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ANALYSIS OF EXISTING AND POSSIBLE REGIMES FOR CARBON CAPTURE AND SEQUESTRATION: A REVIEW FOR POLICYMAKERS

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ANALYSIS OF EXISTING AND POSSIBLE REGIMES FOR CARBON CAPTURE AND SEQUESTRATION: A REVIEW FOR POLICYMAKERS

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Executive Summary

Energy use worldwide continues to increase and while renewables, nuclear, and other energy sources provide carbon-free fuel, these alternatives cannot yet dominate the energy landscape due to technical limitations of integration, cost, and political resistance. Therefore, the Organisation for Economic Co-Operation and Development predicts that the use of coal will increase by 52 percent (MIT Interdisciplinary Team, 2007) and attendant carbon dioxide emissions are expected to climb by an additional 790 million metric tons by 2030 (Dewar and Anderson, 2007). Future laws and regulations to control greenhouse gases will provide a driver for carbon capture and sequestration (CCS), and the International Energy Agency predicts that CCS will comprise up to 19 percent of mitigation activities by 2050 (International Energy Agency (b), 2010).

U.S. state-level policies and proposals have blossomed over the last few years as CCS is considered a global warming solution. Pore space designation is one of the first areas that states have begun to address and is likely to be one of the most contentious issues to resolve as states have trended towards giving pore space ownership to the surface landowner, and the public will be involved in the decision to inject. Pore space is the small, vacuous areas in rocks where CO2 can be stored. The current policies and proposals related to pore space ownership are likely to be contentious and may require national and international coordination in order to allow for the successful commercialization of CCS. Issues of unitization, conversion of enhanced oil recovery wells to CCS wells, reconciliation of the future extraction of minerals with CCS, and consideration of how to handle reservoirs that span state, international, and public land boundaries will elicit controversy and instigate litigation that will likely stall the CCS industry.

Even though the U.S. has trended towards giving the ownership of pore space to the surface landowner, this precedent does not have to continue. There are a variety of ways to allocate pore space. This report evaluates all hypothetical and established pore space ownership structure possibilities. The merits and pitfalls of each of these ownership structures will be

highlighted in order to evaluate which may be the best structure to enable CCS to occur and the goals of climate change mitigation to be achieved.

Possible pore space ownership structures include the water rights owner, application of the English Rule, application of the American Rule, and federal ownership. The water rights owner is implicated due to the displacement of water from subsurface pore space during CCS. Application of the English Rule would entail giving the pore space ownership to the mineral rights owner, who could be a private owner or the federal government in the U.S. The American Rule would involve the designation of pore space ownership to the surface land owner above the site of CCS injection.

Thorough analysis of all of these pore space ownership structures suggests that the most efficient use of pore space ownership is federal ownership, which will negate conflicts that arise due to unitization, conversion of enhanced oil recovery wells to CCS wells, and the split of revenues and ownership from wells that cross state, country, and federal land boundaries.

Introduction

For centuries, there has been a natural interchange of carbon dioxide (CO_2) between the earth and the atmosphere. Following the Industrial Revolution in the late 1800s and early 1900s, the amount of carbon dioxide and other greenhouse gases being released into the atmosphere steeply increased as the burning of coal, gas, and oil also increased. The earth's ability to absorb CO_2 through vegetation and into oceans has remained static, causing more gases to accumulate in the air. Rates of natural resource consumption have been tied to increasing global temperatures at unprecedented rates (Intergovernmental Panel on Climate Change [IPCC], 2007; Williamson & Hull, 2010). Energy use worldwide continues to increase while carbon-free energy sources like nuclear and renewables cannot yet dominate the energy landscape due in part to technical limitations of integration and political resistance. Therefore, it is expected that the use of coal, oil, and gas as fuels will continue to be used in the short- and medium-term.

Coal use will increase by 56 percent of 2007 levels by 2035 because its prevalence allows energy to be created at a price of $1 to $2 per MMBTU instead of the $6 to $12 per MMBTU for oil and gas (Energy Information Agency, 2010 and MIT Interdisciplinary Team, 2007).[1] Combustion of coal supplies the U.S. with 49 percent of its electricity and produces about twice as much carbon dioxide per unit of energy produced as natural gas; therefore, much research has focused on cleaner coal technologies (Energy Information Administration [EIA], 2010). Carbon capture and sequestration (CCS),[2] which involves the separation and geologic sequestration of CO_2 from industrial stack emissions, is an apt technology to address CO_2 emissions from both natural gas and coal-fired power plants.

[1] This study assumes that country-specific greenhouse gas policies, active in 2007 under the Kyoto Protocol, are the only constraints limiting the use of coal.

[2] Throughout the paper, the word sequestration instead of storage will be used to describe the permanent storage of CO_2 in geologic reservoirs because the word "storage" implies that the CO_2 will be retrieved at some future date. Since we assume that the CO_2 will permanently be stored, we prefer to use the word "sequestration," which has a more enduring connotation.

The International Energy Agency predicts that CCS will comprise up to 19 percent of climate mitigation activities by 2050 (International Energy Agency (b), 2010) and the Intergovernmental Panel on Climate Change estimates that CCS will entail 55 percent of mitigation efforts until 2100 (Dewar & Anderson, 2007).

Carbon Capture and Sequestration

Carbon capture and sequestration could prevent up to 90 percent of emissions at a stationary power plant or industrial facility if it were captured directly at the source, separated from other by-products, transported to a geologic formation, and stored for an indefinite period of time (Socolow & Pacala, 2004). Carbon capture directly from the source is the most difficult and expensive step in the process as it often has to be separated from other gases before it is compressed for transport and storage. The additional energy necessary to separate and process this CO2 demands 10-40% more energy than plants without capture (IPCC, 2005). Because of the large amounts of carbon that would constantly be captured and moved over long distances, the most viable transportation system would be through pipelines, similar to existing natural gas lines. Approximately 3,600 miles of these CO2 pipelines currently exist in the U.S. for enhanced oil recovery projects (EPA, 2010). The geologic formations conducive to CCS are often areas where coal, oil, or gas have been extracted or where saline water resides in the pore spaces of certain rock formations, thousands of feet underground. CO2 has inadvertently been sequestered in recent years as it is injected to re-pressurize oil and gas fields in order to increase production. During this process, known as enhanced oil recovery (EOR) or enhanced gas recovery (EGR), approximately 50 to 60 percent of the CO2 injected remains in the ground (International Energy Agency Greenhouse Gas Research and Development Programme, 2010).[3]

The Energy Information Administration (2010) projects that coal consumption will increase 0.4 percent per year through 2035. However, due to the warming potential of the CO2 released, improved use of coal and sequestration of the CO2 from combustion is being pursued avidly

[3] The exact amount of CO2 sequestered is heavily dependent on the capacity of the formation to hold CO2.

with public and private research. The amount of public funding dedicated to CCS research worldwide totals approximately $30 billion USD, which will be used on up to 40 projects (Global CCS Institute, 2010; IEA(a), 2010) See Figure 1. Currently, there are nine operating large-scale geological carbon sequestration projects underway worldwide and many more in various stages of development.

Figure 1. Funding and project announcements from governments and international organizations (International Energy Agency (a), 2010)

Country	Funding committed to date (billion US)	Number of projects committed by 2020
Australia	2 to 6	3 to 5
Canada	3.5	Up to 6
European Commission[1]	4 to 6	6 to 12
Japan	0.1	1 to 2
Norway	1	1 to 2
Korea, Republic of	1	1 to 2
United Kingdom[2]	11 to 14.5	4[3]
United States	4	5 to 10
TOTAL	26.6 to 36.1	19 to 43

This figure includes the 300 million permits that are set aside under the EU-ETS for demonstration of CCS and of innovative renewable energy and € 1 billion from the European Commission (EC) energy recovery package.

[2] UK funding includes operational support for 10 to 15 years of CCS operations. Note that UK funds may be used in conjunction with EC funds.

[3] Within the 'TOTAL' range, the lower number considers two of these four projects as counted within the EC figure; in the larger number, they are all considered additional to EC projects.

Regulatory Changes

Several U.S. states have enacted policies to limit the amount of CO2 being emitted from their coal-fired energy plants. One of the most critical regulatory changes is California SB 1368, which is an emission performance standard for power generators. In 2012, power plants that emit more than 1,100 lbs of CO2/MWh will not be allowed to enter into long-term contracts for supply of electricity to California. This standard affects not only in-state generation, but also imported generation (Natural Resources Defense Council, 2007). Since California currently uses coal-based generation for 20 percent of its electricity, SB 1368 has provided a strong driver for coal-based power plants serving California to consider CCS (Hilton, 2006). Other states like Colorado, Florida, and New Jersey also have greenhouse gas reduction goals and have begun implementing policies to achieve these goals (Database of State Incentives for Renewable Energy [DSIRE], 2010).

