

THE POTENTIAL LAW OF ON-SHORE GEOLOGIC SEQUESTRATION OF CO₂ CAPTURED FROM COAL-FIRED POWER PLANTS

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Synopsis: Coal-fired power plants are major sources of carbon dioxide (CO₂) in the atmosphere. Atmospheric CO₂ has been identified as a cause of global warming. On-shore geologic sequestration (OSGS) is a relatively new technology that may be used to reduce atmospheric accumulations of CO₂ from coal-fired power plants. OSGS involves capturing, compressing and injecting CO₂ deep into the earth and storing it for hundreds or thousands of years or longer. Although the United States Supreme Court's decision in *Massachusetts v. EPA*² may accelerate interest in or the need for CO₂ capture and sequestration, there are no federal or state laws or regulations specifically designed to regulate OSGS, and legal uncertainty could hinder its development and deployment.³

Based on current law, members of the coal-based power industry and owners and operators of OSGS facilities may face excessive liability that provides little additional protection of public health and the environment. A risk-based approach to regulating OSGS⁴ is recommended herein to balance legal requirements with the possible risk of harm that may arise from OSGS and to improve legal certainty for those considering its use. Risk-based regulation is the establishment of performance requirements and criteria that correlate directly with the probability and magnitude of foreseeable harm that arises, or that may arise, from a particular site or activity. Risk-based regulation demands stricter requirements where risks are higher. It will provide a sliding scale in which limits on CO₂ injection and storage at a particular location may tighten or relax based on advancements in technology and understanding of OSGS and the subsurface.⁵ By developing a tailored, streamlined and flexible framework of

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2. See generally *Massachusetts v. EPA*, 127 S. Ct. 1438, 1460 (U.S. 2007) (ruling that the EPA could regulate atmospheric CO₂ emissions as pollutants).

3. MASSACHUSETTS INST. OF TECH., THE FUTURE OF COAL: OPTIONS FOR A CARBON CONSTRAINED WORLD (2007) 43 [hereinafter MIT]; See also Elizabeth J. Wilson & Mark A. de Figueiredo, *Geologic Carbon Dioxide Sequestration: An Analysis of Subsurface Property Law* 36 ENVTL. L. REP. 10114 (2006), available at LEXIS; VERONICA BRIENO RANKIN, CENTRE FOR ENERGY, PETROLEUM AND MINERAL LAW AND POLICY, GEOLOGICAL SEQUESTRATION OF CO₂ INTO AQUIFER SYSTEMS: WHAT LEGAL ISSUES NEED TO BE CONSIDERED UNDER US LAW? (2004), http://www.geo.mtu.edu/~vjbrieno/index_files/GeoSeq_US_Law_VB_Rankin_CEPMLP_Internet_Journal_Vol14_12_2004_reprint%20OGEL_1_2005.pdf.

4. INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, SPECIAL REPORT ON CARBON DIOXIDE CAPTURE AND STORAGE, (Bert Metz, ed., Cambridge University Press 2005) [hereinafter IPCC].

5. A detailed analysis of risk-based OSGS regulation requires additional study and is beyond the scope of the article. General principles are provided as a guide for the development of regulations.

environmental regulations to control OSGS facilities, Congress could efficiently limit long-term liability while still providing strong protection of human health and the environment.

Injecting vast quantities of supercritical⁶ CO₂ underground involves inherent risks. Some risks may be minimal, while others could be significant. However, OSGS may be essential to maintain worldwide energy production while protecting human health and the environment from excess CO₂ in the atmosphere. The balance between potential public benefits derived from atmospheric protection and risks involved in OSGS must be weighed carefully. Both federal and state laws need to provide clear guidance to the energy industry to move forward with OSGS projects. New laws need to protect human health and the environment, but should also limit disparity between jurisdictions and uncertainty.⁷

Current laws, such as the Resource Conservation and Recovery Act (RCRA)⁸ and the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA),⁹ could stifle otherwise beneficial uses of OSGS if owners and operators are unnecessarily subjected to severe operational restrictions and unlimited, long-term liability. Recent developments in energy law do not address needed legal considerations for OSGS. The *Renewable Fuels, Consumer Protection and Energy Efficiency Act of 2007* addresses carbon capture and storage, but does not change either the potentially unduly restrictive application of the hazardous waste aspects of the RCRA nor the potentially unlimited long-term liability imposed under the CERCLA.¹⁰

To advance the policy of risk-based regulation, Congress should consider exempting injected CO₂ from potential regulation as a RCRA hazardous waste,¹¹ if applicable in the first instance, and should consider limitations on long-term liability. While states may remain legal laboratories,¹² the federal government should provide guidance in new OSGS legislation to limit disparate jurisdictional treatment. The overarching goal of protecting public welfare by

6. See *infra* note 79, at 12 (stating that CO₂ is supercritical when highly compressed whereby it possesses the characteristics of both a liquid and a gas).

7. Several states including, but not limited to Alaska, Idaho, Illinois, Minnesota, Montana, North Dakota, New Mexico, Oklahoma, Oregon, South Dakota, Washington, and Wyoming have carbon sequestration programs, but few have substantively addressed OSGS. See MELISSA CHAN & SARAH FORBES, NAT'L ENERGY TECH. LAB., CARBON SEQUESTRATION: ROLE IN STATE AND LOCAL ACTIONS, (2005), http://www.netl.doe.gov/energy-analyses/pubs/slfinal_1.pdf. While differences in jurisdictional OSGS regulation is an important consideration presented herein exemplifying the need for Congressional and state action, a survey of current state law is beyond the scope of the manuscript. See also Leslie R. Dubois, Comment, *Curiosity and Carbon: Examining the Future of Carbon Sequestration and the Accompanying Jurisdictional Issues as Outlined in the Indian Energy Title of the 2005 Energy Policy Act*, 27 ENERGY L. J. 603 (2006).

8. 42 U.S.C. §§ 6901-6987, 9001-9010 (2000).

9. 40 C.F.R. § 302-313. (2006).

10. S. 1419, 110th Cong. §§ 302-304 (2007). Senators Bingaman and Specter introduced global warming legislation (S. 1766) to address new energy technologies and climate issues on May 17, 2007 following a draft of the manuscript. However, it did not address with particularity the issues highlighted herein.

11. One of the issues addressed herein is the possibility that existing hazardous waste regulations may apply to supercritical CO₂ injected into the subsurface. At best it is uncertain whether hazardous waste requirements will be applied. Congress may eliminate the uncertainty by exemption.

12. *Gonzales v. Raich*, 545 U.S. 1, 42 (2005) (O'Connor, J., dissenting).

ensuring that CO₂ injected into the subsurface does not harm human health or the environment can effectively be accomplished by using the recommended risk-based approach. If OSGS is necessary for atmospheric protection, then some relief from the strict application of aspects of the RCRA and CERCLA to OSGS and reasonable consistency among jurisdictions are recommended.

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I. INTRODUCTION

Converting coal to energy produces CO₂ as a by-product. Coal-fired power plants emit more than 2 gigatons (Gt) of CO₂ per year worldwide,¹³ and in the United States, coal-fired power plants account for more than 80% of the CO₂ emissions from electric power generation and more than 30% of total CO₂ emissions.¹⁴ Besides CO₂, coal combustion emits sulfur dioxide, nitrogen oxides, particulates, mercury¹⁵ and small amounts of other, potentially hazardous, constituents.¹⁶ According to the Intergovernmental Panel on Climate Change (IPCC), man-caused (i.e. anthropogenic) CO₂ emissions into the atmosphere are the primary cause of accelerated atmospheric warming.¹⁷

Coal is a worldwide energy staple and will be for the foreseeable future. Alternatives to coal that produce little or no CO₂ cannot supply base load energy demand world wide or within the United States.¹⁸ Nuclear energy comes closest, but to replace coal, nuclear plants would need to expand significantly.¹⁹ There is currently too little public support for the magnitude of growth needed for nuclear energy to replace coal.²⁰ Therefore, realistic evaluations of energy demand and supply conclude that coal use will increase and coal is “certain to play a major role in the world’s energy future”²¹

13. MIT, *supra* note 3, at 56; *see also* IPCC, *supra* note 4, at 1.

14. NATURAL RES. DEF. COUNCIL, NRDC ISSUE PAPER, COAL IN A CHANGING CLIMATE 14 (2007) [hereinafter NRDC].

15. MIT, *supra* note 3, at 5-6.

16. JOHN A. APPS, EARTH SCIENCES DIV., ORLANDO LAWRENCE BERKELEY NAT’L LAB., A REVIEW OF HAZARDOUS CHEMICAL SPECIES ASSOCIATED WITH CO₂ CAPTURE FROM COAL-FIRED POWER PLANTS AND THEIR POTENTIAL FATE DURING CO₂ GEOLOGIC STORAGE (2006) [hereinafter APPS]. It is also possible that other chemical may be mixed with the supercritical CO₂ and injected as a method of waste disposal.

17. IPCC, *supra* note 4, at 54.

18. MASSACHUSETTS INST. OF TECH., THE FUTURE OF NUCLEAR POWER 3 (2003) [hereinafter MIT NUCLEAR].

19. *Id.* at 6.

20. MIT NUCLEAR, *supra* note 18, at 6.

21. *Id.* at 5.

Sequestration is the long-term isolation of CO₂ from the atmosphere through natural or engineered processes.²² Green plants, soil, freshwater and the oceans are natural sinks for CO₂. However, the natural system has apparently been unable to accommodate increased anthropogenic CO₂. Rather than CO₂ being trapped in natural sinks, it is accumulating in the atmosphere. Engineered CO₂ sequestration is a possible interim solution to balance the need for reliable energy and reduced CO₂ emissions.

Geologic sequestration is an engineered method of storing CO₂ deep underground in either on-shore or off-shore reservoirs. It involves capturing CO₂ from coal-fired power plant emissions, compressing it, and transporting it to a storage site for injection below ground. Engineered sequestration is “critical technology,” because it is the only means currently available to allow continued and increasing coal use while substantially reducing CO₂ concentrations in the atmosphere.²³ OSGS is land-based geologic sequestration of CO₂ and is the focus of the legal analysis presented herein.

Current federal and state laws and regulations do not specifically address OSGS,²⁴ and may not provide either the public or the industry with adequate protection or guidance. Legal uncertainty, undue restrictions and liability could discourage the development and deployment of OSGS.²⁵ Based on current law, members of the coal-based power industry and owners and operators of OSGS facilities may be subject to significant liability arising out of inadvertent effects of OSGS that could be limited in some instances. The recommended risk-based approach to regulating OSGS²⁶ will promote a balance between effective protection of human health and the environment and the regulatory burden on the industry. Researchers have focused primarily on technical issues.²⁷ Evaluations of the legal issues and the adequacy of the current framework of potentially applicable environmental regulations have been minimal.

The analysis presented focuses primarily on regulating OSGS during and after CO₂ injection. The analysis includes a detailed evaluation of the novel issues related to the regulation and potential liability of on-shore injection and long-term sequestration of CO₂ below ground. Below are summaries of the legal and technical background needed for analysis and ultimately for the development of the law of OSGS.

II. LEGAL BACKGROUND

Current laws and regulations provide a basis for evaluating the potential law of OSGS even though they do not directly address OSGS. Many of the technical aspects of OSGS are analogous to currently regulated activities, such as enhanced oil and gas recovery (EOR and EGR), natural gas storage, and underground waste injection.²⁸ Potentially applicable laws and regulations

22. MIT, *supra* note 3, at 43.

23. NRDC, *supra* note 14, at 29.

24. MIT, *supra* note 3, at 56.

25. *Id.* at 56; *see also* IPCC, *supra* note 4, at 1.

26. IPCC, *supra* note 4, at 145.

27. MIT, *supra* note 3, at 1.

28. Enhanced oil and gas recovery and waste injection involve many features that are similar to OSGS including, but not limited to, constructing wells to inject fluids deep into porous reservoirs in the subsurface.

include, but may not be limited to, the federal and state Underground Injection Control (UIC) programs,²⁹ the Safe Drinking Water Act (SDWA),³⁰ the RCRA,³¹ the Toxic Substances Control Act (TSCA)³² and the CERCLA.³³ However, regulating OSGS with laws and regulations not designed for that purpose is inefficient and possibly counter productive. To better regulate OSGS, current laws and regulations will require some revisions.

CO₂ captured from coal-fired power plants may contain potentially toxic substances, including mercury or other trace elements and compounds.³⁴ Its contents and potential behavior underground will affect the manner in which it is regulated. Whether it will pose significant risks to human health and the environment is uncertain. The potential application of waste regulations and long-term liability are critical considerations. The recommended risk-based regulatory approach is intended to balance the needs of industry and the public and be sufficiently flexible to address all of the unique aspects of OSGS.

Potential litigation also can be expected from OSGS based on claims of trespass, unjust enrichment, takings, personal injury and injury to property, among others. Although contract, product ownership and liability³⁵ issues will undoubtedly arise from the above-ground activities involved in the capture, compression and transport of CO₂, they may be “easily” addressed under current laws and regulations.³⁶ For example, capturing CO₂ and compressing it will pose legal issues analogous to industrial activities at “any large chemical plant.”³⁷ Such issues may include product liability, transportation and occupation hazards, for example, which are already addressed by current common law, environmental protection, occupational safety and health, and transportation laws and regulations. However, injecting and sequestering CO₂ below ground is “likely to pose new legal challenges.”³⁸

In addition to waste regulations and long-term liability, product liability and strict liability for abnormally dangerous activity are issues that need to be considered, depending upon the actual risks determined to be involved in OSGS. To better understand the legal issues, it is imperative to consider the underlying technical aspects of OSGS.

29. 40 C.F.R. § 144.6 (2006).

30. 42 U.S.C. §§ 300f-300h (2000).

31. 42 U.S.C. §§ 6901-6987, 9001-9010 (2000).

32. 15 U.S.C. § 2601 (2000).

33. 40 C.F.R. §§ 302-313 (2007).

34. APPS, *supra* note 16, at 44.

35. *See generally* MIT, *supra* note 3; *see also* IPCC, *supra* note 4.

36. IPCC, *supra* note 4, at 69.

37. *Id.* (For example, chemical storage, releases into the environment, clean-up, worker and public protection, and disposal, among others, are all issues that are considered routinely at chemical facilities that manufacture, process, or dispose of chemicals. Many chemicals are more hazardous than CO₂. Likewise, contract and tort issues like remedies for inadequate performance and product defects are also commonplace today. However, the potentially large scale application of OSGS may lead to novel factual and legal issues, some of which are addressed herein).

38. IPCC, *supra* note 4, at 69.

III. TECHNICAL BACKGROUND

A. Overview

The coal-based power industry is adapting to a “changing climate” in public opinion. The public demands increasingly more attention to global environmental issues, especially global warming. Power companies may face increasing regulatory and consumer demand to reduce CO₂ emissions. Several prominent power-generating companies have already announced plans to “clean up” coal-fired power plants, including evaluating OSGS.³⁹ The following paragraphs provide introductory technical information relevant to the implementation and ultimately the regulation of OSGS.

