William & Mary Environmental Law and Policy Review

Volume *36 (2011-2012)*
Issue 1 *Symposium Issue Looking Beyond the Deepwater Horizon: The Future of Offshore Drilling*

Article 3

December 2011

The BP Deepwater Horizon: A Cautionary Tale for CCS, Hydrofracking, Geoengineering and Other Emerging Technologies with Environmental and Human Health Risks

Mark A. Latham

THE BP DEEPWATER HORIZON: A CAUTIONARY TALE FOR CCS, HYDROFRACKING, GEOENGINEERING AND OTHER EMERGING TECHNOLOGIES WITH ENVIRONMENTAL AND HUMAN HEALTH RISKS

MARK A. LATHAM*

> *[N]either the industry's nor the federal government's approaches to managing and overseeing the leasing and development of offshore resources have kept pace with rapid changes in the technology, practices, and risks associated with the different geological and ocean environments being explored and developed for oil and gas production.*[1]

INTRODUCTION

Technological innovation in the energy sector has resulted in remarkable feats to produce the fossil fuels that power the global economy, such as the ability to locate and produce oil from reserves thousands of feet beneath the ocean's surface.[2] Similar technical prowess allows for the recovery of natural gas from deep within subsurface shale formations.[3]

Evolving technological innovation also provides a measure of optimism so that we can adequately respond to and mitigate, to some extent, anthropogenic climate change arising from the emission of greenhouse gases ("GHGs") into our atmosphere,[4] which may be the most pressing

---

* Deputy Vice Dean, Professor of Law, Vermont Law School. I am grateful to Paige Davis, Vermont Law School Class of 2013, for her outstanding research assistance in the preparation of this Article.

[1] NAT'L COMM'N ON THE BP DEEPWATER HORIZON OIL SPILL & OFFSHORE DRILLING, REPORT TO THE PRESIDENT, DEEPWATER: THE GULF OIL DISASTER AND THE FUTURE OF OFFSHORE DRILLING 251 (Jan. 2011) [hereinafter REPORT TO THE PRESIDENT], *available at* http://www.oilspillcommission.gov/sites/default/files/documents/DEEPWATER_ReporttothePresident_FINAL.pdf.

[2] *See* WILLIAM L. LEFFLER ET AL., DEEPWATER PETROLEUM EXPLORATION & PRODUCTION: A NONTECHNICAL GUIDE 155–56 (2003).

[3] *See* Ian Urbina, Regulation Lax as Gas Wells' Tainted Water Hits Rivers, N.Y. TIMES, Feb. 26, 2011, at A1.

[4] *See* STAFF OF H. COMM. ON SCI. & TECH., 111TH CONG., ENGINEERING THE CLIMATE: RESEARCH NEEDS AND STRATEGIES FOR INT'L COORDINATION 1–2 (Comm. Print 2010) [hereinafter ENGINEERING THE CLIMATE].

environmental problem to ever confront humankind.[5] Thus engineers have turned a focus toward technological solutions to capture and store GHGs so they will no longer be emitted into the air with the expectation that this technology, carbon capture and sequestration, will become widely employed in the not-too-distant future.[6] Other technological solutions to address the adverse consequences associated with climate change through a variety of geoengineering proposals are also under consideration.[7]

However, as illustrated by the largest oil spill in U.S. history, the BP Deepwater Horizon oil spill, which raged for months, technological innovation such as deepwater oil exploration and production also presents unintended major threats to human health and the environment.[8] If these risks are not properly understood, evaluated, regulated, and worst-case scenarios prepared for well in advance, then catastrophe can and will strike. The BP Deepwater Horizon oil spill provides a potent cautionary tale, which informs us that we need to tread carefully and thoughtfully when we employ either existing or new technologies that can have a profound and perhaps lasting impact on the environment.[9] To do otherwise only serves to invite repeated catastrophic events that can cost lives, adversely affect the environment, and have far ranging negative implications for ecosystems that can take decades to fully comprehend.[10]

Mindful of this cautionary tale, and building on prior work examining the failure to adequately regulate deepwater drilling,[11] I consider here the human and environmental tragedy of the BP Deepwater Horizon oil spill as a lens to explore three other innovative technologies that present potential significant risk to human health and the environment. These technologies include carbon capture and sequestration, a method to reduce atmospheric emissions of carbon dioxide,[12] hydraulic fracturing, an

---

[5] *See, e.g.*, David G. Victor et al., *The Geoengineering Option: A Last Resort Against Global Warming?*, 88 FOREIGN AFF. 64, 76 (2009).
[6] *See* Victor B. Flatt, *Paving the Legal Path for Carbon Sequestration from Coal*, 19 DUKE ENVTL. L. & POL'Y F. 211, 213 (2009).
[7] *See* Victor et al., *supra* note 5, at 65–66.
[8] *See* REPORT TO THE PRESIDENT, *supra* note 1, at viii–ix.
[9] *See id.* at vii.
[10] *See id.* at vi, xi.
[11] *See* Mark A. Latham, *Five Thousand Feet and Below: The Failure to Adequately Regulate Deepwater Oil Production Technology*, 38 B.C. ENVTL. AFF. L. REV. 341 (2011).
[12] *See* KELSI BRACMORT ET AL., CONG. RESEARCH SERV., R41371, GEOENGINEERING: GOVERNANCE AND TECHNOLOGY POLICY 10 (2011) [hereinafter BRACMORT ET AL.].

increasingly controversial method for natural gas production[13] and, lastly, geoengineering, which has not been deployed on a major scale, but is under serious consideration to mitigate the adverse consequences of climate change through the deployment of a variety of interventions to actually cool the earth's temperature or to remove carbon dioxide from the atmosphere.[14]

This Article first discusses the technological issues surrounding the BP Deepwater Horizon and summarizes how regulator and industry reliance on an inadequate fail-safe device played a crucial role in this disaster. Next, I discuss the fundamentals of carbon capture and sequestration, hydraulic fracturing, and geoengineering; that is, I attempt to capture what they involve, followed by the environmental and human health risks they present. I then summarize the current or proposed regulation of these technologies and analyze whether those regulations are sufficient to adequately protect human health and the environment. I conclude with recommendations for policymakers and regulators to consider in light of these rapidly unfolding technologies that, it is hoped, will provide guidance to minimize the risks associated with each of them.

I. THE SEARCH FOR OIL AND THE DEEPWATER HORIZON

The Deepwater Horizon was a floating high-tech miracle of the seas and an illustration of how far oil exploration and production technology have advanced.[15] In the early days of the oil industry exploration and production activities were confined to land.[16] Technological innovations gradually moved oil exploration and production efforts from terrestrial-based operations to the oceans, in particular to the deep waters of the Gulf of Mexico.[17]

---

[13] *See* Angela C. Cupas, Note, *The Not-So-Safe Drinking Water Act: Why We Must Regulate Hydraulic Fracturing at the Federal Level*, 33 WM. & MARY ENVTL. L. & POL'Y REV. 605, 606 (2008).

[14] *See* ENGINEERING THE CLIMATE, *supra* note 4, at 1–2.

[15] *See* REPORT TO THE PRESIDENT, *supra* note 1, at viii.

[16] *See* LEFFLER ET AL., *supra* note 2, at 25.

[17] *See* MINERALS MGMT. SERV., U.S. DEP'T OF THE INTERIOR, DEEP WATER: WHERE THE ENERGY IS 2 (2004), *available at* http://www.boemre.gov/Assets/PressConference11152004/MSGlossySingle_110404.pdf ("With declining production from its near-shore, shallow waters, energy companies have focused their attention on oil and gas resources in water depths of 1000 feet and beyond. Their progress in developing these resources has made the Gulf of Mexico the focal point of deep water oil and gas exploration and production in the world.").

