CREATING SAFE AND EFFECTIVE CARBON SEQUESTRATION

SUMIT SOM[*]

INTRODUCTION

A. *Need for Carbon Capture and Sequestration*

In the effort to combat climate change, many new technologies are being explored. One promising endeavor is carbon capture and sequestration (CCS). This process works by capturing Carbon Dioxide (CO_2) released from fossil fuel combustion and then storing it underground so it does not enter the atmosphere. CCS is a relatively new mitigation strategy, so neither its potential for greenhouse gas mitigation nor its drawbacks are as clearly perceived as those of other climate change mitigation options. However, given the need for a comprehensive solution to global warming, CCS is an important weapon in the arsenal of available policies.

In order to foster CCS, in 2003 the Department of Energy announced FutureGen, an initiative to build a coal fired power plant that will implement CCS.[1] However, due to a higher than expected price tag, the Department of Energy modified FutureGen.[2] Instead of a single plant, federal funding will go to multiple smaller plants that will all individually capture and sequester certain amounts of CO_2.[3] So despite the initial setback, efforts to spur CCS are still strong. This is in a large part due to

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[1] DEP'T OF ENERGY, FACT SHEET: DOE TO DEMONSTRATE CUTTING-EDGE CARBON CAPTURE AND SEQUESTRATION TECH. AT MULTIPLE FUTUREGEN CLEAN COAL PROJECTS 1 (2008), *available at* http://www.fossil.energy.gov/programs/powersystems/futuregen/futuregen_revised_0108.pdf.

[2] DEP'T OF ENERGY, FOSSIL ENERGY: DOE'S FUTUREGEN INITIATIVE, http://www.fossil.energy.gov/programs/powersystems/futuregen (last visited Aug. 29, 2008).

[3] *Id.*

the necessity of finding some way to use coal without destroying the environment. Coal currently produces 49.7 percent of all electricity for the United States.[4] Furthermore, demand for coal is expected to increase by 48 percent in the U.S., and 73 percent worldwide by 2030.[5] Thus, not only the United States, but also big emerging countries like India and China, are going to continue to have a voracious appetite for coal. Coal is such a huge part of modern economies that it is hard to envision replacing it completely with cleaner energy sources. Continued use of coal thus requires something like CCS, which can mitigate its greenhouse effects. Without such technology, effectively stopping climate change could be extremely difficult.

Apart from the environmental need for CCS, there is a domestic political need. CCS would allow continued use of coal as an energy source. This will allow easier passage of climate legislation because there will not be opposition from coal states, and from industry, which could be spared higher energy prices because of switching to more expensive fuels.

B. *Role of CCS in Fighting Climate Change*

There are several compounds that are causing global warming. They include CO_2, methane, nitrous oxide, and other gases that trap heat and result in higher global temperatures.[6] However, among all the greenhouse gases, CO_2 is the primary contributor to climate change. Approximately 60 percent of the anthropogenic global warming effect of greenhouse gases comes from CO_2.[7] Since 75 percent of this CO_2 is a result of fossil fuel use,[8] approximately 45 percent of the anthropogenic global warming effect is a product of fossil fuel use.[9] Anthropogenic CO_2 comes from many sources such as electricity production,

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[4] ENERGY INFO. ADMIN., ENERGY INFORMATION SHEETS INDEX: COAL DEMAND (2007), http://www.eia.doe.gov/neic/infosheets/coaldemand.html (last visited Aug. 29, 2008).

[5] DEP'T OF ENERGY, *supra* note 1.

[6] *See* V. Ramaswamy et al., *Radiative Forcing of Climate Change*, *in* CLIMATE CHANGE 2001: THE SCIENTIFIC BASIS 349, 358 (J.T. Houghton et al. eds., 2001).

[7] Paul Freund, *Introduction*, *in* CARBON DIOXIDE CAPTURE AND STORAGE 51, 56 n.8 (Bert Metz et al. eds., 2005).

[8] *Id.* at 55.

[9] 75 percent of 60 percent is 45 percent.

transportation, and industry.[10] Of these sources, CCS technology can be applied to large point sources such as power generation (the largest source of CO_2), industry, and manufacturing and construction.[11] If CCS were applied to every possible source, then it could capture a total of 13,466 megatons of CO_2 per year ($MtCO_2$/yr).[12] This constitutes 56.9 percent of the 23,684 $MtCO_2$ emitted in 2003.[13] Since CO_2 is the cause of 45 percent of the anthropogenic global warming effect, CCS could potentially be applied to sources causing 25.6 percent of the radiative effect of climate change.[14] Current technology allows for the capture of between 85 to 95 percent of the CO_2 that would be emitted from a plant without CCS technology.[15] However, a source that has CCS technology requires between 10 to 40 percent more energy to capture and compress the CO_2.[16] The net result is that approximately 80–90 percent less CO_2 is released from a CCS plant relative to a normal plant.[17] Applying this figure to the total CO_2 that could be sequestered means that 21.8 percent of the anthropogenic global warming effect could be prevented via the use of CCS.[18] Obviously, nowhere close to all large point sources are going to adopt CCS technology. Thus, this figure should not be seen as an estimate of the CCS's climate mitigation effect.

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[10] *See* Freund, *supra* note 7, at 56:

Sources of Carbon Dioxide Emissions from Fossil Fuel Combustion (2001)

Source	$MtCO_2$ yr
Public Electricity and heat production	8,236
Autoproducers	963
Other energy industries	1,228
Manufacturing and construction	4,294
Transport	5,656
Other sectors	3,307
TOTAL	23,684

[11] *See id.*

[12] *See* Intergovernmental Panel on Climate Change (IPCC), *Summary for Policymakers*, *in* CARBON DIOXIDE CAPTURE AND STORAGE 1, 3 (Bert Metz et al. eds., 2005), *available at* http://www.ipcc.ch/pdf/special-reports/srccs/srccs_summaryforpolicymakers.pdf.

[13] *See* Freund, *supra* note 7, at 56.

[14] 56.9 percent of 45 percent is 25.6 percent.

[15] IPCC, *supra* note 12, at 4.

[16] *Id.*

[17] *Id.*

[18] 85 percent of 25.6 percent is 21.8 percent.

However, it does indicate that a sizable chunk of the world's global warming problem might be solved by the use of CCS. Furthermore, the composition of greenhouse gas emissions could change over time. Depending on future developments, CCS can either grow or diminish in proportional mitigation capacity.

This paper will begin by explaining how CCS works and how much it will cost to implement. The following section will describe the atmospheric and safety risks associated with CCS if there is leakage. Section four will outline the new regulations that need to be implemented to ensure secure storage sites both underground and underneath the seabed. Finally the importance of securing public support for CCS will explained. If these steps are all taken, CCS can become a valuable tool in the effort to halt climate change.