In addition to these state-level actions, regional and federal activity to limit greenhouse gases has begun. The Regional Greenhouse Gas Initiative launched on January 1, 2009 includes 10 Northeastern states and is a cap-and-trade market that covers power generators over 25 MW in the ten participating states (Regional Greenhouse Gas Initiative, 2007). The Western Climate Initiative has created design recommendations for a regional greenhouse gas cap-and-trade market that will begin in 2012 and include Montana, Oregon, Washington, California, Utah, Arizona, New Mexico, and the Canadian Provinces of Quebec, British Columbia, Manitoba, and Ontario (Western Climate Initiative, 2010). A similar initiative called the Midwestern Greenhouse Gas Accord has also formed and is slated to begin in 2012. However, for both of these regional markets to begin, individual states within the markets must formulate cap and trade regulations and implement them.

While many drafts of comprehensive federal greenhouse gas initiatives have been formulated, none have passed Congress. However, federal action is being taken by the Environmental Protection Agency (EPA). In 2007, the State of Massachusetts sued the EPA, claiming that greenhouse gases from new motor vehicles are a threat to human health and should be regulated under the Clean Air Act. The Supreme Court ruled in favor of Massachusetts, and in 2009, the EPA made a finding that CO2 does in fact present a threat to human health. The EPA has begun to regulate CO2 by setting standards for motor vehicles (which have been integrated with Corporate Average Fuel Economy Standards) and is requiring stationary sources that release 100,000 metric tons of CO2 equivalence per year or make changes that result in an increase in 75,000 metric tons of CO2 equivalence per year to obtain permits under Title V of the Clean Air Act and install the Best Available Control Technology (BACT).[4] The EPA has further required mandatory greenhouse gas reporting of most stationary sources that emit more than 25,000 metric tons of CO2 equivalence per year starting in 2011 (Greenhouse Gas Reporting Program, 2008). Emissions stored via CCS will also be tracked through this reporting rule (EPA Finalizes Rules to Foster Safe Carbon Storage Technology Actions, 11/22/2010).

These state, regional, and EPA policies will help move CCS toward economic feasibility as there will soon be a cost and liability associated with greenhouse gas emissions. Additionally, the approximately $30 billion in research funding will help overcome some technological barriers related to CO2 separation, transport, and storage. However, CCS faces regulatory barriers that have not yet been adequately addressed; these regulatory challenges may prove to be the largest hurdles in CCS implementation (Parfomak, 2008).

State-Level Legislative Efforts

There has been much debate over how the responsibilities for CCS management should be divided between the state and national governments. While the federal government has taken minimal action on CCS, some state governments have begun to assume the responsibilities for

[4] Stationary sources with modifications that increase emissions by more than 75,000 metric tons per year and new facilities that emit 100,000 metric tons will also be subject to BACT. These thresholds will be decreased over time (Williamson & Hull, 2010).

creating regulations in regards to permitting, pipelines, liability, and pore space ownership designation.

Permitting

In CCS, permitting must occur for power plants, pipelines, and injection sites. The US EPA has primarily managed injection in the past for the purposes of EOR, but in July 2006 the EPA changed its policies to allow CO2 injection for large-scale, long-term storage projects. A primary concern for injection has been for water quality; therefore, understanding the risks and complexity of siting is very important at the project level. Several states including Kansas, Louisiana, Montana, North Dakota, Oklahoma, Texas, Utah, Washington, West Virginia, and Wyoming have enacted laws and/or established a permitting authority to manage sequestration injection sites.

At the federal level, the EPA has created a rule for CCS, known as Class VI injection wells, under the Underground Injection Control Program. This rule will provide permitting requirements for CCS in order to safeguard underground sources of drinking water. States that have already created permitting requirements will most likely be able to use these requirements if they are more stringent than the federal regulations and they satisfy the primacy requirements.[5]

Pipeline Regulation

Pipelines have different levels of regulation depending on their location and boundaries (interstate, intrastate, or international). In the United States, the Federal Energy Regulatory Commission and the Surface Transportation Board (STB) traditionally regulated oil and gas pipelines and their contents, but currently CO2 pipelines are being regulated by the Office of Pipeline Safety under the Department of Transportation, the STB, and the Bureau of Land Management. These agencies perform a wide array of functions from regulation of design, construction, operation, and maintenance to safety management including spill response. Most of the agencies have delegated some tasks to the states and allow states to create their own

[5] Primacy requirements under the Safe Drinking Water Act can be found at http://water.epa.gov/infrastructure/drinkingwater/pws/primacy.cfm.

regulations as long as the national minimum is being met (Forbes, Verma, Curry, Friedmann, & Wade, 2008).

The greatest challenge to CO_2 pipeline regulation is that there is no national definition of the sequestered CO_2, and states have attempted to set their own definitions. For example, Indiana's pipeline safety code has defined CO_2 as "a fluid in a supercritical state containing more than 90 percent CO_2" (Cowart, Vale, Bushinsky, & Hogan, 2008). Defining CO_2 as a commodity versus a pollutant versus hazardous waste would have dramatically different impacts on how it is regulated for transport. Until this decision about the definition of underground CO_2 is made, managing pipelines will be difficult, and understanding how to charge for the use of both existing and new pipelines is unresolved. The Class VI well designation guidelines have provided some clarity on the definition of CO_2 for sites that comply with the USDW permitting process. Injection well operators will be responsible for determining "whether the CO_2 stream is hazardous under EPA's Resource Conservation and Recovery Application" (75 FR 77260), which is required for hazardous materials and tracks the waste from creation to disposal. If the stream is determined to contain hazardous waste, it cannot be injected into a Class VI well, but the injector must use a Class I injection well (75 FR 77260). While CO_2 has now been defined for injection, it is not yet clear whether or not these designations will remain for CO_2 carried in pipelines. Creating a nationwide network for long-term storage presents several issues including the classification of CO_2 as a pollutant versus a commodity and whether pipelines will have a common carrier requirement or will be privatized (Congressional Research Services, 2008).

Another pipeline regulation issue is that of right-of-way on public land. In order to earn right-of-way privileges, one must apply to Secretary of the Interior. The Secretary determines whether the right-of-way should be granted or not, and if so under either the Mineral Leasing Act or the Federal Land Policy and Management Act (FLPMA). The Mineral Leasing Act obligates the pipeline to have a common carrier[6] designation, which could require more maintenance than private pipelines. FLPMA, on the other hand, does not have this requirement. Due to the implications of common carrier status, many rights-of-way cases have been the subject of litigation (CCS Reg, 2009).

Another issue is whether or not to use eminent domain[7] as a method for acquiring lands for pipelines. Negotiating with landowners to secure rights of way is the preferred method, but if owners are non-compliant and there are no other viable options, sometimes eminent domain must be employed. In this process under the Natural Gas Act, the certificate holder presents his or her case to the state or district court and is required to provide proper compensation to the landowner for the acquisition of the property which has been identified to have a beneficial public use (Natural Gas Act §717f, 1938). With the common carrier requirement, using eminent domain makes more sense than if a pipeline were privately owned and managed, as the pipeline would be a benefit to the public in general and not just one specific company (Parfomak, 2008).

The regulatory environment is even more complicated for the use of public lands where "a site involving even minor risks increasingly requires a myriad of permits from organizations that can include the Army Corps of Engineers, the Fish and Wildlife Service, the EPA, and state and local agencies regulating air and water quality, the oil and gas industry, and occupational health and safety" (Reiner & Hertzog, 2004). This permitting system allows opportunities for public input and can often cause delays if there is opposition.

<u>Liability</u>

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[6] A common carrier is a transporter that (1) serves all customers without discrimination, (2) provides scheduled service to designated points or within a designated area, (3) carries only the type of cargo for which it is certified, and (4) is named as the carrier in the contract of carriage (Mogel & Gregg, 1983).

[7] Eminent domain is the inherent power of a governmental entity to take privately owned property, especially land, and convert it to a public use, subject to reasonable compensation for the taking. (Garner, 2004). This power is limited by the federal Constitution and by state constitutions -- when the government does take private property for public use, it must fairly compensate the owner for the taking. Sometimes the government's use of eminent domain is a straightforward matter, with the government providing the landowner a fair price, and the landowner giving up the property. At other times, however, government and the landowner may disagree over whether a taking has occurred, and how much compensation is due (FindLaw.com legal dictionary, 2011).

Liability protection for states, companies, and individuals against major losses to liability from CCS is a primary concern at this time. This issue will be addressed more comprehensively in a subsequent publication but will be discussed in part here since it is one of the major regulatory hurdles to CCS. One of the major impediments for creating liability legislation is that while some states have created liability regimes, these structures are somewhat incomplete and the issue has not yet been addressed at the national level.

There are many possibilities for owners and managers of CCS sites, pore space owners, or pipeline owners to be held accountable for leakage, tort liability, climate liability, carbon credit assurance, catastrophic disaster coverage, and groundwater contamination remediation. If the CCS industry is going to be viable for the long-term as a critical component to meet public policy needs, these issues make it necessary to identify means to provide certainty for projects and assure adequate funds to pay for any problems in the future. There are still many state and federal liability questions that need to be answered before widespread CCS will be viable. As discussed above, scientists still do not know the long-term impacts of storing large amounts of carbon underground. Most oil and gas companies pay for insurance programs to cover liability for their large projects, but there are few current policies designed to cover sequestration because the time frame is so long. The government of Alberta assumed long-term liability for CCS sites, but this assumption of comprehensive long-term liability by a governmental entity is rare (Brooysman, 2010). Some private insurance companies like SwissRe and ACE have begun exploring insurance for certain aspects of CCS like the injection and closure stage, which can last between 5 and 30 years after injection stops. Zurich Financial Services Group even provides an offering for this type of insurance (Zurich creates two new insurance policies, 2009). However, private companies are reluctant to tackle insurance offerings for the post-closure state that can last indefinitely.