A. Overview of Deepwater Oil Exploration and Production

Initially these efforts to locate and produce oil from the oceans were limited to relatively shallow waters, measured in the tens or perhaps hundreds of feet in depth, due to technological limitations.[18] This changed when Placid Oil attempted to recover oil located more than 1500 feet below the surface of the Gulf of Mexico.[19] Although Placid Oil eventually abandoned the well associated with this first deepwater oil production attempt,[20] this effort represented an important milestone for the offshore oil industry.[21] It was the first time that a floating, rather than a fixed, platform was used in offshore oil exploration and production.[22] Thus, the industry was freed from the limitations associated with fixed platforms, and this technological innovation led to a variety of floating exploration and production platforms that opened up the deep waters of the oceans to oil production,[23] including the Gulf of Mexico, the location of the BP Deepwater Horizon oil spill.[24]

Successfully producing oil from the deepwater first requires finding promising sites where substantial oil reserves may be located.[25] Here, too, advanced technology plays an important role.[26] To locate oil so deep beneath the sea-floor three-dimensional seismic technology is used, which involves vessels with equipment that can transmit sound waves to produce a three-dimensional picture of the ocean floor.[27] This three-dimensional picture, in turn, is evaluated for geological features that are consistent with the presence of subsurface oil.[28] If there are geological features suggestive

[18] *See* REPORT TO THE PRESIDENT, *supra* note 1, at viii.
[19] LEFFLER ET AL., *supra* note 2, at 30.
[20] *Id.*
[21] *See id.*
[22] *Id.*
[23] *See id.* at 90. For a discussion of the different types of floating platforms that make deepwater oil exploration and production feasible see *id.* at 89–106.
[24] *See* REPORT TO THE PRESIDENT, *supra* note 1, at 51.
[25] LEFFLER ET AL., *supra* note 2, at 35.
[26] *See* John T. Cuddington & Diana L. Moss, *Technological Change, Depletion, and the U.S. Petroleum Industry*, 91 AM. ECON. REV. 1135, 1136 (2001).
[27] *See* LEFFLER ET AL., *supra* note 2, at 40 ("Seismic data, especially 3D data, is one of a handful of vital enablers that has made deepwater exploration so rewarding. No one ever *knows* what will turn up when the drill bit hits total depth, but seismic [data] provides a quantum leap in improving probability of success before the well is drilled. With deepwater wells running up to $100 million, that's important.").
[28] *Id.* at 46.

of oil, then a "wildcat," or preliminary, well is drilled to confirm the presence of oil.[29]

Other technological advances have occurred in the oil and gas industry, along with floating platforms and three-dimensional seismic capability, and these other innovations have also played an important role in allowing the industry to reach oil located under thousands of feet of water and then thousands of feet beneath the ocean floor.[30] The Macondo well, which was the source of the BP Deepwater Horizon oil spill, was not only in 5000 feet of water but went another 13,000 feet beneath the ocean floor and even deeper wells have been placed offshore.[31] Drilling for oil and gas in deepwater thousands of feet beneath the sea floor is technically demanding,[32] and to do so not only requires floating platforms and three-dimensional seismic capabilities but also sophisticated drilling technology.[33]

B. The Primary Risk of Deepwater Oil Exploration and Production Technology

The oil that is found in the depths at which deepwater exploration and production operations are conducted is under tremendous pressure.[34] If well pressure control is not adequately maintained a "blowout" will occur, spewing oil and gas into the ocean, as was vividly illustrated by the BP Deepwater Horizon oil spill.[35] Consequently, "[p]ressure control sits at the top of the list of worries for the drilling engineer,"[36] and during drilling operations pressure is controlled through the injection of a heavy fluid, called drilling mud, into the drill pipe.[37] This prevents the uncontrolled

---

[29] *See id.* at 46–48.
[30] *S*ee Cuddington & Moss, *supra* note 26, at 1136 ("Technological advances such as three-dimensional seismic techniques, polycrystalline diamond compact drill bits, horizontal drilling, and offshore platforms capable of operating in hostile, deep-water environments are widely acknowledged to have had significant impact on [oil exploration and development].").
[31] *See* Joel K. Bourne, Jr., *The Deep Dilemma*, NAT'L GEOGRAPHIC, Oct. 2010, at 40, 44 ("BP's Macondo well, in about 5000 feet of water and reaching another 13,000 feet beneath the sea-floor, wasn't particularly deep. The industry has drilled in 10,000 feet of water and to total depths of 35,050 feet—the latter a world record set just last year by the Deepwater Horizon in another BP field in the Gulf.").
[32] *See* LEFFLER ET AL., *supra* note 2, at 57–58 ("[D]rilling a well in 1500 ft of water is comparable to standing on top of the Sears Tower trying to stick a long straw in a bottle of Coke sitting on South Wacker Drive.").
[33] *See* Cuddington & Moss, *supra* note 26, at 1136.
[34] *See* John K. Borchardt, *Avoiding the Blowout*, MECHANICAL ENGINEERING, Aug. 2010, at 40.
[35] *See id.*; *see also* REPORT TO THE PRESIDENT, *supra* note 1, at ix.
[36] LEFFLER ET AL., *supra* note 2, at 58.
[37] *See* Borchardt, *supra* note 34, at 40.

escape of oil through the well as it is drilled;[38] once the well is completed, the drilling mud is replaced with cement and a brine solution that maintains well pressure control.[39] As a related pressure control method, the well casing is cemented at the bottom, to seal the area between rock and casing,[40] and as an additional pre-production pressure control mechanism, a cement plug is added to the well.[41] All throughout the drilling process, pressure is monitored in the event that emergency measures are required to prevent a runaway well from releasing substantial quantities of oil into the ocean.[42]

With any technology it is important to have at least one fail-safe mechanism in place, if not redundant fail-safe systems, in the event the potential risks associated with a particular technology become realized. This is especially true with deepwater oil exploration and production technology because the depths at which operations are conducted do not allow for direct human intervention.[43] Thus a highly reliable fail-safe device, if well pressure control is lost, is critical to avert a catastrophic oil spill.[44]

The fail-safe mechanism recognized by the oil and gas industry in the event that the potential primary risk associated with deepwater oil exploration and production—loss of well pressure control—became an actuality is a device referred to as a "blowout preventer,"[45] in particular the device's "shear rams."[46] Indeed, by applicable regulation at the time of the BP Deepwater Horizon oil spill, those conducting oil exploration and production activities in the Gulf of Mexico were required to have blowout preventers in place as a last resort pressure control mechanism.[47]

---

[38] *See id.*
[39] *See id.*
[40] *See id.*
[41] *See id.* at 41.
[42] *See* REPORT TO THE PRESIDENT, *supra* note 1, at 91–92.
[43] *See* Jad Mouawad & Barry Meier, *Risk-Taking Rises to New Levels as Oil Rigs in Gulf Drill Deeper*, N.Y. TIMES, Aug. 30, 2010, at A1 ("[B]ecause the wells are deeper than human divers can go, oil companies must rely on remote-controlled submarines to maintain their equipment or perform repairs.").
[44] *See generally id.*
[45] *See* Borchardt, *supra* note 34, at 41 ("Massive pieces of equipment called blowout preventers are designed to close valves and use shear rams to seal the drill pipe and well casing to block oil and gas from escaping the wellbore. They are the third and final defense against a blowout.").
[46] *See id.* ("[S]hear rams cut through and crush the pipe and then form a seal. . . . The ram blades also seal against each other forming a barrier blocking fluid flow.").
[47] *See* 30 C.F.R. §§ 250.401(a), 250.440 (2010) (requiring, respectively, operators to "[u]se the best available and safest drilling technology" feasible and mandating the use of

Since they were deemed by the oil and gas industry and regulators as the fail-safe device of choice to regain pressure control, it is important that blowout preventers possess as high a degree of reliability as humanly possible. As a fail-safe device, however, to prevent major oil spills in deep water, blowout preventers leave much to be desired.[48] Importantly, the limitations of blowout preventers as fail-safe devices were well known to regulators and the industry.[49]

First, well before the BP Deepwater Horizon oil spill occurred, several reports pointed out significant problems with consistent reliability of blowout preventers.[50] In 1999, for instance, the Minerals Management Service ("MMS") commissioned a study by the Norwegian research group SINTEF to evaluate the reliability of blowout preventers.[51] More than 100 blowout preventer failures at eighty-three deepwater wells were studied, and fifty-seven percent were labeled "safety critical failures."[52] In another study, WEST Engineering Services was retained by MMS in 2004 "to answer the question 'Can a rig's blowout preventer (BOP) equipment shear the pipe to be used in a given drilling program at the most demanding condition to be expected, and at what pressure?' "[53] This was a crucial question to answer because "[t]he well control function of last resort is to shear pipe and secure the well with the sealing shear ram. As a result, failure to shear when executing this final option would be expected to result in a major safety and/or environmental event."[54]

Second, blowout preventer technology apparently failed to keep pace with the technological advances that made deepwater oil exploration and production possible.[55] The WEST Engineering study also determined that due to stronger, larger and heavier pipe necessary to conduct deepwater

---

blowout preventers for pressure control in the event other measures failed to adequately control pressure).

[48] *See generally* W. ENG'G SERVS., SHEAR RAM CAPABILITIES STUDY (2004), *available at* http://www.boemre.gov/tarprojects/463/(463)%20West%20Engineering%20Final%20Report.pdf; EARL SHANKS ET AL., DEEPWATER BOP CONTROL SYSTEMS—A LOOK AT RELIABILITY ISSUES (2003), *available at* http://media.mcclatchydc.com/static/pdf/Les-oilspill-ABSC.pdf; PER HOLAND, SINTEF, RELIABILITY OF SUBSEA BOP SYSTEMS FOR DEEPWATER APPLICATION, PHASE II DW (1999), *available at* http://www.boemre.gov/tarprojects/319/319AA.pdf.

