stat. 1064 (codified as amended in scattered sections of 47 U.S.C.).

30. 319 U.S. 190, 213 (1943).

31. Coase, *supra* note 14, at 14.

32. *Id.*

33. Coase uses the example of a tract of land to illustrate the chaotic effect in the absence of property rights. One person could use the land to plant crops. A second could come along, remove the crops and construct a building. Finally, a third person could tear down the structure, pave over the land and create a parking lot. *Id.* Without property rights and a corresponding requirement to pay the previous owner for the right to use the land, economic confusion persists. *Id.*

34. *Id.*

35. *Id.*

36. *Id.* at 25.

son who owns the surface estate under which the cave lies?[37] From an economic efficiency perspective, the answer, according to Coase, does not matter, as the law of property may determine who "owns" the cave, but the ultimate use of the cave, whether for "storing bank records, as a natural gas reservoir, or for growing mushrooms depends, not on the law of property"—but upon which entity is willing to pay the most in order to be able to use the cave.[38] The socially optimal allocation is independent upon the initial ownership as determined by the property laws. Accordingly, "[o]ne of the purposes of the legal system is to establish . . . clear delimitation of rights on the basis of which the transfer and recombination of rights can take place through the market."[39]

Based on the previous discussion, one could conclude that eventual development of the CCS industry (and the resulting socially beneficial impact of mitigating climate change) is independent of pore space ownership. If the value of the pore space for carbon sequestration results in the highest value use of the property, the market will allocate these pore space rights to the CCS industry through pricing mechanisms. The socially efficient outcome is independent of the initial allocation of pore space ownership. This, however, is only part of the story, as initial allocation of property rights matters—and matters a lot—to the financial welfare of the individual.[40] Again, one must look to the individual landowner approached with an easement for carbon sequestration. If this individual has a property right in the pore space, he or she can expect compensation for the transfer of this right to another entity. If not, then some other individual (e.g., mineral estate holder) stands to benefit from the transfer.

Before moving to an analysis of the individual's legal rights to pore space, it is important to further explore underlying economic theory. The metamorphosis of Coase's theorem into actuality depends upon the existence of three fundamental conditions to create a frictionless market: well defined property rights in the resource, low transaction costs, and perfect information between the parties.[41] As discussed below, the current legal environment for the CCS industry fails on all three counts. Moreover, to the extent the legal system defines property rights in pore space and the attendant "right to exclude" from this geologic formation, the developing CCS industry faces yet another potential barrier—the

37. *Id.*

38. *Id.*

39. *Id.*

40. Professors Calabresi and Melamed refer to this concept as "distributional preferences." *See* Guido Calabresi & A. Douglas Melamed, *Property Rules, Liability Rules, and Inalienability: One View of the Cathedral*, 85 HARV. L. REV. 1089, 1093 (1972).

41. *See* Coase, *supra* note 26, at 15. "Of course, if market transactions were costless, all that matters (questions of equity apart) is that the rights of the various parties should be well-defined and the results of legal actions easy to forecast." *Id.* at 19.

tragedy of the anticommons.[42] An "anticommons" exists when "multiple owners are each endowed with the right to exclude others from a scarce resource, and no one has an effective privilege of use."[43] A "tragedy" may result "[w]hen there are too many owners holding rights of exclusion" such that "the resource is prone to underuse."[44] If ownership of subsurface pore space for geological sequestration resides in multiple owners (whether the surface or the mineral estate), each with a power to exclude, and the injected CO_2 has the potential to migrate across multiple (tens or even hundreds) property boundaries, the anticommons effect may result in use of pore space for CCS operations at an inefficient level. Tragedy may be averted and resources (i.e., pore space) put to its highest and best use in Coase's theoretical world of costless transactions and nonstrategic behavior.[45] On the other hand, as Professor Heller notes, an anticommons tragedy may exist "in a world of positive transaction costs, strategic behavior, and imperfect information."[46] Accordingly, the following Sections explore the issues of property rights, transaction costs, and information exchanges within the CCS context.

A. Defining the Property Right: Initial Allocation of Pore Space Ownership

As noted by several commentators, property rights for pore space are ill defined and, depending on the character of the operation, may implicate both surface and subsurface interests.[47] For example, Professor Anderson's analysis of Texas property law concluded that the surface estate owner has a stronger argument for ownership of pore space *vis á vis* the mineral estate owner, so long as the CO_2 sequestration rights are not related to enhanced oil recovery.[48] The consensus among other commentators is in accordance with Anderson; the judiciary may interpret storage rights and mineral rights differently,[49] but so long as the geologic carbon sequestration is in conjunction with the production of an underlying mineral right (e.g., enhanced oil recovery, coal bed methane extraction), the owner of the mineral estate controls the pore space.[50] As the mineral estate, absent an agreement to the contrary, is "dominant" with respect to the surface estate, the owner of the mineral right is entitled to use as

42. *See generally* Heller, *supra* note 15 (defining anticommons property and the potential for underutilization as a result of multiple owners exercising the right to exclude).

43. *Id.* at 624.

44. *Id.*

45. *Id.* at 625–26, 673–74.

46. *Id.* at 676.

47. *See supra* note 13 and accompanying text (citing various commentaries on pore space ownership).

48. Anderson, *supra* note 13, at 106.

49. *See* Wilson & de Figueiredo, *supra* note 13, at 10121.

50. *See* IOGCC REGULATORY GUIDE, *supra* note 13, at 20; Klass & Wilson, *Property Rights*, *supra* note 13, at 403–04; Wilson & de Figueiredo, *supra* note 13, at 10118.

much of the surface estate as is reasonably necessary to access the minerals.[51]

The assumption underlying this conclusion with respect to pore space ownership—ongoing mineral extraction—may not always hold true. Eventually, all of the recoverable minerals will be extracted and the resulting pore space used exclusively for geologic carbon sequestration. Does the fact that trace amounts of the mineral remain in the geologic formation perpetuate the right of the mineral estate to continue carbon sequestration activities?[52] If some minerals remain *in situ* but mineral recovery ceases, what royalties or other compensation is the surface estate owner entitled to for these purely sequestration operations? Courts have reached different conclusions on ownership of pore space created by the previous extraction of mineral resources,[53] but, not surprisingly, none have addressed this within the context of permanent geologic carbon sequestration. Due to the lack of consistent case law on pore space ownership in conjunction with mineral extraction, the cautious approach for a CCS operator would be to obtain permission from both the surface estate and mineral estate owners.[54]

Although far from well-defined, property rights in certain mineral estates are much more certain than ownership of pore space in saline aquifers or basalt formations for geologic carbon sequestration. These proposed new uses of newly functional geologic formations present novel questions of property law that lack clear guidance from other areas of law upon which to draw analogies.[55] Resolving this ownership question to facilitate CCS operations in these geological strata is critical, as even

51. 1 EUGENE KUNTZ, A TREATISE ON THE LAW OF OIL AND GAS § 3.2 (1987); Herbert C. Manning, *Mineral Rights Versus Surface Rights*, 2 NAT. RESOURCES L. 329, 330–31 (1969).

52. For example, mineral rights owners may retain a "cushion" of gas in a formation subsequently used for natural gas storage and thus require compensation in the storage context. *See* Wilson & de Figueiredo, *supra* note 13, at 10122; *see also* Cont'l Res. of Ill., Inc. v. Ill. Methane, LLC, 847 N.E.2d 897, 902 (Ill. App. Ct. 2006) (holding that Illinois follows the container space doctrine, which states that the "holder of coal rights also holds the rights to the void after the coal is mined"); Jerry R. Fish & Thomas R. Wood, *Geologic Carbon Sequestration: Property Rights and Regulation*, 54 ROCKY MTN. MIN. L. INST. 3-1, 3-12 & n.37 (2008), www.stoel.com/files/GeologicCarbonSequestration.pdf (discussing *Department of Transportation v. Goike*, 560 N.W.2d 365, 366 (Mich. Ct. App. 1996), for the principle that the surface owner has no right to use pore space until the mineral owner has extracted the remaining gas).