I. CARBON CAPTURE AND SEQUESTRATION PROCESS AND COSTS

A. *Process*

There are three steps in the CCS process: capture, transportation, and storage. For the purposes of the first step of capturing CO_2, there are currently three technologies that separate CO_2 and make it available for sequestration: pre-combustion, post-combustion, and oxy-fuel combustion.[19] The next phase is to transport the captured CO_2 to a storage site. This can be done via pipelines, which have already been transporting CO_2 for twenty-five years[20] across 2500 kilometers in the United States.[21] Finally, once the CO_2 reaches the storage site, it can be injected using existing technology. However, first, injectors must choose an appropriate sequestration site. Geological storage sites require adequate capacity, a sealing caprock or confining unit, and a stable geological environment.[22] If CO_2 is injected into a site with problematic geological features, it could escape into the atmosphere and exacerbate global warming: the sealing

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[19] *See* Kelly Thambimuthu, Mohammad Soltanieh & Juan Carlos Abanades, *Capture of CO_2, in* CARBON DIOXIDE CAPTURE AND STORAGE 105, 107 (Bert Metz et al. eds., 2005).

[20] Richard Doctor & Andrew Palmer, *Transport of CO_2, in* CARBON DIOXIDE CAPTURE AND STORAGE 179, 189 (Bert Metz et al. eds., 2005).

[21] *Id.* at 181.

[22] Sally Benson et al., *Underground Geological Storage, in* CARBON DIOXIDE CAPTURE AND STORAGE 195, 213 (Bert Metz et al. eds., 2005).

mechanism could fail if the stored CO_2 builds up enough pressure that it can pass through the caprock;[23] if the caprock has openings, fractures, and faults, the CO_2 could escape through them;[24] and for injections into former oil and gas fields, CO_2 could escape if the injection wells are not plugged securely.[25] When establishing sequestration sites, these dangers must all be accounted for to ensure sound storage.

There are several different geological formations into which CO_2 can be injected. One option is to inject the CO_2 into saline formations—deep sedimentary rocks saturated with water or brine containing high concentrations of salt.[26] These sites exist in sedimentary basins both onshore and under the seabed on continental shelves.[27] A secure caprock is very important in saline formations because when CO_2 is injected, it will be less dense than the brines it displaces.[28] The buoyancy-driven flow will cause the CO_2 to migrate upwards where it must be stopped by the caprock.[29] However, after the brine is saturated with CO_2, it will become denser and sink, ultimately decreasing the probability of leakage.[30] Saline formations are widespread and have a minimum aggregate storage capacity of one million $MtCO_2$.[31] The ultimate capacity is probably much larger, but not enough studies have been done to make an accurate estimation.[32] Little is known about the geology and storage abilities of saline aquifers relative to other storage options, so development of them as storage sites may be more costly than alternatives.[33]

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[23] *Id.* at 242.

[24] *Id.*

[25] *Id.* at 243.

[26] *Id.* at 217.

[27] *Id.* at 222.

[28] Elizabeth J. Wilson, Timothy L. Johnson & David W. Keith, *Regulating the Ultimate Sink: Managing the Risks of Geologic CO_2 Storage,* 37 ENVTL. SCI. TECH. 3476, 3476 (2003), *available at* http://pubs.acs.org/cgi-bin/article.cgi/esthag/2003/37/i16/pdf/es021038+.pdf.

[29] *Id.*

[30] Benson, *supra* note 22, at 217.

[31] *Id.* at 223. This is extensive storage capacity given that an estimated 23,684 $MtCO_2$ are released annually. *See* Freund, *supra* note 7, at 56.

[32] Benson, *supra* note 22, at 223.

[33] SHALINI VAJJHALA, JENNY GODE & ASBJØRN TORVANGER, AN INTERNATIONAL REGULATORY FRAMEWORK FOR RISK GOVERNANCE OF CARBON CAPTURE AND STORAGE (Resources for the Future Discussion Paper 07-13, 2007), *available at* http://www.rff.org/rff/documents/rff-dp-07-13-rev.pdf.

A second alternative is to inject captured CO_2 into coal seams. Injected CO_2 will be absorbed by the coal surface and displace other gases which have less affinity to the coal.[34] But since the global storage capacity of coal seams is only between 3,000–200,000 $MtCO_2$, this will not serve as a major avenue of sequestration.[35]

The final option is to inject the carbon into abandoned oil and gas fields, which appear to be ideal storage sites for a variety of reasons. First, the oil and gas that had originally accumulated was available for mining because it did not escape, which indicates the ability of the site to seal, and prevent leakage.[36] Additionally, many of the fields still have infrastructure and wells that can be useful for carbon injection and storage.[37] Finally, there is extensive knowledge about these sites. The geological structure and physical properties of most oil and gas fields have been exhaustively studied, and the oil and gas industry has developed sophisticated computer models that can predict the movement and displacement of underground hydrocarbons.[38] Carbon sequestration in abandoned oil fields can also yield economic benefits by allowing for enhanced oil recovery (EOR). Usually only about 5 to 40 percent of oil from a site is recovered.[39] By injecting CO_2, oil is flooded out and an average of 13.2 percent of additional oil can be mined.[40] This is an attractive option because if enough oil is recovered, the sequestration process can become profitable. Globally there is the opportunity to inject between 61,000–123,000 $MtCO_2$ for EOR purposes.[41] Including sites where EOR is not possible, total capacity of CO_2 storage in oil and gas fields is estimated to be between 675,000–900,000 $MtCO_2$.[42]

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[34] Benson, *supra* note 22, at 217.

[35] *See id.* at 221. Every year an estimated 23,684 $MtCO_2$ are released, so these sites could not even store all the CO_2 emissions for just one year. *See* Freund, *supra* note 7, at 56.

[36] Benson, *supra* note 22, at 215.

[37] *Id.*

[38] *Id.*

[39] *Id.*

[40] *Id.*

[41] *Id.* at 222.