Several states like Illinois and Texas have assumed total liability for CCS sites beginning at project initiation while others like Louisiana have only agreed to cover liability after a set number of years, or after the project is deemed completed as in Montana and North Dakota.

Other states, such as Wyoming, refuse to claim any liability for private CCS practices and have placed the burden of liability on the parties injecting the CO2. Wyoming did, however, establish a fund for long-term stewardship expenses (Ingelson, Kleffner, & Nielson, 2010).

Looming questions include whether there is currently adequate legislation for CCS liability in the states that have passed bills, whether this issue is going to require its own management system, and whether there is need for a new agency to oversee implementation.

Pore Space Designation

One of the primary concerns in CCS and the focus of this paper is pore space designation. Pore space is simply the vacuous space inside of geologic formations that can host CO2. CCS is being prospected for development in oil and gas reservoirs, unmineable coal seams, saline aquifers, and basalt formations. Oil and gas reservoirs will most likely be the first deposits developed for CCS since the oil and gas industry has experience injecting CO2 in these sites for enhanced oil recovery (EOR) since 1972 (U.S. Dept. of Energy, 2008). Therefore, injecting in these formations is tested and predictable (Flatt, 2009).

The geologic formations and saline aquifers far below the surface can be large and contiguous, and there is currently no reasonable method for division of ownership in these areas. If there are porous rocks below distinct ownerships, there is a high potential that these spaces continue under other public and private ownerships as well. There has been a great debate in the US over who owns the pore spaces thousands of feet below these surface ownerships, who should have access to them, and who would be responsible for the injection of any materials into that space.

Designation of pore space ownership will require much cooperation between landowners if they would like to participate as beneficiaries in the CCS injection program since most pore spaces lie below diverse ownerships. There is a chance that under future greenhouse gas legislation landowners will receive monetary payments for the amount of carbon dioxide they are able to sequester. As landowners sell or lease the rights to use pore space for geologic sequestration of CO_2, they would be compensated in some way as the CCS injectors will benefit from this activity by helping a polluter comply with future greenhouse gas regulation or by sequestering metric tons from an entity that is not required to reduce greenhouse gases and can create offsets through this activity. Landowners that sell storage space may receive less compensation than those that choose to sell later when greenhouse gas legislation has been implemented at a federal level; the more stringent the legislation, the higher the value of the storage space. When landowners choose to sequester, neighboring landowners will have their pore space partially filled and have a diminished ability to sequester due to subsurface pressure gradients. Therefore, determining the benefits to award is a difficult process for regulators since scientists cannot know with total precision the amount of CO2 stored beneath given plots.

Having large pore space areas available for sequestration is critical to the success of this program and for reduction of large amounts of CO2 emissions. Large-scale capture projects from heavy industries and power producers are going to necessitate sites large enough to be able to input high levels of daily capture over long periods of time. An 800 MW capacity coal-burning power plant will necessitate between 300 to 11,000 km^2 of pore space to store the CO2 from this plant for 30 years; the huge discrepancy in these numbers is due to the depth of the formation and its ability to sequester CO2 (Gresham, 2010). Many landowners are wary of participating in CCS programs because there are still too many unknowns, especially about the long-term consequences. This uncertainty could lead to litigation and delays of CCS projects.

Pore space ownership will most likely be decided by the states, as subsurface property rights are largely privately-owned and are decided at the state level (Duncan, Anderson, & Nicot, 2009). Montana, North Dakota, and Wyoming have passed legislation over pore space ownership, and all three states have relegated surface owners as the owners of the pore space (S.B. 498, S.B. 2095, H.B. 90). Because regulations for access, mineral, and property rights differ so much among states, it does make sense for state and local governments to make decisions for their delegation. However, this ownership issue could become more complicated as states have to come to an agreement when a reservoir extends over state lines or at a national level if the reservoir crosses into another country.

In addition to state boundary issues, conflicts may arise when private land meets public land. Much of the prime potential areas for CCS in the West overlaps with federally-owned land. Not only will federal land managers have to decide how to designate pore space ownership on federal land, but they will also have to consider how to manage carbon credits that may be available in the future for this sequestration. And, there will have to be some protocol for how to handle public input and potential resistance to sequestration on federal land.

Another major issue that could arise if property owners are recognized as holding compensable rights to pore space is the issue of "hold-out" or one property owner that refuses to engage in CCS and therefore prevents an entire project from going through. Surface landowners that are wary of the impacts of CCS could block CCS projects. Protests could slow down, increase the costs, or even block sequestration projects (Wong-Parodi & Ray, 2009). Very little research has been conducted on public acceptance of CCS, and for the most part, it has been based upon hypothetical situations. Most projects will affect specific communities, and similar to large power line projects, opinions are likely to change when a person is asked hypothetically about a topic and when that project is taking place in their backyard. Wong-Parodi & Ray (2009) found that community individuals worried about the technological safety of CCS projects and whether it would change their community by increasing traffic or decreasing property values; they also were hoping to reap some monetary benefit for being the location of the sequestration site.

Further complications of how to handle situations where CO2 sequestration blocks extraction of minerals that were not economical to extract when CCS was conducted, but are later found to be profitable to produce may arise. Conversion of enhanced oil or gas recovery wells (EOR and EGR) to CCS wells may bring unforeseen problems as CO2 that was already inadvertently stored in the plot during the EOR operations now diminishes the ability to store more CO2 in the plot and takes away some of the pore space rights from the surface landowner. Giving the surface owner the full rights to pore space and the ability to decide if CCS will occur on a plot may have implications on the water rights owner as water is displaced from a plot when CCS is conducted.

For these reasons, pore space designation has the potential to be the most contentious and problematic of the regulatory hurdles facing CCS. Even though US states have trended towards giving the ownership of pore space to the surface landowner, this precedent does not have to continue. There are a variety of ways to allocate pore space.

Alternative Pore Space Ownership Structures

Arguably, the largest legal hurdle is pore space designation, which has begun to be tackled in the US with state-level legislation. The remainder of this study evaluates possible pore space ownership structures, hypothetical and established. The merits and pitfalls of each of these ownership structures will be highlighted in order to evaluate which structure will best promote the commercialization of CCS and allow the goal of preventing global warming to be achieved. The pore space ownership structures that will be analyzed include consideration of the mineral rights, surface landowners, and the federal government. Additionally, consideration of whether or not the water rights would be necessary to obtain in order to engage in CCS is considered. Finally, based on these analyses, the best pore space owner to achieve large-scale CCS will be discussed.

English Rule

One common ownership structure for pore space involves the use of the non-ownership in place theory, commonly known as the “English Rule” since it is used in the United Kingdom. This rule specifies that prior to the capture of a mineral in the subsurface, the interest owner merely holds a right to explore and reduce the mineral to possession (Ragsdale, 1993). However, this English Rule maintains that the mineral interest owner has the exclusive right of possession of the whole space and, after all minerals have been extracted, the owner is entitled to the entire and exclusive use of that space for all purposes (Central Kentucky Gas Co. v. Smallwood, 1952).[8] Application of the English Rule to pore space would mean that the current mineral interest owner would also own the geologic formation storage space for the purposes of CCS. In the European Union, Australia, Mexico, and Canada where the English Rule is followed, the federal government owns most of the subsurface minerals and, therefore, would have the unencumbered right to the pore space for CCS after extraction of the mineral (Duncan et. al., 2009; Garcia-Garza & Vazquez-Silveyra, 2006).[9] Despite its common name of the English Rule, evidence or portions of the English Rule are present in some states including Alabama, California, Illinois, Indiana, Kentucky, Louisiana, New York, Ohio, Oklahoma, and Wyoming (Williams & Meyers, 2007).

Application of the English Rule in the US would involve allowing the pore space ownership to be held by the mineral rights owner. If this rule were followed in the US, then there would be no conflict between potential mineral rights owners and those interested in CCS as it would be up to the discretion of the mineral rights owner to either allow or disallow the use of the reservoir for CCS. Therefore, if there was question over whether or not the mineral had been fully extracted, or if it would become lucrative to extract in the mineral in the future, the mineral rights owner would not have to confer with anyone to make the determination about whether or not to inject in the site.

Given the patchwork quilt of mineral rights ownership structures and multiple parties involved, liability related to the injected CO2 could be complicated. Surface landowners would have to allow the wells above the reservoir to be accessed and monitored. Therefore, a high degree of

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[8] The authors will consistently use the English Rule to describe the non-ownership-in-place theory and the American Rule to describe the ownership-in-place theory because these terms are typically used in the literature (see publications by Mark De Figueiredo and Elizabeth Wilson) in order to avoid confusion for the reader; please note, however, that there is some case law in both the US and the UK that deviates from the general rule of subsurface ownership.

[9] The federal government in Canada owns more than 90 percent of the subsurface minerals and pore space (Natural Resources Canada, 2009).

coordination between the mineral rights and surface landowner would be necessary to make this ownership structure successful.