[49] *See* W. ENG'G SERVS., *supra* note 48; SHANKS ET AL., *supra* note 48; HOLAND, *supra* note 48.

[50] *See* SHANKS ET AL., *supra* note 48; HOLAND, *supra* note 48.

[51] *See* HOLAND, *supra* note 48, at 7.

[52] *Id.* at 85 ("All failures that occur in the BOP after the installation test are regarded as safety critical failures.").

[53] *See* W. ENG'G SERVS., *supra* note 48, at 1-1.

[54] *Id.* at 3-1.

[55] *Id.*

drilling activities, such improvements would "adversely affect[ ] the ability of a given ram BOP to successfully shear and seal the pipe in use,"[56] and further noted that "WEST is currently aware of several failures to shear when conducting shear tests using the drill pipe that was to be used in the well."[57]

These blowout preventer shortcomings were no secret from those conducting offshore drilling operations. The authors of a paper presented at the 2003 Offshore Technology Conference, an industry meeting, pointed out that "[f]loating drilling rig downtime due to poor BOP reliability is a common and very costly issue confronting all offshore drilling contractors."[58]

Third, if loss of well control was a rare occurrence then perhaps the above reports raising blowout preventer reliability concerns might be less disconcerting. But blowouts are not rare occurrences.[59] The MMS evaluated well blowouts on the Outer Continental Shelf that occurred between 1971 and 2006,[60] and based on the MMS data from this study blowouts are far from rare events.[61] During the period examined there were 126 blowouts on the Outer Continental Shelf,[62] which corresponds to one blowout for every 246 wells drilled between 1971 and 1991,[63] and one blowout for every 387 wells drilled from 1992 through 2006.[64] To put how alarming such blowout rates are in perspective, it is worth mentioning that there are more than 4000 wells in the Gulf of Mexico and that 700 of these are in waters over 5000 feet deep.[65]

Fourth, there had been a previous, well-publicized failure of a blowout preventer that resulted in a massive oil spill decades before the BP Deepwater Horizon catastrophe.[66] In 1979, PEMEX, the national oil company of Mexico, was drilling an exploratory well referred to as Ixtoc I in

---

[56] *Id.*
[57] *Id.*
[58] *See* SHANKS ET AL., *supra* note 48, at 2.
[59] *See* David Izon et al., *Minerals Mgmt. Serv., Absence of Fatalities in Blowouts Encouraging in MMS Study of OCS Incidents 1992–2006*, DRILLING CONTRACTOR, July/Aug. 2007, at 84, *available at* http://www.drillingcontractor.org/dcpi/dc-julyaug07/DC_July07_MMSBlowouts.pdf.
[60] *Id.*
[61] *See id.*
[62] *Id.*
[63] *Id.*
[64] *Id.*
[65] Mouawad & Meier, *supra* note 43.
[66] *See* Arne Jernelov & Olof Linden, *Ixtoc I: A Case Study of the World's Largest Oil Spill*, 10 AMBIO 299 (1981).

the Gulf of Mexico and lost pressure control.[67] As the loss of control reached a critical stage, the operators activated the blowout preventer's shear rams but to no avail.[68] The shear rams failed to cut through and seal off the well, and oil flowed into the Gulf of Mexico for months.[69]

The questionable reliance on blowout preventers as a fail-safe device is the essence of the cautionary lesson from the BP Deepwater Horizon oil spill for other technologies with the potential to wreak environmental havoc. This massive oil spill reminds us that those employing existing and new technologies must evaluate, understand, and put in place fail-safe measures appropriate to the level of risk presented to human health and the environment.[70] Regulators must understand technologies that have potential devastating environmental consequences if things go awry and regulate commensurate with the level of risk presented to minimize the threats to human health and the environment. Finally, policymakers must understand the risks associated with technology and legislate accordingly.

In the aftermath of the BP Deepwater Horizon oil spill, it is abundantly clear that this fundamental lesson of thoroughly understanding and mitigating the risks associated with sophisticated technology was not heeded. Certainly the basic risk—that of an oil spill—was understood by the oil industry and regulators, but despite this knowledge there was a fundamental failure to appreciate the magnitude of the risk, which led to the failure to have in place an appropriate plan to address the worst case scenario: the loss of pressure control coupled with blowout preventer failure.[71] Well-documented missteps by the operators of the Deepwater Horizon were made and the most basic efforts to mitigate catastrophic risk ignored or performed in a slipshod fashion.[72] The regulatory agency responsible for overseeing deepwater oil exploration and production, the MMS, was found wanting, as well, and was completely restructured in response.[73]

---

[67] *See id.* at 299.
[68] *See id.*; W. ENG'G SERVS., *supra* note 48, at 3–4.
[69] *See* Jernelov & Linden, *supra* note 66, at 299.
[70] *See* Latham, *supra* note 11, at 345.
[71] *See* Bourne, *supra* note 31, at 2; REPORT TO THE PRESIDENT, *supra* note 1, at 56.
[72] *See generally* REPORT TO THE PRESIDENT, *supra* note 1.
[73] *See* Reorganization of Title 30, Code of Federal Regulations, 75 Fed. Reg. 61,051, 61,052 (Oct. 4, 2010) (to be codified at 30 C.F.R. pts. 201–04, 206–08, 201, 212, 217–20, 227–29, 241, 243, 290, 1201–04, 1206–08, 1210, 1212, 1217–20, 1227–29, 1241, 1243, 1290). *See generally* Sec'y of the Interior, Order No. 3302, Change of the Name of the Minerals Management Service to the Bureau of Ocean Energy Management, Regulation, and Enforcement (June 18, 2010), *available at* http://www.doi.gov/deepwaterhorizon/loader.cfm?csModule=security/getfile&PageID=35872.

Finally, policymakers, even post–Exxon-Valdez, apparently did not understand the magnitude of risk presented by deepwater oil exploration and production; how could the $75 million cap on liability applicable to spills from offshore oil exploration and drilling activities be explained?[74]

Certainly we do not want policies that stifle technological innovation, but some technologies may present risks to human health and the environment that are substantial and therefore require an appropriate high level of stringent regulation. A delicate balance in regulating is therefore required, but one that keeps in mind risk and that the resulting regulation must be commensurate with risk.

For example, deployment of certain technologies within densely populated urban areas could present substantial risks and thus demand a high degree of regulation;[75] or, other technologies may be subject to a strict regulatory regime because of the risks posed to sensitive ecosystems, drinking water supplies, or food sources;[76] or, outright bans on some technologies may be appropriate because they are ill-suited to certain areas;[77] or, other technologies may be unacceptable because there are no feasible measures to mitigate their potential threat to human health or the environment.[78] It is highly doubtful, for these reasons and others, for instance, that the Nuclear Regulatory Commission would permit a nuclear reactor in midtown Manhattan or that policymakers would allow offshore oil drilling in Monterey Bay. In any event, the point is that when it comes to existing and new technology, it is crucial that risks be understood and appropriate measures be put in place by industry, regulators, and policymakers to address recognized worse case environmental and human health risk scenarios.

II. EMERGING TECHNOLOGIES AND POTENTIAL ENVIRONMENTAL PERIL

With respect to carbon capture and sequestration, hydraulic fracturing, and geoengineering, are we at risk of ignoring the cautionary

---

[74] *See* 33 U.S.C. § 2704(a)(3) (2006) (limiting oil spill liability for owners and operators of offshore drill rigs to $75 million plus removal costs).

[75] *See, e.g.*, 42 U.S.C. § 7401(a) (2006) (citing development in urban environments as a major impetus for regulation).

[76] *See, e.g.*, 33 U.S.C. § 1251(a) (2006) (creating national policies regarding toxins and pollutants in the nation's waters).

[77] *See, e.g.*, *id.*

[78] *See, e.g.*, Comprehensive Nuclear-Test-Ban Treaty, *opened for signature* Sept. 24, 1996, S. TREATY DOC. NO. 105-28, 35 I.L.M. 1439, *available at* http://www.ctbto.org/fileadmin/content/treaty/treaty_text.pdf.

tale so vividly illustrated by the months-long BP Deepwater Horizon oil spill? That is, have or will we take the necessary steps to comprehend, evaluate, and address the risks associated with these technologies, or are we ignoring one of the fundamental lessons from the BP Deepwater Horizon disaster?