[42] *Id.*

B. *Costs*

The entire CCS process will require expenditures that will raise the price of fossil fuel use. Overall the costs of CCS are highly variable from site to site, so judging if a project is economical requires a detailed analysis for every project. What can be expected with substantial likelihood is that since CCS is a new technology, there will be improvements in the future that should reduce the cost. However, it is important to note that an average CCS project is already estimated to be cheaper than employing other mitigation options such as renewable energy.[43]

CCS can be applied to a variety of sectors, but the most widely studied cost increases have been done for power plants.[44] It is estimated that capturing the CO_2 from power plants would raise the cost of electricity production by 20 to 70 percent[45] which would increase the price by 0.9 to 3.4 cents per kilowatt hour (ct kWh).[46] This estimation differs depending on the type of plant and a host of other factors. The cost of transportation depends on construction, operation, maintenance, and management costs.[47] These factors also vary by enormous degrees, so any estimated standard cost would be highly inaccurate. Finally, the cost of storing the captured CO_2 imposes an additional negligible charge of only -1 to 1 ct kWh.[48] In fact, negative costs are possible if the captured CO_2 is used for EOR: a profit of $10–16 per ton of CO_2 can be derived when oil prices are between $15–20 per barrel of oil.[49] Since the present price of a barrel of oil is well above this figure, carbon sequestration used for EOR purposes could generate substantial profit.[50]

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[43] *See* Thomas E. Curry, Public Awareness of Carbon Capture and Storage: A Survey of Attitudes Toward Climate Change Mitigation 55 (June 2004) (unpublished B.S. thesis, Massachusetts Institute of Technology), *available at* http://sequestration.mit.edu/pdf/Tom_Curry_Thesis_June2004.pdf (studies indicate that continuing with current energy options costs a family $1200 in electricity bills. Reducing emissions by 90 percent using CCS would cost $2400 while a similar cut using renewable energy would cost $4000).

[44] Howard Herzog & Koen Smekens, *Cost and Economic Potential*, *in* CARBON DIOXIDE CAPTURE AND STORAGE 339, 342 (Bert Metz et al. eds., 2005).

[45] *Id.*

[46] *Id.* at 341.

[47] Doctor, *supra* note 20, at 190.

[48] Herzog, *supra* note 44, at 341.

[49] Benson, *supra* note 22, at 197.

[50] *See* WTRG ECONOMICS, CRUDE OIL FUTURE PRICES-NYMEX, *available at* http://www.wtrg.com/daily/crudeoilprice.html (Oil prices were at $136 a

II. RISKS OF STORAGE

Once CO_2 is injected and stored, there is still the ever present risk of the CO_2 escaping. Average expected leakage rates, however, are well below 1 percent. Geological storage sites have a 90 to 99 percent probability of storing 99 percent of total injected CO_2 over one hundred years.[51] Over a thousand years there is a 60 to 99 percent probability of retaining 99 percent of the sequestered CO_2.[52] However, these predictions have a high degree of uncertainty due to the difficulties of predicting over such an extended time period. Ultimately the ability of a site to contain CO_2 is very site specific, and preventing future CO_2 releases is dependent on using the best storage sites and diligent maintenance. Retention rates will depend on the storage system design and geological characteristics of the site, the engineering of the site and injection wells, and how the site is cared for and treated in the future.[53] This could potentially be a problem in the future if CCS becomes a widely used technology. Over the long term, less than ideal sites may be employed as the most secure ones are injected to capacity. The dearth of secure sites could become very problematic because the most important component to ensuring safe CCS sites is using sites that have ideal geology.[54] The use of substandard sites will significantly increase the probability of leakage.

The risks of leakage can be divided into safety and atmospheric risks. Safety risks are those of a local character involving harm to the environment or people located around a storage site. Atmospheric risks are of much greater concern because they are not a localized problem, but, rather, there is the risk that the CO_2 will reach the atmosphere and cause global warming. While the probability of CO_2 leakage occurring is low, it

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barrel as of June 11, 2008).

[51] GEORGE PERIDAS, NATURAL RESOURCES DEF. COUNCIL, ATTRIBUTES OF AN EFFECTIVE REGULATORY REGIME FOR CARBON CAPTURE & STORAGE 8 (2007), http://www.irgc.org/IMG/pdf/IRGC_CCS_Peridas07.pdf.

[52] *Id.*

[53] Benson, *supra* note 22, at 246.

[54] *See* M.A. De Figueiredo, D.M. Reiner & H.J. Herzog, *Framing the Long-Term* In Situ *Liability Issues for Geologic Carbon Storage in the United States*, 10 MITIGATION & ADAPTATION STRATEGIES FOR GLOBAL CHANGE 647, 648 (2005), *available at* http://sequestration.mit.edu/pdf/Framing_the_Long-Term_Liability_Issue.pdf ("The choice of appropriate sites is the best way to minimize any adverse effects related to carbon dioxide storage.").

remains a concern largely because predicting conditions centuries in the future is difficult.[55]

A. *Safety Risks*

If CO_2 were to leak above ground, it could potentially cause harm in the vicinity. Minor amounts of above ground leakage are safe because CO_2 is a natural gas that is not harmful until it reaches certain concentrations. Physiological effects such as impairment of respiration do not occur until concentrations of 3 percent, while death can occur if concentrations exceed 10 percent.[56] These concentrations may occur either through a slow buildup or through an explosion.[57] For example, CO_2 buildup, which has inundated soils at Mammoth Mountain, California, has resulted in an extensive tree die off.[58] At Lake Nyos, Cameroon, a concentration of CO_2 was confined close to the surface and then suddenly released, causing an explosion which resulted in the death of thousands of people.[59]

Even if CO_2 escapes from the storage zone but never leaks above ground, it can still cause safety risks. If CO_2 migrates into the groundwater it will dissolve and form carbonic acid which will increase the water's acidity.[60] The higher acidity could mobilize toxic metals such as sulphate or lead, which, at sufficient levels, could make the water unsafe for drinking.[61] CO_2 storage might also result in brine displacement, causing salt to migrate into

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[55] *See* Peridas, *supra* note 51, at 8 (Geological storage sites have a 90 to 99 percent probability of storing 99 percent of total injected CO2 over one hundred years. Over a thousand years there is a 60 to 99 percent probability of retaining 99 percent of the sequestered CO2.).

[56] Wilson, *supra* note 28, at 3477.

[57] A dramatic explosion can occur if a slow leakage of CO_2 gets confined close to the surface and then is suddenly released. Wilson, *supra* note 28, at 3477.

[58] C.D. Farrar, M.L. Sorey, W.C. Evans, J.F. Howie, B.D. Kerr, B.M. Kennedy, C.Y. King & J.R. Southon, *Forest-Killing Diffuse CO_2 Emission at Mammoth Mountain as a Sign of Magmatic Unrest*, 376 NATURE 675, 675 (1995).

[59] Richard Black, *Action Needed on Deadly Lakes*, BBC NEWS, Sept. 27, 2005, *available at* http://news.bbc.co.uk/2/hi/science/nature/4285878.stm.

[60] Curtis M. Oldenburg, *Migration Mechanisms and Potential Impacts of CO_2 Leakage and Seepage*, *in* CARBON CAPTURE AND SEQUESTRATION 127, 138 (Elizabeth J. Wilson & David Gerrard, eds., 2007).