B. The Carbonate Cycle and Global Warming

CO₂ is a natural and essential part of the biosphere playing major roles in biological processes⁴⁰ and water chemistry.⁴¹ It is one of the “most abundant dissolved gases in groundwater.”⁴² CO₂ is a relatively “safe, non-toxic gas” at low concentrations.⁴³ However, at high concentrations, it can displace air causing asphyxiation⁴⁴ and possibly “environmental and ecosystem damage”⁴⁵ and atmospheric effects. CO₂ cycles through the atmosphere, hydrosphere, lithosphere, and biosphere. Approximately 99% of earth’s carbon is bound up in carbonate rocks and minerals like calcite and dolomite⁴⁶ of which CO₂ is an integral part. Rain and snow in “non-urban, non-industrial areas have pH values normally between 5 and 6” based on the presence of CO₂ in the atmosphere and the carbonate cycle.⁴⁷

Many scientists have concluded that increasing CO₂ concentrations in the atmosphere contribute to global warming and may cause worldwide ecological and economic harm.⁴⁸ Some environmental advocates have taken a dim view of coal and advocate for alternative sources of energy that produce far less CO₂ than coal.⁴⁹ According to the Natural Resources Defense Counsel (NRDC),

39. NRDC, *supra* note 14, at 29-30.

40. VERNON L. SNOEYINK & DAVID JENKINS, WATER CHEMISTRY 156 (John Wiley & Sons, Inc. 1980).

41. *See generally*, WERNER STUMM & JAMES J. MORGAN, AQUATIC CHEMISTRY: AN INTRODUCTION EMPHASIZING CHEMICAL EQUILIBRIA IN NATURAL WATERS (Wiley-Interscience 1970).

42. R. ALLAN FREEZE & JOHN A. CHERRY, GROUNDWATER 86 (Prentice-Hall, Inc. 1979) [hereinafter FREEZE].

43. M. A. DE FIGUEIREDO, D.M. REINER & H.J. HERZOG, MASS. INST. OF TECH., CARBON CAPTURE AND SEQUESTRATION TECHNOLOGIES, FRAMING THE LONG-TERM IN SITU LIABILITY ISSUES FOR GEOLOGIC CARBON STORAGE IN THE UNITED STATES 3 (2005), http://sequestration.mit.edu/pdf/Liability_Issues.pdf. [hereinafter DE FIGUEIREDO].

44. NATIONAL INSTITUTE OF OCCUPATIONAL SAFETY AND HEALTH, POCKET GUIDE TO CHEMICAL HAZARDS (2005).

45. DE FIGUEIREDO, *supra* note 43, at 3.

46. FREEZE, *supra* note 42, at 108.

47. FREEZE, *supra* note 42, at 238.

48. MIT, *supra* note 3, at 1.

49. NRDC, *supra* note 14, at 1.

coal-fired power plants “are the largest source of global warming pollution in the United States”⁵⁰ and the NRDC has advocated for CO₂ sequestration.

There is debate about the role of CO₂ in global warming. Some of the debate is whether increasing CO₂ concentrations caused warming or whether warming caused increased CO₂ concentrations.⁵¹ However, much of the CO₂ in the atmosphere is believed to have resulted from burning coal to generate electricity. For millennia, background concentrations of CO₂ in the atmosphere have reportedly been approximately 280 parts per million (ppm).⁵² Since the late seventeenth century, CO₂ concentrations have rapidly risen to more than 380 ppm.⁵³ The residence time for CO₂ in the atmosphere is approximately a century.⁵⁴ To reduce atmospheric CO₂ concentrations, OSGS will have to sequester CO₂ for longer than its atmospheric residence time.

C. Coal-Fired Power Generation

Coal provides the lowest cost “base-load electricity”⁵⁵ of any fuel and is abundant throughout the world.⁵⁶ Developing countries, namely China and India, are expected to rely more heavily on coal for their increasing energy needs mainly because it is readily available and cost-effective.⁵⁷ Presently, global CO₂ emissions from coal are approximately 2.5 Gt per year as carbon.⁵⁸ To achieve significant reductions of atmospheric CO₂ concentrations, OSGS needs to reduce emissions by approximately 1 Gt per year as carbon, which is equivalent to a reduction in CO₂ emissions of more than 3.5 Gt per year as CO₂.⁵⁹ To be effective, the scale of future OSGS efforts will need to be large. With developing nations relying on coal-fired power generation and assuming that CO₂ from coal-fired power plants contributes to global warming, it is particularly important for the United States to lead the world in responsible coal use by promoting OSGS, provided it is both ultimately warranted and safe, as many believe.

Most of the coal-fired power plants in the United States were constructed between 20 and 55 years ago.⁶⁰ Many are expected to operate for another 30 or more years.⁶¹ Carbon capture technology can be retrofitted on older, conventional power plants. However, it robs the power plant of approximately

50. *Id.* at 14.

51. See Keith Sherwood & Craig Idso, *Ice Core Studies Prove CO₂ is Not the Powerful Climate Driver Climate Alarmists Make It Out to Be*, CO₂ SCIENCE, June 25, 2003, <http://www.co2science.org/scripts/CO2ScienceB2C/articles/V6/N26/EDIT.jsp>; see also Arthur B. Robinson & Zachary W. Robison, *Science Has Spoken: Global Warming is a Myth*, WALL ST. J., Dec. 4, 1997, at A22.

52. IPCC, *supra* note 4, at 282.

53. *Id.*

54. JONATHAN PERSHING, WORLD RES. INST., CLIMATE, ENERGY AND POLLUTION PROGRAM, REVIEWING THE STATE OF THE CLIMATE: SCIENCE AND POLICY PERSPECTIVES (2007).

55. MIT, *supra* note 3, at 5.

56. NRDC, *supra* note 14, at 1.

57. See generally *id.*

58. MIT, *supra* note 3, at 43.

59. *Id.*

60. MIT, *supra* note 3, at 17.

61. *Id.*

30% to 40%⁶² of its energy. The energy losses are made up by burning more coal, which is counter-productive. Newer power plants such as integrated gasification combined cycle (IGCC) plants, avoid some of the energy loss by recycling formerly wasted heat to produce additional power.⁶³

IGCC is a multi-step process in which coal is first converted to a gas.⁶⁴ The gas is then burned to generate electricity. IGCC plants are more efficient than conventional coal plants and produce less, but more concentrated CO₂,⁶⁵ which is more amenable to capture. It also produces hydrogen which may be useful to power fuel cells.⁶⁶ Wastes and emissions from IGCC plants tend to contain lower levels of pollutants⁶⁷ than conventional coal-fired plants. However, the CO₂ from IGCC plants contains other constituents as impurities that are not prevalent in conventional coal power plant emissions, such as hydrogen sulfide (H₂S),⁶⁸ which may affect the way in which captured CO₂ is regulated during OSGS.

Two IGCC plants are operating in the United States.⁶⁹ Power companies, including American Electric Power (AEP), Cinergy and Texas Utilities (TXU) have announced their intention to build additional IGCC plants.⁷⁰ TXU announced plans to build two “clean coal” power demonstration plants in Texas⁷¹ and to reduce the number of conventional coal-fired power plants that it plans to build.⁷² TXU is also considering CO₂ capture and sequestration. OSGS is not yet being performed on a commercial scale, but TXU’s plants could be the world’s first to capture and sequester CO₂.⁷³ IGCC plants are superior to conventional coal-fired plants for CO₂ capture and are “an attractive opportunity” for OSGS.⁷⁴ OSGS is only now being tested in a few areas, but early results are promising.⁷⁵

62. APPS, *supra* note 16, at 53.

63. IPCC, *supra* note 4, at 41.

64. MIT, *supra* note 3, at 32.

65. APPS, *supra* note 16, at 53.

66. IPCC, *supra* note 4, at 130.

67. MIT, *supra* note 3, at 37.

68. APPS, *supra* note 16, at 44.

69. NRDC, *supra* note 14, at 29-30 (Indiana and Florida).

70. *Id.* at 29, 30.

71. Brian Wingfield, *TXU’s Seeing Green*, FORBES, Mar. 9, 2007, http://www.forbes.com/businessinthebeltway/2007/03/09/txu-green-power-plants-biz-wash-cx_bw_0309txu.html.

72. Timothy Gardner, *Greens Rejoice as Analyst Sours on U.S. Coal*, REUTERS, July 20, 2007, <http://www.reuters.com/article/environment/News/idUSN20897022007021>.

73. Clifford Krauss & Matthew L. Wald, *TXU Announces Plans for 2 Coal Plants Designed to be Cleaner-Burning*, N.Y. TIMES, Mar. 10, 2007, at C3..

74. APPS, *supra* note 16, at 53.

75. IPCC, *supra* note 4, at 200-01. CO₂ injections began at nearly a dozen projects since 1996. *See also infra* note 81.

D. Subsurface Fate and Potential Releases

1. Overview

CO₂ has been captured from industrial processes for more than eighty years⁷⁶ using solvents, membranes and distillation.⁷⁷ For OSGS, the captured CO₂ can be purified to remove the bulk of the contaminants.⁷⁸ The captured CO₂ will be compressed to at least 1,070 pounds per square inch (psi), which is “supercritical” for CO₂⁷⁹ and then injected below ground. CO₂ is a gas at atmospheric temperature and pressure, but when compressed to supercritical, it has characteristics of both a liquid and a gas.⁸⁰ Data from commercial and demonstration CO₂ injection projects⁸¹ are encouraging, and based on the data, CO₂ sequestration appears to be generally feasible and safe even though some CO₂ is expected to escape from storage.

The likelihood of CO₂ releases causing large-scale damage is small, because leakage rates are expected to be low.⁸² Unplugged wells in oil fields, which can act as conduits for CO₂ to escape, are considered a potentially significant leakage risk.⁸³ Injected CO₂ is expected to expand into large areas underground and possibly affect underground sources of drinking water (USDWs) or escape to the land surface and eventually into the atmosphere. The long-term effectiveness of OSGS and possible interactions between injected CO₂ and the subsurface environment are uncertain. Critical subsurface considerations and possible mechanisms of CO₂ release are presented below.

2. Hydrogeology

To geologically sequester supercritical CO₂, it will be injected through injection wells into porous reservoirs deep below the land surface. Deep porous rocks that are thousands of feet (e.g. 3,000 to greater than 15,000 feet)⁸⁴ below the land surface are “promising geological reservoirs.”⁸⁵ The lithosphere⁸⁶ is composed of sedimentary, metamorphic, and igneous rocks and unconsolidated sediments. Sedimentary rock is formed in layers from materials like sand, mud or the shells of ancient sea creatures. Some of the layers, like sandstone, are porous and allow the passage of fluids. Other layers, like mudstone, can be nearly impermeable. Sedimentary rock is generally the material in which oil and

76. IPCC, *supra* note 4, at 108.

77. *Id.* at 109-110.

78. IPCC, *supra* note 4, at 116.

79. U.S. EPA, USING THE CLASS V EXPERIMENTAL TECHNOLOGY WELL CLASSIFICATION FOR PILOT GEOLOGIC SEQUESTRATION PROJECTS – UIC PROGRAM GUIDANCE (UICPG #83) 9 (2007) [hereinafter UICPG # 83].

80. *Id.* at 12.

81. MIT, *supra* note 3, at 48 (including the following commercial-scale projects: Sleipner in Norway, Weyburn in Canada, Salt Creek in the United States, and In Salah in Algeria. There are approximately fifteen proposed large-scale, carbon capture and sequestration projects).

82. *Id.* at 51.

83. MIT, *supra* note 3, at 50.

84. W. WESLEY ECKENFELDER, JR., PRINCIPLES OF WATER QUALITY MANAGEMENT (CBI Publishing Co. 1980) [hereinafter ECKENFELDER].

85. MIT, *supra* note 3, at 44.

86. Solid earth comprised of rock, sediment, and minerals.

gas reserves are located. The better supplies of groundwater are also found in porous sedimentary rock or sediment. Generally, a sequence of sandstone, mudstone, or shale and limestone repeats, many times between the land surface and the depth of the potential target OSGS reservoirs.

Impermeable rock and clay restrict fluid flow and can trap water, petroleum and gas beneath them. Limestone can contain little pore space or be riddled with solution holes or even caverns from eons of interactions with groundwater. Layered rock and sediment form reservoirs for oil, natural gas, groundwater and potentially CO₂. The rock containing oil is typically also filled with briny groundwater. The water in oil reservoirs is saline or brine, because it has not been in contact with surface water for many thousands or even millions of years and it slowly dissolves constituents from the surrounding geological formation. Oil floats on the briny groundwater and rises to the top of the porous formation where it is trapped beneath low-permeability layers, such as mudstone. Saline groundwater, oil and gas are generally separated from overlying USDWs by the low-permeability rock, known as cap rock, or clay.

USDWs are aquifers filled with high-quality potable groundwater. Deep below the land surface, groundwater quality tends to decline. Groundwater ages and “evolve[s] chemically toward the composition of seawater.”⁸⁷ In large sedimentary basins, there are three main groundwater zones.⁸⁸ The shallower or upper zone is “characterized by active groundwater flushing through relatively well-leached rocks.”⁸⁹ The upper zone contains the higher quality USDWs. Groundwater in the intermediate zone is separated from “active groundwater circulation”⁹⁰ and generally contains high concentrations of dissolved solids. The deeper or lower zone, in which the target OSGS reservoirs are found, contains saline aquifers with “very sluggish groundwater flow . . . very little groundwater flushing . . . and high total dissolved solids” concentrations.⁹¹ Groundwater in the deeper zone is “usually very old” ranging in age from “thousands to millions of years.”⁹²

Aquifers containing ancient, saline water are prime targets for OSGS, because the water is “useless” and it can take groundwater up to millions of years to cycle through the deep zone.⁹³ In addition to deep saline aquifers, depleted oil and gas fields and deep, un-minable coal seams are possible target reservoirs for OSGS.⁹⁴ Other possible reservoirs may include oil shale, abandoned coal mines and basalts, but they are not as “well tested or understood.”⁹⁵ The potential storage capacity in known geologic reservoirs worldwide is estimated to be able to accommodate hundreds to hundreds of

87. FREEZE, *supra* note 42, at 241-42.

88. *Id.* at 242.

89. FREEZE, *supra* note 42, at 242.

90. *Id.*

91. FREEZE, *supra* note 42, at 242.

92. *Id.*

93. FREEZE, *supra* note 42, at 242.

94. MIT, *supra* note 3, at 44.

95. *Id.*

thousands of gigatons of CO₂.⁹⁶ Storage capacity in the United States may be on the order of 2 to 4,000 Gt of CO₂.⁹⁷

3. CO₂ Storage and Trapping Mechanisms

Naturally-occurring CO₂ has been trapped safely below ground for millions of years in some areas.⁹⁸ The bulk of injected, supercritical CO₂ is expected to remain trapped for at least hundreds or thousands of years. It may also migrate laterally for more than 100 kilometers,⁹⁹ and some of it may rise vertically through saline aquifers and some oil fields until it encounters cap rock, clay, or some other barrier. The primary trapping mechanisms for supercritical CO₂ will be stratigraphic and structural geologic features, including cap rock, faults, clay, and facies changes (i.e. increasingly smaller pore spaces, for example).¹⁰⁰ However, hydraulic and geochemical trapping mechanisms also will be important. Some of the injected CO₂ will dissolve into the formation fluids and some will remain a separate fluid phase.¹⁰¹ Injected supercritical CO₂ will migrate below ground away from the injection sites both laterally and vertically until it reaches a boundary or otherwise becomes geochemically trapped.¹⁰²

Injected into a deep saline aquifer, supercritical CO₂ is expected to flow as a separate, immiscible fluid in saline water to the top of the aquifer where the confining cap rock or clay material will trap it.¹⁰³ In a gas reservoir, it will likely mix with natural gas to form a single fluid.¹⁰⁴ In an oil field, the CO₂ may mix with oil or remain immiscible, depending upon the composition, pressure, and temperature of the oil.¹⁰⁵ Oil density is lower than that of saline water so in some cases, rather than floating on the oil, the supercritical CO₂ may flow laterally.¹⁰⁶ Injected into a coal bed, the supercritical CO₂ will be trapped in "microscopic pore spaces" of the coal.¹⁰⁷ CO₂ may become hydrodynamically trapped (i.e. move so slowly that it essentially remains in place for thousands of years)¹⁰⁸ or be chemically altered. Reaction rates may vary widely and the formation of minerals, which become permanently trapped, may require thousands of years.¹⁰⁹

Through geologic sequestration, more than 99% of the injected CO₂ could be retained in the subsurface for at least 100 years, and it is likely that it will

96. MIT, *supra* note 3, at 45.

97. *Id.* at 46.