A. *Overview of Carbon Capture and Sequestration*

Carbon capture and sequestration ("CCS") is perhaps the most frequently touted technology to address climate change by capturing and then storing the carbon dioxide currently emitted from coal-fired power plants.[79] While subsurface injection of carbon dioxide is used in the oil and gas industries to increase yields,[80] the amount injected for enhanced oil recovery ("EOR") pales in comparison to the amounts contemplated by CCS advocates, and long-term storage is also not a concern with EOR.[81] CCS has never been deployed on a worldwide scale and, if it is to serve as an effective technological mitigation response to climate change, it must be used not just in the United States but globally.[82] Thus, if widely adopted as a technological response to climate change, CCS will result in the injection of billions of tons of carbon dioxide into the earth's subsurface each year,[83]

---

[79] *See* Flatt, *supra* note 6, at 213 (noting that when it comes to addressing climate change by reducing carbon emissions while still allowing the generation of electricity from coal, "[t]he option that has received the most attention is . . . to sequester the carbon dioxide produced by coal-fired emissions and prevent it from entering the atmosphere. . . . This process, known as carbon capture and storage (CCS), can potentially remove eighty to ninety-five percent of the CO_2 emitted from power plants."); *see also* MASS. INST. TECH., THE FUTURE OF COAL: AN INTERDISCIPLINARY MIT STUDY: OPTIONS FOR A CARBON CONSTRAINED WORLD x (2007), *available at* http://web.mit.edu/coal/The_Future_of_Coal_Summary_Report.pdf (concluding "that CO_2 capture and sequestration (CCS) is the critical enabling technology that would reduce CO_2 emissions significantly while also allowing coal to meet the world's pressing energy needs."). The Department of Energy is conducting basic research with the goal of developing viable CCS technologies that can be used on a large scale basis. *See Carbon Sequestration Regional Partnerships*, DEP'T OF ENERGY, http://www.fossil.energy.gov/programs/sequestration/partnerships/index.html (last visited Oct. 13, 2011).

[80] *See* REPORT OF THE INTERAGENCY TASK FORCE ON CARBON CAPTURE AND STORAGE 38–39 (2010), *available at* http://fossil.energy.gov/programs/sequestration/ccstf/CCSTaskForceReport2010.pdf.

[81] *See id.*

[82] *See id.* at 19 ("Globally, CCS can play a major role in reducing GHG emissions, with 20–40 percent of global CO_2 emissions in 2050 projected to be suitable for capture—including 30–60 percent of all emissions from electric power.").

[83] *See id.* at 23–25 (discussing various projections of worldwide CCS deployment by the year 2050).

which makes it imperative we understand the process and the risks that it entails.

1. The CCS Process

CCS involves several steps: the separation and capture of carbon dioxide before it is emitted into the atmosphere, then transporting the captured carbon dioxide from the emission source, and then lastly injecting it deep underground.[84] A range of industrial activities emit carbon dioxide, but "its application to coal-fired power plant emissions offers the greatest potential for GHG reductions."[85] Consequently, the proponents of CCS target application of this technology toward the coal-fired electric power industry and not the other industrial sectors with substantial carbon dioxide emissions.[86]

There are several methods to separate and capture carbon dioxide from coal-fired power plants. Each method has its advantages and disadvantages in terms of cost, applicability to existing facilities, and amount of energy required.[87] Pre-combustion separation is feasible for plants that use a newer technology, the integrated gasification combined cycle process, to generate electricity from coal.[88] Post-combustion separation and capture can be used at existing coal-fired power plants,[89] and a third process that involves burning coal with pure oxygen or "oxy-combustion" is another method that can be used to separate and capture carbon dioxide from coal-fired power plants.[90]

Once the carbon dioxide is separated from the emission stream and captured, it then requires transportation from the source to its final sequestration area.[91] The most likely candidate for captured carbon dioxide

[84] *See id.* at 27.
[85] *Id.* at 7.
[86] *See* REPORT OF THE INTERAGENCY TASK FORCE ON CARBON CAPTURE AND STORAGE, *supra* note 80, at 28; *see also* Philip M. Marston & Patricia A. Moore, *From EOR to CCS: The Evolving Legal and Regulatory Framework for Carbon Capture and Storage*, 29 ENERGY L.J. 421, 432 (2008) ("[T]he current focus has shifted to the possibility of capturing carbon dioxide from coal-fired electricity generating facilities. This change of focus is due of course to the large role played by coal-fired power plants in overall CO_2 emissions. Coal is recognized as the single largest contributing fuel source to global CO_2 emissions.").
[87] *See generally* REPORT OF THE INTERAGENCY TASK FORCE ON CARBON CAPTURE AND STORAGE, *supra* note 80, at 28–31.
[88] *See id.* at 29.
[89] *See id.* at 29–30.
[90] *See id.* at 30.
[91] *See id.* at 27.

transportation is a network of pipelines similar to the networks used to transport natural gas, which would require high pressure compression of the carbon dioxide to facilitate.[92] While pipelines currently exist to transport carbon dioxide for use in EOR operations,[93] CCS will require construction of a substantial new pipeline network dedicated to this effort to mitigate the adverse consequences of climate change while allowing the continued use of coal.[94]

After the carbon dioxide is separated, captured, and transported, it requires long-term storage or sequestration to keep it from exacerbating anthropogenic climate change by escaping into the atmosphere.[95] Several subsurface formations are considered suitable for long-term sequestration.[96] First, depleted oil and gas formations offer long-term storage capabilities, since such formations already successfully contained large amounts of oil and natural gas.[97] Another potential carbon dioxide injection location is "coal seams that [are] unsuitable" for mining due to the presence of gases such as methane,[98] or other factors that make mining impractical.[99] A benefit of sequestering carbon dioxide in non-viable coal seams is that the injected carbon dioxide may aid in the recovery of natural gas from the formations.[100] The third potential location for sequestration involves disposal of carbon dioxide into non-potable saline aquifers far below ground.[101] In fact, many saline aquifers are so deep below ground that it is anticipated

---

[92] *See id.* at 36; Marston & Moore, *supra* note 86, at 435 ("For pipeline transportation, the CO_2 gas stream will be compressed to a dense phase at around 2,000 psi.").
[93] *See* REPORT OF THE INTERAGENCY TASK FORCE ON CARBON CAPTURE AND STORAGE, *supra* note 80, at 36.
[94] *See id.* ("Pipelines are expected . . . to be the most economical and efficient method of transporting CO_2 for future commercial CCS facilities.").
[95] *See id.* at F-2.
[96] *See* Marston & Moore, *supra* note 86, at 437–40.
[97] *See id.* at 437–38 ("[A]s the original oil or gas in place in the reservoir had been trapped for millions of years prior to the commencement of production, such formations are likely to be viewed as the best sites from the standpoint of retaining stored CO_2 over lengthy—even geological—time periods.").
[98] *See id.* at 439.
[99] *See* PETER FOLGER, CONG. RESEARCH SERV., RL 33801, CARBON CAPTURE AND SEQUESTRATION (CCS) 12 (2009) ("According to DOE, nearly 90% of U.S. coal resources are not mineable with current technology, because the coal beds are not thick enough, the beds are too deep, or the structural integrity of the coal bed is inadequate for mining.").
[100] *See* Marston & Moore, *supra* note 86, at 439; *see also* FOLGER, *supra* note 99, at 12 ("Carbon dioxide injected into permeable coal seams could displace methane, which could be recovered by wells and brought to the surface, providing a source of revenue to offset the costs of CO_2 injection.").
[101] *See* Marston & Moore, *supra* note 86, at 439.

that once injected, the carbon dioxide would remain in a supercritical state and thus less likely to migrate.[102]

2. CCS Risks

Storing billions of tons of carbon dioxide long-term is not without risk to human health and the environment.[103] The risks that CCS presents include those associated with a sudden release of a large volume of carbon dioxide, which is toxic to humans and animals in sufficient concentrations.[104] Specifically if such a large release occurred, it "would pose significant risks for asphyxiation to humans and animals in surrounding areas."[105]

There are at least three possible sources of a major carbon dioxide release associated with CCS. One source of a potential catastrophic release is the well through which the captured carbon dioxide is injected.[106] Abandoned wells, that were previously put in place but are no longer in use and could also allow carbon dioxide to escape from the subsurface after injection, are another potential release source.[107] A third potential source of a release, based on the oil and gas industry experience, is the pipeline that is used to transport carbon dioxide to the ultimate injection location.[108]

Some have asserted that the risk of a massive, fatal release of carbon dioxide from a CCS project is remote, since injection of the captured carbon dioxide will occur under tremendous pressure, causing the gas to form a "supercritical state" that is not likely to escape once stored