53. *See* Anderson, *supra* note 13, at 106 (questioning whether the mineral estate owns title in generic, naturally occurring subsurface pore space that was not created by the mineral owners' extraction of a mineral deposit); Klass & Wilson, *Property Rights*, *supra* note 13, at 402 n.263 (citing cases and commentary); Wilson & de Figueiredo, *supra* note 13, at 10121 (noting different treatment by courts).

54. Anderson, *supra* note 13, at 99.

55. *See* Victor B. Flatt, *Paving the Legal Path for Carbon Sequestration from Coal*, 19 DUKE ENVTL. L. & POL'Y F. 211, 234 (2009) ("[T]here is virtually no case law on the use of saline aquifers for storage and associated property rights."); Wilson & de Figueiredo, *supra* note 13, at 10117 (arguing that property rights of saline aquifers for use in geologic carbon sequestration is a function of the jurisdiction's treatment of groundwater withdrawal); Thomas R. DeCesar, Comment, *An Evaluation of Eminent Domain and a National Carbon Capture and Geologic Sequestration Program: Redefining the Space Below*, 45 WAKE FOREST L. REV. 261 (2010) (discussing ambiguity in saline aquifers ownership).

conservative estimates of the North American CO_2 storage potential in deep saline formations is more than twenty times the potential storage capacity in conjunction with enhanced oil recovery.[56] To place the amounts in the chart below into perspective, three thousand gigatons of storage space is enough to sequester the combined CO_2 emissions over one thousand years from one thousand coal-fired power plants.[57]

TABLE 1

Geologic Formation	CO_2 Storage Estimate in Gigatons	
	LOW	HIGH
Deep Saline Aquifer	3300	12,600
Oil and Gas Field	140	140
Unmineable Coal Seam	160	160

As a starting point, the ancient doctrines of *ad coelum* and *ad inferos* allocate to the surface estate owner dominion over the airspace above and geologic formations below the Earth's surface.[58] In 1946, however, the Supreme Court, within the context of a dispute over low-flying airplanes, noted that the doctrine of *ad coelum* "has no place in the modern world,"[59] but that the surface estate owner controls only as much space above the ground as can be used in connection with the land.[60] Professors Klass and Wilson conclude that the dual effect of a significant public interest in airspace rights and explicit Congressional recognition of this public interest via enactment of the Air Commerce Act of 1926[61] provided courts justification for limiting a landowner's protectable property interests.[62] Unlike the relatively early severing of airspace from the surface estate before the full-scale development of other potentially infringing activities on the resource, subsurface rights have long been viewed as severable from the surface estate, with many of the competing uses squarely in the public interest.[63] This theoretical difference, however, has not prevented courts from applying limits to the *ad inferos* doctrine based on factors articulated in various interpretations of *ad coelum* principles.[64] As described by Professor Sprankling, just as the *ad coelum*

56. *Carbon Sequestration*, *supra* note 17.

57. *See* EPA Proposed CCS Permit Rules, *supra* note 2, at 43,496.

58. *See* United States v. Causby, 328 U.S. 256, 260–61 (1946); *see also* Laird v. Nelms, 406 U.S. 797, 799–800 (1972) (citing *United States v. Causby* as support for denying plaintiff's trespass claim arising from sonic booms created by military aircraft).

59. *Causby*, 328 U.S. at 261.

60. *Id.* at 264.

61. Pub. L. No. 69-254, 44 Stat. 568.

62. Klass & Wilson, *Property Rights*, *supra* note 13, at 388.

63. *Id.* at 389 (noting competing public interest of oil and gas development, groundwater, natural gas storage, etc.).

64. *See id.* at 401 (discussing court's rejection of the *ad coelum* doctrine within the context of hazardous waste injection and claims for trespass); *see also* John G. Sprankling, *Owning the Center of the Earth*, 55 UCLA L. REV. 979, 982 (2008) (arguing for limits on the depth at which private property rights may extend and reserving the balance for the federal government). *But see* Kankakee Cnty. Bd. of Review v. Prop. Tax Appeal Bd., 871 N.E.2d 38, 47 (Ill. 2007) (stating in dicta that the surface estate

doctrine crumbled with the invention of the airplane, so too should the doctrine of *ad inferos* yield with implementation of new subsurface technologies.[65]

Although not framed precisely within the context of the *ad inferos* doctrine, limitations on the property rights attached to the use of groundwater provide guidance on who may own saline aquifers.[66] The law of water rights, unfortunately, suffers from much of the same complexity as defining the mineral estate. More importantly, with only limited exceptions discussed below,[67] a water right confers only a usufructuary right to use a water flow, rather than an ownership interest in the water itself or the subterranean space occupied by the water.[68]

For example, in *Clark v. Lindsay Light & Chemical Co.*, the Illinois Supreme Court held that the riparian owner had no property interest in surface waters running over the land, but merely a usufruct in the water as it passes.[69] The same principles apply to groundwater in Illinois. Under the Water Use Act of 1983, a usufructuary rule of reasonable use applies to groundwater, replacing the previous rule of absolute ownership.[70] The Florida Supreme Court adopted a similar rule in *Village of Tequesta v. Jupiter Inlet Corp*., holding that even under the more expansive common law rule of absolute dominion, "ownership" of groundwater never meant "a property or proprietary interest in the corpus of the water itself. . . . The right of the owner to ground water underlying his land is to the usufruct of the water and not to the water itself."[71] Several other states, including California, have similar usufructuary rules relating to the appropriation of groundwater without establishing a possessory right.[72]

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owns the land to the "center of the Earth" within the context of a tax assessment for natural gas storage).

65. Sprankling, *supra* note 64, at 981.

66. *See* Logan, *supra* note 13, at 588–89 (noting the lack of distinction between historically useable freshwater aquifers and saline, non-potable aquifers); Wilson & de Figueiredo, *supra* note 13, at 10117–18 (discussing the five major doctrines with respect to ownership of groundwater); DeCesar, *supra* note 55, at 273–74 (same).

67. *See infra* notes 71–72 and accompanying text (discussing freshwater storage rights).

68. *See* Adam Mossoff, *Exclusion and Exclusive Use in Patent Law*, 22 HARV. J.L. & TECH. 321, 333–34 (2009) (describing use rights in water law as point of departure for comparison of patent use rights).

69. 89 N.E.2d 900, 902 (Ill. 1950); *see also* Druley v. Adam, 102 Ill. 177, 193 (1882) ("[O]wner of land over which a stream of water flows, has, as incident to his ownership of the land, a property right in the flow of the water . . . in other words, he has a *usufruct* in the water while it passes . . . .").

70. 525 ILL. COMP. STAT. 45/6 (2006) (establishing a reasonable use rule for groundwater withdrawals).

71. Village of Tequesta v. Jupiter Inlet Corp., 371 So. 2d 663, 667 (Fla. 1979).

72. *See* City of Barstow v. Mojave Water Agency, 5 P.3d 853, 860 n.7 (Cal. 2000) ("Both riparian and overlying water rights are usufructuary only, and while conferring the legal right to use the water that is superior to all other users, confer no right of private ownership . . . ."); *In re* Application U-2, 413 N.W.2d 290, 298 (Neb. 1987) ("The protected right of landowners is the right to the use of the ground water, and does not reach the ownership of the water itself."); *In re* Town of Nottingham, 904 A.2d 582, 592 (N.H. 2006) (quoting *Village of Tequesta* for the proposition that groundwater rights are a "use" right rather than a possessory right).