[61] *See* Benson, *supra* note 22, at 247.

groundwater and thereby increase the salinity.[62] This also creates unsafe drinking water. However, contamination from brine is rare and is expected to remain so, even if large-scale CCS projects are instituted.[63] Finally, injecting large volumes of CO_2 into the subsurface will displace some original subsurface material.[64] This could induce fracturing or other kinds of seismic events.[65] However, these are usually minute in scale: more than 99% of seismic activity induced by injection wells is undetectable.[66]

If any of the safety concerns of CCS transpire in the near future, the prospects for further CCS development will be severely hampered. Since CCS is a new technology, an initial perception that it is dangerous could slow adoption. Even if the overall damage to the environment or society is far outweighed by the utility of preventing greenhouse gas emissions, the public will probably react negatively towards CCS. Thus, secure carbon storage is essential to prevent any of the safety risks from occurring, not only to prevent any damage to local environments, but, more importantly, to avoid a political backlash against CCS.

B. *Atmospheric Risk*

The atmospheric risk of CCS is that the CO_2 will eventually leak out to the atmosphere and over time exacerbate global warming. In order for CCS to effectively mitigate climate change, extremely low seepage rates are required. If as little as 1% of the stored CO_2 were to escape each year, over half of the sequestered CO_2 would reach the atmosphere within a century.[67] Allowing CO_2 to escape is especially damaging because in addition to the monetary cost required to capture and store CO_2, there is an energy cost for operation of CCS facilities. If leakage is extensive enough, more CO_2 will be produced per unit of usable energy than if CCS were never employed in the first place. But the most

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[62] *Id.* at 248.

[63] *Id.*

[64] Wilson, *supra* note 28, at 3477.

[65] *Id.*

[66] Elizabeth J. Wilson & David Gerrard, *Risk Assessment and Management for Geologic Sequestration of Carbon Dioxide*, *in* CARBON CAPTURE AND SEQUESTRATION 101, 112–13 (Elizabeth J. Wilson & David Gerrard eds., 2007).

[67] CARLO C. JAEGER, POTSDAM INST. FOR CLIMATE IMPACT RESEARCH, CARBON CAPTURE AND STORAGE: RISK GOVERNANCE AND RENT SEEKING 4 (2007), *available at* http://www.irgc.org/IMG/pdf/IRGC_CCS_Jaeger07.pdf.

damaging aspect of leaky CCS projects is that they will lull society into thinking they are combating global warming and thus may forgo other mitigation options. Thus, valuable time and political will could be squandered if CCS projects do not deliver the CO_2 mitigation they promise.

In order to prevent atmospheric risks, not only must CCS projects have extremely low seepage rates, but they must be maintained for centuries. The exact length of time CO_2 must be stored to prevent climate change is difficult to estimate. It depends on how much greenhouse gas (GHG) emissions occur over time, which in turn depends on a host of factors such as economic performance and the development of new technologies. If GHG emissions are reduced to a great extent, then the harm of premature CO_2 releases from CCS sites is less damaging, while the opposite is true if emissions reductions are minor. Scientists usually look at sequestration over a 500 to 1,000 year period to see how much CO_2 is retained.[68] This provides a very rough estimation of how long the CO_2 must be stored for CCS to have a meaningful effect in reducing global warming; however an exact time frame of how long sequestration must operate is still unascertained by the scientific community.

The atmospheric risk of CSS is a more serious concern than the safety risks. The potential damage from large amounts of CO_2 leaking into the atmosphere and causing global warming is much greater than that from localized seepages or explosions. Society would probably rely on sequestered carbon to stay underground, and thus neglect to take other greenhouse gas mitigation efforts. So, the failure to securely keep all the CO_2 could be doubly damaging to the global environment in that CO_2 would be reaching the atmosphere and no alternative steps would have been taken to prevent climate change. Granted, this could be true for all global warming mitigation initiatives. However, unlike with other mitigation strategies, the knowledge that CCS is not working could be delayed for a long time. For example, an inability to develop cleaner energy sources is known at the testing phases of those technologies, whereas it may be a century before a storage leak is detected.

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[68] *See* Freund, *supra* note 7, at 66–67 nn.17–18 (Several studies were conducted by various scientists trying to determine how much CO2 would escape under different leakage rates. The time scales they employed ranged from 500 to 1,000 years.).

III. CREATION OF A LEGAL FRAMEWORK TO SUPPORT CARBON STORAGE

There are already laws governing the injection and storage of materials underground. However, they are not ideally suited for preventing leakage from CCS projects, thus a new regulatory system must be created for geological sequestration. In addition, in order to take advantage of storage opportunities beneath the ocean, subseabed sequestration must be legalized. Whatever legal framework is ultimately created must also include a liability scheme so that someone maintains responsibility for the stored CO_2 over both the short and long run.

A. *Regulation of Carbon Storage on Land Under the Safe Drinking Water Act*

1. *Current Regulations*

The U.S. Environmental Protection Agency (EPA) has established the Underground Injection Control (UIC) program to provide a regulatory framework for underground injections.[69] UIC's passage occurred after passage of the Safe Drinking Water Act (SDWA), which required the EPA to create minimum standards for state UIC programs to prevent injection from harming underground sources of drinking water.[70] This system gave the states the power to tailor the laws to their local needs. If states choose, they can petition the EPA for primacy and assume the lead role in implementation and enforcement of UIC.[71] Currently thirty-four states have been granted primacy, while the EPA implements the program directly in ten states, and shares responsibility in the remaining six states.[72]

Underground injections are divided into classes one through five: Class I, hazardous waste, industrial, and radioactive injection; Class II, natural gas, oil, and hydrocarbon storage and recovery

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[69] M.A. DE FIGUEIREDO ET AL., REGULATING CARBON DIOXIDE CAPTURE AND STORAGE 7 (2007), *available at* http://web.mit.edu/ceepr/www/2007-003.pdf.

[70] *See* Earle Herbert, *The Regulation of Deep Well Injection: A Changing Environment Beneath the Sea*, 14 PACE ENVTL. L. REV. 169, 192–95 (1996).

[71] Elizabeth J. Wilson & David Gerard, *Geologic Sequestration Under Current U.S. Regulations: Problems and Prospects*, *in* CARBON CAPTURE AND SEQUESTRATION 169, 171 (Elizabeth J. Wilson & David Gerrard, eds., 2007).