---

[102] *See id.*
[103] *See* ENVTL. PROT. AGENCY, VULNERABILITY EVALUATION FRAMEWORK FOR GEOLOGIC SEQUESTRATION OF CARBON DIOXIDE 1 (2008), *available at* http://www.epa.gov/climatechange/emissions/downloads/VEF-Technical_Document_072408.pdf.
[104] *See* John Fogarty & Michael McCally, *Health and Safety Risks of Carbon Capture and Storage*, 303 J. AM. MED. ASS'N 67, 67 (2010). The authors note that "[c]oncentrations of carbon dioxide of more than 7% to 10% pose an immediate threat to human life." *Id.*
[105] *Id.*
[106] *See* SALLY M. BENSON, LAWRENCE BERKELEY NAT'L LAB., CARBON DIOXIDE CAPTURE AND STORAGE IN UNDERGROUND GEOLOGIC FORMATIONS 9 (2004), *available at* http://www.pewclimate.org/docUploads/10-50_Benson.pdf.
[107] *See id.*
[108] *Cf.* Anahad O'Connor, *Ruptured Pipeline Spills Oil Into Yellowstone River*, N.Y. TIMES (July 2, 2011), http://www.nytimes.com/2011/07/03/us/03oilspill.html?_r=1&scp=6&sq=montana%20oil%20spill&st=cse (detailing a recent Exxon-Mobil pipeline rupture that resulted in a major release of crude oil into Montana's Yellowstone River).

deep beneath the surface of the earth.[109] Such a release, unfortunately, does seem possible nonetheless. There have been two documented releases of naturally occurring carbon dioxide from lakes in Cameroon in the late 1980s that resulted in fatalities.[110] One release occurred in 1986 from a natural underground reservoir beneath Lake Nyos, and in a matter of hours it killed more than 1700 people along with numerous livestock.[111] Thousands more people suffered burns when some of the carbon dioxide reacted with water to form carbolic acid.[112] The amount of carbon dioxide involved in the Lake Nyos release was approximately the same amount produced in a single week by one coal-fired power plant,[113] which is especially alarming given the massive amounts of carbon dioxide that would be injected into the earth if CCS is adopted on a global basis.[114] Another similar release at Lake Monoun occurred in 1988 killing 40 people.[115]

Not only have fatal releases of naturally occurring carbon dioxide occurred, but releases of carbon dioxide associated with subsurface injection have occurred as well.[116] Consequently, the potential threat to human health that an inadvertent massive release of carbon dioxide poses is not to be taken lightly, and is a risk worthy of significant contemplation by CCS proponents and policymakers.

In addition to human health risk, the U.S. Environmental Protection Agency ("EPA"), among others,[117] has recognized that CCS

---

[109] *See* Will Reisinger et al., *Reconciling King Coal and Climate Change: A Regulatory Framework for Carbon Capture and Storage*, 11 VT. J. ENVTL. L. 1, 23 (2009).
[110] *See* Donna M. Attanasio, *Surveying the Risks of Carbon Dioxide: Geological Sequestration and Storage Projects in the United States*, 39 ENVTL. L. REP. NEWS & ANALYSIS 10,376, 10,386 (2009).
[111] *Id.*
[112] *Id.*
[113] Fogarty & McCally, *supra* note 104, at 67.
[114] *See generally* REPORT OF THE INTERAGENCY TASK FORCE ON CARBON CAPTURE AND STORAGE, *supra* note 80, at 23–25 (discussing various projections of worldwide CCS deployment by the year 2050).
[115] *See* Attanasio, *supra* note 110, at 10,386.
[116] *See* Federal Requirements Under the Underground Injection Control (UIC) Program for Carbon Dioxide (CO_2) Geologic Sequestration (GS) Wells Proposed Rule, 73 Fed. Reg. 43,492, 43,498 (July 25, 2008). Here, it is noted that "[a]n example of a significant CO_2 leak occurred at Crystal Geyser, Utah. CO_2 and water erupted from an abandoned oil exploration well due to improper well plugging. This well continues to erupt periodically and discharges 12,000 kilotons of CO_2 annually." *Id.* This leak does not, however, present a risk to human health. *Id.*
[117] *See, e.g.*, Allan Ingelson et al., *Long-Term Liability for Carbon Capture and Storage in Depleted North American Oil and Gas Reservoirs—A Comparative Analysis*, 31 ENERGY L.J. 431, 435–38 (2010).

also presents environmental risks.[118] These risks include contamination of potable groundwater supplies caused by leaching of arsenic, lead or other background contaminates,[119] or by the presence of other chemical contaminates in the carbon dioxide injectate,[120] or by the intrusion of salt water into groundwater from underground reservoirs.[121] While perhaps the possibility of a large scale release of carbon dioxide resulting in mass casualties may be remote from a CCS site, "[a] more plausible risk associated with CCS is groundwater contamination at nonperforming sites."[122] The intended environmental benefit of CCS—keeping carbon dioxide out of the atmosphere—could also be defeated by releases into the air from CCS sites.[123] One more environmental-related risk arising from the injection of massive quantities of carbon dioxide in the subsurface includes induced seismic activity, although proper site selection may minimize this risk.[124]

3. CCS Federal Regulation Summary

At the federal level, CCS is subject to regulation under the Safe Drinking Water Act,[125] which specifically authorizes the EPA to regulate "underground injection which endangers drinking water sources."[126]

---

[118] *See id.*

[119] *See* Fogarty & McCally, *supra* note 104, at 68 ("Injecting carbon dioxide into or near underground aquifers leads to the formation of carbonic acid. Such acidification can dramatically alter water quality by increasing the leaching of contaminates such as arsenic, lead, mercury, and organic compounds.").

[120] *See* Federal Requirements Under the Underground Injection Control (UIC) Program for Carbon Dioxide (CO_2) Geologic Sequestration (GS) Wells, 73 Fed. Reg. at 43,497.

[121] *See id.*

[122] Reisinger et al., *supra* note 109, at 24.

[123] *See* Sumit Som, Note, *Creating a Safe and Effective Carbon Sequestration*, 17 N.Y.U. ENVTL. L. J. 961, 970 (2008) ("The atmospheric risk of CCS is that the CO_2 will eventually leak out to the atmosphere and over time exacerbate global warming."). *Id.*

[124] *See* Reisinger et al., *supra* note 109, at 24.

[125] 42 U.S.C. §§ 300f–300j-26 (2006). The Safe Drinking Water Act in essence protects the public health and the nation's potable water supplies by imposing maximum contaminate levels for a range of chemical substances. *Id.*

[126] *Id.* at § 300h(b)(1) (2006). Endangerment occurs when:

> Underground injection endangers drinking water sources if such injection may result in the presence in underground water which supplies or can reasonably be expected to supply any public water system of any contaminant, and if the presence of such contaminant may result in

Underground injection wells used for CCS are designated as "Class VI" injection wells,[127] and the owners or operators of Class VI injection wells have eight fundamental regulatory obligations.

In sum, first, they must prepare an assessment of the geologic, hydrogeologic, geochemical, and geomechanical properties of proposed CCS sites to confirm that they are suitable for use.[128] Second, modeling is required of the areas that potentially could be impacted by CCS to confirm that carbon dioxide will not migrate and contaminate underground drinking water sources.[129] An integral part of the modeling obligation is to also develop a corrective action plan in the event the well develops problems.[130] Third, the regulations impose certain injection well construction requirements.[131] Fourth, the EPA imposed specific CCS injection well operating parameters "including injection pressure limitations, use of down-hole shut-off systems, and annulus pressure requirements to ensure that injection of CO_2 does not endanger [underground sources of drinking water.]"[132] Fifth, the owners and operators of CCS injection wells have a testing obligation to determine the physical and chemical characteristics of the carbon dioxide injectate and to perform internal and external mechanical integrity testing of the injection wells.[133] Sixth, monitoring is a key aspect of the CCS regulatory structure and accordingly groundwater monitoring is required,[134] along with monitoring of the carbon dioxide plume.[135] Seventh, the results of testing and monitoring must be kept

---

> such system's not complying with any national primary drinking water regulation or may otherwise adversely affect the health of persons.

Id. at § 300h(d)(2) (2006).

[127] Pursuant to its authority under the Safe Drinking Water Act, the EPA enacted regulations designating several classes of underground injection wells, Class I through V, and to regulate CCS the EPA added another class of injection wells designated as Class VI. *See* Federal Requirements Under the Underground Injection Control (UIC) Program for Carbon Dioxide (CO_2) Geologic Sequestration (GS) Wells, 75 Fed. Reg. 77,230, 77,233 (Dec. 10, 2010) (to be codified at 40 C.F.R. pts. 124, 144–47) ("Today's rule defines a new class of injection well (Class VI), along with technical criteria that tailor the existing UIC regulatory framework to address the unique nature of [CCS].").

[128] 75 Fed. Reg. at 77,247.

[129] *Id.* at 77,248.

[130] *Id.* at 77,250.

[131] *Id.*

[132] *Id.* at 77,257.

[133] *Id.* at 77,259.

[134] 75 Fed. Reg. at 77,259.