The legal status of deep saline aquifers are relevant in the CCS context not for the usufructuary interest in extracting the brine, but rather for the possessory use of the pore space in which the aquifer exists to inject carbon dioxide for sequestration. Some commentators seem to conclude that because the surface estate has a right to the groundwater, the right to the pore space containing the groundwater also attaches to the surface estate owner.[73] But a usufructuary interest is not a possessory interest.[74] To the contrary, it is akin to an easement or license.[75] Because there is no possessory interest in groundwater, actions for trespass or conversion are unavailable.[76] Accordingly, it follows that a usufructuary right to groundwater does not *a priori* include an ownership interest in the physical space occupied by the aquifer. Determination of dominion over the aquifer's pore space, therefore, is a function of general property law of the state rather than groundwater use rights.

A few recent cases regarding subsurface freshwater storage rights do implicate pore space ownership. In states with freshwater shortages, such as Florida, California, or Colorado, water is stored in subsurface basins through a process of withdrawal and recharging.[77] As a general rule, public entities or individuals with permits have the right to inject the water into the subsurface basin without compensating surface owners, and they also retain ownership of the stored water.[78] For example, in *Alame-*

73. *See* Flatt, *supra* note 55, at 234–35 (discussing control of aquifer without distinguishing between usufructuary right to water and control of accompanying pore space); Klass & Wilson, *Property Rights*, *supra* note 13, at 411 (discussing whether displaced brines from CO_2 sequestration would give rise to a physical takings claim based on the surface estate owners); Nettles & Conner, *supra* note 13, at 45–47 (assuming that fee simple owner owns all underground storage space unless interest severed into mineral estate and surface estate); Wilson & de Figueiredo, *supra* note 13, at 10117 (discussing ownership of groundwater rights). *But see* Klass & Wilson, *Property Rights*, *supra* note 13, at 393 (acknowledging that it is important to focus on the ownership of the space more so than ownership of the resource and putting aside the issue of subsurface water); Logan, *supra* note 13, at 589 ("[W]ater law provides no regulatory guidance regarding ownership of the [aquifer] formations themselves."); DeCesar, *supra* note 55, at 274 (distinguishing between groundwater rights and the subterranean pore space).

74. Spear T Ranch, Inc. v. Knaub, 691 N.W.2d 116, 127 (Neb. 2005).

75. *See* 3 HERBERT THORNDIKE TIFFANY, THE LAW OF REAL PROPERTY § 841 (3d ed. 1939) (stating that the right to take water is an easement); *id.* § 829 (stating that a license does not confer a possessory interest).

76. "Trespass is unavailable in a typical well interference case because a physical invasion of the plaintiff's property is lacking. Similarly, an action in conversion is unavailable, since the plaintiff has no private property interest in groundwater, at least not prior to capture." *Spear T Ranch, Inc.*, 691 N.W.2d at 127 (quoting RICHARD S. HARNSBERGER & NORMAN W. THORSON, NEBRASKA WATER LAW & ADMINISTRATION § 5.27, at 266–67 (1984)); *see also* W. PAGE KEETON ET AL., PROSSER AND KEETON ON TORTS § 13, at 77 n.92 (5th ed. 1984) ("A mere licensee, having no interest in the premises, can bring no action for trespass . . . . The same is true of the holder of an easement.") (internal citations omitted).

77. *See generally* Michael L. Merritt, *Subsurface Storage of Freshwater in South Florida: A Digital Model Analysis of Recoverability* (U.S. Geological Survey Water-Supply, Working Paper No. 2261, 1985).

78. *See* Kevin S. Hennessy & R. David Jackson Lewis, *What You Gonna Do When the Well Runs Dry? Protection of Rights to ASR Water*, WATER RESOURCES COMMITTEE NEWSL. (ABA, Chicago, Ill.), Jan. 2010, at 5, 9; Tara L. Taguchi, Comment, *Whose Space Is It, Anyway?: Protecting the Public Interest in Allocating Storage Space in California's Groundwater Basins*, 32 SW. U. L. REV. 117, 135–37 (2003).

da County Water District v. Niles Sand & Gravel Co., a California appellate court held that underground storage rights for water act as a limitation on overlying private property rights.[79] Colorado's approach is slightly different, but reaches the same result regarding pore space ownership. The right to inject water into a subsurface basin in Colorado for later withdrawal vests with the right of a private individual to use groundwater, without consideration of rights held by the surface estate.[80]

This is an important distinction from the national regime for natural gas storage[81] whereby the entity injecting the gas for storage has the right of eminent domain, but must compensate the surface estate.[82] In the groundwater context, the individual injecting freshwater to recharge the aquifer does not have to compensate the surface owners for use of the pore space underlying their land. Thus, a property rights rule based on the freshwater storage analogy, whereby the state retains ownership of aquifer pore space, could simplify otherwise disparate property law rules regarding ownership and compensation issues for CCS operations injecting into saline aquifers.

B. Transaction Costs in Securing Pore Space Ownership

In addition to the relatively unsettled nature of subsurface possessory interests, suitable pore space for a commercial-scale geologic sequestration project conceivably could span thousands of surface and subsurface property boundaries as the injected CO_2 migrates to fill the available space.[83] The Midwest Geologic Sequestration Consortium (MGSC) has identified potential sequestration storage potential in the Illinois Basin area[84] in both saline aquifers and as part of enhanced oil recovery operations. Potential pore space locations, not surprisingly, do not conform to the grid system of property boundaries laid out in the

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79. 112 Cal. Rptr. 846, 853 (Cal. Ct. App. 1974).

80. As the Supreme Court of Colorado explained,

> "[T]he holders of water use rights may employ underground as well as surface water bearing formations in the state *for the placement of water into*, occupation of water in, conveyance of water through, and withdrawal of water from the natural water bearing formations in the exercise of water use rights."

Bd. of Cnty. Comm'r v. Park Cnty. Sportsmen's Ranch, LLP, 45 P.3d 693, 710 (Colo. 2002) (emphasis added).

81. Natural gas distributors often inject natural gas into depleted oil and gas fields, aquifers, and salt caverns for off-season storage. *The Basics of Underground Natural Gas Storage*, U.S. ENERGY INFO. ADMIN., http://www.eia.doe.gov/pub/oil_gas/natural_gas/analysis_publications/storagebasics/storagebasics.html (last updated Aug. 2004).

82. For a discussion of the Natural Gas Act and court interpretation of the gas storage provisions, see Klass & Wilson, *Property Rights*, *supra* note 13, at 401–03.

83. *See* IPCC SPECIAL REPORT ON CCS, *supra* note 3, at 202 (describing the Sleipner North Sea commercial-scale CCS project and noting that a plume comprised of a total of only seven metric tons of CO_2 injected into a saline aquifer formation since 1996 has migrated five square kilometers); *see also id.* at 205–10 (discussing post-injection migration of CO_2 in various geologic formations).