[72] *Id.* at 172.

wells; Class III, injections for mineral extraction; Class IV, injections very close to drinking water; and Class V, other.[73] There has yet to be a definitive decision on what class carbon sequestration projects will fall into. Currently, there is a greater focus on research and development of CCS. The first stage is the validation stage, involving twenty-five sites that will inject low quantities of CO_2.[74] Then, in 2009, the deployment stage will commence, which will involve higher quantities of CO_2 sequestration.[75] The goals of the two stages of development include "testing the effectiveness of various well materials and injection practices, assessing the usefulness of geophysical survey and monitoring techniques, testing failure scenarios, and/or validating models of the fate and transport of CO_2 in the subsurface."[76]

2. *New Regulations*

Once CCS technology moves out of the experimental phase, there are several options, ranging from loose to stringent oversight, for regulating the wells. The most flexible option is to have Congress exempt CCS storage projects from the UIC program. An example of this is the regulation of natural gas storage, which is conducted at the state and county levels, which have the freedom to tailor laws to meet local conditions.[77] However, this is a high risk strategy for regulating CCS because local regulators can set up lax standards in an effort to bring projects and the associated jobs to their locale. This could increase the safety and atmospheric risks from resulting leakages of $CO_{2,}$ which would harm both individuals and the environment. Even if this only occurred on a limited scale, it is possible that such results could have far-reaching effects by endangering public confidence and support for CCS in general.

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[73] *See* 40 C.F.R. § 144.6.

[74] Memorandum from Cynthia C. Dougherty, Director of Office of Ground Water and Drinking Water & Brian McLean, Director of Office of Atmospheric Programs to Water Management Division Directors, Air Division Directors & EPA Regions I to X, Using the Class V Experimental Technology Well Classification for Pilot Geologic Sequestration Projects – UIC Program Guidance 2 (Mar. 2007), *available at* http://www.epa.gov/safewater/uic/pdfs/guide_uic_carbonsequestration_final-03-07.pdf.

[75] *Id.*

[76] *Id.*

[77] Wilson & Gerard, *supra* note 71, at 189.

The second option is to continue treating the wells as Class V wells, but to use the data collected during the experimental phase to then tailor rules for CCS projects. The focus of the regulations would be the necessary geologic requirements to prevent CO_2 from escaping. Keeping Class V regulations is advantageous because the regulations are less onerous than the other classes, so the lack of red tape could speed up CCS development. However, the more onerous regulations of the other classes often play important safety roles. Since Class V wells do not require procedures that help protect surface populations from leakages, such as inventory assessment, additional reporting, and closure requirements, regulating CCS wells under Class V might not provide enough safety and security.[78]

A similar option to writing new regulations within Class V is to create a new class for CCS projects and, thus, not involve previous Class V regulations. This would allow maximum flexibility and oversight, and an appropriate degree of consistency in regulations. Theoretically, this sounds like the ideal solution; however, it will be politically difficult. This method requires the promulgation of a new rule, which would involve notice of proposed rulemaking in the Federal Register, review by the Office of Management and Budget, a public comment period, and final notice in the Federal Register.[79] In addition, there is the possibility that environmental groups or industry will institute lawsuits challenging the rule depending on the stringency of regulations. This could be enormously time-consuming and expensive.

The final alternative is to classify the wells either as Class I or Class II. Class II wells regulate waste from hydrocarbon production, which could already include injection wells used for EOR or gas recovery.[80] Class I wells cover hazardous and industrial waste injection, which would include CO_2 from industrial facilities and power plants.[81] The main focus of both classifications is preventing contamination of drinking water.[82] While this is also a concern for carbon storage, the main risk of carbon storage is CO_2 leaking up through the surface. Thus, while

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[78] *See id.* at 187.

[79] *Id.* at 188.

[80] *See* 40 C.F.R. § 144.6.

[81] *See id.*

[82] Wilson & Gerard, *supra* note 71, at 185.

the Class I and II regulations would be helpful because they are designed to prevent migration, these classifications are not ideally suited for CCS because they do not cover crucial issues such as ensuring a solid caprock and a stable geologic state. The other problem is that certification of a Class I well is time-consuming and expensive because they have the most "stringent siting, construction, and operational standards."[83] However, it might be beneficial to retain these tough standards for CCS regulation because ensuring full capture of all CO_2 is of paramount importance.

Of all the options, the best solution would probably be to avoid existing requirements and create a new rule after the experimental phase. If the experimental results are positive, and there is a desire to strongly push CCS technology, then the effort required to promulgate a new rule would be worthwhile. Ensuring safety and minimal leakage are of the utmost importance, so regulations should be designed to focus on these risks rather than on just preventing drinking water contamination. By designing new regulations, appropriate emphasis can be placed on issues specific to carbon storage, such as a tightly sealed caprock and a stable geological environment.[84] In order to avoid a lawsuit, early observations of experimental CCS projects should be used to start a dialogue among concerned parties such as environmental groups and industry. With time, a consensus could be reached that will allow a smooth and successful rule making process.

In July 2008, the EPA began the process of creating a new class of wells.[85] They issued a proposal to create Class VI wells which will focus on issues specifically related to carbon sequestration such as site selection, injection requirements, and storage.[86] This is currently a draft rule, but ultimately it should be implemented in some form. As discussed above, the creation of a new class creates the best opportunity for carbon sequestration to

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[83] *Id.*

[84] *See* Benson, *supra* note 22, at 213.

[85] U.S. ENVIRONMENTAL PROTECTION AGENCY, EPA PROPOSES NEW REQUIREMENTS FOR GEOLOGICAL SEQUESTRATION OF CARBON DIOXIDE 1 (2008), *available at* http://www.epa.gov/safewater/uic/pdfs/fs_uic_co2_proposedrule.pdf.

[86] *See id.* at 2 ("EPA's proposed rule would establish a new class of injection well—Class VI—and technical criteria for geologic site characterization; area of review and corrective action; well construction and operation; mechanical integrity testing and monitoring; well plugging; post-injection site care; and site closure for the purposes of protecting underground sources of drinking water.").

proceed in a safe manner.

Whatever regulations are eventually settled on, they should be enforced in a similar manner as the current UIC regulations, which will allow CCS regulation to be tailored to local needs while still ensuring minimum federal standards. The EPA would create the minimum standards for state CCS programs. Then, if states wish, they would be able to petition the EPA to take up a lead role in implementation and enforcement.

B. *Regulation of Carbon Storage Below the Seabed Under the Marine Protection Reseach and Sanctuaries Act*

Saline formations are the sequestration sites that have the most global storage capacity.[87] Much of these sites exist offshore, underneath the seabed.[88] Currently, the legality of subseabed CCS is unclear, so it is very important to clarify its legality to ensure that there is adequate CO_2 storage capacity over the long term.[89] An inability to use subseabed sites will hasten the period when unsafe storage sites must be used, thus increasing the overall expected leakage rates.