American Rule

In contrast to the English Rule, the ownership-in-place rule, commonly known as the “American Rule,” involves the severance of a mineral right from the interest in the whole geological formation. Using the ownership-in-place rule, a mineral rights holder owns the mineral beneath the land, but the rest of the geological formation—including the pore space in which the CO2 would be stored—is owned by the surface interest owner (de Figueiredo, 2007). States with evidence in their courts of supporting this theory through ownership of depleted oil and gas reservoirs are Arkansas, Colorado, Kansas, Maryland, Mississippi, Montana, New Mexico, North Dakota, Pennsylvania, Tennessee, Texas, Washington, and West Virginia (Williams & Meyers, 2007).

The implications of application of the American Rule ownership structure to pore space for CCS are many and varied. Because the surface landowner owns the formation, he would have to be compensated for the use of subsurface pore space. One major complication in awarding landowners with royalties is the complexity of subsurface reservoirs. Experience from the oil and gas industry has shown that the size and shape of geologic formations that hold these minerals do not always coincide with the property lines above. Some states have established laws for the sharing of royalties based on surface ownership and subsurface reservoir geology. Managing one oil field as a single site for extraction or injection purposes is known as unitization and sharing the profits among those who own the site is known as pooling (Flatt, 2009).

CCS pore space legislation passed in 2008 and 2009 in Wyoming, Montana, and North Dakota supports the American Rule, giving the pore space to the surface landowner (CCS Reg. Project, 2009). These states have selected the American Rule and taken action ahead of the federal government in part to ensure that their landowners retain a portion of the revenues associated with carbon sequestration. Allowing the federal government to determine pore space designation could take away a potential revenue stream from landowners.

Application of the American Rule on Federal Land

The mission of some public lands is consistent with the goals of climate change mitigation; therefore, there is the possibility that these lands could engage in CCS to reduce warming. Federal and state agencies often have different goals for their lands and regulations that may either prevent or promote activities like CCS. The Department of the Interior (DOI) (including the Bureau of Land Management (BLM), Fish & Wildlife Service, National Park Service, Bureau of Reclamation, and Bureau of Indian Affairs) has a mission of not only protecting and providing wise stewardship over U.S. resources but also fostering sound use of them. DOI agencies have multiple purposes and some agency missions, such as the National Park Service, are not congruent with CCS. The lands managed by the DOI provide nearly 30 percent of the nation's energy production resources (DOI, 2009), and using some of these acreages like Bureau of Land Management lands for CCS might be a viable option. Forest Service lands provide multiple-uses such as timber harvesting and recreation, although their values differ significantly from other multiple-use land management agencies such as state trust land[10] agencies. Although both agencies intend to manage forests and grasslands sustainably and to make money in doing so, the primary focus of state land managers is to earn an income, and state land managers constantly seek to diversify their ability to earn money from their lands. Where federal lands allow mining claims and recreation for either little or no fee, state lands compete to provide the same services but at a cost to the user. This management difference may suggest that state trust lands' diverse management portfolio may be more suited to allowing CCS at this time than

[10] Beginning in 1803, Congress created a program where as each new state joined the Union, they were awarded a certain amount of land to be managed, in perpetuity, for the benefit of their citizens and often to primarily fund public schooling institutions. Thirty-three of the 50 states currently manage trust lands to provide revenue to public schools, universities, hospitals, penitentiaries, and other public entities (which vary by state mandate). Some states like Nevada saw the greatest benefit in selling these lands as commercial properties, while others manage them for timber, minerals, and grazing or lease them for other uses like communication and radio towers. The primary management direction for these lands is to receive the greatest benefit for their trustees now and in the future (Souder & Fairfax, 1996).

federal lands since state trust lands would stand to gain from selling the rights to engage in CCS. See Figure 2 below for a summary of the amount of land owned by various public agencies and whether or not the land could be managed for CCS.

Figure 2: Acres Managed by Federal and State Agencies and their Potential Use in CCS

Agency	Lands Managed (in millions of acres)	Agency mission	Could land be used for CCS under current management?
Bureau of Land Management (DOI[1])	256 (700 million acres of subsurface managed)	Multiple-use: sustaining the health, diversity, and productivity of the public lands for the use and enjoyment of present and future generations.	Y
Fish & Wildlife Service (DOI)	96.2	Working with others to conserve, protect and enhance fish, wildlife, plants, and their habitats for the continuing benefit of the American people.[5]	N
National Park Service (DOI)	84.6	Cooperates with partners to extend the benefits of natural and cultural resource conservation and outdoor recreation throughout this country and the world.[6]	N
Bureau of Reclamation (DOI)	8.7	Manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.[7]	Y

Bureau of Indian Affairs (DOI)	**66**	**Enhance the quality of life, to promote economic opportunity, and to carry out the responsibility to protect and improve the trust assets of American Indians, Indian tribes and Alaska Natives.[8]**	**Y**
Office of Surface Mining's Abandoned Land Program (DOI)	0.2	Ensure that coal mines are operated in a manner that protects citizens and the environment during mining and assures that the land is restored to beneficial use following mining, and to mitigate the effects of past mining by aggressively pursuing reclamation of abandoned coal mines.[9]	Maybe
Forest Service[2]	193	Advocating a conservation ethic, protecting and managing National Forests and Grasslands to best demonstrate the sustainable multiple-use management concept, and providing technical assistance to sustain and enhance global resources.	Maybe
Department of Defense[3]	**30**	**To provide the military forces needed to deter war and to protect the security of the United States.** **Everything we do supports that primary mission. Nothing less is**	**N**

		acceptable to us, or to the American people.[10]	
State Trust Lands[4]	135-153	Manage state lands for multiple uses (grazing, timber, mineral production, commercial purposes) to produce the greatest monetary benefit for their beneficiaries now and in perpetuity.	Y

1 DOI land management acreage values came from: http://www.doi.gov/facts.html

2 Forest Service land management acreage values came from: http://www.fs.fed.us/

3 Department of Defense acres came from: http://www.defense.gov/pubs/dod101/dod101.html

4 State trust land acreage estimates came from: (Souder & Fairfax, 1996)

5 Mission from: http://www.fws.gov/irm/

6 Mission from: http://www.nps.gov/legacy/mission.html

7 Mission from: http://www.usbr.gov/main/about/mission.html

8 Information from: http://www.bia.gov/WhoWeAre/BIA/index.htm

9 Mission from: http://www.osmre.gov/aboutus/Mission.shtm

10 Information from: http://www.defense.gov/

States that have passed pore space legislation tend to be in the West where enormous amounts of land are publicly owned. These states realized that if they did not address the issue of pore space ownership, it was likely that the federal government would benefit from geologic sequestration not only on the public land in the state, but also on private land. The federal government has not yet ruled conclusively on the ownership of pore space in public or tribal land, but it is beginning to trend in this direction.

In October of 2009, Senate Bill 1856, introduced by Senator John Barrasso of Wyoming, proposed an amendment to the 2005 Energy Policy Act to clarify ownership of subsurface pore space on federal land. The Bill gives pore space ownership to the federal government but allows existing mineral rights to take precedence (Wyoming House Bill 57, 2007).

In April of 2010, Anne Castle, Assistant Secretary for Water and Science U.S. Department of the Interior, and Tim Spisak, the Bureau of Land Management Deputy Assistant Director for

Minerals and Realty Management, supported the application of the American Rule in a public statement at a CCS Legislative Hearing on Senate Bill 1856 (U.S. Congress, 2010). Prior to this statement in 2009, a paper entitled "Framework for Geologic Carbon Sequestration on Public Land" that supported this notion of the American Rule for sequestration on public land was prepared by the Department of the Interior and submitted to Congress (Framework for Geologic Carbon Sequestration on Public Land, 2009).

Having the federal government own the pore space under federal lands has implications for public acceptance of projects, public-private property disputes, and carbon credit revenues. How to handle public resistance may present an even larger problem under this ownership structure than under a private ownership structure. The unknown risks associated with CCS, magnitude of CO2 that will be injected, and large amount of underground storage space that would be used could cause public outcry as CCS opponents voice their opinion. While typical leasing of public land for grazing and mineral extraction can be very controversial, CCS has the potential to be even more controversial due to the fledging nature of the industry and technology. Plans to test CCS in Ohio at an ethanol plant met resistance from community members who objected to the project due to concerns that it would lower property values, induce seismic activity, and contaminate groundwater supplies (Fairley, 2009). Widespread deployment of CCS in order to achieve climate mitigation goals would require a much larger deployment of CCS on public lands and may be equally as controversial as the attempt at CCS in Ohio.

Another issue that could occur with the application of the American Rule on federal land is the creation of conflicts where injection occurs on a boundary between public and private land. If the private landowner is opposed to injection, he may sue for intrusion of subsurface CO2 migration into his land. Issues of how to split carbon revenues for this injection will also arise as it may be impossible to determine exactly how much CO2 was injected into the public and private parcels of land.

A third complication of the application of the American Rule on federal land is the creation of carbon credits associated with the storage of CO_2.[11] By application of CCS on federal land, the federal government will benefit from having sold the pore space to a CCS injector and possibly from the attendant carbon credit associated with permanent storage of the CO_2. These two new revenue streams have no guidelines for collection or use. The royalty structure that has been set up for grazing and mineral rights extraction requires those who lease to pay $2 per acre (after 5 years) and 12.5 percent of the value of the product extracted in return for the use of the land (Humphries, 2004). It is unclear what the royalty structure will be for CCS and how that money will be used.