84. *See The Illinois Basin*, MIDWEST GEOLOGICAL SEQUESTRATION CONSORTIUM, http://www.sequestration.org/basin.htm (last visited Jan. 24, 2011) (describing generally the geology of the Illinois Basin and its potential for carbon sequestration in the Mt. Simon and St. Peter Sandstone geologic formations).

original meridian and baseline survey systems in the Northwest Territory, but rather follow geologic formations.[85]

To illustrate the magnitude of potential negotiations regarding access to pore space, consider an airline flight from Chicago to St. Louis of approximately 262 miles.[86] The number of individual properties the flight passes over could number in the thousands. Next, consider the number of mineral estates crossed over on this flight that may have been severed from the surface estates. As noted above, a cautious approach for the CCS operation would be to secure permission from both the surface and mineral estate owners prior to commencing operations to minimize the risk of litigation.[87] Accordingly, after modeling the projected subsurface migration of the CO_2 plume (potentially spanning tens of miles in each direction), a commercial-scale CCS operation in the Illinois Basin would have to identify each surface estate owner, determine if the mineral estate has been severed from the surface estate, and, if severed, identify the holder of the mineral estate. The number of potential owners quickly boggles the mind, and the information costs to acquire this knowledge[88] coupled with a negotiation process for securing the necessary property rights from each owner imposes high up-front transaction costs on the CCS industry.

Moreover, the injection of CO_2 under high pressure has the potential to interfere with other subsurface uses (e.g., drinking water extraction, natural gas storage, nonhydrocarbon minerals) as well as to areas under other surface estates or unintended subsurface geologic formations.[89] Although the regulatory (permitting) process theoretically would minimize these issues,[90] the risks associated with the injection remain, and planning for these contingencies increases transaction costs as well as creates information asymmetry between the CCS operator and the potential pore space owners. The result is considerable friction in potential market-based transactions to allocate pore space usage from the surface or mineral estate to the CCS operator.

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85. *See The Public Land Survey System (PLSS)*, NATIONALATLAS.GOV. (Sept. 17, 2009), http://www.nationalatlas.gov/articles/boundaries/a_plss.html (describing grid survey system of the Northwest Territory).

86. *See Air Distances Between U.S. Cities in Statute Miles*, INFOPLEASE, http://www.infoplease.com/ipa/A0004594.html (last visited Jan. 24, 2011) (citing data from the National Geodetic Survey).

87. *See supra* note 54 and accompanying text.

88. *See* Heller, *supra* note 15, at 661 (discussing information costs as a source of ambiguity in establishing property rights).

89. *See* Elizabeth J. Wilson et al., *Regulating the Ultimate Sink: Managing the Risks of Geologic CO_2 Storage*, 37 ENVTL. SCI. & TECH. 3476, 3477 (2003) (discussing potential negative externalities of geologic carbon sequestration and formulating a taxonomy of the risk).

90. Elizabeth J. Wilson et al., *Liability and Financial Responsibility Frameworks for Carbon Capture and Sequestration*, WORLD RES. INST. ISSUE BRIEF (Dec. 2007), http://pdf.wri.org/liability-and-financial-responsibility.pdf.

C. *Imperfect Information*

As a novel technology in an evolving regulatory and financial environment, the economic aspects of the CCS industry are quite uncertain. Accordingly, the CCS operator may hold proprietary information not available to the pore space owner. Examples include: risk to the environment and other property rights from migrating CO_2, uncertainty in geologic formations and potential pore space volumes, capital investment of the CCS infrastructure, and the potential financial return from the sale of carbon credits from the sequestered CO_2.

These uncertainties create the potential for asymmetrical information between the pore space owner and the CCS operator. Dealing with these uncertainties in a property transfer agreement presents challenges to both parties as potential returns on investment are unknown and fail to reveal the bounds of Pareto optimality whereby one party cannot be made better off without the other being worse off.[91] These legal and financial uncertainties in the current CCS industry also impede market allocation of an economically efficient result from the Coasian perspective. It follows that when setting the initial allocation of a resource, in this case property rights in the "new" resource of pore space, one would prefer a policy-supporting Pareto optimality—a result that allows a welfare improvement by one entity that does not harm the welfare of anyone else.[92] As described by Professors Greenwald and Stiglitz, Pareto efficiency does not exist in "economies in which there are incomplete markets and imperfect information . . . . [G]overnment interventions . . . can make everyone better off."[93]

D. *The Case for "Special Regulations" for Pore Space Ownership*

As noted above, the efficient allocation of resources under Coase's theorem requires well defined property rights, low transaction costs, and perfect information among the parties.[94] But when the property right is uncertain and the transfer of these rights involves large numbers of individuals acting jointly, the process of negotiation may be so difficult and time-consuming that the market becomes too costly to operate as a means to achieve an economically efficient outcome.[95] In these circumstances, Coase acknowledges that the better solution may be for the gov-

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91. *See* HAL R. VARIAN, INTERMEDIATE MICROECONOMICS: A MODERN APPROACH 15 (2d ed. 1990) (describing a Pareto-efficient resource allocation as one in which "there is no alternative allocation that leaves everyone at least as well off and makes some people strictly better off").

92. *See id.*

93. *See* Bruce C. Greenwald & Joseph E. Stiglitz, *Externalities in Economies with Imperfect Information and Incomplete Markets*, 101 Q.J. ECON. 229, 230 (1986).

94. *See supra* note 41 and accompanying text.

95. Coase, *supra* note 14, at 29; Heller, *supra* note 15, at 625–26.

ernment to impose special regulations to confer rights and obligations to determine the location of economic activities.[96]

In *The Problem of Social Cost*, Coase uses the example of a smoke nuisance that impacts a vast number of people.[97] In this example, the administrative costs of dealing with each affected individual would be so high that obtaining a market-based solution between individuals may be impossible.[98] The alternative solution—government regulation—can deal with the problem more efficiently.[99]

As of this writing, three states have conferred rights via legislative enactment in subsurface pore space for geologic sequestration on the surface owner.[100] As discussed below, this may create some certainty in the property rights issue (i.e., the CCS operation need only contract with the surface estate owner), but simple placement of the initial property right in the surface estate fails to address many of the lingering questions regarding compensation and liability uncertainties. Nor does it necessarily eliminate transaction costs or information asymmetry. The following Part describes these statutory developments.

II. LEGISLATIVE RESPONSES TO PORE SPACE OWNERSHIP

States have begun to grapple with pore space ownership issues relating to CCS operations. Three states—Wyoming, Montana, and North Dakota—enacted statutory regimes to clarify pore space ownership for CCS operations in their respective jurisdictions. As described below, each state adopted a politically expedient regime allocating ownership of pore space to the surface estate owner despite the potential complications this may create in CCS commercialization or potentially competing public uses of pore space later on.