98. IPCC, *supra* note 4, at 244-245. The Pisgah Anticline in Mississippi contains large natural gas reserves that have not leaked appreciably.

99. Chin-Fu Tsang, Sally M. Benson, Bruce Kobelski, & Robert Smith, *Scientific Considerations Related to Regulations Development for CO₂ Sequestration in Brine Aquifers*, 42 ENVTL. GEOLOGY 275, 279 (2000) [hereinafter Tsang].

100. MIT, *supra* note 3; *see also* IPCC, *supra* note 4, at 145.

101. IPCC, *supra* note 4, at 206.

102. *Id.*

103. IPCC, *supra* note 4, at 205.

104. *Id.*

105. IPCC, *supra* note 4, at 205.

106. *Id.*

107. IPCC, *supra* note 4, at 205.

108. *Id.* at 206.

109. IPCC, *supra* note 4, at 209.

remain trapped for more than 1,000 years, exceeding the residence time of CO₂ in the atmosphere.¹¹⁰ Escaping CO₂, and any impurities contained in it, could potentially affect USDWs or reach the land surface and eventually the atmosphere. However, CO₂ leakage is not expected to pose significant harm to human health or the environment and may not require remediation,¹¹¹ primarily because leakage rates are expected to be low.

4. Potential Exposure Pathways and Impacts

The technical potential for OSGS to succeed is excellent.¹¹² Industry may first select injection sites near power plants or sites in jurisdictions that have lenient injection requirements, but will eventually expand to more distant areas based on cost, reservoir suitability, and prevailing laws and regulations.¹¹³ During injection of the highly pressurized CO₂, the receiving reservoir will be pressurized and injection pressure can cause rock to fracture. In some instances, fracturing may improve injection efficiency by allowing fluid to move more freely into the formation.¹¹⁴ In other cases, fractures could promote CO₂ leakage.

Pathways for potential releases of CO₂ from OSGS sites include vertical leakage through connected pore spaces, fractures, and unplugged wells.¹¹⁵ Leaking CO₂ may affect USDWs overlying the sequestration reservoir or reach the land surface where it could accumulate in soil and affect biotic respiration, or in structures where it could harm human health.¹¹⁶ The most probable routes of human exposure to CO₂ leaking from OSGS sites are through inhalation or skin contact.¹¹⁷ Although CO₂ is harmless at low concentrations¹¹⁸ it can displace air and asphyxiate or cause chronic health effects at high concentrations.¹¹⁹ In areas where radon gas is prevalent, rising CO₂ could displace radon gas causing radon to accumulate in structures exacerbating human health concerns.

Current practices in EOR, underground waste injection, and natural gas storage demonstrate that the likelihood of a significant CO₂ leak is low and a catastrophic leak is improbable,¹²⁰ but some CO₂ leakage from OSGS is inevitable¹²¹ from at least some sites. The risk of CO₂ being released by seismic activity is extremely low.¹²² Large quantities of CO₂ have been injected into the

110. MIT, *supra* note 3, at 44.

111. IPCC, *supra* note 4.

112. MIT, *supra* note 3, at 59.

113. Leslie R. Dubois, Comment, *Curiosity and Carbon: Examining the Future of Carbon Sequestration and the Accompanying Jurisdictional Issues as Outlined in the Indian Energy Title of the 2005 Energy Policy Act*, 27 ENERGY L.J. 603, 613 (2006) (noting that the Energy Policy Act of 2005 promoted participation by Indian tribes in energy development, carbon markets and carbon sequestration. Should OSGS on tribal lands avoid federal or state regulation, it is possible that tribal lands may be early favorites for CO₂ injection).

114. Tsang, *supra* note 99, at 8.

115. IPCC, *supra* note 4, at 242-43.

116. *Id.*

117. IPCC, *supra* note 4, at 145.

118. *Id.*

119. IPCC, *supra* note 4, at 145.

120. MIT, *supra* note 3.

121. *Id.*

122. MIT, *supra* note 3, at 52.

Rangely Oil Field in northwest Colorado for EOR and local seismic activity has been moderate and has not led to leakage.¹²³

OSGS sites need to be selected carefully based on geologic characteristics, other subsurface uses, and additional criteria that are currently being developed. Supercritical CO₂ may contain other constituents, or other chemicals may be mixed with it for disposal.¹²⁴ Injected CO₂ and any constituents contained in it may chemically react with the geologic formation and surrounding fluid forming new chemicals and possibly minerals like siderite or other carbonate minerals. Impurities may have varying mobilities and may participate in a wide array of chemical reactions that could lead to mobilization of other contaminants.¹²⁵ Monitoring will be required to ensure that the injected CO₂ does not cause harm.¹²⁶

While, some of the injected CO₂ may leak from the storage reservoirs, most of it will likely remain sequestered for centuries or millennia through a combination of physical and geochemical trapping mechanisms. Any impurities contained in the injected CO₂ could increase risks to human health and the environment. However, even if risks remain small, impurities could have important regulatory implications under current law.

IV. LEGAL ANALYSIS

A. Overview

Although generally considered minor, OSGS may pose potential risks to human health and the environment from accidental releases of injected CO₂, which could contain other constituents. The regulatory approach ultimately used should address any risks posed by releases without undue burden on the industry. Actual risks will be highly dependent upon the underground characteristics of the sites selected and procedures used for OSGS. Ultimately, regulations should be adaptable to site and application-specific concerns. Unlike current laws and regulations, the risk-based approach recommended herein will promote a balance between the probability and the magnitude of any actual or reasonably foreseeable harm by establishing a regulatory burden that is commensurate with risk.¹²⁷

Rather than requiring strict conformity with procedure, which may not adequately protect human health and the environment, a preliminary law and economics¹²⁸ evaluation reveals that a risk-based regulatory approach would be beneficial.¹²⁹ Generally, the magnitude of the anticipated harm is expected to be small,¹³⁰ but the probability of a release from at least some sites is expected to be

123. *Id.*

124. APPS, *supra* note 16, at 1 (noting that injection of hazardous waste with supercritical CO₂ may be a method of co-disposal).

125. *Id.*

126. MIT, *supra* note 3, at 47.

127. *See generally* United States v. Carroll Towing Co., 159 F.2d 169 (2d Cir. 1947).

128. *Id.*

129. IPCC, *supra* note 4, at 145.

130. *See generally* IPCC, *supra* note 4.

high. In fact, some releases are almost certain.¹³¹ The risk-based approach is well suited to balance interests by requiring better performance from owners and operators where risks to human health and the environment are higher. Current potentially applicable laws and regulations may not adequately protect human health and the environment and will not promote the large-scale deployment of OSGS without revision.

B. Current, Potentially Applicable Laws and Regulations

1. Overview

The procedures that will be used to regulate OSGS are expected to be similar to the long-standing practices of injecting wastes underground and injecting CO₂ for EOR based on technical similarities.¹³² Both underground waste injection and EOR are regulated by federal and state UIC programs. Interacting with UIC programs are other potentially applicable laws¹³³ including the RCRA¹³⁴ which regulates waste disposal, and the CERCLA¹³⁵ which regulates releases and potential releases of “hazardous substances” often at closed or abandoned facilities.¹³⁶ Current laws and regulations provide a basis for the evaluation of potential OSGS law and the recommendation of the risk-based regulatory approach.

2. UIC and SDWA

In the United States, analogs for OSGS include natural gas storage, EOR, EGR, and underground waste injection.¹³⁷ Acid gas (i.e. CO₂ and H₂S) injection also is a possible analog.¹³⁸ However, acid gas injection, practiced in Canada, has not been entirely successful due to over-pressurized injection zones. Therefore, acid gas injection is less instructive in the legal analysis than the other analogs. The oil and gas industry has been injecting CO₂ underground for decades.¹³⁹ However, the purpose of their CO₂ injections is not to store CO₂, but instead to force oil and gas from the reservoirs for recovery. Underground waste injection is practiced worldwide and has particular relevance in the United States where it is a very common waste disposal practice.¹⁴⁰

131. *Id.*; see also MIT, *supra* note 3, at 56.

132. See *supra* note 28.

133. 33 U.S.C. §§ 1251-1387 (2000) (stating the SDWA requires that underground injection activities not harm USDWs).

134. 42 U.S.C. §§ 6901-6987, 9001-9010 (stating that disposal includes injected waste and releases of chemicals into the environment).

135. 40 C.F.R. §§ 302-313 (2007).

136. *Id.*

137. IPCC, *supra* note 4.

138. *Id.* at 212. Acid gas injection involves injecting a mixture of H₂S, CO₂, and other constituents into the subsurface for disposal. Several of the operations have been suspended, because the disposal reservoirs have been over pressurized. IPCC, *supra* note 4.

139. *Id.*

140. IPCC, *supra* note 4.

Underground injection is “placing fluids underground, in porous formations of rocks, through wells or other similar conveyance systems.”¹⁴¹ The SDWA authorized the EPA to create the federal UIC program to regulate underground injection of fluids.¹⁴² The main purpose of the UIC program is to prevent contamination of USDWs.¹⁴³ The UIC program regulates injection of “fluids, including solids, semi-solids, liquids, and gases (e.g. CO₂).”¹⁴⁴ In general, the UIC program regulations govern “siting, construction, operation, and closure of wells that inject a wide variety of fluids, including those that are considered commodities or wastes.”¹⁴⁵ Underground injection requires authorization under general rules or specific permits¹⁴⁶ and each permit requires the owner or operator to demonstrate that the planned injection will not harm USDWs.¹⁴⁷

States may regulate underground injection provided they meet EPA requirements.¹⁴⁸ To obtain primacy, a state must submit to the EPA a proposed UIC program that meets minimum requirements and receive EPA approval.¹⁴⁹ A state “retains primary responsibility until EPA determines, by rule, that the state UIC program no longer meets the minimum requirements established under the SDWA.”¹⁵⁰ The EPA directly regulates the UIC program in states that do not have primacy.¹⁵¹ Thirty-three states and three territories have obtained primacy for all of five classes of injection wells and seven states share primacy with the EPA.¹⁵² States with primacy may more strictly regulate underground injections based on state-specific factors including geology, which has caused disparate regulation of the same activity among the jurisdictions.

The EPA functionally distinguishes between five classes of injection activity. Each class includes injection wells grouped based on purpose, target injection zone, and construction characteristics “so that technical requirements

141. U.S. EPA, WHAT IS THE UIC PROGRAM?, <http://www.epa.gov/safewater/uic/whatis.html> (last visited Sept. 24, 2007) [hereinafter WHAT IS THE UIC PROGRAM].

142. MIT, *supra* note 3, at 56.

143. 42 U.S.C. § 300h (2000); *see also* Legal Envtl. Assistance Found., Inc. v. United States EPA, 118 F.3d 1467, 1469 (11th Cir. 1997).

144. UICPG # 83, *supra* note 79, at 5. The EPA listed considerations for the selection of injection sites. To prevent harm to USDWs, an adequate site should include: “[i] sufficient depth, a real extent, thickness, porosity, and permeability; [ii] a trapping mechanism that is free of major non-sealing faults; [iii] a confining system of sufficient regional thickness and competency; and [iv] a secondary containment system, which could include buffer aquifers and/or thick, impermeable confining rock layers.” Considerations for site closure include abandonment of the injection well in accordance with 40 CFR 144.12 to protect USDWs and financial assurance requirements to cover the cost of well abandonment. Commercial scale operations may require additional financial requirements to ensure adequate protection. The EPA acknowledged that some CO₂ leakage was possible and expressly noted that certain experiments may be designed to leak so that a more complete understanding of OSGS can be developed. *Id.*

145. UICPG # 83, *supra* note 79, at 5.

146. *Id.*

147. 40 CFR § 144.12(a) (2006).

148. 42 U.S.C. § 300h (2000).

149. *Id.* § 300h-1.

150. Legal Envtl. Assistance Found., Inc. v. EPA, 118 F.3d 1467, 1469-70; *see also* 42 U.S.C. § 300h-1(b)(3).

151. 42 U.S.C. § 300h-1(c).

152. WHAT IS THE UIC PROGRAM, *supra* note 141 (There are five classes of injection wells as explained *infra* and in footnote 156).

can be applied consistently to the class.”¹⁵³ The UIC program is intended to protect USDWs by preventing fluid migration into them.

Some injections are made into USDWs. When fluids are disposed into a USDW, the UIC program requires that they not “cause a public water system to violate drinking water standards or otherwise adversely affect public health.”¹⁵⁴ Under each class in the UIC program, owners or operators are required to comply with construction, operation, and monitoring requirements. All classes are subject to the same minimum requirements regarding siting, construction, operation, maintenance, monitoring, testing, and closure of the wells.¹⁵⁵ Of the five injection well classes, Classes I, II, and V are possible classifications for OSGS.¹⁵⁶

a. Class I Injection Wells

Class I injection wells are used for disposal of hazardous and non-hazardous wastes.¹⁵⁷ Underground waste injection is a traditional waste management technique used for corrosive liquids and hazardous wastes that are difficult or expensive to otherwise manage.¹⁵⁸ Wastes disposed of by injection are usually “highly concentrated toxic, acidic, or radioactive wastes or wastes high in inorganic content which are difficult or excessively expensive to treat” using other techniques.¹⁵⁹ Billions of gallons of fluid wastes are injected each year in the United States with relative safety.¹⁶⁰ Hazardous and non-hazardous waste disposal by deep-well injection is a relatively common practice “where the wastes can be isolated from drinking water resources.”¹⁶¹

Class I injections must be made below the lowermost USDW and there must be a low-permeability layer separating the USDW from the “injection zone.”¹⁶² Injection zones are typically 1,700 to more than 10,000 feet below the surface¹⁶³ although some are deeper than 15,000 feet.¹⁶⁴ The RCRA applies to

153. *Id.*

154. WHAT IS THE UIC PROGRAM, *supra* note 141.

155. *Id.*

156. WHAT IS THE UIC PROGRAM, *supra* note 141. Class III wells are mining wells. They are commonly used for salt and uranium mining by injecting fluids to dissolve minerals then extracting the fluid and the minerals through the well. The UIC program require mining well owners and operators to plug their wells to prevent the migration of fluids into a USDW, refrain from injecting fluid between the outer-most casing and the well bore and to test the well casing for leaks at least once every five years. Some states include mining wells in Class I. There is no foreseeable application of Class III to OSGS. Class IV includes shallow hazardous and radioactive waste injection, which is prohibited unless the injection wells are used in connection with a contaminated site cleanup. Class IV wells may inject contaminated groundwater that has been treated and is being injected into the same formation from which it was extracted pursuant to the CERCLA or the RCRA. Class IV is inapplicable to OSGS.

157. 42 U.S.C. §§ 6921-6934 (2000).

158. FLETCHER G. DRISCOLL, GROUNDWATER AND WELLS, (Johnson Division 1986) [hereinafter DRISCOLL]; *see also* ECKENFELDER *supra* note 84.

159. ECKENFELDER, *supra* note 84, at 662.

160. IPCC, *supra* note 4, at 211.

161. DRISCOLL, *supra* note 158, at 776-77.

162. U.S. EPA, DEEP WELLS (CLASS I), <http://www.epa.gov/safewater/uic/classi.html> (last visited Sept. 24, 2007) [hereinafter EPA].