Forestry projects that generate carbon credits on public land can serve as a guide for how the federal government might approach rents and royalties for CCS projects. Terrestrial carbon sequestration projects on public lands will need to manage carbon credits and the money earned from selling these credits to other entities. There are two options for the credits: the government could either sell them in a carbon market or use them to offset their own operations or that of another government agency (if required) that has greater carbon intensive practices. The money earned through the carbon sequestration project if sold into a carbon market would most likely need to be reinvested in project monitoring and hiring an auditor to validate the program's practices and carbon accounting methods. If the funds obtained from these projects exceed the management costs, the government may dedicate a part of the earnings to a particular purpose.[12] However, if the earnings are not specifically allocated, they may be used for any number of purposes (Brodie, A., personal communication, October 29, 2010).

[11] CCS for offsetting purposes is already accepted in some voluntary crediting markets and was recently accepted as a basis for offset crediting under the Clean Development Mechanism at the under the Clean Development Mechanism at the United Nations Framework Convention on Climate Change's Conference of Parties 16 in Cancún, Mexico. Details about how crediting will occur will be determined by the Subsidiary Body for Scientific and Technological Advice in upcoming meetings (Reyes, O. (2011, January 11). Carbon markets after Cancun: Carbon Capture and Storage in the Clean Development Mechanism. Carbon Trade Watch.

[12] Washington uses part of the state lottery funds to support public education (Brodie, A., personal communication, October 29, 2010).

Pooling and Unitization

While the federal government has begun to speculate about how CCS should be handled on federal land, as previously mentioned, some states have begun to implement policies clarifying who owns the pore space. In 2008 and 2009, Wyoming, North Dakota, and Montana passed bills that designate pore space ownership to the surface landowner. Despite these legislative initiatives, CCS operators are destined to encounter many obstacles as they attempt to implement the first few projects due to the details of these bills.

The first major issue that may arise in an attempt to implement this legislation is the controversy that will arise due to the forced unitization of CCS sites. Wyoming's HB 80 reads:

> No order of the Wyoming Oil and Gas Conservation Commission authorizing the commencement of unit operations shall become effective until the plan of unitization has been signed or in writing ratified or approved by those persons who own at least eighty percent (80%) of the pore space storage capacity within the unit area. (Wyoming House Bill 80, 2009, p.5)

The first contentious point of this legislation is the fact that it could be difficult with current scientific models to determine with complete certainty storage potential under a given plot of land. So, the question of who constitutes a majority pore space owner may be raised. It does not necessarily follow that the landowner with the most acreage is the one with the most ability to store CO_2 since reservoirs can extend vertically as well as horizontally. The issue becomes even more complex as one considers smaller plots of land like those that may exist in cities and on the East Coast in places like Pennsylvania, which uses coal-fired generation that would be amenable to CCS for 53% of its electricity generating portfolio (Energy Information Agency, 2008). Beyond these uncertainties, a given plot of land may be able to host CO_2 injection in multiple reservoirs at different depths. Accurately characterizing the storage potential of all of these reservoirs may be impossible, though. Models that attempt to measure the in-situ concentration of CO_2

that has been injected in reservoirs are only able to measure within a +/- 20% accuracy due to the portion CO2 that is dissolved in oil, water, and minerals (Benson, 2006). If the error margin on an entire reservoir is 20%, it is likely that it could be even higher for small individual portions of this reservoir since it would take more precision to determine the exact amount of sequestration potential in one plot. Therefore, the science to back up the legislation that has passed in Wyoming, Montana, and North Dakota is not yet available.

This issue becomes paramount when one realizes that hundreds or thousands of landowners may have to be involved in and give their consent to each CCS project created. Determining the exact amount of pore space that each of these land owners has will most likely be contentious, and those who oppose CCS injection will most likely point to the fact that the science is not yet certain enough to provide assurance that 80% of the pore space owners consent to injection. A strong minority of 20 percent or less who may be opposed to the injection of the CO2 could cause a considerable headache for project developers as they partner with groups that oppose CCS.[13] North Dakota and Montana's legislation, which allows a 60 percent majority ownership to allow CCS to occur, could be even more controversial as it would steamroll the opinions of a larger percentage of dissenting landowners. While some non-governmental organizations see CCS as a necessary solution to global warming, many are wary of its potential hazardous impacts on groundwater and air contamination and seismic activity (Greenpeace, 2008). These groups could help mobilize landowners against the injection of CO2 and prevent successful permitting. Therefore, there is a need to clarify how issues of controversy will be resolved and whether or not Wyoming, North Dakota, and Montana state law will uphold the newly-passed bills when tested.

Given that the majority ownership is decided based on the storage capacity below land, the carbon credits may also be awarded based on the amount of CO2 sequestered under each plot. This scheme is dramatically different from most oil and gas pooling, which is typically done

[13] Wyoming's HB 80 also allows for a petition to be made to lower this majority decision to 75% if the 80% majority cannot be gathered after six months.

based on acreage size of the landowners instead of based on the amount of oil or gas in each plot. Given the uncertainty in storage capacity for CO_2, each landowner may hire experts to vie for the maximum storage capacity that would be scientifically possible in order to benefit from the carbon credits associated with injection. Divvying up carbon credits accurately and administering the sale and disbursement of proceeds from this sale, as well as retracting revenue for any credits sold that were later found to have leaked from the site, will most likely prove complex, with transaction costs possibly overwhelming potential revenue for landowners.

Further complicating pooling of profits is the issue of pressure gradients. Injection of CO_2 will have the highest concentration at the epicenter of injection; peripheral landowners may not have all of their pore space filled and may later be approached by another CCS operator to have their pore space saturated. Compensation will most likely have to be based on the actual amount of CO_2 stored in a given plot, which may be very difficult to determine as pore space if partially filled. Some landowners may not even know that their pore space was filled and receive no compensation. Case study shows that it is likely that landowners would bear the burden of proof that CO_2 had been injected into their land. In a related oil industry case, members of an oil field that declined to participate in a field unitization scheme were denied royalties and had claims of subsurface trespass ignored (Wilson, 2005). In a case of subsurface migration of liquid waste (Chance v. BP Chemicals, 1996), the burden of proof fell on the landowners to prove that their property had been trespassed (Sprankling, 2008).

As an alternative to compensation based on the volume of pore space available under a plot of land, an acreage designation to unitize the land would be the simplest way to solve this matter. There is a need to clarify how the assessment of available storage volume will occur, its cost, and how scientifically defensible it is.

Conversion of Enhanced Oil and Gas Recovery Sites to CCS

Wyoming House Bill 90, which details the permitting of CCS activities, states, "the injection of carbon dioxide for purposes of a project for enhanced recovery of oil or other minerals approved by the Wyoming oil and gas conservation commission shall not be subject to the provisions of this chapter." According to this definition, it would appear that enhanced gas recovery at injection sites would not qualify. If the site began as an enhanced gas recovery facility under an EPA Underground Safe Drinking Water Class II well designation and then transitioned into a Class VI well CCS site, then the six pieces of legislation Wyoming has passed related to the siting and operations of CCS would apply. However, how this transition would occur and how smooth it would be are unanswered questions.

This conversion would also be complicated by the differing permitting, construction, monitoring, and mechanical integrity testing required of each well type. Class VI wells have much more stringent requirements than Class II wells in each of these categories. Groups like the American Water Works Association and the Association of Metropolitan Water Agencies worry that Class II wells that are converted for CCS could be "grandfathered" and exempt from complying with the more stringent Class VI requirements (Potential impacts of GCS to underground sources of drinking water, 2010).

Another issue related to this conversion is how the surface landowner will be compensated. Some of the pore space available for sequestration would already be filled since CO2 was injected for enhanced oil and gas recovery. During EOR approximately 50 to 60 percent of the CO2 inadvertently remains sequestered in the site (International Energy Agency Greenhouse Gas Research and Development Programme, 2010). Twenty to 30 percent of this injected CO2 is trapped up in pore space while another 15-20 percent dissolves in oil that cannot be removed. Whether or not the other 50 percent of the injected CO2 is recovered is largely dependent on the level of effort to extract and reuse the CO2 (Horvorka, S., personal communication, November 18, 2010). Therefore, the CCS injector's ability to inject in the plot will be diminished by the amount of CO2 that has already been injected.

Currently, there are a few voluntary carbon offset programs that allow for crediting of EOR activities. The Oklahoma Conservation Commission has a state sequestration program that credits geologic sequestration based on the amount of CO2 that remains in the site (Oklahoma Conservation Commission, 2009). The American Carbon Registry allows for crediting of EOR if the CO2 comes from stack emissions that would have been vented (Blue Source LLC, 2008). If another entity or the EOR operator already received credit for the CO2 sequestered before the site was converted from a Class II to a Class VI well for CCS, perhaps he would owe the surface landowner the credits awarded since the pore space is now partially filled. It appears as though the surface landowner does not receive any of the credits for the American Carbon Registry projects, and there are no Oklahoma Conservation Commission geologic sequestration projects to date.