A. Wyoming

Wyoming has been at the forefront of developing a property rights regime for geologic carbon sequestration, having passed a number of related property rights statutes in recent years. Most notably, in 2008 the Wyoming legislature passed House Bill (HB) 89[101] and HB 90,[102] governing pore space ownership and permits for carbon sequestration operations, respectively. HB 89 vested ownership of subsurface pore space "in

96. Coase, *supra* note 14, at 29.
97. Coase, *supra* note 26, at 17.
98. *Id.*
99. *Id.* at 17–18.
100. See *infra* Part II (discussing statutory schemes in Wyoming, Montana, and North Dakota).
101. H.R. 89, 59th Leg., Budget Sess. (Wyo. 2008) (codified at WYO. STAT. ANN. §§ 34-1-152, 34-1-202(e) (2009)).
102. H.R. 90, 59th Leg., Budget Sess. (Wyo. 2008) (codified at titles 30 and 35 of WYO. STAT. ANN.).

all strata" with the surface estate owner.[103] The bill further defined pore space to include, without any further qualifications, any "subsurface space which can be used as storage space for carbon dioxide or other substances."[104] On its face, this definition appears to include deep saline aquifers, thereby expanding any usufructuary rights. Moreover, the holder of the surface estate may sever pore space into a separate estate.[105] Unlike severance of the mineral estate with its accompanying "dominance" over the surface estate for extraction activities,[106] contracts to sever pore space do not include the right to access the surface estate unless specifically included in the property transfer document.[107] In 2009, the legislature passed HB 57, clarifying the preservation of traditional mineral estate dominance over both the surface estate, as well as any newly severed estate in pore space.[108] HB 58 creates a presumption that the CCS operator retains ownership of the injected CO_2, rather than the pore space or other subsurface (mineral estate) owner.[109] Finally, HB 80 authorized the Wyoming Oil and Gas Conservation Commission to unitize a pore space once eighty percent of the pore space storage capacity is under contract with the CCS operator.[110]

In sum, Wyoming, in the past two years, has enacted a baseline statutory scheme addressing many of the property rights issues identified in Part I that have the potential to hinder development of a commercial CCS industry. Specifically, HB 90 and HB 57 clarified pore space ownership and the relative priorities of the various estates, whereas HB 80 solved the issue of potential holdouts in the negotiation process that could lead to a tragedy of the anticommons. Two important elements, however, remain. First, the Wyoming regime does not address—and perhaps cannot—the problem of imperfect information. Second, despite knowing the default estate with rights to pore space (i.e., surface estate), CCS operators still must identify and negotiate a contract with at least eighty percent of the individuals with pore space rights within the geologic formation—a potentially formidable task with high transaction costs.

B. Montana

Montana and its neighbor to the north, Saskatchewan, entered into a memorandum of understanding to develop CCS technologies to assist Saskatchewan in meeting the Canadian federal government's GHG re-

103. Wyo. H.R. 89 (codified at WYO. STAT. ANN. § 34-1-152(a)).
104. *Id.* (codified at WYO. STAT. ANN. § 34-1-152(d)).
105. *Id.* (codified at WYO. STAT. ANN. § 34-1-152(b)).
106. *See supra* note 22 (describing the concept of mineral estate dominance).
107. Wyo. H.R. 89 (codified at WYO. STAT. ANN. § 34-1-152(f)).
108. H.R. 57 § 1, 60th Leg., Gen. Sess. (Wyo. 2009) (codified at WYO. STAT. ANN. § 34-1-152(e)).
109. H.R. 58, 60th Leg. § 1, Gen. Sess. (Wyo. 2009) (codified at WYO. STAT. ANN. § 34-1-153(e)).
110. H.R. 80, 60th Leg., Gen. Sess. (Wyo. 2009) (codified at WYO. STAT. ANN. § 35-11-316(c)).

duction goals, while continuing to purchase coal from Montana.[111] Specifically, the governments have proposed construction of a coal-fired electric generation facility in Saskatchewan with carbon capture technology and the construction in eastern Montana of a geologic sequestration project along with a pipeline infrastructure to transport the captured CO_2 from Canada to the injection site.[112]

Also in 2009, the Montana legislature debated two competing bills relating to pore space ownership and CCS operations—HB 498[113] and HB 502.[114] HB 502 proposed classifying geologic pore space as a common natural resource held in public trust by the state of Montana and created a public easement to utilize the pore space for the public benefit.[115] Pore space was defined broadly to include "subsurface space of any size, whether vacant or filled, that can be used as storage space for carbon dioxide, compressed air, or other substances injected into the space for storage" with the exception of existing natural gas reservoirs.[116] In contrast, HB 498, which the legislature ultimately passed,[117] created a presumption that the surface estate owns geologic storage reservoirs,[118] subject to mineral estate dominance.[119] The bill provided a sweeping definition of "geologic storage reservoir," which, in addition to including any natural or artificially created cavity, explicitly incorporated both aquifers and saline formations capable of storing CO_2.[120] HB 498 also adopted provisions for "pooling" or unitization hearings by the Board of Oil and Gas Conservation upon a petition by persons holding rights to sixty percent of the pore space storage capacity.[121]

C. North Dakota

Like Wyoming and Montana, North Dakota's statute grants pore space—defined as "a cavity or void, whether natural or artificially created, in a subsurface sedimentary stratum"[122]—to the owner of the overlying surface estate.[123] This broad definition probably includes access to pore space occupied by aquifers. Unlike provisions in other states, the

111. News Release, Gov't of Saskatchewan, Saskatchewan and Montana Join Forces on Carbon Capture and Storage (May 7, 2009), http://www.gov.sk.ca/news?newsId=c06068a6-59d6-40ba-a2f7-43d07b24441c.
112. *Id.*
113. H.R. 498, 61st Leg., Reg. Sess. (Mont. 2009) (codified at various sections in titles 75, 77, and 82 of MONT. CODE ANN. (2009)).
114. H.R. 502, 61st Leg., Reg. Sess. (Mont. 2009).
115. *Id.* § 11(1).
116. *Id.* § 10(1).
117. Mont. H.R. 498 (codified at various sections in titles 75, 77, and 82 of MONT. CODE ANN.).
118. *Id.* § 1 (codified at MONT. CODE ANN. § 82-11).
119. *Id.*
120. *Id.* § 12 (codified at MONT. CODE ANN. § 82-11-101(12)(A)).
121. *Id.* § 24 (codified at MONT. CODE ANN. § 82-11-204(b)).
122. S.B. 2139, 61st Leg. § 1, Reg. Sess. (N.D. 2009) (codified at N.D. CENT. CODE § 47-31-02 (2009)).
123. N.D. S.B. 2139 (codified at N.D. CENT. CODE § 47-31-03).

North Dakota statute prohibits the severance of pore space from the surface estate.[124] Leases for pore space, however, are allowed.[125] It is unclear why the legislature elected to prohibit this alienation of property, but it may have an indirect (and relatively minor) effect of simplifying the process of identifying pore space ownership for proposed CCS operations.

The legislative initiatives discussed above uniformly allocate pore space rights to the surface estate, while preserving mineral estate dominance. They fail to address explicitly, however, whether rights to groundwater located in a pore space remain with the surface estate or transfer to the current holder of the pore space. As society adapts to an increasingly freshwater-constrained world[126] and technological advancements lower costs of desalinization, deep aquifers previously deemed too saline for conversion to potability[127] may be more attractive options. Accordingly, states that have not already relinquished rights to pore space in deep saline aquifers should consider how to address this potential resource conflict before enacting legislation relating to pore space. Moreover, the state statutes passed thus far do little to address information asymmetry issues or lower the transaction costs involved in negotiating access rights for large-scale CCS operations.

III. A CASE STUDY OF TWO ILLINOIS CCS OPERATIONS

As in most states, pore space ownership for geologic carbon sequestration in Illinois remains an open question, subject to the uncertainties outlined in Part I. This ambiguity, however, has not prevented CCS operators from moving forward in the state. At this early stage in development of the industry, firms have adopted two[128] strategic models for re-

124. *Id.* (codified at N.D. CENT. CODE § 47-31-05).

125. *Id.* (codified at N.D. CENT. CODE § 47-31-06).

126. *See* UNITED NATIONS EDUC., SCIENTIFIC AND CULTURAL ORG. (UNESCO), WATER IN A CHANGING WORLD 3 (2009), http://webworld.unesco.org/water/wwap/wwdr/wwdr3/pdf/WWDR3_Water_in_a_Changing_World.pdf (noting continually increasing demand for finite water resources).

127. *Id.* at 45 (discussing potential of nanotechnology in advanced desalinization technology).