[135] *Id.* at 77,262. At the discretion of the EPA the owner or operator may also be required to monitor the air and soil in the vicinity of the CCS site. *Id.* at 77,263.

and periodically submitted electronically to regulators.[136] Finally, the CCS regulations impose postinjection well-site closure and financial assurance obligations on site owners or operators.[137]

Pursuant to section 114,[138] the Clean Air Act also imposes certain record-keeping, reporting, and monitoring obligations on CCS facilities.[139] In brief, the owners or operators of CCS facilities must report the amount of carbon dioxide received and injected, the amount of any releases and the total amount sequestered.[140] Records relevant to such reporting obligations must also be kept.[141] Finally, the EPA requires development of a monitoring, reporting, and verification plan that is subject to agency approval for each CCS facility.[142] The basic purposes of the plan are to identify pathways that could result in surface leaks and to detect and quantify any leaks that may occur of sequestered carbon dioxide.[143]

In addition to regulating sequestration sites, the federal government will also regulate the network of pipelines that ultimately will deliver the captured carbon dioxide to the sequestration sites. The Department of Transportation, through its Pipeline and Hazardous Materials Safety Administration, in particular the Office of Pipeline Safety, would implement this aspect of CCS regulation.[144] The statutory authority to regulate the pipeline component of CCS projects is derived from the authority granted by Congress under the Hazardous Liquid Pipeline Act of 1979,[145] and its implementing regulations,[146] which together impose a host of pipeline safety, design, construction, and maintenance obligations on owners and operators of interstate pipelines.[147]

---

[136] *Id.* at 77,264.
[137] *Id.* at 77,266–68.
[138] Under section 114, specifically 42 U.S.C. § 7414(a)(1) (2006), the EPA has broad authorization to require monitoring and to request information in order to "carry out any provision" of the Clean Air Act.
[139] *See id.*
[140] *See* Mandatory Reporting of Greenhouse Gases: Injection and Geologic Sequestration of Carbon Dioxide; 75 Fed. Reg. 75,060, 75,064–65 (Dec. 1, 2010) (to be codified at 40 C.F.R. pts. 72, 78, 98).
[141] *See* 75 Fed. Reg. at 75,067.
[142] *See id.* at 75,065.
[143] *See id.*
[144] *See* Marston & Moore, *supra* note 86, at 449–52.
[145] *See* 49 U.S.C. § 60101 et seq. (2006), *see also PHMSA—State Programs*, U.S. DEP'T OF TRANSP. PIPELINE AND HAZARDOUS MATERIALS SAFETY ADMIN., http://www.phmsa.dot.gov/pipeline/state-programs (last visited Oct. 13, 2011).
[146] *See* 49 C.F.R. pts. 190, 195–99 (2010).
[147] *See* 49 C.F.R. pts. 192, 195.

4. Sufficiency of CCS Regulations to Protect Human Health and the Environment

Whether the federal CCS regulatory approach is sufficient to prevent a BP Deepwater Horizon magnitude catastrophic event remains to be seen. While injection of carbon dioxide is fairly commonplace to enhance oil recovery, the scale at which CCS will be conducted as a climate change mitigation approach will dwarf the use of carbon dioxide in EOR operations.[148] According to the Department of Energy and the International Energy Agency, there is the potential capacity to sequester 3,000,000 megatons of carbon dioxide in the United States.[149] Furthermore, to effectively address rising GHG levels that are contributing to climate change will require deployment of CCS on a global basis. The precise amount of carbon dioxide that would be subject to sequestration around the world is difficult to quantify,[150] but as more widespread CCS is employed throughout the world, it is far from unreasonable to expect an increase in the potential for operational errors that could result in fatal or environmentally damaging releases of carbon dioxide.

The primary federal regulatory program enacted by the EPA to minimize the risk of catastrophic releases, the underground injection control program,[151] is also less than comforting. Its regulatory focus is primarily preventing potable groundwater contamination, an important and laudable regulatory goal, but when it comes to regulating releases of carbon dioxide to the air, the EPA expressly notes that "regulating such surface/atmospheric releases of CO_2 are outside the scope of this proposal and [Safe Drinking Water Act] authority."[152]

One may logically ask about the Clean Air Act's regulatory authority to require owners and operators of CCS projects to respond to releases. All the EPA has implemented under this statute, however, is a record-keeping, reporting, and monitoring obligation; the regulations governing CCS under

---

[148] *See* Federal Requirements Under the Underground Injection Control (UIC) Program for Carbon Dioxide (CO_2) Geologic Sequestration (GS) Wells, 73 Fed. Reg. 43,496 (proposed July 25, 2008) (to be codified at 40 C.F.R. pts. 144, 146).

[149] *See id.* ("Theoretically, this capacity could be large enough to store a thousand years of CO_2 emissions from nearly 1,000 coal-fired power plants.").

[150] *See id.* (noting that "predictions about large-scale availability and the rate of CCS project deployment are subject to considerable uncertainty.").

[151] *See Underground Injection Control Program*, U.S. ENVTL. PROT. AGENCY, http://water.epa.gov/type/groundwater/uic/index.cfm (last visited Oct. 13, 2011).

[152] Federal Requirements Under the Underground Injection Control (UIC) Program for Carbon Dioxide (CO_2) Geologic Sequestration (GS) Wells, 73 Fed. Reg. at 43,497.

the Clean Air Act do not include an express corrective action requirement in the event of a release.[153]

In terms of responding in the event that groundwater contamination does occur, it appears that CCS presents a similar conundrum that drilling for oil and gas in thousands of feet of ocean does. That is, if corrective action is necessary to address groundwater contamination, how will remedial measures be conducted so deep beneath the earth's surface? What technologies exist to remediate a major aquifer that becomes contaminated as the result of a CCS project? None of the Federal Register announcements discussing the regulation of CCS as Class VI injection wells provides answers or discusses readily available remediation technologies,[154] but reminiscent of the MMS regulations in place at the time of the BP Deepwater Horizon disaster, EPA requires CCS owners or operators to develop a site-specific, risk-based emergency and remedial response plan in the event a drinking water supply is threatened or contaminated.[155]

While demonstration projects examining the deployment of CCS are underway, "because these early projects will be carried out in a variety of jurisdictions, under a variety of (perhaps insufficient) funding mechanisms, there is substantial risk that, despite the best intentions, these early projects could be completed without providing the scientific and technical underpinnings needed for wide-scale deployment."[156] Put simply, despite current CCS research and development activities, "[p]ractical experiences with injecting CO_2 for the purpose of long-term storage and empirical evidence of its stability over the long term are still scant."[157] Much like the use of fossil fuels and their impact on the environment, the fact is that global deployment of CCS will be, to some degree, an experiment where we wait for the results of injecting massive amounts of carbon dioxide deep within the earth's subsurface. No doubt as we have learned from our experiment for over 100 years with fossil fuel combustion emissions and their impacts on human health and the environment, currently unknowable, unintended consequences are certainly possible with CCS.

---

[153] *See* Mandatory Reporting of Greenhouse Gases: Injection and Geologic Sequestration of Carbon Dioxide, 75 Fed. Reg. 75,060, 75,078–86 (Dec. 1, 2010) (to be codified at 40 C.F.R. §§ 98.440–98.449).

[154] *See, e.g.*, Federal Requirements Under the Underground Injection Control (UIC) Program for Carbon Dioxide (CO_2) Geological Sequestration (GS) Wells, 75 Fed. Reg. 77,230, 77,233 (Dec. 10, 2010) (to be codified at 40 C.F.R. pts. 124, 144–147).

[155] *See id.* at 77,272–73.

[156] INT'L RISK GOVERNANCE COUNCIL, POLICY BRIEF, REGULATION OF CARBON CAPTURE AND STORAGE 19 (2008), *available at* http://www.irgc.org/IMG/pdf/Policy_Brief_CCS.pdf.

[157] Attanasio, *supra* note 110, at 10,378.