The United States is governed by the Marine Protection Research and Sanctuaries Act (MPRSA), which prohibits dumping in the ocean unless a party has a permit.[90] The MPRSA defines dumping as "a disposition of material."[91] Material is defined as "matter of any kind."[92] This broad term clearly encompasses CO_2. The MPRSA was established to "regulate the dumping of all types of materials into ocean waters and to prevent or strictly limit the dumping into ocean waters of any material which would adversely affect human health, welfare, or amenities, or the marine environment, ecological systems, or economic potentialities."[93] If the sequestered carbon were to leak into the ocean, it could easily

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[87] *See* Benson, *supra* note 22, at 221 (observing that deep saline formations can store a minimum of 1,000 GtCO2, more than the maximum estimate of 900 GtCO2 storage capacity for oil and gas fields).

[88] *See id.* at 222 ("Saline formations occur in sedimentary basins throughout the world, both onshore and on the continental shelves. . . .").

[89] Note that this section refers to geological sequestration under the seabed. There is a different kind of sequestration where CO_2 is pumped directly into the water. This second form of sequestration is not discussed in this paper.

[90] *See* 33 U.S.C. § 1414b(a) (2000).

[91] 33 U.S.C. § 1402(f) (2000).

[92] Id. § 1402(c).

[93] Id. § 1401(b).

adversely affect the marine environment.[94] Thus the MPRSA should be interpreted as including subseabed sequestration as a form of dumping.

Given that carbon sequestration will probably be considered dumping under the MPRSA, the process of storing carbon in saline formations will require a permit. However, the MPRSA explicitly bans dumping any industrial waste into ocean waters, so no permits may be given for dumping substances deemed "industrial waste."[95] Industrial waste is defined as "any solid, semisolid, or liquid waste generated by a manufacturing or processing plant."[96] CO_2 would not fall under this definition of industrial waste since it is a gas. Therefore, there is no absolute bar on CO_2 dumping, so carbon sequestration could potentially proceed under a permit.

The EPA has established standards to consider for granting a permit for dumping under the MPRSA.[97] In order to allow dumping, the environmental impact must cause no unacceptable adverse effects on human health or the ecosystem.[98] However, what constitutes "unacceptable" effects is not spelled out. Unfortunately, the extremely limited case law on MPRSA dumping permits indicates that obtaining a permit may be difficult. In *Seaburn, Inc. v. U.S. EPA*,[99] the plaintiff was a commercial waste disposal company seeking a permit to dispose of the residue

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[94] *See* Ken Caldeira & Makoto Akai, *Ocean Storage*, *in* CARBON DIOXIDE CAPTURE AND STORAGE 301–02 (Bert Metz et al., eds., 2005) (observing that exposure to CO_2 can cause mortality in marine life).

[95] 33 U.S.C. § 1414b(a)(1)(B).

[96] 33 U.S.C. § 1414b(k)(4).

[97] *See* 40 C.F.R. § 227 (2000).

[98] *Id.* at § 227.4.

> "Criteria for evaluating environmental impact.
>
> This subpart B sets specific environmental impact prohibitions, limits, and conditions for the dumping of materials into ocean waters. If the applicable prohibitions, limits, and conditions are satisfied, it is the determination of EPA that the proposed disposal will not unduly degrade or endanger the marine environment and that the disposal will present:
>
> (a) No unacceptable adverse effects on human health and no significant damage to the resources of the marine environment;
>
> (b) No unacceptable adverse effect on the marine ecosystem;
>
> (c) No unacceptable adverse persistent or permanent effects due to the dumping of the particular volumes or concentrations of these materials; and
>
> (d) No unacceptable adverse effect on the ocean for other uses as a result of direct environmental impact."

[99] Seaburn v. U.S. Envtl. Prot. Agency, 712 F. Supp. 218 (D.D.C. 1989).

or stack emissions from waste incineration.[100] The court held that the EPA was reasonable in concluding that the action was prohibited dumping in light of Congress's "increasing awareness of environmental concerns," MPRSA's broad definition of "material," and the fact that the legislative history shows Congress intended to preclude the EPA "from making after-the-fact determinations that a particular type of material could be dumped."[101] This case can be distinguished from carbon sequestration because the substances that were going to be disposed of were probably more environmentally damaging. However, it does suggest that the EPA would be wary of granting permits because the legislative intent of Congress was interpreted to be extremely protective of the ocean environment.

Subseabed sequestration is likely to be considered dumping and therefore will require a permit. However, receiving the permit is not a forgone conclusion. In order to remove any ambiguity and to provide assurances to CCS developers, Congress should amend the MPRSA. The amendment should specifically state that CO_2 may be sequestered underneath the seabed. By taking out the permitting risk factor there will be more parties willing to invest in subseabed sequestration, thus increasing the number of available storage sites.

C. *Storage Liability*

In addition to ensuring that storage sites are secure, in order for CCS to be effective, the CO_2 must be stored for several centuries. Over this time horizon, someone must be accountable for the CO_2 so as to ensure that it causes no harm. Due to the enormously long time scale, responsibility must be bifurcated between short and long-term liability. Responsible parties will then be required to pay set penalties for CO_2 that escapes into the atmosphere and will also have to cover any tortuous damages resulting from faulty storage.

1. *Short Term Liability*

Once the CO_2 has been injected underground, the all-important task of ensuring it does not escape begins. The issue of

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[100] *Id*. at 219 & n.3.

[101] *Id*. at 222 (citing H.R. Conf. Rep. No. 1090, 100th Cong., 2d Sess. 24, 35 (1988)).

who will assume this responsibility and be liable if leakage does occur and subsequently cause damage comes down to the question of who owns the CO_2 after it has been injected. Since injectors of the CO_2 will have the most control of a storage site, it would be sensible to impose the maximum amount of responsibility on them.

The issue of ownership of injected CO_2 has never appeared before the courts. However, there have been cases dealing with injection of natural gas which could serve as a model for courts to follow.[102] A fundamental concept for ownership of underground gases is the rule of capture. The rule of capture states that fugitive and wandering beings (i.e., animals or gas) belong to the owner of the land so long as they remain there and are subject to the owner's control.[103] However, as soon as they are no longer on the land, or if they come under someone else's control, the former owner loses possession.[104] "Possession of the land, therefore, is not necessarily possession of the gas."[105]

This has lead to two contrasting ownership paradigms: the doctrines of nonownership and ownership. The doctrine of nonownership was first articulated in *Hammonds v. Central Kentucky Natural Gas Co*.[106] In this case, the plaintiff owned land that was in the middle of a 15,000 acre depleted natural gas field that Central Kentucky Natural Gas Company was using for storage.[107] The plaintiff sued on the grounds of trespass because the natural gas was entering into her subsurface property without consent.[108] The court used the rule of capture to hold that natural gas is someone's property only after there is actual possession at the surface.[109] The court analogized the gas to wild animals in that both have the tendency to escape without the owner's volition.[110]

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[102] Mark A. de Figueiredo, *Property Interests and Liability of Geologic Carbon Dioxide Storage*, *in* CARBON DIOXIDE CAPTURE AND STORAGE 247–48 (Bert Metz, O. Davidson, H. Coninck, M. Loos & L. Meyer, eds., Cambridge University Press 2005).