Some natural gas extractors in Alberta and British Columbia have begun disposing of CO2 and hydrogen sulfide, byproducts of the natural gas they extract and sell, by reinjecting them into the site of extraction. Reinjection of these by-products helps enhance the recovery of the gas through a process called enhanced gas recovery. Natural gas companies in Wyoming have begun to consider the same process since injection of these byproducts can be cheaper than remediating them to ground level standards, and some carbon crediting bodies like the Alberta Greenhouse Gas Offset Credit System recognizes CO2 sequestered in this way as a valid offset (Alberta Environment, 2008). The issue of how to compensate a landowner who owns the subsurface pore space of a site has been permanently closed for gas extraction and reinjection of by-products becomes challenging when the operator of this site may have already used much of this pore space to inject hydrogen sulfide and CO2, which will diminish the surface landowner's ability to store CO2 in the future.

<u>CCS and Mineral Rights Conflicts</u>

Achieving consensus on sequestration under application of the American Rule could also be problematic because sequestering CO2 under the ground would prevent future landowners from reopening sites for mineral extraction since doing so would compromise the long-term storage of the CO_2. While there may be some on-going financial benefit to having the CO_2 under a given plot, the most likely situation is that the landowner would receive most compensation for injection activities during the years of injection. So, subsequent landowners may not receive any benefit from the sequestered CO_2, but instead may simply suffer from the inability to profit from the future extraction of minerals or the leasing of the extraction of these minerals to the mineral rights owner. In the future when the price of minerals increase significantly or improved technology makes hard-to-reach deposits more accessible, this issue may become more pronounced.

Case law provides some guidance on how the issue of these future mineral rights will be addressed. In 1989, *International Salt Co. v. Geostow* clarified that mineral rights can preclude storage of natural gas if the storage site prevents unmined minerals from being accessed. Therefore, while one surface landowner may think that he can conduct CCS on his land, this storage may be precluded due to the land's mineral potential. And, mineral rights owners may find their rights to a deposit have expired if they leave a mine site dormant for too long. In the aforementioned case, the court found that the mineral owner's interest in the minerals "reverts to the surface landowner by operation of law at some time subsequent to removal of the [minerals]" (Fesmire et. al., 2007).

Wyoming House Bill 57, as well as North Dakota SB 2139 and Montana SB 498, makes it very clear that the mineral estate remains dominant over the ability to sequester CO_2. However, once the decision has been made to sequester CO_2 in a plot that holds a subsurface mineral, the mineral estate owner has essentially given up his rights to this site (Wyoming HB 57, 2009). It is also possible that injection into a formation above or (most likely) below the mineral formation could occur and not impact the ability for the site to be mined.

In order to simplify future mineral rights conflicts, there is the potential for existing legislation to be modified to apply to CCS. The "rule of capture" in mining allows a mineral rights owner to capture oil and gas that migrates from adjoining property to a well on his land (Fesmire et. al., 2007). As EOR developed, another rule called the "negative rule of capture" was created to prevent liability from being incurred for a less valuable substance like CO_2 that replaces a more valuable substance like oil and is often employed for EOR projects that extend into land surrounding the site of extraction (DeCesar, 2010). Perhaps this rule needs to have another evolution to apply to a situation where the less valuable substance such as CO_2 does not replace, but instead blocks the future extraction of a more valuable substance in order to prevent future litigation over this point.

CCS Projects across State Boundaries

Placing pore space ownership in the hands of private residents has the implication of creating confusion when projects span state boundaries. Injection near state borders could fill pore space in a state that has not yet decided on pore space ownership. In this case, the injecting entity may be able to fill pore space in the undecided jurisdiction and receive benefit for this sequestration while taking away the future possibility for injection on this land.

This situation has the possibility of occurring in the Vermillion Basin that spans the borders of Wyoming and Colorado. In Wyoming, this area is open to oil and gas development while it is being considered protected status in Colorado (BLM proposal would keep Vermillion off-limits, 2010). After the oil and gas wells in Wyoming have been depleted, the site could be converted to hold CO_2. In this way, the State of Colorado would not benefit from injection into this land but would in fact host CO_2 in the subsurface and face a diminished ability to profit from future injection, if that development path was chosen.

As long as states continue to push ahead with CCS regulations on their own, the possibility of some states moving ahead of others and creating problematic ownership structures across borders will exist. Regardless of Colorado's decision regarding ownership of the pore space, the possibility of disagreements and litigation over the amount of CO_2 injected into each interstate site exists, just as it does between neighboring pore space owners in the same state. And, the issue of who will accept liability for injection that crosses into a state that does not yet have a liability structure in place for CCS arises. These disputes over the amount of CO_2 injected and who will accept liability for the project are only exacerbated by injection that occurs across country boundaries.

Federal Ownership of Pore Space

For instances where subsurface rights exist more than two miles below the surface, American law has been inconsistent, supporting both the English Rule and the American Rule (Klass & Wilson, 2010). Also, application of both of these rules leads to complications as a variety of owners would be involved. Therefore, perhaps a new ownership structure should be considered. Having the federal government assume ownership of subsurface pore space may be unpopular in many areas of the US, but it greatly simplifies the complex process of compensating landowners based on the amount of CO_2 stored and greatly abridges liability schemes. An ownership structure of this type would be similar to the 1930s designation of air space above private property as a public good. Enforcing the passage of gas through pore space will be difficult to control just as it is hard to prevent aircraft from passing over certain areas of land (Sprankling, 2008). Likewise, sequestering CO_2 underground can be seen as achieving a public good just as allowing air travel throughout the US is in the public interest. The Ohio Supreme Court explained in the case of Chance v. BP Chemicals Inc. in 1996 stating that ownership of airspace to indefinite heights "has no place in the modern world,"(United States v. Causby, 1946) which can be likened to ownership of subsurface rights. Having the federal government manage CCS for the public good would prevent the problem of individual land owners whose consent is necessary under other ownership schemes from stopping or slowing the process.

While application of the English Rule in the US would not create a structure that assigns ownership to the federal government for CCS as it would in the UK, most of Canada, and Australia where the subsurface minerals are owned by the federal government, separate legislation that designates the federal government as owner of all subsurface pore space could be created. Federal ownership of pore space could be a less complicated structure that allows global warming mitigation goals to be realized more effectively. Since plots where CCS could occur may range in size from several thousand acres to partial-acre city plots in a state like Pennsylvania under an ownership scheme where each landowner own his pore space, it could be very difficult to determine the exact amount of CO_2 injected in each plot. Therefore, knowing how much one should be compensated in the form of carbon credits that could be awarded for this activity in a future where CCS can help regulated entities comply with mandates is complex.

Having long-term liability reside with the government places responsibility with the entity that is probably most able to handle complications that could occur. If liability was assigned to the pore space owner who was either the mineral rights or surface landowner, then divvying up this liability based on the amount of CO_2 stored below a given plot could be prohibitively challenging. In order to ensure that injection sites are well-cared for, both the EU and Australia have created a method for collecting annual fees from CCS operators that will sustain a long-term stewardship fund to assist the government in monitoring the injection sites, as well as protecting public health and the environment. Additional fees are collected by these governments for permits, leases, and licenses (CCS Reg. Project, 2009). Also, in the EU and Australia rules have been created to compensate private landowners for easements, surface damage, loss of amenity, and decrease in market value tied to CCS projects (CCS Reg. Project, 2009). These expenses and liability coverage could also be paid by the lease and/or royalty structure set up for CCS injection on public land. Aligning the liability responsibility with the entity that owns the pore space and will earn the credit for sequestration in the plot is probably the best way to allow a fund for damages and liability to accrue.

The precedent set by the natural gas industry suggests that federal assumption of pore space ownership is not unthinkable. In some instances of underground natural gas storage where gas is injected for storage and later extracted in order to store natural gas during winter months when it is in higher demand, eminent domain and payment of just compensation to landowners has occurred when voluntary agreements cannot be forged. It should be noted that in these instances, ownership discussions have focused on the natural gas itself in the subsurface as opposed to the ownership of the pore space, as it would be in CCS (Klass & Wilson, 2010). It is unclear if eminent domain would be employed for CCS since global warming mitigation may not be seen as a public good that is as necessary for price stabilization of fossil fuels.

In order for federal legislation to apply to pore space designation, federal law would have to preempt well-developed state property law. This action could prompt "takings" claims by landowners or state governments. Such an issue could complicate this ownership structure and has led some scholars to believe that the federal government should not assume pore space ownership, but instead that limited federal regulation should apply to CCS to provide consistency and comprehensive legal coverage (Flatt, 2009).

Despite these advantages to the federal ownership of pore space, this ownership distinction limits the rights of citizens to decide whether they want injection to take place under their property, which may be deemed unacceptable in the US and states that have already designated pore space ownership may claim primacy over pore space designation.

Governmental Ownership Below a Threshold

As a compromise between the designation of pore space to the state or private landowners, an ownership structure that allocates pore space below a certain depth to the government could be adopted. Sprankling (2008) evaluates this ownership structure and points out that it may make the most logical sense as surface landowners' pore space assets would begin to overlap as the plots go further into the Earth. Alabama, California, Georgia, and Idaho law stipulates that property rights extend indefinitely. But, as a surface landowners' land nears the center of the earth, the plot becomes conically-shaped due to the spherical structure of the Earth. Therefore, it is illogical that a surface landowner could hold the rights to pore space below all of his surface land. Perhaps having the government own the pore space below a certain depth would avoid issues of overlapping pore space for deep CCS injection (Sprankling, 2008).