B. *Hydraulic Fracturing*

Natural gas comprises approximately twenty-five percent of domestic energy needs in the United States,[158] and is thus a vital fuel. Proponents of expanding natural gas use point to the fact that its combustion results in less carbon dioxide emissions than other fossil fuels.[159] It was expected, however, that domestic natural gas supplies would not keep pace with growing demand.[160]

1. Overview of Hydraulic Fracturing

That outlook of insufficient domestic supplies changed dramatically with the so-called "unconventional natural gas revolution,"[161] which has been brought about by the recent discovery of massive natural gas reserves thousands of feet below the earth's surface,[162] coupled with advances in drilling technology and the use of a process called hydraulic fracturing to coax natural gas from formations that previously were unproductive.[163] This is especially true with respect to a shale formation thousands of feet beneath the surface of the southeast and eastern United States referred to as the Marcellus Shale formation.[164] Shale gas activity involving hydraulic fracturing has been particularly widespread in Pennsylvania.[165] However, shale gas formations are present in other parts of the country, too, and indeed throughout the world, and hydraulic fracturing has followed as a process.[166]

---

158 *See* IHS CAMBRIDGE ENERGY RESEARCH ASSOCS., FUELING NORTH AMERICA'S ENERGY FUTURE: THE UNCONVENTIONAL NATURAL GAS REVOLUTION AND THE CARBON AGENDA: EXECUTIVE SUMMARY 2 (2010), *available at* http://www2.cera.com/docs/Executive_Summary.pdf.
159 *See, e.g.*, *id.* at 5.
160 *See id.* at 3.
161 *Id.* at 1.
162 *See* John Manuel, *EPA Tackles Fracking*, 118 ENVTL. HEALTH PERSP. at A199 (2010).
163 IHS CAMBRIDGE ENERGY RESEARCH ASSOCS., *supra* note 158, at 4 ("The combination of hydraulic fracturing (fraccing) and horizontal drilling has opened up vast new resources of natural gas from shale formations and tight sandstones. These innovations have unlocked the potential of natural gas shales that have greatly increased the potential supply of natural gas in North America and at a much lower cost than conventional natural gas.").
164 *See* Urbina, *supra* note 3 (noting that the Marcellus Shale formation is "roughly the size of Greece, lies more than a mile beneath the Appalachian landscape, from Virginia to the southern half of New York. It is believed to hold enough gas to supply the country's energy needs . . . for more than 15 years.").
165 *See id.*
166 *See* Carl T. Montgomery & Michael B. Smith, *Hydraulic Fracturing: History of An Enduring Technology*, J. PETROLEUM TECH. 26, 27 (Dec. 2010), *available at* http://www

Hydraulic fracturing, also referred to as hydrofracking or fracking, initially requires drilling a well.[167] As summarized by the EPA, once the well is drilled:

> Hydraulic fracturing involves the pressurized injection of fluids commonly made up of water and chemical additives into a geologic formation. The pressure exceeds the rock strength and the fluid opens or enlarges fractures in the rock. As the formation is fractured, a "propping agent," such as sand or ceramic beads, is pumped into the fractures to keep them from closing as the pumping pressure is released. The fracturing fluids (water and chemical additives) are then returned back to the surface. Natural gas will flow from pores and fractures in the rock into the well for subsequent extraction.[168]

While not a new technology, the use of hydraulic fracturing has dramatically increased and is anticipated to further grow in importance as a source of natural gas in the United States in the foreseeable future.[169]

.spe.org/jpt/print/archives/2010/12/10Hydraulic.pdf (noting that since 1949 "close to 2.5 million fracture treatments have been performed worldwide.").

[167] *See* IHS CAMBRIDGE ENERGY RESEARCH ASSOCS., *supra* note 158, at 5.

[168] OFFICE OF RESEARCH & DEV., ENVTL. PROT. AGENCY, HYDRAULIC FRACTURING RESEARCH STUDY 1 (2010), *available at* http://www.epa.gov/safewater/uic/pdfs/hfresearchstudyfs.pdf; *see also* U.S. Patent No. 7,325,608 B2 col.1 l.21 (filed Aug. 31, 2006):

> Hydrocarbon-producing wells are often stimulated by hydraulic fracturing operations. In hydraulic fracturing operations, a viscous fracturing fluid, which also functions as a carrier fluid, is pumped into a producing zone at a rate and pressure such that the subterranean formation breaks down and at least one fracture is formed in the zone. Typically, particulate solids, such as sand, suspended in a portion of the fracturing fluid are then deposited in the fractures. These particulate solids, commonly referred to as "proppant particulates," serve to prevent the fractures from fully closing so that conductive channels are formed through which produced hydrocarbons can flow.
>
> The proppant particulates used to prevent fractures from fully closing generally are particulate solids, such as sand, bauxite, ceramics, or nut hulls, which are deposited into fractures using traditional high proppant loading techniques.

For a short video depiction of the hydraulic fracturing process, see *Extracting Natural Gas From Rock*, N.Y. TIMES (Feb. 26, 2011), http://www.nytimes.com/interactive/2011/02/27/us/fracking.html?hp.

[169] *See* OFFICE OF RESEARCH & DEV., ENVTL. PROT. AGENCY, DRAFT PLAN TO STUDY THE POTENTIAL IMPACTS OF HYDRAULIC FRACTURING ON DRINKING WATER RESOURCES 8 (2011),

2. Risks of Hydraulic Fracturing

Hydraulic fracturing presents several potential risks to human health and the environment.[170] Because of the amounts of water required by the hydraulic fracturing process, one environmental concern arises from the adverse impact that withdrawing substantial quantities of water can have on surface water and groundwater.[171] Water in the range of two to four million gallons per well is required to successfully develop shale gas through hydraulic fracturing.[172] In the United States, an estimated 35,000 wells are developed through hydraulic fracturing annually.[173] Thus, each year hydraulic fracturing may consume 70 billion to 140 billion gallons of water, which must come from either surface water or groundwater sources.[174] Once injected, much of this water may not be recovered for reuse.[175] The EPA recognized that, depending on the region, time of year, and weather events, the withdrawal of so much water could adversely impact both the availability and quality of surface water and groundwater.[176]

Perhaps the most publicized risk to human health and the environment is that associated with the possible contamination of potable water sources.[177] This potential risk arises from several activities associated with hydraulic fracturing.[178] First, there is a concern that the injection of massive amounts of water mixed with chemicals could result in migration that would adversely affect potable drinking water sources.[179] Whether this is

---

available at http://water.epa.gov/type/groundwater/uic/class2/hydraulicfracturing/upload/HFStudyPlanDraft_SAB_020711-08.pdf [hereinafter DRAFT STUDY PLAN] (stating that in 2009 shale gas supplied fourteen percent of domestic natural gas and is expected to rise to forty-five percent of domestic supplies by 2035).

170 *See* Urbina, *supra* note 3.

171 *See* DRAFT STUDY PLAN, *supra* note 169, at 20.

172 *Id.* at 19.

173 *Id.*

174 *Id.*

175 *Id.* at 20.

176 *See id.* ("The removal of large volumes of water could stress drinking water supplies, especially in drier regions where aquifer or surface water recharge is limited. This could lead to lowering of water tables or dewatering of drinking water aquifers, decreased stream flows, and reduced volumes of water in surface water reservoirs.").

177 *See, e.g.*, Urbina, *supra* note 3.

178 *See* David Biello, *What the Frack? Natural Gas From Subterranean Shale Promises U.S. Energy Independence—With Environmental Costs*, SCI. AM. (Mar. 30, 2010), http://www.scientificamerican.com/article.cfm?id=shale-gas-and-hydraulic-fracturing.

179 *See id.*

a legitimate concern is subject to dispute because shale gas is typically separated by thousands of feet of rock from potable water aquifers.[180] However, there have been reported instances of groundwater contamination associated with hydraulic fracturing. In Dimock, Pennsylvania, for example, improperly installed wells resulted in the contamination of drinking water wells, causing one to explode.[181]

The assertions that hydraulic fracturing has contaminated drinking water sources in Pennsylvania are also supported by state regulatory action.[182] By letter dated October 19, 2010, the Pennsylvania Department of Environmental Protection advised a number of Susquehanna residents that there was "overwhelming evidence" that Cabot Oil & Gas had contaminated several drinking water wells while conducting hydraulic fracturing operations in the Marcellus Shale formation.[183]

There are also a number of pending suits that allege that hydraulic fracturing caused contamination of drinking water.[184] In *Baker v. Anschutz Exploration Corp.*, for example, it is alleged that, as a result of the defendants' hydraulic fracturing operations conducted in upstate New York, the "Plaintiffs can no longer drink their water because their potable water supplies have been contaminated with combustible gases, toxic sediments and hazardous chemicals."[185] The plaintiffs seek $150 million in damages under a variety of legal theories, including negligence, negligence per se, private nuisance, premises liability, strict liability, and deceptive business practices.[186]

Evidence suggests potable groundwater supplies, in addition to suffering potential contamination with fracturing fluids, may also be contaminated by natural gas—methane—that migrates unimpeded into drinking