128. A third model exists in Illinois, but is not a function of the private firm. The FutureGen Alliance, a public-private research consortium to build a zero-emission, coal-fired power plant was proposed originally for Mattoon, Illinois, as part of a competitive bidding process. *See* Press Release, FutureGen Alliance, FutureGen Alliance Selects Mattoon, Illinois as the Final Site for the First-of-a-kind, Near-Zero Emissions Coal-Fueled Power Plant (Dec. 18, 2007), http://www.futuregenalliance.org/news/releases/pr_12-18-07.stm. As part of this process, the bid organizers (Coles Together) entered into easements with surface estate owners for a fixed, per-acre payment of fifty dollars. Although there was no legal determination that the surface landowner actually had a right to the pore space (at least that this author's research could locate), the documentation of an "easement" provided an important piece to the competitive bidding process, as well as generated public support for the project among local landowners and community leaders. This nominal per-acre fee is unlikely to appeal to future landowners as adequate compensation due to a much higher expected value for their pore space in a carbon-constrained economy. As a postscript, the Department of Energy later cancelled the proposed project. *See* Herb Meeker, *Coles Together Expects to Get Title to FutureGen Land, Market Its Development*, HERALD-REVIEW.COM (Aug. 21, 2010, 4:01 AM), http://www.herald-review.com/business/local/article_f377c528-f8c9-58c1-a0e1-8c7f1e7cb207.html.

solving uncertainty in property rights—*ex-post* litigation or *ex-ante* assignment. Not surprisingly, each model has both positive and negative attributes. But the point of departure for the firm in adopting a strategy, at least based on this limited case study, is whether primary CO_2 injection activities are in conjunction with hydrocarbon recovery. A brief discussion of two CCS operations follows.

A. Ex-Post *Litigation: Archer Daniels Midland Co.*

As part of a team including the MGSC, the Illinois State Geologic Survey, Schlumberger Carbon Services, Dow Chemical Company, Alstom Power, and the U.S. Department of Energy, Archer Daniels Midland Co. (ADM) completed drilling of a well 7200 feet deep for injecting CO_2 captured from ADM's Decatur, Illinois, ethanol plant.[129] In late 2010, the operation intends to begin injecting one thousand tons per day of CO_2 captured from its ethanol-fermentation operation, emissions that previously would be emitted into the atmosphere.[130] The U.S. Department of Energy, in June 2010, awarded the ADM consortium an additional $99.2 million for development of a second commercial-scale carbon sequestration project at the company's ethanol facility.[131] This project hopes to sequester an additional 2755 tons of CO_2 per day, with a combined total of 3.6 million tons of CO_2 sequestered by the two projects within three years.[132]

At a depth of 7000 feet, ADM's two CCS projects will penetrate the Mt. Simon Sandstone, the thickest and most widespread saline aquifer in the Illinois Basin.[133] The Illinois EPA, as part of its Underground Injection Control (UIC) Program,[134] approved a permit for the initial seques-

129. *See Two Large-Scale Carbon-Sequestration Research Projects Put Emissions-Reduction Technology to the Test*, ARCHER DANIELS MIDLAND CO., http://www.adm.com/enUS/responsibility/enviro_stewardship/Pages/Carbon.aspx (last visited Jan. 24, 2011).

130. *Id.*

131. *See* Press Release, Archer Daniels Midland Co., *supra* note 8.

132. *Id.*

133. *Id.* The Illinois Basin extends 60,000 square miles and underlies most of Illinois, western Indiana and western Kentucky. *The Illinois Basin*, *supra* note 84. The Cambrian-age Mt. Simon Sandstone is a major regional saline-water bearing formation and is the thickest saline aquifer in the Illinois Basin. *Factsheet for Partnership Field Validation Test*, MIDWEST GEOLOGICAL SEQUESTRATION CONSORTIUM (2007), http://www.netl.doe.gov/publications/proceedings/07/rcsp/factsheets/4-MGSC_Large-Volume%20Sequestration%20Test%20with%20Ethanol%20Plant%20So.pdf.

134. Under its Safe Drinking Water Act authority, the U.S. EPA enforces the UIC Program, under which owners and operators must obtain federal permits for injection well activities. The EPA sets the minimum federal standards for the injection and maintenance of these injection wells. *See* 40 C.F.R. § 144.1–.79 (2009). The U.S. EPA may transfer the responsibility for the permitting process to a state, a process referred to as primacy. *See* 40 C.F.R. § 145.11 (establishing requirements for a state to obtain primacy). Currently, thirty-three states, including Illinois, have primacy over aspects of the UIC Program within their respective jurisdictions. *See Underground Injection Control, UIC Program Primacy*, U.S. ENVTL. PROT. AGENCY, http://www.epa.gov/safewater/uic/primacy.html (last visited Jan. 24, 2011).

tration injection well in December 2008.[135] The permit, however, did not address ownership of the pore space, in this case the Mt. Simon Sandstone saline aquifer.[136] Nor was the author able to identify any steps taken by ADM to secure pore space rights from landowners surrounding its Decatur, Illinois, facility.

The ADM approach, to move forward with injection operations prior to formalizing property rights in the receiving pore space, minimizes up-front costs on these capital-intensive projects and, as a first-mover in the industry, establishes precedent regarding the state's policy of encouraging CCS activities. On the other hand, moving forward without settled property rights in the pore space may subject the operation to post-injection claims for trespass or other causes of action.[137]

Despite the potential for *ex-post* litigation and liability, ADM's strategy has considerable appeal. As noted above, given the usufructuary nature of groundwater rights in Illinois,[138] it is unlikely that another private landowner could successfully pursue a claim for trespass.[139] If ADM had to defend itself against a group of landowner-citizens, as a Fortune Global 2000 company (212th in 2010)[140] and the second largest employer in the local area,[141] it would have the financial resources and political backing to vigorously oppose adverse claims seeking to establish a precedent that requires compensation for use of pore space in saline aquifers.[142] If ownership of the aquifer's pore space rests with the state, the issuance of a permit grants, at the very least, an implied license to use

135. *See* ILL. ENVTL. PROT. AGENCY, UNDERGROUND INJECTION CONTROL (UIC) FINAL PERMIT DECISION (Dec. 2008), http://www.epa.state.il.us/public-notices/2008/adm-underground-injection/final-decision-notice.pdf.

136. *See* BUREAU OF LAND, ILL. ENVTL. PROT. AGENCY, PERMIT SECTION, CLASS I UNDERGROUND INJECTION CONTROL (UIC) WELL DRAFT PERMIT FOR ARCHER DANIELS MIDLAND COMPANY (ADM), DECATUR (Sept. 2008), http://www.epa.state.il.us/public-notices/2008/adm-underground-injection/fact-sheet.pdf.

137. Modeling can predict the migration of CO_2 within a given pore space and facilitate the injector's ability to "manage" the CO_2 plume to minimize potential migration to other properties. Scott M. Frailey & Hannes Leetaru, *Geological Factors Affecting CO_2 Plume Distribution*, 1 ENERGY PROCEDIA 3107, 3110 (2009). Although this may minimize CO_2 migration, the injection nonetheless alters the subsurface pressure in pore space underlying adjacent lands making subsequent CO_2 sequestration operations more difficult. A discussion of these and other subsurface pressure effects and their legal implications, however, is beyond the scope of this Article and a subject for future research.

138. *See supra* notes 66–70 and accompanying text.

139. *See supra* notes 71–74 and accompanying text. Of course, one with rights to use of the groundwater, as opposed to the pore space, could make a claim if the sequestration activities damaged the groundwater itself. *See* Womble v. State, 27 Ill. Ct. Cl. 150, 150 (1971) (stating that landowner has right to groundwater in its unpolluted, natural state, even if pollution is caused by activity conducted or permitted by the state).