163. *Id.*

164. ECKENFELDER, *supra* note 84.

wastes injected under the UIC program. The RCRA added a “strict no-migration standards and a petition approval process”¹⁶⁵ for owners and operators of Class I injection wells injecting hazardous waste. The no-migration standard requires owners or operators to demonstrate that injected hazardous waste will not impact the biosphere for as long as it is hazardous or for 10,000 years.¹⁶⁶

The United States Court of Appeals for the District of Columbia Circuit explained that the RCRA imposes a stricter standard than the SDWA in requiring “no migration” of hazardous constituents from the injection zone.¹⁶⁷ However, an owner or operator may qualify for an exemption to the “no migration” requirement. To qualify for the exemption, the applicant must adhere to permit requirements, and “file with the EPA a petition demonstrating ‘to a reasonable degree of certainty’ that the hazardous constituents will not migrate” and that the facility will comply with the regulations.¹⁶⁸ To date, the EPA has not provided guidance clarifying whether supercritical CO₂ is hazardous waste.

Non-hazardous waste, including industrial, low-level radioactive, and municipal wastes also are injected using Class I wells. The no-migration standard does not apply to non-hazardous waste, but otherwise, the same requirements apply as for hazardous waste injections.¹⁶⁹ If supercritical CO₂ captured from coal-fired power plants is not deemed hazardous waste, as many would argue,¹⁷⁰ then it will not be subject to the “no-migration” standard. However, if supercritical CO₂ captured from coal-fired power plants is deemed hazardous waste, then it will be subject to the strict “no-migration” standard under the RCRA, unless exempted. Excessive migration could lead to CO₂ releases and frustrate the sequestration objective, but some migration is inevitable.¹⁷¹

b. Class II Injection Wells

Injection wells are Class II “wherever there is production of oil and gas.”¹⁷² Class II wells must meet strict construction standards, unless historical practices and state-specific geologic characteristics allow for relaxed standards. In lieu of the strict construction standards, states are allowed to demonstrate that they have an “effective program (including adequate record-keeping and reporting)” to prevent underground injection from endangering USDWs.¹⁷³ The SDWA relieved states from having to meet the technical requirements for Class II wells.¹⁷⁴ Also, wastes derived from oil and natural gas exploration and

165. EPA, *supra* note 162; see also 42 U.S.C. § 6924(d)(1) (2000).

166. *Natural Res. Def. Council, Inc. v. EPA*, 907 F.2d 1146, 1157 (D. C. Cir. 1990) (holding that “EPA’s interpretation of RCRA as imposing a stricter standard on deep well injection of hazardous waste than SDWA was reasonable and consistent with RCRA’s purpose.”).

167. *Id.* at 1146.

168. *Hazardous Waste Treatment Council v. EPA*, 910 F.2d 974, 976 (D.C. Cir. 1990).

169. EPA, *supra* note 162.

170. Telephone Interview with Mark de Figueiredo, MIT (Mar. 29, 2007).

171. APPS, *supra* note 16.

172. EPA, UNDERGROUND INJECTION CONTROL PROGRAM OIL AND GAS INJECTION WELLS (CLASS II), <http://www.epa.gov/safewater/uic/classii.html> (last visited Sept. 28, 2007).

173. *Id.* (emphasis removed).

174. Congress added § 1425 to the Safe Drinking Water Act in 1980.

production are exempt from the RCRA hazardous waste regulations.¹⁷⁵ Therefore, the underground injection of oil field waste, regardless of its characteristics, need not comply with the strict no-migration standard imposed on hazardous waste injection.

Injecting CO₂ into declining or depleted oil and gas fields for OSGS can increase the recovery of marketable oil and gas. The value of the recovered oil and gas can offset somewhat the cost of OSGS, which is an advantage over injections into deep saline aquifers under Class I.¹⁷⁶ The EPA has noted that certain wells may have dual functions, such as injecting CO₂ into one reservoir to recover oil or gas and then injecting the CO₂ into another reservoir for OSGS. Dual function wells could be classified as both Class II and Class V.¹⁷⁷ Class V is the classification for experimental technology.

If OSGS is not associated with oil or gas production, then wells used for OSGS may not be classified as Class II wells. CO₂ also may be injected into unminable coal seams. Similar to EOR and EGR, an advantage of injecting CO₂ into a coal seam is that it displaces methane, which can be captured and used commercially, offsetting some of the sequestration cost.¹⁷⁸ However, more study is required before coal seam injections are deemed practical and safe.

c. Class V Injection Wells

Class V injection wells are those not included in Classes I through IV. Typically, Class V injection wells are used to inject non-hazardous fluids into or above an aquifer. They are usually shallow, on-site disposal systems, such as floor and sink drains that discharge into dry wells, septic systems, leach fields, and similar facilities.¹⁷⁹ However, some Class V wells are deep. Class V is also used for experimental wells. “Experimental technology” is technology that is not “proven feasible under the conditions in which it is being tested.”¹⁸⁰ According to the EPA, OSGS initially will be permitted as a Class V activity, because it is experimental technology.¹⁸¹

OSGS may be performed as a Class V injection without limits on the volume of CO₂ injected as long as it remains experimental.¹⁸² The EPA’s rationale for using Class V for OSGS is to “encourage innovation” by applying “flexible, yet fully protective, technical standards” as opposed to the standards required for proven, commercial operations.¹⁸³ There are more than 500,000 Class V wells in operation.¹⁸⁴ There are no federal requirements written specifically for Class V “experimental technology” wells, but there are

175. Regulatory Determination for Oil and Gas and Geothermal Exploration, Development and Production Wastes, 53 Fed. Reg. 25,447 (July 6, 1988).

176. MIT, *supra* note 3.

177. UICPG # 83, *supra* note 79, at 6.

178. *Id.* at 3.

179. UICPG # 83, *supra* note 79, at 5.

180. Underground Injection Control Program Criteria and Standards, 47 Fed. Reg. 4992 (Feb. 3, 1982).

181. UICPG #83, *supra* note 79.

182. *Id.*

183. UICPG #83, *supra* note 79, at 5.

184. *Id.*; see also EPA, UNDERGROUND INJECTION CONTROL PROGRAM OIL AND GAS INJECTION WELLS (CLASS V), <http://www.epa.gov/safewater/uic/classv.html> (last visited Sept. 24, 2007).

requirements for Class V wells, such as dry wells where liquid wastes are injected and allowed to drain into the subsurface.¹⁸⁵ Class V well owners and operators are required to provide the agency with information describing the nature of the injection and the well.¹⁸⁶ Assuming OSGS will be proven successful, based on past policy, it might be reasonable to exempt it from certain requirements.

3. Natural Gas Exemption

Natural gas storage, while an analog for OSGS, is exempt from regulation under the UIC program. Natural gas is injected into shallow, porous formations for temporary storage to maintain reserves.¹⁸⁷ Subsurface natural gas storage has been performed for nearly a century and is considered safe and effective.¹⁸⁸ The natural gas exemption will not apply to supercritical CO₂ injected for geologic sequestration.¹⁸⁹ Even though CO₂ is a naturally-occurring gas, the natural gas exemption applies only to “natural gas as it is [commonly] defined” (i.e. gaseous hydrocarbons), and “not to other injections of matter in a gaseous state.”¹⁹⁰ The EPA has concluded that CO₂ is not a natural gas under the UIC program. Moreover, the United States Court of Appeals for the Tenth Circuit has concluded that CO₂ is not a natural gas under the SDWA.¹⁹¹

C. Regulating OSGS Under The Current UIC Program

1. Overview

The analogs provide insight into possible issues involved in regulating OSGS. While some aspects of OSGS closely resemble underground waste injection, natural gas storage and EOR and EGR,¹⁹² the goal of OSGS is to ensure that injected CO₂ remains sequestered. An understanding of subsurface characteristics and a well conceived monitoring plan will be required to accomplish that goal.¹⁹³

2. Potential Problems Under the UIC Program

The current federal UIC program focuses more on the injection well than the subsurface environment. Under the current UIC program well construction requirements tend to be more stringent than requirements for characterizing the

185. 40 C.F.R. §§ 144.12, 144.24, 144.27, 144.70-.89 (2006); *see also* UICPG # 83, *supra* note 79, at 7.

186. 40 C.F.R. § 144.26 (2006); *see also* UICPG # 83, *supra* note 79, at 6-7.

187. IPCC, *supra* note 4, at 211.

188. *Id.*

189. IPCC, *supra* note 4, at 211.

190. UICPG # 83, *supra* note 79, at 5; *see also* Elizabeth J. Wilson, Timothy L. Johnson, & David Keith, *Regulating the Ultimate Sink: Managing the Risks of Geologic CO₂ Storage*, 37 ENVTL. SCI. & TECH. 16, at 3477-78 (2003), available at <http://pubs.acs.org/cgi-bin/article.cgi/esthag/2003/37/i16/html/es021038+.html> [hereinafter Wilson].

191. *Arco Oil & Gas Co. v. EPA*, 14 F.3d 1431, 1436 (10th Cir. 1993).

192. MARK A. DE FIGUEIREDO, SPECIAL REPORT TO THE MIT CARBON SEQUESTRATION INITIATIVE, THE UNDERGROUND INJECTION OF CARBON DIOXIDE (2005).

193. *See generally*, Wilson, *supra* note 190.

subsurface or ensuring that injected fluids do not migrate.¹⁹⁴ The UIC program essentially relies on procedural controls to regulate injection activities.¹⁹⁵ Other than the no-migration restriction for hazardous waste, the UIC program does not ensure that injected fluids remain in the injection zone.¹⁹⁶

The current federal and state UIC programs may not sufficiently protect human health and the environment from the potential effects of injected supercritical CO₂. For example, a Florida aquifer was contaminated with waste constituents from Class I injection wells regulated under Florida's UIC program.¹⁹⁷ Constituent concentrations were low and posed little risk, but the lack of adequate monitoring failed to provide sufficient warning to prevent the waste injections from contaminating the USDW.¹⁹⁸ As a result, the EPA provided owners and operators in south Florida a risk-based alternative to the UIC program to allow them to operate their injection wells even though USDWs were impacted.¹⁹⁹

Disparities in state UIC programs also could lead to a concentration of OSGS activity in states with more lenient regulations and could cause uncertainty among regulated entities. In geologically superior areas where subsurface geology is well suited to OSGS, consistent and well understood, CO₂ leakage may be improbable and monitoring requirements can be moderate. In other areas where the geology is more complex and less consistently suited for OSGS, CO₂ leakage may be more likely and monitoring should be more diligent to avoid potential public health risks that may arise from inadequate warning.

Subsurface characteristics should be well understood at every OSGS site. Modeling should be used to demonstrate that each site is suitable at the outset, and periodic updates and monitoring should be required to verify safe operation. In areas more prone to problems, contingency plans will need to be devised to address CO₂ releases, which can be mandated in the regulations. Jurisdictions that do not require adequate knowledge of the subsurface and monitoring may place the public at risk.

3. Retaining OSGS as a Class V Activity

The EPA has not yet designated a UIC program class for OSGS. However, in previous guidance, the EPA stated that some wells "revert" to the class into which they presumably would have originally belonged based on their purpose

194. David W. Keith, Julie A. Giardina, M. Granger Morgan and Elizabeth J. Wilson, *Regulating the Underground Injection of CO₂*, 39 ENVTL. SCI. & TECH. 24, 499A-505A, available at http://pubs.acs.org/subscribe/journals/esthag-a/39/124/html/12150feature_keith.html [hereinafter Keith].

195. *Id.*

196. Keith, *supra* note 194, at 499A-505A.

197. *Id.*

198. Keith, *supra* note 194, at 499A-505A.

199. Notice, *Underground Injection Control Program-Revision of Underground Injection Control Requirements for Class I Municipal Wells in Florida*, 40 C.F.R. § 146 (2003). In July 2000, the EPA proposed revisions to the UIC program to allow continued operation of Class I municipal wastewater injection wells that "caused or may cause" fluid movement into USDWs in South Florida essentially providing owners and operators a risk-based alternative.

and function.²⁰⁰ The regulations do not specify whether a well or technology reverts automatically to the presumed class upon being proven, or whether it may remain regulated under Class V until the EPA develops new standards, if ever.²⁰¹ The reversion to the presumed class is used for injections that are sufficiently similar to currently regulated injections. Where a technology is “truly new” and so different from other regulated technologies that standards may be inappropriate, or “fail to address the environmental hazards of the practice even when fully met”²⁰² it may remain in Class V. The EPA has not yet determined whether OSGS requires new standards.

The flexibility of Class V may promote risk-based regulation, similar to that which the EPA allowed in Florida. Risk-based requirements could be specified on a permit-by-rule basis under Class V.²⁰³ To reduce disparate regulation of OSGS among the states, the EPA can specify new minimum requirements for OSGS such as subsurface characterization, modeling, and monitoring. Alternatively, the EPA can create a new subclass within Class I, specific to OSGS, and specify the same new minimum requirements if it prefers to avoid permanent regulation of OSGS under Class V. A risk-based regulatory approach would promote protection of USDWs from harmful levels of contaminants, avoid human exposure to unsafe conditions, and not unduly burden the industry.

D. Risk-Based Regulatory Approach Under the UIC Program

1. Overview

Currently, under the UIC program owners and operators need not verify the safety of injections on a continuing basis. However, when using a risk-based approach, an owner or operator of an OSGS facility will be required to demonstrate from the outset that CO₂ injections will not pose risks to human health and the environment. Furthermore, owners and operators of OSGS facilities must verify that injections remain safe as they proceed.

2. Balancing Risk and Regulation

The key to regulation will be to balance public welfare and economics. A risk-based approach to OSGS regulation will likely reduce legal uncertainty, because members of the industry will better understand subsurface characteristics and OSGS performance than under the current UIC program. Using an adaptable risk-based approach, the regulatory burden on industry and, ultimately the cost to the public will largely depend on site selection, injection techniques, and diligence in verifying that the injected, supercritical CO₂ remains sequestered.

200. EPA, APPROPRIATE CLASSIFICATION AND REGULATORY TREATMENT OF EXPERIMENTAL TECHNOLOGIES. GROUND-WATER PROGRAM GUIDANCE NO. 28 (GWPG #28) 2 (1983) [hereinafter GWPG #28].

201. *Id.*

202. GWPG #28, *supra* note 200, at 3; *see generally* 40 C.F.R. § 146.05(e)(16) (giving examples of some technologies that were identified explicitly by regulation include those listed in such as in-situ mining of lignite coal, tar sands, and oil shale).

203. Streamlined, site-specific permit procedure tailored to prevailing conditions and concerns.

Under a risk-based approach, an owner or operator will be required to evaluate subsurface conditions and continually monitor injection activity at a level commensurate with the complexity of the site geology and potential leakage to verify that the operation remains safe. Risk-based requirements would require more from owners and operators in terms of understanding site conditions and operational effectiveness, but would not mandate migration limits unreasonably. If impacts are detected that cause or could cause risks to human health and the environment, then corrective actions must be rapid and thorough, because the scale of impacts when first detected may not illuminate the full potential impacts as harmful conditions could develop or worsen even after injections cease.

The risk-based approach will be consistent with the SDWA requirement to protect drinking water.²⁰⁴ Provided leaking CO₂ does not harm human health or the environment, there is no need for a strict “no-migration” requirement, which is currently required for injection of hazardous waste.²⁰⁵ Even if supercritical CO₂ is a hazardous waste when it is injected, as long as it does not pose risks to human health or the environment, then whether it migrates is less important than its actual effect in the environment, if any. Instead, protection of human health and the environment, which could be evaluated through existing or modified risk assessment techniques, would be the standard.