[103] Westmoreland & Cambria Nat. Gas Co. v. De Witt, 18 A. 724, 725 (Pa. 1889).

[104] *See id.*

[105] *Id.*

[106] Hammons v. Cent. Ky. Natural Gas Co., 75 S.W.2d 204 (Ky. 1934).

[107] *See id.* at 204.

[108] *See id.*

[109] *See id.* at 205 ("When gas is thus severed and brought under dominion and into actual possession at the surface, it, of course, becomes the personal property of the one who has extracted it under a right so to do.").

[110] *See id.*

Thus, if the natural gas migrates into someone else's land and causes damages, the injector is not liable because the natural gas has been restored to its natural state and must be recaptured for it to be owned by someone. Consequently, the nonownership theory posits that responsibility over gas in lost upon injection.

The alternative theory is the doctrine of ownership, which was articulated in *Lone Star Gas Company v. Murchison*.[111] That court rejected the *Hammonds* court's analogy of natural gas to wild animals. The court stated that "[g]as has no similarity to wild animals. Gas is an inanimate, diminishing non-reproductive substance lacking any will of its own, and, instead of running wild and roaming at large as animals do, is subject to be moved solely by pressure or mechanical means."[112] Instead of a wild substance, the court found that gas is a privately owned commodity that has been stored for use and is subject to control and withdrawal at any time.[113] Thus, the court held that "the owner of gas does not lose title thereof by storing the same in a well-defined underground reservoir."[114] The necessity of a well-defined reservoir was further clarified in *Texas American Energy Corporation v. Citizens Fidelity Bank & Trust Company*.[115] In that case, the Supreme Court of Kentucky distinguished their earlier *Hammonds* ruling by pointing out that in *Hammonds*, the storage company did not have all the property rights to the reservoir, so they did not have control over all of the gas.[116] However, "in those instances when previously extracted oil or gas is subsequently stored in underground reservoirs capable of being defined with certainty and the integrity of said reservoirs is capable of being maintained, title to such oil or gas is not lost."[117] Thus, the ownership theory holds that responsibility of gas is maintained if it is injected in a well defined reservoir.

Currently both interpretations could be employed. This will

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[111] Lone Star Gas Co. v. Murchison, 353 S.W.2d 870 (Tex. Civ. App. 1962).

[112] *Id.* at 879.

[113] *Id.*

[114] *Id.*

[115] Tex. Am. Energy Corp. v. Citizens Fid. Bank & Trust Co., 736 S.W.2d 25 (Ky. 1987).

[116] *See id.* at 28 ("In *Hammonds* there was a known 'leak' in the gas storage reservoir inasmuch as Mrs. Hammonds' land was, in fact, a part of the natural reservoir, though not controlled by the storage company.").

[117] *Id.*

lead to differing results of whether or not the injectors of CO_2 have ownership of the gas. The nonownership concept should be rejected for purposes of carbon storage. If nobody is liable for the CO_2 after it has been injected, then there will be no incentive to take due care to prevent leakages and other accidents. Fortunately, only California, Wyoming, Louisiana, and Oklahoma subscribe to the nonownership theory, and there is always the possibility that these states will amend their laws in the future.[118] For all of the other states, which employ the ownership theory, the requirement of having a well-defined reservoir to impose ownership should be beneficial for CCS purposes. If a storage space cannot be defined with certainty and integrity, it should not be utilized as a CO_2 storage site in the first place. Thus, for most of the United States, the injectors of the CO_2 will be liable for any damages and will need to take due care to prevent leakages and attendant liability.

2. *Long-Term Liability*

Over the first few decades of a carbon storage project the injectors should have ownership of the CO_2 and liability for any leakage of the CO_2. However, since the CO_2 must be stored for several centuries, it is unrealistic for any private company to assume responsibility for such a long time period. Thus, as with the storage of nuclear waste, the only institution that could be expected to assume such long-term liability is the federal government. At some point, ownership of the CO_2 must be transferred from the injectors to the government. One possible transfer point is when the storage site will no longer be actively used for new storage because no more CO_2 can be injected. The CCS operators presumably would have little active interest in a site at this point, so it is a logical time for the government to assume ownership.

However, such a transfer scheme would not ensure that the operator is properly incentivized to prevent leakages. In order to insure a financial stake over the long term, the operators should be required to build up a fund over time which could be used to pay out any damages from leakages.[119] The size of this fund will

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[118] BLACK'S LAW DICTIONARY 1082 (8th ed. 2004).

[119] *See generally* CHRISTINA ULARDIC, ENVIRONMENTAL IMPAIRMENT LIABILITY INSURANCE FOR GEOLOGICAL CARBON SEQUESTRATION PROJECTS 5–6, http://www.irgc.org/IMG/pdf/IRGC_CCS_SwissRe07.pdf (proposing that a fund be built up over time and be used to pay out future damages from carbon

depend on an evaluation of the storage site at the transfer point. Independent auditors or government officials could estimate the risk of potential damages and mandate the transfer of an appropriately sized fund before assuming liability of the CO_2. By varying the size of the insurance fund, CCS operators are given a financial incentive to find the safest sites and to take extensive steps to ensure a site is tightly sealed.

The damages covered by this fund will have to cover not just possible compensation for harm from safety risks, but a penalty for the atmospheric risk of allowing CO_2 to escape and contribute to climate change. Because calculating the damages that CO_2 causes in the form of global warming is extremely difficult, an appropriate penalty would have to be agreed upon beforehand that sets out clear payments for leakages. This money could be used to fund alternative greenhouse gas mitigation projects such as planting trees or retrofitting factories. Alternatively, if a carbon market is established, the fund could be used to pay the requisite permit prices for emissions from the storage site.

IV. PUBLIC INVOLVEMENT

In order to push CCS projects forward, public involvement would be extremely helpful in creating political support and advocacy. Unfortunately, currently the public is apprehensive about CCS. Because CCS is a new technology, there have been relatively few surveys of public opinion on it. What is known is that few people are familiar with CCS. Only between 2.5% to 4% of U.S. citizens have heard of CCS within the past year.[120] Thus, in order to probe public views, a survey was designed where respondents were first educated about what CCS is, then questioned about their opinion of it. The survey designers attempted to convey information as neutrally as possible. However, it is highly possible that if CCS becomes more widely known, the information the public would actually receive would be more sensational than was provided in the survey. The media are more likely to publicize stories involving disasters than to present

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storage).