This type of ownership structure could be complicated as these formations, which can be as shallow as 2,500 or deep as 16,000 feet for oil and gas reservoirs in the Great Plains, cannot be easily divided by category of storage reservoir. The average injection depth for saline aquifers, unmineable coal seams, oil and gas reservoirs, and basalt formations range widely based on the site, and some sites such as the Mt. Simon saline aquifer in the Illinois Basin ranges from 2,000 to 12,000 feet (National Energy Technology Laboratory, 2007). Therefore, having a different ownership structure for different depths of injection would mean that one reservoir could have multiple owners if it started shallow and extended deep. This ownership structure of the government owning the pore space below a certain depth threshold may pose even more complications than simply having just one pore space ownership designation.

Water Rights

When weighing who should be deemed the appropriate pore space owner for CCS, consideration of the water rights owner should also be analyzed. Because pore space deep saline aquifers and other possible storage reservoirs is often filled with brine that is displaced when CO2 is injected, it is logical that rights to the water that is displaced must be secured in order to conduct this activity (DeCesar, 2010). Simulations conducted on the Rock Springs Uplift in Wyoming show that injection of 80% of the CO2 from the nearby 2.2 GW Jim Bridger Power Plant will displace 810,000 acre-feet of water over 75 years (50 years of injection and 25 years post-injection). If the water is not pumped out of the reservoir and the pressure managed, there is a danger of large-scale hydrofracture of the subsurface minerals. Pressure management would result in 10,000 acre-feet of water per year that would need to be pumped to the surface and remediated (Surdam, et. al, 2009).

Water rights refer to the ability to take the water, but by filling the pore space, the water is essentially taken since it is displaced and may be unavailable for future use. In case law based on the State's constitution and statues, Colorado ruled that "neither surface water, nor ground water, nor the use rights thereto, nor the water-bearing capacity of natural formations belong to a landowner as a stick in the property rights bundle." Instead, these rights are owned by the water rights owner. And, in Colorado and California, storage aquifers are considered to be in the public domain (Alameda County Water District v. Niles Sand & Gravel Co., 1974; Board of County Commissioners v. Park County Sportsmen's Ranch, LLP, 2002). By contrast in New Mexico, waters may be appropriable, but aquifer storage is not in the public domain. Instead, the aquifer storage space is owned by the surface estate (Fesmire, Rankin, Brooks, & Jones, 2007). These contrasting views of water rights, combined with a lack of case law on the use of saline aquifers for natural gas or other storage, highlights the need to clarify whether or not an injector must obtain the water right for CCS.

The impact of injection on the underground brine or brackish water is likely to differ based on the geologic formation. When injection occurs in saline aquifers, which typically occur at depths of 2500 feet or more, simulations show that whether or not the brine is displaced depends on the porosity of the cap rock layers above the aquifer (National Energy Technology Laboratory, 2007). If the seal is impermeable, then pressure buildup is likely to occur. If the seal is permeable, then the brine can be displaced. Lateral displacement is small, and migration of the brine upwards is unlikely. Further research on downward displacement may be necessary as CCS nears commercialization (Birkholzer, Zhou, & Tsang, 2008; National Energy Technology Laboratory, 2007). If brine is displaced, but remains in the reservoir during CO2 injection for CCS, it is unclear if the water right would be necessary. The acquisition of this right is likely to be based on a case-by-case basis as the porosity of each injection site and the potential for brine migration will vary. If the brine is not displaced, and the pressure of the site is simply increased, the brine will most likely not be available for extraction in the future due to the risk of releasing the CO2 when the brine is harvested. Therefore, by displacing or increasing the pressure of a site that contains brine through CCS, it may be necessary for the water rights to be secured due to this displacement of groundwater.

The presence of brine or brackish water in pore space suggests that a water right would be necessary under some water regimes. Therefore, an analysis of water rights regimes will follow.

Groundwater Appropriation Doctrines

Groundwater in the US is typically appropriated through one of six doctrines: prior appropriation, absolute ownership, correlative use, reasonable use, the Restatement Rule, and public ownership. Absolute ownership means the surface estate has control over all resources on, above, or below the property. Thus, groundwater is the absolute property of the surface owner (Wilson & de Figueiredo, 2006). This water right structure would work well in conjunction with the assignment of pore space ownership to the surface landowner, but would cause complications if the pore space were owned by another entity.

The water right regime of prior appropriation will be addressed first since most of the Western US, where the majority of CCS would most likely occur first, adheres to this regime. Prior appropriation holds that the first person to make beneficial use of a water source establishes precedence over its continued use (Wilson & de Figueiredo, 2006). This rule is applied widely throughout the West and has been used to justify water displacement for mineral extraction. If CCS were seen as a beneficial use, then water may be displaced under this rule. A requirement for a beneficial use of the water brought to the surface, as is employed in Utah and Wyoming, may be required for CCS under this type of permitting. Under prior appropriation, water rights may often not be implicated as they were never claimed and will not be claimed since water in reservoirs that are ripe for CCS is most likely too deep to extract economically, and the energy to remediate the displaced fluid to drinking water standards may be exorbitant.

While prior appropriation rights have been used widely throughout the West, there are four other doctrines that dictate water rights and some states use multiple doctrines for underground water rights. It is more likely that water rights will be necessary under some of these other water right regimes.

Absolute ownership states that the surface estate has control over all resources on, above, or below the property. This doctrine was widely adopted in the 1850s and is still used today, with some modifications, in Connecticut, Georgia, Illinois, Indiana, Maryland, Massachusetts, Mississippi, Rhode Island, and the District of Columbia (Getches, 1990). Thus, any groundwater, in an aquifer or otherwise, is the absolute property of the surface owner (Wilson & de Figueiredo, 2006). This water right structure would work well in conjunction with the assignment of pore space ownership to the surface landowner, but would cause complications if the pore space were owned by another entity since the pore space owner may have to get permission from the water rights owner for injection.

The correlative rights rule states that surface right owners over an aquifer have apportioned shares of the aquifer dependent upon the amount of their land that overlies the resource (Wilson & de Figueiredo, 2006). Since this rule addresses use of an aquifer, it most likely would not be applicable to CCS since sequestration of CO2 would typically not be done in a drinking water aquifer.

The Restatement Rule allows for groundwater water to be extracted even if the water rights owner does not own the land above the aquifer. Since this rule focuses on aquifers, it also may not be appropriate for CCS reservoirs unless injected CO2 displaces water in an aquifer. This Rule imposes liability for usage causing unreasonable harm to neighboring landowners or for a withdrawal exceeding a reasonable portion of the annual storage of the aquifer (The American Law Institute, 1977).

Under the reasonable use doctrine, there is no restriction on use of groundwater, as long as it is in a reasonable and beneficial manner (Wilson & de Figueiredo, 2006). This doctrine could facilitate CCS as sequestration of CO2 could be deemed a reasonable and beneficial use that warrants the displacement of this water.

Lastly, groundwater is considered in many states to be public property. Rights to use the water are created through a permitting process. In this way, the state government decides how to use the resource. Colorado's Supreme Court ruled that groundwater is to be managed in this way. Under this doctrine, CCS would be at the mercy of the state; if it were deemed worthy of displacement or contamination of water or brine, then it may be supported (Hutches, 1990).

In comparison to these complicated regimes, injection in a deep saline aquifer in Alberta, Canada, has only one set of regulations for compliance: "The property in and the right to the diversion and use of all water in the Province is vested in Her Majesty in the right of Alberta" (Bankes, Poschwatta, & Shier, 2008, p. 9). Therefore, an operator who wanted to inject would need to acquire that right from the Crown. Thus far, earning these underground storage rights has involved a request of permission and indemnification of the Crown, but no charge for use of underground pore space has been incurred. As CCS becomes more prevalent and pore space more scarce, perhaps the Crown will start charging for injection (Bankes et. al., 2008). In contrast to Alberta, the regulatory landscape in the US is more complicated as each state can follow its own or multiple doctrines dictating the ownership of groundwater.

Because ownership of saline water is an unsettled doctrine in the US, it is possible that state legislatures or Congress will act to make the ownership of saline water uniform, such as by granting the states or federal government ownership as occurs in Alberta, in order to encourage CCS. There is a possibility that the Courts could deem CCS an activity that promotes the well-being of the public, and therefore, water rights could be deemed eligible for a "taking" and the impacted individual would receive just compensation. In instances of dam building and war efforts, water rights have been seized (Klass and Wilson, 2010).

<u>Mineral Extraction Corollaries</u>

Water is also displaced during mineral extraction. Consideration of how water rights are handled in this context could provide insight into how CCS that interferes with water rights will be handled. For more shallow deposits ripe for CCS, the water may be pumped to the surface as is done during mine dewatering at coal operations. In most states in order for the water to be extracted, a permit from the Ground Water Division of the State Engineer's Office must be obtained, and the water must be put to beneficial use, which may include crop or rangeland watering, dust abatement at the site, or cooling for power plants (Wyoming State Engineer's Office, 2005; Kolman, 2010). The precedent from coal mining implies that a water permit, and attendant groundwater remediation, would be necessary for brine that is pumped to the surface for CCS operations to occur. However, it may be less likely that during CCS operations brine would be pumped to the surface due to the cost associated with removal of the volumes of water necessary for large-scale CCS operations and pumping from deep aquifers.