3. Implementing Risk-Based Regulation

The risk-based approach could be established in a subclass within Class I created specifically for OSGS.²⁰⁶ For example, owners and operators could be required to demonstrate detailed knowledge of subsurface conditions before injections begin. During operations, results of monitoring would be continually evaluated to verify safe operation. Impacts that do not cause risk would not require cessation of injections, but would require a thorough demonstration that conditions will remain safe to continue operation. If the demonstration of continued safe conditions could not be successfully made, then the owners and operators could be mandated to take corrective actions.

OSGS wells will more likely than not inject supercritical CO₂ deep into saline aquifers, which will be a Class I activity under the UIC. However, based on technical uncertainties, the actual fate of injected CO₂ and possible risks involved, OSGS will likely require more regulation than a non-hazardous waste injection, but less than the strict no-migration requirement imposed by the RCRA for hazardous wastes, even if supercritical CO₂ is hazardous when injected.

Managing the “unique” technical issues posed by OSGS based on the expected migration, reactivity, and leakage of CO₂ will require effective site evaluation, modeling, and monitoring programs to adequately assess potential risk.²⁰⁷ The OSGS-specific permit requirements for a new subclass under Class I might include stricter monitoring requirements than non-hazardous injections

204. *Id.*

205. Tsang, *supra* note 99, at 208.

206. Underground Injection Control Program Data Availability, 68 Fed. Reg. 23,666, 23,667-23,668 (2003).

207. Keith, *supra* note 194, at 501A.

and verification that OSGS does not pose risks to human health and the environment. However, assuming some migration will not be harmful, therefore, the strict no-migration standard is unwarranted.²⁰⁸ Early warning procedures could be specified to provide adequate notice of potential problems so that corrective actions could be implemented to protect human health and the environment without the need, for example, to shut down a power plant relying on a problematic injection site.

Corrective actions under a risk-based approach should proceed similarly to corrective actions under prevailing laws and regulations for current environmental impacts. Early warnings of potential impacts will promote more effective mitigation of potential harms. Where impacts cause risks, then the corrective action response should be rapid and thorough. More detailed summaries of possible requirements are provided below.

a. Site Characterization

As the science progresses, the relationship between site characteristics and sequestration effectiveness will become clear. It is likely, sites that are remote from sensitive areas and population centers with stable, deep saline aquifers, separated from USDWs by competent cap rock and layers of clay or other buffering material, will be desirable.²⁰⁹ Under a risk-based approach, owners and operators should demonstrate that injected supercritical CO₂ will remain safely isolated from the rest of the environment. Alternatively, they must demonstrate that any CO₂ migration or any other impact caused by OSGS will not adversely affect human health or the environment.

Site specific data must be obtained and verified as part of a successful demonstration. For example, detailed geophysical and chemical investigations should be required. Lithological, biochemical, and structural evaluations must demonstrate adequate and appropriate storage conditions. Unusual physical and chemical features should be identified and evaluated for potential adverse impacts. Site specific models should be developed to aid in anticipating physical and biochemical reactions that may occur during OSGS. Potential locations for anticipated monitoring devices should be identified and evaluated. Data obtained from on-going and upcoming demonstration studies will significantly advance site evaluation and modeling effectiveness. Successful demonstrations will document the suitability of selected sites for OSGS and the ability to safely and effectively inject and sequester supercritical CO₂ and monitor conditions for extended periods.

b. Monitoring and Reporting

An effective monitoring system must be designed and installed prior to initiating OSGS. The data would be reported to the regulating agency for confirmation that subsurface conditions remain safe. The purpose of monitoring and reporting the results is to provide an early warning of potential human health

208. Tsang, *supra* note 99, at 280.

209. UICPG #83, *supra* note 79, at 9 (stating the EPA has published preliminary guidance on the considerations for site selection).

or environmental risks. Monitoring can be costly, but it may be the only way to ensure that OSGS remains safe.

Monitoring the subsurface to ensure the protection of human health and the environment should include, but not be limited to, groundwater, soil vapor, and seismic effects. Monitoring may be challenging, because it may be expensive and could cause problems.²¹⁰ While its purpose is to ensure protection of human health and the environment by providing early detection of potential CO₂ migration or leaks, monitoring devices could become conduits for CO₂ releases. Some Class I injection wells are deeper than 15,000 feet. For OSGS, monitoring devices may need to be installed to similar depths. Each device, if improperly constructed or used, could become a conduit for CO₂ to escape.²¹¹

A failed monitoring device could lead to an accumulation of CO₂ at the surface which could have the potential to displace air and potentially harm humans, unless adequately guarded against with leak prevention and mitigation mechanisms. Some types of devices could be installed at shallower depths. For example, some devices might be installed in USDWs located at shallower depths to monitor water quality. Other devices might be installed at or near the surface to monitor for upwardly leaking CO₂. Shallower installations may be safer and still be effective.²¹²

c. Corrective Actions

In the event that OSGS causes groundwater contamination or monitoring devices lead to leaking problems, federal and state agencies must require effective corrective actions. In many environmental media, contamination problems often grow to significant proportions before impacts are detected and often worsen after detection.²¹³ Early detection is important if impacts are to be effectively mitigated.

Supercritical CO₂ injected into deep saline aquifers will spread and affect large areas. Although the movement of CO₂ from the injection zone may not be harmful in many instances, it may impact USDWs in other instances. It is possible that only CO₂ will pass into and out of USDWs without harm. However, it is also possible that leaking CO₂, or constituents mobilized by leaking CO₂, will contaminate USDWs and other environmental media. CO₂ may also accumulate and migrate in soil vapor, possibly affecting biota or humans. Impacts may be small, but could accumulate with repeated or long-term leakage. If the effects of leaking CO₂ and any constituents contained in the injectate are small, but cumulative, impacts may go undetected for significant periods, but worsen with time. Also, impacts may continue for significant periods after injections are terminated in affected areas.

210. Keith, *supra* note 194. For example, deep monitoring wells may be needed to measure groundwater quality. Deep wells are costly to install because they must protect all shallower zones from contamination from deeper zones. A deep well could allow CO₂ to escape to the land surface and the atmosphere if improperly installed or maintained.

211. DRISCOLL, *supra* note 158; *see also* UICPG #83, *supra* note 79; IPCC, *supra* note 4.

212. Tsang, *supra* note 99.

213. Groundwater contamination cases provide examples of discovering constituents in groundwater after impacted areas have expanded significantly. Often contamination plumes expand after detection if not properly mitigated.

Regulatory actions for groundwater, soil vapor, and other impacts should proceed similarly to current enforcement actions. Where impacts to the environment are unlikely to affect human health, corrective actions may be passive (e.g. monitored natural attenuation). However, where risks are higher, more aggressive remediation techniques will be necessary (e.g. installing, operating, and maintaining engineered remediation techniques). Where minor impacts from OSGS pose no current or future risks to human health and the environment, no corrective action would be needed.

4. Summary

Based on the technical analogs available and the analysis presented herein, regulating OSGS under the UIC program will most effectively be accomplished if the program is modified to include a risk-based approach whereby site and operation characteristics are well understood and safe operation is verified through monitoring. Unsafe conditions must be detected early and mitigated. While there may be uncertainty in creating new requirements, there is also uncertainty in trying to regulate a new industrial process with marginally applicable rules. Protecting human health and the environment is the sole reason for OSGS. Therefore, a site-specific risk-based approach providing continuing proof that human health and the environment are protected will be effective and workable, rather than requiring unnecessary limits on migration or failing to require verification of safe operation.

The characteristics of OSGS sites, such as geology and proximity to population centers, will be site-specific and should be considered in regulating activities at each site. Much like the UIC program, federal law could establish certain minimum criteria and allow states primacy where they demonstrate the ability to regulate effectively. The risk based approach to regulating OSGS will be self-adjusting and will protect the local population and environment, because site-specific characteristics and potential receptors form the basis of the risk evaluations. The risk-based approach may foster the development of reasonably consistent state law because participants may more confidently anticipate requirements that could be modeled on a federal program.

E. Characterizing and Regulating Supercritical CO₂

1. Overview

Characterizing supercritical CO₂ from coal-fired power plants can have important regulatory implications. Injected CO₂ could be considered a product or a waste and be regulated differently based on its characterization.²¹⁴ Products are regulated under the TSCA²¹⁵ and wastes are regulated under the RCRA.²¹⁶ It is yet uncertain whether supercritical CO₂ will be regulated as a product, like a synthetic gas for example, or a waste.²¹⁷ Waste management regulations can impose significant costs on the OSGS process and expose owners and operators

214. MIT, *supra* note 3.

215. 15 U.S.C. § 2603 (2000); *see also* 15 U.S.C. § 2605(a) (2000).

216. 42 U.S.C. §§ 6901-87 (2000).

217. DE FIGUEIREDO, *supra* note 43, at 656.

to significant liability not encountered under the TSCA. However, even though captured CO₂ may be considered a product, if it is released into the environment it will likely be subject to regulation under the RCRA.²¹⁸ After injection, the CERCLA²¹⁹ will govern the long-term liability of owners, operators, and potentially other entities engaged in OSGS activities. Considerations for regulation under the TSCA, RCRA and CERCLA are presented below.

2. Product Regulation Under the TSCA

The TSCA will govern the use and potentially the disposal of supercritical CO₂ captured from coal-fired power plants if it is characterized as a product.²²⁰ The TSCA authorizes the EPA to obtain and use information about chemicals to protect human health from unreasonable risk²²¹ and to take regulatory measures to protect against risks posed by hazardous chemical substances and mixtures.²²² The TSCA requires testing when processing, using, or disposing of a chemical substance “may present an unreasonable risk of injury to health or the environment”²²³ and when humans have been or reasonably may be substantially exposed to substantial quantities of a chemical.²²⁴ Courts have interpreted substantial quantities to include infrequent or intermittent emissions²²⁵ and interpreted unreasonable risk to include a “substantial probability” of harm.²²⁶

It may be reasonable to classify supercritical CO₂ captured from coal-fired power plants as a product, because there is a market for supercritical CO₂. Supercritical CO₂ is currently used in the cleaning industry as a “sustainable” solvent.²²⁷ Among other uses, supercritical CO₂ is effective for decaffeinating coffee, high pressure cleaning, environmental remediation,²²⁸ EOR, fluid carbonation, fire extinguishers, and dry ice. If pure, the CO₂ captured from coal-fired power plants will be materially equivalent to commercially available CO₂.

Supercritical CO₂ is described as having “green”²²⁹ properties, because it is relatively harmless when released into the above-ground environment in small quantities. It “is non-flammable, relatively non-toxic and relatively inert.”²³⁰ When mixed with water it can temporarily lower the pH of the mixture to less

218. IPCC, *supra* note 4, at 116 (noting it may be possible to achieve a purity of greater than ninety-nine percent for captured CO₂).

219. 42 U.S.C. §§ 9601-9662 (2000) (amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA)).

220. 15 U.S.C. § 2603 (2000); *see also* 15 U.S.C. § 2605(a) (2000).

221. *Id.*

222. 15 U.S.C. § 2605(a) (2000).

223. 15 U.S.C. § 2603(a)(1)(A)(i) (2000).

224. 15 U.S.C. § 2603(a)(1)(B)(i) (2000).

225. *Chemical Mfrs. Ass’n v. EPA*, 899 F.2d 344 (5th Cir. 1990).

226. *Chemical Mfrs. Ass’n v. EPA*, 859 F.2d 977 (D.C. Cir. 1988).

227. Eric J. Beckman, *Supercritical and Near-Critical CO₂ in Green Chemical Synthesis and Processing*, 28 J. OF SUPERCRITICAL FLUIDS 121, 121-22 (2003).

228. LOS ALAMOS NAT’L LABORATORY, SUPERCRITICAL CARBON DIOXIDE/WATER EMULSION FOUND EFFECTIVE FOR REMEDIATING METAL CONTAMINANTS IN WASTE (2002), http://www.lanl.gov/news/index.php/fuseaction/homes.story/story_id/1265; *see also*, U.S. NAVY, SUPERCRITICAL FLUID CLEANING AS A SOLVENT ALTERNATIVE, (2004), http://p2library.nfesc.navy.mil/P2_Opportunity_Handbook/11_4.html.

229. Beckman, *supra* note 227, at 121.

230. *Id.*

than three.²³¹ However, the water-CO₂ mixture, if exposed to the atmosphere, will eventually equilibrate to a higher pH.²³² Commercial grade supercritical CO₂ can be greater than 99% pure.²³³

CO₂ is included in the TSCA Inventory.²³⁴ When released, supercritical CO₂ depressurizes into a gas and has the potential to asphyxiate humans at high concentrations,²³⁵ among other possible adverse health effects. As it evaporates it leaves no waste residue, therefore, commercial grade supercritical CO₂ does not need to be disposed and has avoided classification under the RCRA.

Given the anticipated large scale of future sequestration operations, there will be substantial quantities of supercritical CO₂ injected and the TSCA will govern its management if it is a product. It may be possible that leaking CO₂ could displace radon gas causing it to accumulate in structures exacerbating an existing human health concern. Radon is regulated under the TSCA and may be a cause of lung cancer.²³⁶ Based on the possible accumulation of CO₂ and radon in above-ground structures, the EPA will likely gather and disseminate information on CO₂ captured from coal-fired power plants and injected below ground to aid in its detection and mitigation should leaks cause harm. However, leaking (i.e. released) CO₂ will be regulated by the RCRA and it could lead to product liability and numerous other tort claims.

3. Regulation of Disposed or Released Supercritical CO₂ Under the Resource Conservation and Recovery Act

a. Overview

Based on foreseeable technology, it is inconceivable that all of the vast quantity of CO₂, postulated to be sequestered in the subsurface, will be used commercially or stored as a product under the TSCA. Any impurities in the captured CO₂ may affect its fitness for certain commercial uses and its regulatory classification. If it is a waste, then it will be regulated under the RCRA. Unlike commercial supercritical CO₂, which evaporates when released avoiding the need for disposal, supercritical CO₂ injected underground will likely remain as a separate phase fluid for an extended period.²³⁷ Depending upon their concentrations or other characteristics, impurities like H₂S and mercury may cause supercritical CO₂ captured from coal-fired power to be regulated as a hazardous waste, unless it is exempted by rule or legislation. Even supercritical CO₂ that is considered a product will be regulated by the RCRA if it is stored speculatively or released into the environment. Therefore, a large majority of the

231. Beckman, *supra* note 227, at 126.

232. STUMM AND MORGAN, *supra* note 41.

233. See, e.g., AIR PRODUCTS, MATERIAL SAFETY DATA SHEET NO. 1005 Sec. 15 (1994), <http://www.airproducts.com/NR/rdonlyres/A58B7E05-ECE0-4121-8854-91E2B067F135/0/carbondioxide.doc>.

234. *Id.* The TSCA Inventory is the list of chemicals for which the EPA is obtaining information. The CAS number for CO₂ is 124-38-9.

235. Beckman, *supra* note 227, at 123.

236. 15 U.S.C. §§ 2661-2671 (2000).

237. Tsang, *supra* note 99, at 8; APPS, *supra* note 16.

CO₂ captured from coal-fired power plants and sequestered geologically will be a RCRA-regulated waste.