[120] Claire R. Palmgren, M. Granger Morgan, Wandi Bruine de Bruin & David W. Keith, *Initial Public Perceptions of Deep Geological and Oceanic Disposal of Carbon Dioxide*, *in* CARBON CAPTURE AND SEQUESTRATION 216 (Elizabeth J. Wilson & David Gerrard, eds., 2007).

dry statistics explaining the actual risk of leakages. Thus, ultimately, future public perception will be highly dependent on media portrayal, and it is the responsibility of CCS developers to ensure as accurate a depiction as possible.

Overall, the survey indicates that even when people are educated on the subject, there is little support for CCS. Respondents were asked to rank nine carbon reduction plans both before and after receiving information about the option.[121] Their choices are displayed in the footnote below where a lower score indicates a higher preference.[122] The overall aversion toward disposal options is due to the perceived riskiness of the strategy. In the same survey, respondents were asked to indicate how strongly they agreed with given statements on a scale from one to seven, seven indicating complete agreement.[123] Respondents expressed concern that the CO_2 would migrate out, causing future global warming, damage to plants and animals, and other unintended consequences.[124] This fear is due in large part to the uncertainty surrounding the technology. Respondents think that the CO_2 will cause unforeseen problems, and that before implementation of CCS "we need to know how well it will do what they say it will do."[125]

The apprehensive attitudes toward CCS can be improved if the public is informed about the cost. In a separate survey, respondents were asked to pick one of seven options on how to

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[121] *Id.* at 205, 207–08.

[122] *Id.*

Technology	Before Information	After Information
Solar	3.4	3.5
Hydro	3.8	3.7
Wind	4.0	4.1
Natural Gas	4.4	4.3
Energy Efficiency	4.8	4.9
Nuclear	5.3	5.4
Biomass	5.4	5.4
Geological Disposal	6.9	6.7
Ocean Disposal	7.0	7.1

[123] *Id.* at 204.

[124] *See id.* at 215 (These statements were all rated with a five or higher.).

[125] *See id.* at 209 (These statements were rated with a 5 or higher.).

deal with global warming.[126] Half of the respondents received information that approximated the price of each option, while the other half did not.[127] The percentage of respondents who picked each choice is shown in the footnote below.[128] This data indicates that when the public is given information about pricing, carbon sequestration enjoys the greatest increase in support. However, price information's most drastic effect is to lower support for renewable energy. The ultimate goal of CCS is to decrease global warming, and the use of renewable energy is an important tool in accomplishing this task. Thus, pointing out that CCS is cheaper than renewable energy might not actually be that helpful for the

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[126] Curry, *supra* note 43, at 54–55.

[127] *Id.* at 55. The information they received is:

> Based on published studies, we can summarize electricity production costs as follows:
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> 1) Using coal and natural gas, the typical family pays $1200 per year for electricity
> 2) Using all nuclear power would emit no carbon dioxide and would increase electricity costs for families to $2400 per year
> 3) Using carbon sequestration along with coal and natural gas would reduce carbon dioxide emissions by 90 percent and would also increase electricity costs to $2400 per year
> 4) Using renewable (solar and wind power) would increase annual electricity costs to $4000.

[128] *Id.* at 56.

Method to address global warming	No Price Information (%)	Price Information (%)
Do nothing. We can live with global warming.	4	5
Invest in research and development. A new technology will solve global warming.	24	28
Continue using fossil fuels but with capture and storage of carbon dioxide Capture and storage of CO2.	6	16
Expand nuclear power.	7	11
Expand renewables (solar and wind power).	49	25
Reduce electricity consumption, even if it means lower economic growth.	4	10
Do nothing. There is no threat of global warming.	7	6

environment. However, while preventing climate change is the overarching goal, there is also a desire to achieve this task as economically as possible. Thus, the public desire to achieve cheaper emission reductions should be honored when possible. Furthermore, introducing pricing information had minimal effect on the percentage of people who wanted to do something about climate change; it merely affected what policy choice to implement.[129] While introducing price information does make CCS more attractive, it is important to note that the pricing information resulted in wide but shallow support. After pricing information was provided, no initiative received more than 28% support, and CCS was only the third most popular option.[130] Thus even with pricing information, any attempt to build up public support for CCS will likely be of limited utility because the people do not trust the technology.

The tepid approval of CCS is largely a product of uncertainty about a new technology. However this can quickly change. CCS is such a new technology that the public cannot possibly have formed deeply ingrained opinions. Initial experiences will have an important first impression that can fundamentally change the perception of CCS. An absence of any leakage incidents could assuage fears of CCS and allow projects to go forward unimpeded. However, any leaks that cause harm are likely to garner media attention and thus confirm the public's apprehensive views. This could lead to strong public opposition to CCS, which might severely hamper expansion, similar to what has occurred with nuclear power. Thus, in order to have public support it is extremely important, especially in the short-term, to ensure safe operation of all CCS projects. This can be accomplished by implementing regulations for storage sites that are specifically tailored to CCS's risks.

CONCLUSION

CCS is a promising technology that can help mitigate global warming's disastrous effects. However, the safety and especially the atmospheric risks inherent to CCS projects are significant. In order to curtail these risks, preventing leakage should be first

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[129] *See id.* (6–7% of respondents wanted to do nothing whether information was introduced or not).

[130] *Id.*

priority of CCS regulation. The most important step that can be taken to prevent leakage is to use only ideal storage sites.[131] In order to achieve this, three steps need to be taken.

First, new regulations need to be created to ensure the integrity of storage sites since the current regulations are not designed for CCS. These regulations must include requirements that there is a tightly sealed caprock and a stable geological environment.[132] Additionally, a liability scheme must be created where the CCS operators will initially be responsible for a site. However, after ensuring that a site is adequately protected, the long-term responsibility for sequestration will switch to the federal government.

Second, sequestration underwater needs to be officially legalized so that subseabed saline formations can be used without risk of violating the MPRSA. These sites have the most global storage capacity,[133] so allowing the use of them could result in the creation of numerous safe storage sites.

Finally, in the early stages of CCS development, it is important to be extra cautious. It is imperative not to engender public opposition to CCS so that the technology can expand enough to make an appreciable dent in the battle against global warming. CCS can be very effective in preventing CO_2 emissions from reaching the atmosphere, as long as enough attention is spent on preventing leakage. This is a vital technology in the effort to curb climate change, and the regulations necessary to ensure its safe, but prompt, development need to be implemented now.

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[131] *See* Figueiredo, *supra* note 54, at 648 (“The choice of appropriate sites is the best way to minimize any adverse effects related to carbon dioxide storage.”).

[132] Benson, *supra* note 22, at 213.

[133] *See id*. at 221 (finding that saline formations can store a minimum of 1,000 $GtCO_2$, more than the maximum estimate of 900 $GtCO_2$ storage capacity for oil and gas fields).