140. *The Global 2000*, FORBES.COM (Apr. 21, 2010, 6:00 PM), http://www.forbes.com/lists/2010/18/global-2000-10_The-Global-2000_Rank_3.html.

141. *See Decatur, Illinois*, ILL. DEP'T OF COMMERCE & ECON. OPPORTUNITY, http://www2.illinoisbiz.biz/communityprofiles/profiles/DECATUR.htm (last updated Feb. 5, 2009) (listing 4000 ADM employees in Decatur, Illinois, out of a total employment base of 55,000).

142. *See* Marc Galanter, *Why the "Haves" Come Out Ahead: Speculations on the Limits of Legal Change*, 9 LAW & SOC'Y REV. 95, 107, 125 (1974) (describing typology of litigation by strategic players and why the "haves" tend to come out ahead in litigation).

the pore space for carbon sequestration. Moreover, to the extent the state of Illinois wishes to capture the economic growth potential of this new technology, it is unlikely to engage in a protracted dispute over pore space ownership. Illinois, due to its favorable geologic formations, abundance of coal, and proximity to several GHG intensive industries (including coal-fired power plants),[143] is well-positioned to serve as a center of activity for CCS and its accompanying economic benefits. As demonstrated by the ADM operation, a default approach of state ownership in aquifer pore space minimizes the potential legal barrier to CCS development.

B. Ex-Ante *Assignment: Willow Grove Carbon Solutions LLC*

Willow Grove Carbon Solutions LLC (Willow Grove), a newly organized Delaware company with a principal place of business in Bloomington, Illinois, has pursued an alternative approach to securing a leading position in the carbon sequestration industry. Willow Grove identified potential pore space for carbon sequestration activities in southeastern Illinois (in and around Lawrence County) and began negotiations with individual surface estate owners to secure an easement for the storage of CO_2.[144]

In addition to potential saline aquifer formations similar to those accessed by ADM, the southeast region of Illinois has significant potential for sequestration in connection with enhanced oil recovery.[145] As discussed in Part I, there is relative consensus among commentators that the mineral estate has possession over pore space ownership for carbon sequestration in the enhanced oil recovery context.[146] Accordingly, the proposed pore space easement carves out any prior grants or reservations of mineral interests.[147] The cautious CCS operator,[148] or perhaps in this case the aggressive speculator seeking as many potential rights to pore space as possible, elected to approach the surface estate for a transfer of rights. This approach minimizes the possibility of *ex-post* litigation, but drastically increases up-front transaction costs on the mere expectation of some future sequestration activity.

There is also considerable uncertainty among the parties regarding the potential revenue, and thus the economically efficient allocation of this resource. To account for the uncertainty, the proposed easement for

143. *See* MIDWEST GEOLOGIC SEQUESTRATION CONSORTIUM, ASSESS CARBON DIOXIDE CAPTURE OPTIONS FOR ILLINOIS BASIN CARBON DIOXIDE SOURCES 8–11 (Dec. 2005), http://www.sequestration.org/publish/phase1_seq_optimization_topical_rpt.pdf.

144. *See* Contract Template from Willow Grove Carbon Solutions LLC, "Grantee," to "Grantor" (on file with author) [hereinafter Willow Grove Contract Template].

145. *See CO_2 Storage Potential for Illinois Basin Oil Fields*, *supra* note 16 (containing map of potential sequestration potential in Illinois Basin from EOR operations).

146. *See supra* notes 47–53 and accompanying text.

147. *See* Willow Grove Contract Template, *supra* note 144, § 8.

148. *See supra* note 54 and accompanying text.

pore space establishes a fixed, per-acre fee as a floor with potentially higher payments based on revenue from sequestration operations.[149] Specifically, the grantor of the easement would receive a minimum payment of twenty dollars per acre of surface estate subject to the sequestration easement or eight percent of the gross revenue from sequestration operations.[150]

The parcel-by-parcel approach also lacks a process to deal with potential "holdouts," or landowners refusing to grant an easement. Wyoming and Montana's statutory schemes addressed the holdout problem and the potential tragedy of the anticommons with forced unitization or pooling arrangements.[151] The common law situation in Illinois lacks a process for resolving potential windows in the pore space. Of course, one possible solution with respect to holdouts is to adopt the ADM approach, commencing sequestration operations with the possibility of *ex-post* litigation. On the other hand, in this two-party game, the holdout landowner faces a risk of zero compensation if a court declines to find an infringement of a property right. This uncertainty may propel a landowner to accept a lower price, foreclosing the possibility of obtaining Pareto optimality.

IV. CONCLUDING THOUGHTS: RETAINING PUBLIC SECTOR OWNERSHIP OF PORE SPACE

In the forty-plus years since publication of Professor Hardin's *Tragedy of the Commons*,[152] modern American culture has embraced the trinity of private property, individual liberty, and free markets as the solution to most environmental and resource management issues.[153] A conclusion "accorded by some the status of scientific law. . . . [, t]he tragedy of the commons has become part of the conventional wisdom in environmental studies, resource science and policy, economics, ecology, and political science."[154] But, as noted by Professor Feeny and others, undifferentiated allocation of potential property rights to the private sector overlooks the unique nature of particular resources, decision-making arrangements, and interactions between users and regulators—all of which must be taken into account in a commons situation and may warrant community or even state ownership options.[155] Accordingly, this Ar-

149. *See* Willow Grove Contract Template, *supra* note 144.

150. *See id.* § 4(b). An amendment to the easement established a floor of ten dollars per ton of sequestered carbon as a measurement of gross revenue from operations (amendment on file with author).

151. *See supra* notes 110, 121 and accompanying text (discussing Wyoming and Montana's pooling regimes, respectively).

152. Garrett Hardin, *The Tragedy of the Commons*, 162 SCIENCE 1243 (1968).

153. *See* FREYFOGLE, *supra* note 24, at 157.

154. David Feeny et al., *The Tragedy of the Commons: Twenty-two Years Later*, 18 HUM. ECOLOGY 1, 2 (1990).

155. *Id.* at 13.

ticle seeks to step back from the assumption that ownership of geologic pore space, at depths heretofore unexplored and unutilized except in the most unique situations,[156] must vest in either the surface or mineral estate.

It is essential to put into context the primary and secondary policy motivations underlying support for a commercial CCS industry—reducing GHG emissions to combat the impacts of global climate change and capturing economic development opportunities from this new technology. How to best mitigate GHG emissions and stimulate development of a vibrant CCS industry presents a complex problem of resource allocation and public-private interaction. Global climate change precipitated by the oversaturation of GHGs within the atmosphere is the reverse of the commons tragedy of unconstrained livestock grazing—a situation specifically noted by Hardin whereby he acknowledged it costs the individual less to emit "fumes into the air" than to treat and purify wastes before releasing them into the atmosphere.[157] Because the market has failed to internalize the environmental costs of GHG emissions, governments are left to devise policies to restrict GHGs through both compulsory measures and financial incentives.[158]

Permanent sequestration of CO_2 via CCS provides a limited technological solution to the degradation of our atmospheric commons. But how to resolve the property rights issues in another commons, geologic pore space, is a separate question. There is general agreement that property rights to pore space used for carbon sequestration as part of enhanced oil recovery (or other hydrocarbon extraction) rest with the mineral estate.[159] Moreover, as an already economically viable endeavor with a forty-year history,[160] any change in these pore space ownership regimes would upset long-settled expectations.