Solid wastes are regulated differently based on their characteristics. The RCRA classifies solid wastes as either non-hazardous or hazardous wastes. A non-hazardous waste is regulated under RCRA Subtitle D regulations.²³⁸ A hazardous waste is regulated under RCRA Subtitle C regulations.²³⁹ Hazardous waste is more stringently controlled than non-hazardous waste. Therefore, the classification of supercritical CO₂ captured from coal-fired power plants is important.

b. Solid Waste

The RCRA regulations apply to wastes that are discarded or disposed and will include injection of supercritical CO₂ into the subsurface for OSGS in all likelihood.²⁴⁰ Specifically, the RCRA applies to “solid wastes” which are defined as “any garbage, refuse, sludge from a waste treatment plant, water supply treatment plant, or air pollution control facility and other discarded material, including solid, *liquid*, and semisolid, or *contained gaseous material* resulting from industrial, commercial, mining, and agricultural operations, and from community activities”²⁴¹

The terms “liquids” and “contained gaseous material” probably encompass supercritical CO₂, which has characteristics of both. Moreover, supercritical CO₂ is captured from an industrial or commercial operation and appears to come under the broad reach of the RCRA. Only a few wastes are excluded from strict regulation under the RCRA, such as household waste, mining wastes, and wastes related to exploration and production of oil and gas.²⁴² The RCRA is a complicated law that imposes onerous requirements for hazardous waste management.

The EPA has defined “discarded material” regulated under the RCRA as any material that is either “abandoned,” “recycled,” or considered “inherently waste-like.”²⁴³ Disposal includes “discharge, deposit, injection, dumping, spilling, or leaking” of waste into the environment.²⁴⁴ Even a potentially recyclable product is considered discarded if it is “accumulated speculatively.”²⁴⁵ When a product is discarded, disposed, or abandoned it is considered a solid waste and regulated under the RCRA.

It is possible that a recycling exemption might apply if demonstrations can be made that supercritical CO₂ is being stored underground for later use. The RCRA does not regulate materials that are recycled, reclaimed, or still useful.²⁴⁶ However, defining material as recycled under the RCRA requires a negative

238. 42 U.S.C. § 6903(27) (2000).

239. 42 U.S.C. §§ 6921-6934 (2000).

240. 42 U.S.C. §§ 6901-6987, 9001-9010 (2000).

241. 42 U.S.C. § 6903(27) (2000) (emphasis added).

242. 42 U.S.C. § 6921(b)(2)-(3) (2000).

243. 40 C.F.R. § 261.2(a)(2) (2006).

244. 42 U.S.C. § 6903(3) (2000).

245. LINDA A. MALONE, ENVIRONMENTAL LAW, EMANUEL LAW OUTLINES 106-07 (Aspen Publishers, 2003) [hereinafter MALONE].

246. 40 C.F.R. § 261.2 (2006).

implication.²⁴⁷ For example, material that is not considered disposed, burned for energy recovery, reclaimed, or accumulated speculatively may be considered recycled material and would not be regulated under the RCRA.²⁴⁸ To meet the recycling test, supercritical CO₂ must be a ready substitute for a commercial product or raw material feedstock.²⁴⁹

Some CO₂ captured from coal-fired power plants will likely readily substitute for commercial CO₂ and avoid regulation under the RCRA. The D.C. Circuit Court has held that materials are not waste when they were “destined for beneficial reuse or recycling in a continuous process by the generating industry itself.”²⁵⁰ However, the court later stated that a material might not be excluded from regulation under the RCRA even when it might eventually be reclaimed.²⁵¹ The EPA has stated that CO₂ is not a natural gas for reasons of injection, so it will not qualify for the natural gas exemption.²⁵² Case law supports the EPA’s conclusion.²⁵³ Therefore, at least some of the supercritical CO₂ captured from coal-fired power plants and injected into the subsurface will likely be regulated as a solid waste under the RCRA.

c. Hazardous Waste

The composition of injected CO₂ will determine whether it is a RCRA hazardous waste, unless the EPA or Congress provides an exemption. The RCRA defines a hazardous waste as:

a solid waste, or combination of solid wastes, which because of its quantity, concentration, or physical, chemical, or infectious characteristics may—
(A) cause, or significantly contribute to an increase in mortality or an increase in serious irreversible, or incapacitating reversible, illness; or
(B) pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, disposed of, or otherwise managed.²⁵⁴

A waste may be hazardous by characteristic or by rule (i.e. listing).²⁵⁵ The EPA may list a waste through rulemaking if it is ignitable, corrosive, reactive, toxic, acutely toxic to humans, or if it contains toxic constituents and is capable of posing substantial harm to human health.²⁵⁶ A material is characteristically hazardous if it is sufficiently ignitable, corrosive, reactive, or toxic.²⁵⁷ CO₂ is not a listed hazardous waste.²⁵⁸ However, it is possible that supercritical CO₂ captured from coal-fired power plants might be deemed by the EPA to have hazardous characteristics. Characteristically hazardous waste is a solid waste that may “(A) cause, or significantly contribute to an increase in mortality or an

247. MALONE, *supra* note 245.

248. *Id.*

249. 40 C.F.R. § 261.2(e) (2006).

250. American Mining Cong. v. EPA, 824 F.2d 1177, 1186 (D.C. Cir. 1987).

251. American Mining Cong. v. EPA, 907 F.2d 1179, 1187 (D.C. Cir. 1990).

252. UICPG # 83, *supra* note 79, at 5; *see also* Wilson, *supra* note 190.

253. Arco Oil & Gas Co. v. EPA, 14 F.3d 1431, 1436 (10th Cir. 1993).

254. 42 U.S.C. § 6903(5) (2006).

255. *Id.*

256. 40 C.F.R. § 261.11(a)(1)-(3) (2003).

257. 40 C.F.R. § 261.10 (2006).

258. 42 U.S.C. § 6903(5) (2000).

increase in serious irreversible, or incapacitating reversible illness; or (B) pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, disposed of, or otherwise managed.”²⁵⁹

The hazardous characteristic may be:

- (i) measured by an available standardized test method which is reasonably within the capability of generators of solid waste or private sector laboratories that are available to serve generators of solid waste; or (ii) reasonably detected by generators of solid waste through their knowledge of their waste.²⁶⁰

The Toxicity Characteristic Leachate Procedure (TCLP) is used to test for hazardous characteristics under the RCRA. However, the TCLP is applicable to solids or semi-solids. It is not applicable to water or gases, because it is a test of the ability of a toxic constituent to leach from a solid or semi-solid. The TCLP will not likely suffice for supercritical CO₂, because there is no practical way to apply the standard method to test leaching toxics from supercritical CO₂. However, commercially available tests applicable to evaluating gases and liquids will likely provide the basis for characterizing supercritical CO₂.

No data are available to determine whether supercritical CO₂ captured from coal-fired power plants will pose the kinds of risks that would prompt the EPA to list it as a hazardous waste. Commercially available CO₂ is corrosive, but generally, it is either not sufficiently corrosive to warrant the EPA listing as a hazardous waste, or it is not hazardous by characteristic.²⁶¹ A third possibility is that commercially-available supercritical CO₂ is deemed outside the scope of the RCRA, because it evaporates and is not deemed discarded as a supercritical fluid.

Supercritical CO₂ captured from coal-fired power plants may contain other constituents which may be toxic.²⁶² If it is deemed to be a hazardous waste, then owners and operators must demonstrate compliance with the no-migration standard before the supercritical CO₂ can be injected under Class I of the current UIC program. Explaining the interaction between the RCRA, and the SDWA, which authorized the federal UIC program, the D. C. Circuit Court has stated that “SDWA protects sources of drinking water; RCRA protects human health and the environment.”²⁶³ The SDWA requires that injections “not endanger” USDWs.²⁶⁴ The RCRA requires that hazardous waste remain in the “injection zone for as long as the wastes remain hazardous.”²⁶⁵ However, relatively insignificant²⁶⁶ migration of CO₂ is expected and is possibly desirable.²⁶⁷ Therefore, if supercritical CO₂ is hazardous waste, exemption from the RCRA hazardous waste regulation may promote deployment of OSGS without detriment to human health or the environment.

259. *Id.*

260. 40 C.F.R. § 261.10 (2006).

261. STUMM AND MORGAN, *supra* note 41.

262. APPS, *supra* note 16, at 46.

263. *Chemical Waste Mgmt., Inc. v. EPA*, 298 U.S. App. D.C. 54, 77-78 (D.C. Cir. 1992).

264. *Id.* at 78.

265. *Chemical Waste Mgmt.*, 298 U.S. App. D.C. at 78.

266. MIT, *supra* note 3.

267. Tsang, *supra* note 99, at 8.

Complying with the RCRA requirements can affect operational costs and drive up risk premiums. To lessen the burden on industry, and ultimately the cost to the consumer, an exemption for supercritical CO₂, similar to that used for petroleum, could be made, provided operational data currently being obtained are favorable. The exemption from regulation as a hazardous waste could avoid a potential obstacle to the deployment of OSGS and promote effective risk-based regulation under a new subclass within the UIC program if any CO₂ captured from coal-fired power plants for OSGS is ultimately determined to be hazardous waste.

d. Potential Exemption

Assuming supercritical CO₂ captured from coal-fired power plants is deemed to be a hazardous waste, exempting it from the RCRA hazardous waste regulation could promote OSGS deployment. Wastes produced during the exploration, development, and production of crude oil, natural gas, and geothermal energy were exempted from regulation as a RCRA hazardous waste based largely on the crucial importance of oil and gas to the public welfare and regulatory efficiency.²⁶⁸ The rationale for the oil and gas exemption was essentially to promote efficiency and avoid interruption of oil and gas production.

The EPA's reasoning was that regulating oil and gas waste as hazardous wastes would "not provide sufficient flexibility to consider costs and avoid the serious economic impacts that regulation would create" for industry.²⁶⁹ OSGS may become inextricably linked to the production of electricity from coal so that burdening industry with unduly restrictive regulations could interfere with crucial power generation activity. A policy similar to that used to exempt oil and gas production wastes from the hazardous waste regulations should apply to OSGS.²⁷⁰

Energy production from petroleum and natural gas is crucial, which was a major factor in exempting petroleum and natural gas waste from regulation as a RCRA hazardous waste. Exempting supercritical CO₂ captured from coal-fired power plants from RCRA hazardous waste regulation, assuming it is hazardous in the first instance, will promote adoption of the risk-based regulatory approach described previously. However, in cases in which OSGS is used to co-dispose hazardous wastes along with supercritical CO₂, the exemption would be

268. Regulatory Determination for Oil and Gas and Geothermal Exploration, Development and Production Wastes, 53 Fed. Reg. 25,446, 25,447 (July 6, 1988). In 1980, Congress conditionally exempted oil and gas exploration production wastes from the hazardous waste management requirements of the RCRA §3001(b)(2)(A) and §8002(m).

269. 53 Fed. Reg. 25,446, at 25,447. The EPA's rationale for exempting oil and gas production wastes from RCRA hazardous waste regulations included the following: i) regulating oil and gas waste as hazardous wastes would "not provide sufficient flexibility to consider costs and avoid the serious economic impacts that regulation would create" for industry; ii) existing federal and state regulatory programs were deemed "adequate for controlling" the wastes; iii) "[r]egulatory gaps" were being "addressed" by "formulating" non-hazardous waste requirements; iv) "[p]ermitting delays would hinder new facilities, disrupting" progress; v) hazardous waste treatment would "severely strain existing" hazardous waste facilities; vi) the agency thought it "impractical and inefficient" to regulate "all or some of these wastes because of the disruption and, in some cases, duplication of State authorities;" and vii) it was "impractical and inefficient to implement" the regulations and would cause a "permitting burden that the regulatory agencies . . ." *Id.*

270. 53 Fed. Reg. 25,446, at 25,447.

inappropriate.²⁷¹ Not only are considerations of the regulation of OSGS important to guide industry during deployment of the technology and initial injections, but also during commercial operation when long-term liability is a “key element.”²⁷²

4. Regulation under Comprehensive Environmental Response, Compensation and Liability Act

After injection, supercritical CO₂ will remain in the subsurface for long periods. Sequestered CO₂ could remain in place for tens of thousands of years or longer. Industry must strongly consider risks and the duration of their liability before committing to OSGS, because someone or some entity will be responsible for harms caused even if they are far in the future.

Long-term liability may arise from leaks or migration of CO₂ after it is injected.²⁷³ If performed reasonably, it is unlikely that OSGS will leave a legacy of polluted sites requiring remediation.²⁷⁴ However, long-term liability issues are looming. Recent developments in energy law have not changed or clarified possible long-term liability issues.²⁷⁵ Therefore, the CERCLA²⁷⁶ will likely provide the regulatory framework for long-term CO₂ storage.

The CERCLA is intended to provide for the clean up of potentially harmful releases of hazardous substances.²⁷⁷ Even after potentially harmful sites are closed or abandoned or after owners become bankrupt, the CERCLA provides a remedy. Under the CERCLA, the EPA and authorized states identify potentially responsible parties (PRPs) and attach strict, joint and several liability to current and past owners or operators. In addition, liability extends to any person who arranged for treatment or disposal of a hazardous substances and anyone who transported hazardous substances to the facility where there is a release or threatened release of hazardous substances.²⁷⁸ It also may also reach successors to PRPs and parent companies.

The CERCLA incorporates the definitions of hazardous waste and toxic substances under the RCRA, the Clean Water Act,²⁷⁹ the Clean Air Act²⁸⁰ and the TSCA. Petroleum and natural gas are exempted. Petroleum includes “crude oil or any fraction thereof which is not otherwise specifically listed or designated as a hazardous substance”²⁸¹ Natural gas includes “natural gas, natural gas

271. Wastes mixed with supercritical CO₂ for co-disposal should remain regulated as they are currently.

272. MASSACHUSETTS INST. OF TECH., CARBON CAPTURE & SEQUESTRATION TECHNOLOGIES AT MIT, REGULATORY AND LEGAL ISSUES SUMMARY, http://sequestration.mit.edu/research/regulatory_legal_issues.html (last visited Sept. 25, 2007).

273. MIT, *supra* note 3, at 58.

274. IPCC, *supra* note 4, at 146 (The CERCLA includes “site” within the definition of “facility,” as described *infra*).

275. S. 1419, 110th Cong. §§ 302-304 (2007).

276. 42 U.S.C. §§ 9601-9662 (2000) (as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA)).

277. MALONE, *supra* note 245, at 117.

278. 42 U.S.C. § 9607(b) (2000).

279. 33 U.S.C. §§ 1251-1387 (2000).

280. 42 U.S.C. § 7401 (2000).

281. 42 U.S.C. § 9601(14) (2000).

liquids, liquefied natural gas, or synthetic gas usable for fuel (or mixtures of natural gas and such synthetic gas).”²⁸²

Under the CERCLA, the property limits of a site used for OSGS may not be relevant in assessing liability. Liability extends to the facility, which is defined without regard to legal property boundaries. Facility is defined as:

(A) any building, structure, installation, equipment, pipe or pipeline (including any pipe into a sewer or publicly owned treatment works), well, pit, pond, lagoon, impoundment, ditch, landfill, storage container, motor vehicle, rolling stock, or aircraft, or (B) any site or area where a hazardous substance has been deposited, stored, disposed of, or placed, *or otherwise come to be located*; but does not include any consumer product in consumer use or any vessel.²⁸³

The CERCLA encompasses the full extent of contamination wherever it has “come to be located.”²⁸⁴ The CERCLA-assigned responsibility may extend over many properties, both private and public, and potentially over hundreds of kilometers.²⁸⁵ Years after the injection has ceased and an injection facility has closed, parent and successor corporations, among others, may be liable for releases of hazardous substances.²⁸⁶ Because the nature of OSGS is to permanently, or nearly so, sequester CO₂ below ground, companies concerned about long-term liability may raise rates to offset long-term risks or obtain insurance, if available, and pass the cost on to consumers.