Other oil and gas development can help serve as a guide for how CCS and water conflicts may be addressed. However, whether or not a water permit is necessary for development of oil, gas, coal bed methane, and minerals is inconsistent from state to state. A chart describing these different approaches is shown below in Figure 3, which highlights that water rights are not consistently required in a given state for extraction of all underground commodities. If CCS follows this state-specific approach, then a complex landscape will likely arise for future CCS injectors.

Figure 3: Water Rights Required for Development (Adapted from Kolman, 2010)

	Oil	**Gas**	**Coal bed methane**	**Minerals**
CO	N	N	Y	N
MT	N*	N*	Y	N*
NM	N	N	N	Y
UT	Y	Y	Y	N*
WY	N*	N*	Y	Depends on the permitting agency

*Denotes need for water right if water is being put to a beneficial use such as agriculture, livestock, mineral washing, or dust abatement.

Water Rights Jurisdiction

The issue of what qualifies as “water” for the designation of water rights becomes paramount as much of the liquid tied up in the pore space is of high saline concentration. An underground safe drinking water source is defined as fluid containing less than 10,000 milligrams/Liter (mg/L) of total dissolved solids (Consideration of underground sources of drinking water, 2000). Under the new EPA rule for Class VI wells for CCS under the Underground Injection Control Program, aquifers that have less than 10,000 mg/L and could possibly be used for drinking water sources are not eligible for injection, unless the injector applies for a permit exemption (Federal Requirements Under the Underground Injection Control Program for Carbon Geologic Sequestration Wells, 2010).

While it may not currently be economical to extract and remediate groundwater that has a high number of dissolved solids, future water shortages could make this activity worthwhile. Water rights owners of fluids that were displaced for CCS prior to these shortages may claim that they are owed compensation for the use of this resource.[14]

Within the oil and gas sector, corollaries for how to handle future water shortages due to extraction exist. The Montana Department of Natural Resources and Conservation created the Powder River Basin Controlled Ground Water Area Order that allowed groundwater to be drawn down for long periods of time due to mineral extraction. The water pulled to the surface, however, must be put to beneficial use. In contrast, Colorado has proposed rules that would prevent extraction that depletes underground water at greater than an annual rate of 1/10 of one percent of annual withdrawal rates (Kolman, 2010).

Another issue that may arise is how deep water rights extend. Water extracted from aquifers is typically no more than 1,500 feet from the surface (Bendixsen, 1994). However, none of the

[14] Water displaced by CCS may have productive uses outside of its drinking water potential. In some states water with a high number of total dissolved solids can still be useful if it is heated by geothermal resources and can be used to produce electricity or building heat. States like Idaho require a water permit for this type of use (Neely, K. personal communication, November 9, 2010).

current water rights ownership options mention a limit on the depth of the resource, and future water availability may make extraction of deeper water economical. In New Mexico, groundwater is owned by the state and appropriated for beneficial use, but the State Engineer is not permitted to allow aquifer extraction at depths below 2,500 feet and with more than 1,000 ppm of total dissolved solids (Fesmire et. al., 2007). Therefore, there may be a regulatory gap as water in deep saline aquifers falls outside of the typical domains that have been regulated for public use. To avoid this regulatory uncertainty, clarifying legislation allowing the government to assume pore space ownership and water rights below a certain depth (as is described in the next section) may simplify this situation. Due to the potential complications with water rights owners as fluids are displaced through CO2 injection, consideration of the legal structure for acquiring these groundwater rights is necessary.

Water Contamination

Like mining industries that have the potential to contaminate groundwater, CCS may impact not only water rights owners whose water is displaced, but also water rights owners who hold title to water that is not even in the deposit where CCS occurs could be affected if the CCS operation erodes a formation and contaminates a reservoir. This situation could arise if the CO2 combines with water to form carbonic acid, which can leach away soft minerals like limestone. Hydrogen sulfide and CO2 are also often injected in underground reservoirs during the refining of natural gas (Alberta Environment, 2008). Injection of these gases could also cause unexpected erosion impacts on a reservoir as hydrogen sulfide is corrosive. The Class VI rule for CCS wells under the Underground Injection Control Program does not have a minimum CO2 requirement for injected products (Federal Requirements Under the Underground Injection Control Program for Carbon Geologic Sequestration Wells, 2010). Therefore, testing of the impacts of injecting CO2 with common co-contaminants in stack emissions and by-products of industrial operations is essential to prevent the contamination of underground sources of drinking water and CO2 leakage. In order to protect against groundwater contamination damages such as this, Montana has a Coal Bed Methane Protection Program that pays damages for contaminated surface or ground resources (Kolman, 2010).

This section raises the question of whether or not water rights will be necessary in order to engage in CCS. However, it is not certain that one must retain the water rights in order to inject since water rights are necessary only if the resource is deemed economical for extraction. Potential future water shortages could complicate the landscape. Therefore, it is probably safer for CCS injectors to procure the water rights, even if the water has a high number of total dissolved solids and the injection would only displace or pressurize the site. Simply owning groundwater rights, however, will probably not be sufficient for engaging in CCS since, as previously mentioned, CCS involves not only displacing the water but then filling the vacuous pore space. Each of these activities may involve a separate legal right. Adjacent water rights owners may suffer from water contamination from injection, especially if no minimum threshold for CO_2 composition is set by well injection permitting bodies.

Conclusion

Issues related to unitization, conversion of an EOR well to a CCS well, future mineral extraction, and reservoirs that span state boundaries point to some of the problems with state-level pore space ownership decisions and the application of the American Rule in some states that have moved ahead with pore space designation. Application of the English Rule in the US would be equally as complicated since mineral rights ownership is a patchwork quilt of public and private interests. Allowing the federal government to assume pore space ownership would not solve all of these problems, but would certainly simplify some of them by reducing the amount of future litigation.

Federal ownership of all subsurface pore space in the US would prevent disputes over how much CO_2 was injected into a particular plot and how much each landowner should be compensated. There would be no delays to CCS due to hold-outs of property owners that disagree with CCS. If a well were converted from a Class II oil or gas extraction well that was engaged in EOR or enhanced gas recovery to a Class VI CO_2 storage well, the federal government may decide not to require any payment for the CO_2 already sequestered since the sequestered CO_2 would represent a tiny amount of the overall potential for the US. Also, the federal government would be well-equipped to assume responsibility for injection in these sites. Conflicts over future mineral extraction in reservoirs that already had CO_2 injected may be less contentious since mineral rights owners would be challenging the federal government instead of a private landowner over reopening of a site. Finally, for issues of pore space that span state boundaries, CCS would greatly be simplified if the federal government owned the pore space. Disputes over liability, amount injected, and whether or not injection was permissible would be moot. These issues would also be simplified for reservoirs that span the US borders since in both Canada and Mexico, the federal government owns most of the mineral rights and the country ascribes to the English Rule where the pore space defers to the mineral rights owner once the site has had its useful minerals extracted. Therefore, from the standpoint of achieving global warming mitigation through CCS, assigning pore space ownership to the federal government seems to be the best way to achieve this goal.

The federal government may be able to take the proceeds from carbon credits for geologic sequestration and put them into an insurance fund to protect against long-term groundwater contamination, induced seismic activity, leakage, or other unwanted impacts of CCS. If private citizens were compensated for CCS based on their ownership of pore space, they would still need outside liability protection for a time horizon beyond injection and closure of the well, which will most likely be covered by the CCS injector. This long-term protection will most likely be provided by the federal government since there is no other entity that is enduring and powerful enough to handle disaster response on the scale that is necessary for CCS. Therefore, allowing the federal government to own pore space correctly aligns the payments for the injection with the entity that is assuming responsibility for injection.

Federal ownership of pore space is not without flaws. States may fight fiercely against this designation as it takes away their sovereign authority over property law traditionally overseen by states. States and citizens will most likely be opposed to federal ownership of pore space since it would take away the potential boon to the economy that would result from citizens receiving payments for use of the pore space below their ground. Some states with large tracts of public land may argue that the federal government will already benefit greatly by sequestration due to the potential application of the American Rule on public land. States like Wyoming, North Dakota, and Montana that have already assigned pore space to the surface landowner may claim that their law has primacy over any future federal legislation that is passed. Citizens may also be upset with this decision because it would prevent them from stopping CCS under their land if they are opposed to it. Also, this designation does not solve the problem of pre-existing mineral and water rights, which may lead to usage conflicts.

While federal assumption of pore space is not a panacea for all potential problems that could arise, it could help mitigate the impact of many issues on the horizon. Therefore, federal pore space ownership is the ownership structure that has the most potential to allow for successful commercialization of CCS. However, given the obstacles to passing federal legislation, the delays inherent in this ownership designation may stand as a hurdle to the CCS industry. If additional states pass legislation supporting the American Rule or any other ownership structure, the issues will become only more complex without the federal government addressing ownership in an expedient manner.

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