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156. Two examples of deep subsurface utilization include hazardous waste injection and geothermal exploration. Hazardous waste injection wells, regulated by the EPA's UIC Program, may reach as far as 10,000 feet below the surface. *See Underground Injection Control, Industrial & Municipal Waste Disposal Wells (Class I)*, U.S. ENVTL. PROT. AGENCY, http://water.epa.gov/type/groundwater/uic/wells_class1.cfm (last visited Jan. 24, 2011). Geothermal wells may extend to 5000 feet to reach liquid solutions heated by the inner core of the Earth. *See Oil, Gas & Geothermal—Geothermal Production Wells*, CAL. DEP'T OF CONSERVATION, http://www.consrv.ca.gov/dog/geothermal/general_info/pages/production_wells.aspx (last visited Jan. 24, 2011).

157. Hardin, *supra* note 152, at 1245.

158. *See generally* Food, Conservation, and Energy Act of 2008, Pub. L. No. 110-246, 122 Stat. 1651 (codified as amended at 7 U.S.C. §§ 8101–8114 (Supp. III 2010)) (establishing tax credits and research subsidies for bioenergy and GHG reductions); Energy Independence and Security Act of 2007, Pub. L. No. 110-140, 121 Stat. 1492 (codified as amended in scattered sections of 42 U.S.C. & 49 U.S.C.) (establishing mandatory GHG reductions for biofuels and energy efficiency standards); PEW CTR. ON GLOBAL CLIMATE CHANGE, THE EUROPEAN UNION EMISSIONS TRADING SCHEME (EU-ETS): INSIGHTS AND OPPORTUNITIES (2006), http://www.pewclimate.org/docUploads/EU-ETS%20White%20Paper.pdf (discussing the EU's mandatory emissions reduction program).

159. *See supra* notes 47–54 and accompanying text.

160. NAT'L ENERGY TECH. LAB., U.S. DEP'T OF ENERGY, CARBON SEQUESTRATION THROUGH ENHANCED OIL RECOVERY (Apr. 2008), http://www.netl.doe.gov/publications/factsheets/program/Prog053.pdf (noting that the oil industry has used EOR for forty years and current operations inject forty-eight million tons of CO_2 per year).

The ownership status of other pore space for geologic carbon sequestration, such as in saline aquifers or basalt formations, however, is a novel concept and, at least in the aquifer context, rooted in the common law of usufructuary rather than possessory rights. A neoclassical economic approach would presume to allocate ownership to the private sector. Legislatures in three states have done so, creating a new stick in the proverbial bundle of property rights for the surface estate. But does the creation of a new private property right optimize the legal environment for an economically efficient allocation of resources to mitigate the impact of climate change at the least cost to society?

This question raises two distinct considerations—efficiency and distributional preferences. From a Coasian economic efficiency perspective, allocation does not matter so long as there are settled property rights, low transaction costs, and perfect information. Legislative proclamations vesting pore space ownership in the surface estate resolves ambiguity in property rights. But the number of potential surface owners over a commercial-scale CCS operation and the scientific uncertainty in the migration of the CO_2 plume through the geological strata raises potential transaction costs in negotiating access among surface owners with disparate preferences. Moreover, the risk accompanying the CCS operation, potential impact on the surface estate, and uncertainty in financial returns from the carbon sequestration service (e.g., sale of carbon credits) results in imperfect information between the CCS operator and landowners. The potential for a holdout landowner also creates the danger of an anticommons effect unless a second legislative provision imposes a unitization or pooling requirement. In sum, the neoclassical allocation of property rights to the surface estate, in light of the imperfect market conditions, may not result in an economically efficient allocation of resources.

On the other hand, if the state were to retain ownership of pore space in instances other than in the hydrocarbon recovery context, property rights are clear and transaction costs minimized. The CCS operator must negotiate with a single entity—the state. As a regulated activity under the UIC Program of the Safe Drinking Water Act, each CCS operation already must apply for a permit from the state regulatory authority (assuming state primacy).[161] An allocation system for pore space, modeled in part on the federal government's offshore oil and gas leasing auctions, could reduce information asymmetry by the seller (in this case, the state)[162] and, from an efficiency perspective, obtain a socially optimal distribution of resources.

161. *See Underground Injection Control, UIC Program Primacy*, *supra* note 134 (outlining state authority to issue permits under the federal Safe Drinking Water Act for underground injections).

162. *See* Robert H. Porter, *The Role of Information in U.S. Offshore Oil and Gas Lease Auctions* 63 ECONOMETRICA 1, 25–26 (1995) (concluding that the offshore leasing auction is well designed and that the government captures a reasonable share of the rents given the uncertainty in exploratory drilling).

Professors Calabresi and Melamed argue, however, that when a state is determining entitlements (e.g., property rights), administrative/economic efficiency is only one consideration alongside distributional preferences and other justice considerations.[163] "[T]he placement of entitlements has a fundamental effect on a society's distribution of wealth" and thus is subject to policy preferences.[164] Distributional preferences, however, are dynamic and difficult to construe within a single conceptual framework.[165] Whether society decides to sell or give away an entitlement "will likely depend in part on which determination promotes the wealth distribution that society favors."[166] Legislatures, accordingly, should evaluate wealth distribution preferences within the context of the underlying policy considerations noted above—mitigation of global climate change via GHG reductions and economic development accompanying CCS operations.

Assignment of property rights in pore space to the surface estate transfers wealth from the state to the individual via the price that the surface owner can extract from the CCS operator for the right to inject CO_2 into his or her pore space. This certainly is a plausible distributional preference in line with the current emphasis on private property and free markets. But is this enough to justify the loss in economic efficiency noted above, and does this conform to the baseline policy goal? Moreover, what potential costs are borne by society at large due to this wealth transfer from the state to the individual?

If the state retains ownership of the pore space, in addition to capturing the economic efficiency arguments described above, revenue from the sale of pore space access rights remains with the state, potentially lowering the tax burden on its citizens.[167] In the alternative, the state could hold pore space as a public trust, providing access for CCS operations without charge (or at a reduced price), thereby lowering the cost of GHG reduction and indirectly lowering prices for GHG intensive products such as electric power. Freely allocating pore space, moreover, could encourage development of this nascent industry and the accompanying positive economic externalities, such as job creation.

With the exception of three states, ownership of pore space at the depths necessary for permanent geologic carbon sequestration is unsettled, especially with respect to saline aquifers and basalt formations. Moving away from the current default assumption of carving out pro-

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163. *See* Calabresi & Melamed, *supra* note 40, at 1093. "Economic efficiency is not, however, the sole reason which induces a society to select a set of entitlements." *Id.* at 1097–98.

164. *Id.* at 1098.

165. *Id.*

166. *Id.* at 1099.

167. Professors Klass and Wilson express concern that public ownership of pore space rights would invite takings claims and thus leave the issue for the courts to decide. *See* Klass & Wilson, *Property Rights*, *supra* note 13, at 406. Although certainly possible, litigation may be necessary to sort through the various pore space ownership issues resulting from migrating CO_2 plumes if CCS operators have to negotiate with individual surface estates.

gressively discrete interests in private property, however, is a difficult proposition. Accordingly, this Article does not recommend a result (state versus private ownership), but rather a framework through which policymakers can step back and consider the implications of alternative allocations of property rights in previously inaccessible pore space so that they may achieve the policy priorities of GHG reduction and development of a commercial-scale CCS industry at the lowest cost to society. It is clear, however, that states must resolve the current thicket of potential property rights claims to geologic pore space for carbon sequestration in the near term to enable evolution of the CCS industry.