Methods to limit long-term liability should be considered to avoid discouraging investment in OSGS caused by strict, joint and several liability imposed by the CERCLA. The public will ultimately pay the cost of OSGS either to companies involved in OSGS or by funding government clean-ups of abandoned facilities, if there are any harmful releases or potential releases. Liability can be limited using liability caps, or by having the federal or state governments assume ultimate responsibility for the sequestered CO₂.²⁸⁷

Limits on liability similar to the Price-Anderson Act may be appropriate and effective.²⁸⁸ The Price-Anderson Act requires members of the nuclear power industry to maintain certain levels of insurance and to contribute to a trust fund for use in case of a nuclear accident. The Act caps industry costs by requiring the federal government take over financial responsibility for accident costs that exceed the insured and funded amount. Also, a model similar to the Low Level Radioactive Waste Policy Act (LRWPA) may be effective.²⁸⁹ Under the LRWPA, states “are responsible for the disposal of low-level radioactive waste generated within their borders.”²⁹⁰

282. *Id.*

283. 42 U.S.C. § 9601 (2000). (emphasis added)

284. *Id.*

285. Tsang, *supra* note 99, at 7. (When supercritical CO₂ is injected it may migrate laterally for more than 100 km).

286. *See* United States v. Bestfoods, 524 U.S. 51 (1998) (holding parent company may be liable under direct or derivative liability theories); *see also* United States v. Exide Corp., No. 00-CV-3057, 2002 WL 319940 (E.D. Pa. 2002) (holding a corporation that continues the business of its predecessor may be found liable based on the “de facto merger” or “substantial continuity of business” test).

287. DE FIGUEIREDO, *supra* note 43, at 653.

288. 42 U.S.C. § 2210 (2000).

289. 42 U.S.C. § 2021b (2000).

290. DE FIGUEIREDO, *supra* note 43, at 653.

Long-term OSGS liability could be limited similarly to nuclear liability. If the federal government takes responsibility for any remediation costs that exceed a specified amount, it would essentially be shifting costs to the public. An advantage of federal liability limits could be to avoid disparate treatment in cases where migrating CO₂ crosses jurisdictional boundaries. However, states could provide liability protection to industry as a means of stimulating business, which at many sites where CO₂ migration across jurisdictional boundaries is not a concern, would be sufficient.

F. Common Law Considerations

1. Overview

OSGS will inevitably lead to litigation. Disputes arising over property and contract rights as well as suits based on injury to persons or property will be virtually unavoidable based on the large scale and extended period through which supercritical CO₂ will be sequestered. Expanding plumes of supercritical CO₂ will cross property boundaries deep below ground. Leaking CO₂ could interfere with property rights or accumulate in structures causing personal harm. Contract, product liability, and warranty claims will arise. Several causes of action that might arise from OSGS are presented below as possible examples of the likely development of OSGS law.²⁹¹

2. Trespass

Although there is no case law addressing sequestered CO₂, there is analogous case law that is instructive in assessing the development of the law of CO₂ sequestration. Issues arising out of injected waste are instructive in considering potential issues arising from injected supercritical CO₂, because both may cross property boundaries below the land surface and affect property rights. The Supreme Court of Ohio addressed the issue of injectate migration onto adjacent property in 1996. In *Chance v. BP Chemicals*,²⁹² property owners sued a chemical refiner for trespass arising out of alleged lateral migration of injectate from deep well injection of waste chemicals. The court said that the claim was “previously unrecognized by any court.”²⁹³

The court stated that even if injected waste migrated under the plaintiff’s property, “physical damage or actual interference with the reasonable and foreseeable use of the properties must be demonstrated” to prevail on a trespass claim and that “evidence of trespass was simply too speculative.”²⁹⁴ Injectate migrates and mixes with other fluids. Therefore, the court in *Chance* concluded that it is theoretically impossible to define an absolute perimeter on the extent of lateral migration, since any statement on the extent of migration must be in terms of a particular concentration level at that perimeter. In addition, there was

291. A complete survey of state common law and regulations is beyond the scope of the manuscript. Additional examples of subsurface property rights law relevant to geologic sequestration is provided at Elizabeth J. Wilson & Mark A. de Figueiredo, *Geologic Carbon Dioxide Sequestration: An Analysis of Subsurface Property Law*, 36 ENVTL. LAW REP. 10114 (2006), available at LEXIS.

292. *Chance v. BP Chems., Inc.* 670 N.E.2d 985 (Ohio 1996).

293. *Id.* at 993.

294. *Chance*, at 993.

testimony about the degradation of the injectate, and how that degradation would affect the injectate's migration over time.²⁹⁵

The court explained that "ownership rights in today's world are not so clear-cut as they were before the advent of airplanes and injection wells"²⁹⁶ and that "subsurface property rights are not absolute" and under the circumstances "are contingent upon interference with the reasonable and foreseeable use of the properties."²⁹⁷ Battling experts may produce unsatisfactory results without direct measurement of CO₂ invading subsurface pore spaces or above-ground structures. It is likely that case law arising from OSGS of CO₂ will follow similar reasoning and that claimants will face similar evidentiary issues.

Proof of subsurface trespass may elude claimants with limited resources and a lack of knowledge of subsurface science. In *Nunez v. Wainco Oil & Gas Company*,²⁹⁸ the Louisiana Supreme Court addressed the inadvertent injection of waste below ground onto adjacent property and explained that traditional property rights yield to the public interest.²⁹⁹ In *Raymond v. Union Texas Petroleum Corp.*,³⁰⁰ the court explained that *Nunez* did not preclude property owners from receiving compensation for damages from subsurface injectate migration, but it required the claimant to bear the burden of proof. In *Mongrue v. Monsanto Co.*,³⁰¹ the court explained that the "Commissioner does not necessarily bar claims of trespass when authorizing the disposal of waste through underground injection wells."³⁰² However, the court cited *Chance*³⁰³ to explain that the claimant has the "burden of demonstrating that the migration of [injectate] interfered with a reasonable and foreseeable use of their property."³⁰⁴

Thus, only claimants with reasonably foreseeable expectations of using the pore spaces under their property and armed with convincing subsurface data will likely recover damages for trespass caused by migrating supercritical CO₂. Evidence of trespasses that occur thousands of feet below the land surface may be extremely expensive and difficult to obtain. However, if CO₂ escapes to the land surface, the cases of trespass and possibly personal harm may be much easier to sustain because evidence may be more accessible.

3. Nuisance and Stigma

Property owners adjacent to OSGS sites may find their property value affected as concerns over the effects of OSGS on the public and the environment may arise. Courts addressed nuisance and stigma associated with underground waste injection and other waste disposal activities. The U.S. District Court for the Western District of New York decided that without proof of "actual physical

295. *Id.* at 992-93.

296. *Chance*, 670 N.E.2d at 992.

297. *Id.* at 993.

298. *Nunez v. Wainoco Oil & Gas Co.*, 488 So.2d 955 (La. 1986).

299. *Id.* at 963-64.

300. *Raymond v. Union Texas Petroleum Corp.*, 697 F. Supp. 270, 274 (D. La. 1988).

301. *Mongrue v. Monsanto Co.*, No. 98-2531, 1999 WL 970354 (E.D. La. 1999).

302. *Id.* at *3.

303. *Chance v. BP Chems., Inc.* 670 N.E.2d 985, 993-94 (Ohio 1996) (holding that the trial court correctly required plaintiffs in subsurface migration case to prove damages at trial as part of their trespass claim.).

304. *Mongrue*, 1999 WL 970354, at *4.

damage to a plaintiff's property, stigma damages alone are too remote and speculative to be recoverable."³⁰⁵ In *Hammond v City of Warner Robbins*, the Court of Appeals of Georgia held that "[s]tigma to realty, in and of itself, is too remote and speculative to be a damage and is of first impression"³⁰⁶ In *Chance*,³⁰⁷ the Supreme Court of Ohio stated that because no physical damage or interference with use of subsurface land had been shown, the trial court did not abuse its discretion in foreclosing the plaintiffs from introducing evidence of stigma damages.³⁰⁸ Nuisance and stigma claims arising out of OSGS will not likely bear much fruit mainly because of the same evidence problem described for trespass claims.

4. Takings

Takings issues may arise from the spread of injected supercritical CO₂ into the subsurface. When the government either physically invades or authorizes a private party to physically invade another's property it is a per se taking.³⁰⁹ Injected supercritical CO₂ is expected to spread laterally over great distances. Depending upon the government's interest in promoting OSGS, it may authorize or ultimately require geologic sequestration of CO₂. If CO₂ is injected by the government or on behalf of the government and it spreads into pore spaces beneath neighboring properties, then it will be a taking unless property rights to deep pore spaces are limited either through legislation or case law.³¹⁰

Eminent domain mechanisms akin to public convenience certificates used in siting natural gas pipelines may be a way for the government to gain access to deep pore spaces. In common law, pore spaces may not have any value to a property owner unless the owner has an investment-backed, reasonably foreseeable expectation of using the deep pore spaces at the time of the invasion. The government's use, or authorization of use, of pore spaces will infringe upon the owner's right to exclude others, but if the pore spaces have no value and provided the owner cannot demonstrate investment-backed expectations of using the pore spaces, then the taking of pore-spaces may require only nominal compensation.

The government could not operate if it had to pay for every encroachment.³¹¹ Therefore, ownership rights to deep pore spaces will need to be clarified. Possibly, OSGS facilities will be developed in unpopulated areas so that if any compensation is paid, it will be small sums to relatively few individuals. Limitations on subsurface property rights, especially rights to deep pore spaces, may become clearer as case law and legislation develops.

305. *Mehlenbacher v. Akzo Nobel Salt, Inc.*, 71 F. Supp.2d 179, 193 (W.D.N.Y. 1999), *vacated in part*, 216 F.3d 291 (2d Cir. 2000).

306. *Hammond v. City of Warner Robbins*, 482 S.E.2d 422, 428 (Ga. App. 1997).

307. *Chance*, 670 N.E.2d at 985 (stated property owners sued a chemical refiner for damages arising out of alleged lateral migration of an injectate used in connection with disposal of waste chemicals by deep well injection).

308. *Mehlenbacher*, 71 F. Supp.2d at 187.

309. *Lorretto v. Teleprompter Manhattan CATV Corp.*, 458 U.S. 419 (1982).

310. For example, in *Raymond*, the court held that legislation superseded in part prior legislation regarding the concept of limitations on ownership of the subsurface by the surface owner of the land. *Raymond v. Union Texas Petroleum Corp.*, 697 F. Supp. 270, 274 (D. La. 1988).

311. *Hadacheck v. Sebastian*, 239 U.S. 394, 410 (1915).

5. Unjust Enrichment and the Negative Rule of Capture

Assuming that a market may one day develop for subsurface CO₂ storage space, claims of unjust enrichment will likely arise. Unjust enrichment claims may arise where an owner or operator of an OSGS facility injects CO₂ into another's pore space. However, claimants in unjust enrichment claims will suffer from the same evidence issues facing claimants for trespass, nuisance, and stigma. The United States Court of Appeals for the Fifth Circuit has held that an equity claim of unjust enrichment in Louisiana may only proceed when there is no remedy at law.³¹² In *Mongrue*,³¹³ the court held that "plaintiffs are not entitled to a claim of unjust enrichment because the law provides them a viable trespass remedy."³¹⁴ Obtaining proof may be a daunting task because CO₂ will tend to be injected into deep reservoirs.

Whenever proof that CO₂ injected thousands of feet below the land surface migrated into another's deep pore spaces is required, claims will be difficult to sustain. However, between members of industry, especially where deep wells are installed, evidentiary issues may be easier to overcome. As OSGS proceeds, deep pore spaces may become valuable. There may be more interest in subsurface storage space and more subsurface investigation may make it easier to obtain the vital data needed to succeed in tort claims.

In oil and gas extraction, the rule of capture permits one to extract all of the oil and gas from a reservoir that migrates to one's property even if others own land above the reservoir and even if it drains the oil and gas from another's property.³¹⁵ The rule of capture leads to inefficiencies as one entity tries to maximize its extraction of oil and gas, which tends to compel others, with interests in the same reservoir, to do likewise. The rush to extract migratory minerals, like oil and gas, can result in waste.

In a "negative"³¹⁶ rule of capture scenario, it is hypothesized that one entity may be able to inject supercritical CO₂ into the subsurface on one's property and allow it to migrate and fill pore spaces owned by others.³¹⁷ However, unlike extracting oil and gas, OSGS will involve the physical invasion of another's property by pressurized CO₂. Without legislative action, such an invasion will be a trespass, provided it can be proved.

States have recognized the inefficiencies in the rule of capture and have passed unitization laws to improve harmony among landowners and interested parties to promote more efficient oil and gas extraction. Similar legislation, addressing use of pore spaces and other reservoir uses, could benefit owners and operators of OSGS facilities, as explained below.

312. *Sheets v. Yamaha Motors Corp.*, 849 F.2d 179, 184 (5th Cir. 1988).

313. *Mongrue v. Monsanto Co.*, No. 98-2531, 1999 WL 970354 (E.D. La. 1999).

314. *Id.*

315. Provided extraction wells remain on one's property. Where deep drilling is involved, wells sometimes deviate from plumb and bottom on adjacent property.

316. OIL CONSERVATION DIV., NEW MEXICO ENERGY, MINERALS, NATURAL RES. DEPT., CARBON DIOXIDE SEQUESTRATION: INTERIM REPORT ON IDENTIFIED STATUTORY AND REGULATORY ISSUES (2007), www.emnrd.state.nm.us/OCD/documents/InterimReportCO2Sequestration.pdf.

317. *de Figueiredo*, *supra* note 3. (noting the negative rule of capture has been applied where injectate of lesser value entered pore spaces under adjacent landowners' property for the purpose of enhancing the recovery of more valuable petroleum).

6. Incompatible Uses and Unitization

Due diligence will be required in selecting locations for OSGS to avoid incompatible uses and possibly other claims. In *Sunoco Partners Marketing & Terminals L.P. v EPA*,³¹⁸ Sunoco was unable to use its subsurface pore space for natural gas storage based on incompatibility with a prior permitted waste injection. State law provided that “[a] well shall not be located or drilled to an objective formation which will result in operations incompatible with existing or permitted uses” and further required applicants to “demonstrate its operations are not incompatible with those uses.”³¹⁹ The court concluded that Sunoco’s proposed natural gas storage and the prior use of the reservoir for waste disposal were “profoundly incompatible with each other.”³²⁰ It is likely that any use that would increase the likelihood of CO₂ escape will be incompatible with OSGS.

In a Louisiana case, *Raymond*,³²¹ the Commissioner of Conservation “declared that landowners share a common interest in a reservoir of natural resources beneath their adjacent tracts” and that the “common interest does not permit one participant to rely on a concept of individual ownership to thwart the common right to the resource as well as the important state interest in developing its resources fully and efficiently.”³²² While the Louisiana court was addressing mineral rights, rights to pore spaces could be decided similarly.

Reservoir unitization may be an effective tool in managing pore space use and avoiding tort claims. Reservoir unitization is the treatment of oil and gas fields as a unit in which surface property owners share in the proceeds from the oil and gas based on negotiated arrangements with an entity extracting the oil and gas. State mandatory unitization laws lessen the problem of negotiating agreements with property owners and improve extraction efficiency.³²³ OSGS reservoirs could be unitized similarly to oil and gas reservoirs. Under mandatory laws, property owners could receive benefits based on rules prescribed by the state. Recognizing the possibility that injected CO₂ may migrate great distances, states may address reservoir use compatibility and pore space utilization through unitization laws.

7. Groundwater Contamination and Strict Liability for Abnormally Dangerous Activity

OSGS could lead to the contamination or potential contamination of USDWs. If the recommended risk-based approach is adopted, then some small impact in groundwater that is safe could be allowed. However, if OSGS contaminates groundwater and causes risk to human health and the environment,

318. *Sunoco Partners Mktg. & Terminals L.P. v EPA*, No. 05-74742, 2006 U.S. Dist. LEXIS 2817, at *30-32 (D. Mich. 2006).

319. MICH. ADMIN. CODE R. 299.2341(2) (2004).

320. *Sunoco Partners Mktg.*, 2006 U.S. Dist. LEXIS, at *31.

321. *Raymond v. Union Texas Petroleum Corp.*, 697 F. Supp. 270, 274 (D. La. 1988).

322. *Id.* (holding that legislation superseded in part prior legislation regarding the general concept of ownership of the subsurface by the surface owner of the land).

323. GARY LIBECAP, NAT’L BUREAU OF ECON. RESEARCH, HOOVER INST., PERC, UNIV. OF ARIZONA, TUCSON, ASSIGNING PROPERTY RIGHTS IN THE COMMON POOL. IMPLICATIONS OF THE PREVALENCE OF FIRST-POSSESSION RULES (2006), www2.bren.ucsb.edu/~glibecap/Allocation_within_Sectors1.doc (stating a key issue is the allocation of net proceeds among the parties).

then corrective actions will be required and litigation may arise. Regulatory enforcement actions will proceed under federal and state environmental laws and regulations.³²⁴ Methyl-tertiary butyl ether (MTBE) cases provide a possible analogy for future OSGS issues. MTBE was used to replace lead as an enhancement to the performance of gasoline as transportation fuel. However, it was later discovered that MTBE persisted for long periods below ground when released and posed significant risks to human health and the environment. The MTBE analogy demonstrates the type of reaction courts may have to the claims of damages caused by CO₂ migrating underground.

MTBE, the banned gasoline oxygenate, released from underground storage tanks into the environment has caused groundwater contamination throughout the United States. In the MTBE cases evidentiary hurdles were substantial. Claimants were unable to prove harm in some cases and in other cases have been time barred because there was a lag period between when the harm should have been discovered and when litigation began. In multi-district litigation, the District Court for the Southern District of New York explained that the statute of limitations begins to run when a claimant has suffered some “appreciable and actual harm” and that the harm must be “more than nominal,” but that a claimant need not “have ascertained the full scope of its injury.”³²⁵ However, the court also noted that neither uncertainty of harm nor “difficulty of proof” would toll the limitations period.³²⁶

As OSGS sites develop and more is learned about the effects of CO₂ in the subsurface, claimants may be charged with constructive discovery of groundwater contamination before readily ascertainable proof is available. For example, a claimant having a suspicion of leaking CO₂ may be charged with constructive discovery. However, the claimant may have no data to demonstrate any impact to groundwater, because it is either too expensive to obtain or any effects that leaking CO₂ may have on groundwater may require significant time to accrue to a level that can be documented with reasonable certainty.

The District Court for the Southern District of New York has addressed the “vexing issue” of determining when the claimants in the multi-district litigation should be charged with knowledge of injury from leaking MTBE to groundwater resources.³²⁷ The court concluded that there were three possibilities including (i) when gasoline containing MTBE leaked from a tank or pipeline; (ii) when MTBE was actually detected in groundwater; and (iii) when released MTBE caused or should have caused action by the regulatory agency.³²⁸ The court explained that the “mere release” of gasoline containing MTBE did not cause appreciable harm and that it was only when the MTBE actually migrated into a

324. The material presented herein is limited to private litigation, because evidentiary issues peculiar to OSGS are expected to affect significantly claimant successes. Regulatory actions for groundwater impacts should proceed similarly to current enforcement actions. Where groundwater quality is less critical and unlikely to affect human health, corrective actions may be passive (e.g. monitored natural attenuation). However, where risks are higher, more aggressive remedial techniques will be necessary (e.g. installing, operating, and maintaining engineered remedial techniques).

325. *In re Methyl Tertiary Butyl Ether Prods. Liab. Litig.*, 475 F. Supp. 2d 286, 291 (D.N.Y. 2006).

326. *Id.*

327. *Methyl*, 475 F. Supp. 2d 286.

328. *Id.* (the responsible agency was Orange County Water District).

USDW that appreciable harm might occur, but that some impacts were “fleeting” or “de minimis” and thus did not cause appreciable harm.³²⁹

An impact to groundwater may constitute a harm, even if the water remains safe to drink. The court concluded that when the concentration of MTBE increased to a level that caused or should have caused the agency to act, appreciable harm had occurred.³³⁰ It is uncertain at what level the effects from leaking CO₂, or a contaminant in the CO₂, will constitute harm. For OSGS to succeed and for the recommended risk-based approach to be effective, trigger levels will have to be established. Necessarily, trigger levels will be below drinking water standards to provide early warning of potential harms and opportunity to mitigate harms before the water is unfit to drink. However, if OSGS is more dangerous than is currently expected and is determined to be an abnormally dangerous activity, then claimants will succeed regardless of fault provided they can prove harm. Strict liability for abnormally dangerous activity would expose owners and operators of OSGS facilities to claims regardless of fault to foreseeable claimants for cognizable harm.

In Maryland, a leaking underground storage tank released gasoline containing MTBE into the subsurface. Plaintiffs who owned real property near a gas station were certified as a homeowner subclass among individuals who suffered a legally cognizable injury.³³¹ The plaintiffs sought recovery based on theories of public and private nuisance, trespass to property, and strict liability for an abnormally dangerous activity.³³² If strict liability for abnormally dangerous activity were extended to OSGS, then owners and operators of OSGS facilities could potentially be liable to a large number of claimants based on the possibly large scale effects of leaking CO₂. Claimants living and working within tens or hundreds of kilometers of injection sites might be foreseeable claimants.

The recommended risk-based approach would allow industry to impact USDWs as long as human health and the environment are protected. Only if OSGS causes risk or future risks to human health or the environment should it be deemed to be a harm and only then should owners and operators of OSGS facilities be liable.

8. Risk-Based Regulation

Measurable levels of certain constituents may affect groundwater and not pose risks to human health or the environment. If leaks occur that affect groundwater quality, then at some point before groundwater becomes unsafe, industry will have to take corrective actions to prevent further impacts and continue to protect human health and the environment. As long as OSGS remains safe and injections of supercritical CO₂ are performed and monitored appropriately, then owners and operators of OSGS facilities should receive liability protection.

Owners and operators of OSGS facilities who fail to protect human health and the environment will be subject to tort liability as well as regulatory action. OSGS participants may seek to insure themselves against damage claims from

329. *Methyl*, 475 F. Supp. 2d at 293.

330. *Id.* at 293.

331. *In re Methyl Tertiary Butyl Ether Prods. Liab. Litig.*, 241 F.R.D. 185 (S.D.N.Y. 2007).

332. *Id.*

third parties. Insurance companies may face risks similar to those encountered in other impacted groundwater cases. In *UMC/Stamford, Inc. v. Allianz Underwriters Ins. Co.*, claimants sued insurance companies for clean-up costs to address groundwater contamination caused by releases of trichloroethylene on their sites.³³³ The insurance companies asserted an owned-property exclusion to avoid the claim. The Superior Court of New Jersey explained that insurance companies owed claimants payment for on-site clean-up costs when the clean up was performed to prevent off-site damage even before the off-site damage occurred.

The court stated that groundwater is “inherently migratory” and that claimants who proved that groundwater on their sites was actually contaminated and posed a “substantial risk that a third-party’s property will be contaminated” were entitled to coverage for the clean-up costs.³³⁴ It explained that the claimant only needed to establish to a “reasonable degree of certainty that the groundwater is likely to migrate and cause off-site damage” for the owned-property exclusion in insurance policies not to apply allowing claimants to recover costs to mitigate releases, preventing off-site impacts.³³⁵ The court explained that in California property owners do not own the groundwater³³⁶ and that state law obligated insurance companies to cover claims of groundwater contamination “even without evidence of actual or potential damage to off-site property.”³³⁷

In *Waltz v. Exxon Mobil Corp.*, claimants sued gasoline producers for MTBE impacts in groundwater supplies.³³⁸ Exxon defended by arguing that it was acting in conformance with provisions of the Clean Air Act (CAA)³³⁹ and that conflict preemption under the Supremacy Clause of the United States Constitution, barred the tort claims.³⁴⁰ The court disagreed, stating that it could not find Congress’s clear intention for the CAA to preempt state law causes of action.³⁴¹ Assuming that the EPA will likely regulate CO₂ emissions under the CAA,³⁴² it is possible that owners and operators of coal-fired power plants might respond to regulatory requirements by employing OSGS. However, assuming that some CO₂ will leak from the storage reservoirs and impacts to groundwater or other environmental media are likely, industry may find itself subject to law suits and regulatory enforcement arising essentially out of efforts to protect the atmosphere.

9. Working Toward Risk-Based Regulation

As OSGS proceeds, data from studies and any monitoring data that are reported to regulatory agencies will become available to the public. As data

333. *UMC/Stamford, Inc. v. Allianz Underwriters Ins. Co.*, 276 N.J. Super. 52, 63 (Law Div. 1994).

334. *Id.* at 62.

335. *UMC/Stamford*, 276 N.J. Super. at 62.

336. *Id.* at 63 (citing *AIU Ins. Co. v. FMC Corp.*, 799 P.2d 1253 (Cal.1990)).

337. *UMC/Stamford*, 276 N.J. Super. at 63.

338. *Waltz v. Exxon Mobil Corp.*, 2007 R.I. Super. LEXIS 10 (R.I. Super. Ct. 2007).

339. 42 U.S.C. § 9607(b) (2000).

340. *Waltz*, 2007 R.I. Super. LEXIS 10 (citing U.S. Const. art. VI, cl. 2).

341. *Id.* at 16

342. *Massachusetts v. EPA*, 127 S. Ct. 1438, 1460 (2007) (ruling that the EPA could regulate atmospheric CO₂ emissions as pollutants).

becomes available evidence of damages may become easier for claimants to obtain. As claimants begin to accumulate data, members of industry will be subjected to uncertain liability. Without a regulatory bar to claims for impacts that are unappreciable or *de minimis*, industry may be unable to effectively perform OSGS. Based on a review of the likely behavior of supercritical CO₂ injected for OSGS, circumstances analogous to the facts of the cases presented above will likely arise, and disparate treatment among jurisdictions could foster uncertainty.³⁴³

OSGS participants may not track CO₂ movement into neighboring property unless compelled to do so by regulation. Without a direct measurement of invading CO₂, a claimant will not fare better than those above who failed for lack of evidence. Regulations designed to govern OSGS should limit liability for *de minimis* impacts in the environment including USDWs. The recommended risk-based approach to OSGS regulation would allow certain impacts to proceed with limited liability provided USDWs remain safe for use.

V. SALIENT POINTS SUMMARY

Coal is essential to foreseeable energy production, and there are no viable substitutes readily available.³⁴⁴ OSGS is a promising technology to reduce CO₂ emissions into the atmosphere from coal-fired power plants. OSGS involves capturing CO₂ from flue emissions, compressing the CO₂, and transporting it to storage sites where it is injected deep underground. Preferred storage sites may include deep saline aquifers, depleted oil and gas reservoirs, and un-minable coal seams. Researchers have developed a reasonable understanding of the physical and chemical mechanisms likely to play major roles in sequestering CO₂. Some of the injected CO₂ will leak, but leaks are not expected to cause significant harm and they may even be beneficial to future sequestration efforts by lowering pressure in the storage reservoir. The key to successful OSGS is that high levels of leaking CO₂ be avoided to prevent harm to human health and the environment.

Federal and state laws and regulations governing the waste injection and the petroleum industries are well developed, but do not squarely address OSGS.³⁴⁵ Similarities between OSGS and currently regulated activities suggest that prevailing law provides a good basis for future regulation, but issues unique to OSGS argue for the adoption of a risk-based approach. Characterization of injected CO₂ as a waste, and potentially a hazardous waste, can impede OSGS by unnecessarily elevating the regulatory burden, costs, and liability imposed on owners and operators. Likewise, unlimited long-term liability may be too daunting for industry to incur, thus discouraging OSGS development and deployment.

Leaking CO₂ may affect USDWs and may escape to the land surface and ultimately the atmosphere. Before it can accumulate in above-ground structures, it will rise through thousands of feet of groundwater, rock, and soil. Monitoring could provide early warning of potential harm. Provided any impacts in USDWs

343. de Figueiredo, *supra* note 3.

344. *Id.*

345. S. 1419, 110th Cong. §§ 302-304 (2007) (Neither current energy law nor environmental laws and regulations specifically address OSGS).

either do not progress or can be detected before they reach harmful levels, some CO₂ leakage may be acceptable. Managing risks without requiring overly protective performance from OSGS participants will protect human health and the environment, avoid undue burden on industry, and promote OSGS deployment. The adaptation of existing laws and regulations to include a risk-based approach to regulating OSGS is recommended.³⁴⁶

To advance the policy of risk-based regulation, the EPA and Congress should consider exempting injected CO₂ from RCRA hazardous waste regulation. There is precedent for the exemption because petroleum and natural gas-related products and activities were exempted from RCRA hazardous waste regulation. The rationale for exempting waste related to petroleum and natural gas exploration and production from RCRA hazardous waste regulation is that Congress did not want to jeopardize critical energy supply by zealously regulating the industry. The same or similar rationale applies to the potentially critical relationship between OSGS and continued energy production from coal.

Energy production is essential and OSGS may need to occur on a very large scale. Therefore, not only should the injection of supercritical CO₂ be regulated specifically, but also, liability for sequestered CO₂ should be limited. As was done for wastes derived from nuclear power plants, limits on CERCLA liability should be developed for OSGS. Otherwise, given the extended periods through which supercritical CO₂ will be sequestered, members of the coal-fired power industry, owners and operators of OSGS facilities, as well as others involved in the process, will practically never be relieved of what might seemingly be untenable liability.

If ensuring reliable energy is critical to public welfare, it seems logical to relieve owners and operators of power plants and OSGS facilities of excessive costs and liability that might otherwise be incurred if supercritical CO₂ is governed under current laws and regulations. The policy considerations that led Congress and the EPA to exempt petroleum and natural gas-related products and activities from regulation as an RCRA hazardous waste are equally applicable to OSGS. Likewise, terminating long-term liability for those who practice OSGS is important to promoting the technology. States can promote OSGS by enhancing legal certainty through unitization laws and development of regulations that are consistent with the recommended risk-based approach. The overarching goal of protecting public welfare by ensuring that supercritical CO₂ injected into the subsurface does not harm human health or the environment can effectively be accomplished by using the recommended risk-based approach provided OSGS is ultimately proven safe and necessary.

VI. CONCLUSION

Injecting vast quantities of supercritical CO₂ underground involves inherent risks. While risks envisioned by experts tend to be manageable, only practice will reveal their true magnitude. The balance between potential public benefits derived from atmospheric protection and risks involved in OSGS need to be weighed carefully. Subjecting USDWs to potential adverse impacts from OSGS is unreasonable unless the need to reduce atmospheric concentrations of CO₂

346. IPCC, *supra* note 4, at 145.

actually warrants it. It is imperative that atmospheric considerations be scrutinized before mandating or allowing OSGS to proceed in full scale. If OSGS is actually necessary and is demonstrated to be safe, then industry should be regulated using the recommended risk-based approach.

The risk-based regulatory approach for OSGS will protect human health and the environment without undue burden on the regulated. It will limit uncertainty and promote development of OSGS. Congress should consider adapting current law to better address OSGS as well as new legislation. New legislation should include limiting the liability of owners and operators for any impacts in USDWs that do not jeopardize human health or the environment. Federal and state agencies should consider regulating OSGS consistently based on the probability and magnitude of harm that could reasonably result from injecting large amounts of CO₂ underground. Through effective development of OSGS laws and regulations, the United States may emerge as a world leader in atmospheric protection, substantially contribute to a reduction of atmospheric CO₂ concentrations and advance the public welfare.³⁴⁷

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