---

[180] *See* Manuel, *supra* note 162, at 199 ("[B]ecause groundwater supplies and natural gas deposits are often separated by thousands of feet of rock and earth . . . it is difficult to establish a definitive connection between contaminated drinking water and fracking.").
[181] *See* Biello, *supra* note 178.
[182] *See* Mark D. Christiansen, *Legal Developments in 2010 Affecting the Oil and Gas Exploration and Production Industry*, 48 ROCKY MTN. MIN. L. FOUND. J. 177, 212–13 (2011).
[183] *Id.* at 212.
[184] *See* Eric Waeckerlin, *The Plaintiffs' Bar Zeros in on Fracking*, FRACKING INSIDER (Feb. 2, 2011) http://www.frackinginsider.com/litigation/the-plaintiffs-bar-zeros-in-on-fracking/.
[185] Complaint at ¶ 96, Baker v. Anschutz Exploration Corp., No. 2011-1168 (N.Y. Sup. Ct. Feb. 10, 2011).
[186] *See id.* at ¶¶ 104–196. The case was filed in state court but removed by the defendants to federal district court. *See* Jon Cooperman, *Well-Known Plaintiff's Firm Files Lawsuit Against Gas Exploration Company in Upstate New York*, FRACKING INSIDER (Mar. 14, 2011) http://www.frackinginsider.com/litigation/hydraulic-fracturing-fracking-during-natural/.

water sources once recovery wells are put in place and the shale is fractured. Researchers from Duke University analyzed methane levels in drinking water wells located in areas subject to hydraulic fracturing in Pennsylvania and New York, and compared the results with samples from wells not located near hydraulic fracturing sites.[187] The results showed methane present in eighty-five percent of all wells tested, but average levels of methane from the wells located near hydraulic fracturing areas were higher than recommended action levels.[188] The researchers surmised that the methane contamination resulted from either natural gas displaced during the hydraulic fracturing process, leaky wells, or new migration routes created as a result of the hydraulic fracturing process.[189]

Spills of hydraulic fracturing fluid are another potential source of drinking water contamination, since the large quantities of water and chemicals are stored on-site in tanks.[190] Documented spills have taken place in Pennsylvania, and regulators have detected the presence of fracturing fluid in a drinking water source, the Monongahela River.[191]

Yet another threat to drinking water is the disposal of spent fracturing fluids or "flowback," either by underground injection or through discharge following treatment by publicly owned treatment works ("POTWs").[192] Disposal of spent hydraulic fracturing fluids through discharge to POTWs predominates in Pennsylvania and is especially troubling.[193] The spent hydraulic fracturing fluid frequently became contaminated with a variety of chemical substances, including naturally occurring radium, and this radioactive substance is not susceptible to the conventional secondary biological treatment that POTWs typically use to treat wastewater prior to discharge in order to meet effluent limitations and water quality standards.[194] One reason why this is especially disconcerting

---

[187] *See* Stephen G. Osborn et al., *Methane Contamination of Drinking Water Accompanying Gas-Well Drilling and Hydraulic Fracturing*, 108 PROC. NAT'L ACAD. SCI. 8172, 8172–73 (2011), *available at* http://www.pnas.org/content/108/20/8172.full.pdf.
[188] *Id.* at 8173.
[189] *Id.* at 8175.
[190] *See* Hannah Wiseman, *Regulatory Adaptation in Fractured Appalachia*, 21 VILL. ENVTL. L.J. 229, 258 (2010).
[191] *See* Biello, *supra* note 178.
[192] *See* DRAFT STUDY PLAN, *supra* note 169, at 40.
[193] *See* Joseph P. Koncelik, *Ohio and Pennsylvania Debate Regulation of Hydraulic Fracturing Wastewater*, OHIO ENVTL. L. BLOG (June 9, 2011), http://www.ohioenvironmentallawblog.com/2011/06/articles/water/ohio-and-pennsylvania-debate-regulation-of-hydraulic-fracking-wastewater/.
[194] *See* Urbina, *supra* note 3 (discussing how a number of POTWs in Pennsylvania were receiving spent hydraulic fracturing fluids that contained levels of radioactivity up to 2122

from an environmental and human health perspective is that the POTWs discharge into major rivers, including the Monongahela River, a source of drinking water for hundreds of thousands, including the City of Pittsburgh,[195] as well as into the Susquehanna River, which eventually discharges into the Chesapeake Bay and is a source of drinking water for greater than six million people.[196] Importantly, because it is radioactive, "[o]nce radium enters a person's body, by eating, drinking or breathing, it can cause cancer and other health problems, many federal studies show."[197]

However, the precise impact that hydraulic fracturing may have on drinking water supplies is difficult to ascertain for at least three reasons. First, a wide range of commercial and industrial facilities can adversely impact surface water and groundwater.[198] Thus linking the exact cause of contamination at a site to a specific source can be difficult.[199] Second, this contamination source determination is also difficult because the gas industry treats the composition of the fluids used in hydraulic fracturing as proprietary, confidential business information, so even knowing what specific contaminates to sample for is a challenge.[200] Third, there is simply a dearth of solid research on the potential for hydraulic fracturing to contaminate drinking water supplies.[201] Consequently, the EPA is undertaking, at the direction of Congress, comprehensive research into hydraulic fracturing and drinking water supplies.[202]

---

times greater than the drinking water standard. According to the article, data on the impact of radium levels in the spent hydraulic fracturing fluid sent to POTWs in Pennsylvania is essentially nonexistent because there is no requirement to sample for such pollutants in the treatment plants' effluent.).

[195] *Id.*

[196] *Id.*

[197] *Id.*

[198] *See* TEX. GROUNDWATER PROT. COMM., JOINT GROUNDWATER MONITORING AND CONTAMINATION REPORT—2004 6–7 (2005), *available at* http://www.tceq.state.tx.us/assets/public/comm_exec/pubs/sfr/056_04/056_04.pdf.

[199] *See* David H. Getches, *Groundwater Quality Protection: Setting a National Goal for State and Federal Programs*, 65 CHI.-KENT L. REV. 387, 410 (1989).

[200] *See* DRAFT STUDY PLAN, *supra* note 169, at 25 ("This makes identifying the toxicity and human health effects associated with these chemicals difficult.").

[201] *See* Manuel, *supra* note 162, at 199.

[202] *See* DRAFT STUDY PLAN, *supra* note 169, at vii (recognizing that "[a]s natural gas production has increased, so have concerns about the potential environmental and human health impacts of hydraulic fracturing in the United States. . . . In response to public concern, Congress directed the United States Environmental Protection Agency [EPA] to conduct research to examine the relationship between hydraulic fracturing and drinking water resources."). The agency expects to issue the results of the study in 2014. *See* *Hydraulic Fracturing*, EPA, http://water.epa.gov/type/groundwater/uic/class2/hydraulicfracturing/index.cfm (last visited Oct. 13, 2011).

Soil and surface water can also suffer contamination as a result of hydraulic fracturing. In several incidents eerily reminiscent of the BP Deepwater Horizon oil spill, well blowouts have occurred at hydraulic fracturing sites resulting in contamination. For example, in 2010, EOG Resources suffered a well blowout in the Marcellus Shale formation beneath Pennsylvania, causing a seventy-five foot spout of fracking fluid and natural gas.[203] In April 2011, Chesapeake Energy Corp. lost control of a well at a hydraulic fracturing site when the well's blowout preventer failed.[204] The blowout spewed hydraulic fracturing fluid onto a nearby property and into a creek for more than twelve hours and resulted in the evacuation of several families.[205] This incident resulted in interstate implications, namely, the issuance of a sixty-day notice of intent to sue under the Clean Water Act and the Resource Conservation and Recovery Act by the Maryland attorney general because the creek contaminated in Pennsylvania by the blowout discharges into the Susquehanna River, which eventually discharges into the Chesapeake Bay.[206]

Another environmental risk arising from hydraulic fracturing is air pollution. As an illustration of the significant levels of air emissions associated with hydraulic fracturing, consider Dish, Texas, the location of several hydraulic fracturing operations:

> A set of seven samples collected throughout the town analyzed for a variety of air pollutants . . . found that benzene was present at levels as much as 55 times higher than allowed by the Texas Commission on Environmental Quality (TCEQ). Similarly, xylene and carbon disulfide (neurotoxicants), along with naphthalene (a blood poison) and pyridines (potential carcinogens) all exceeded legal limits, as much as 384 times levels deemed safe.[207]

---

[203] *See* David Wethe & Asjylyn Loder, *Shale Gas Well Blowout Raises Specter of New, Onshore BP*, BLOOMBERG NEWS (June 7, 2010, 12:46 PM), http://www.bloomberg.com/news/2010-06-07/natural-gas-shale-well-blowout-raises-specter-of-next-bp-energy-markets.html.

[204] Laura Legere, *After Blowout, Most Evacuated Families Return to Their Homes in Bradford County*, THE SCRANTON TIMES-TRIB. (Apr. 11, 2011), *available at* http://thetimes-tribune.com/news/gas-drilling/after-blowout-most-evacuated-families-return-to-their-homes-in-bradford-county-1.1135253#axzz1WpRTnwcR.

[205] *Id.*

[206] Press Release, Maryland Attorney General, Attorney General Gansler Notifies Chesapeake Energy of the State's Intent to Sue for Endangering the Health of Citizens and the Environment (May 2, 2011), *available at* http://www.oag.state.md.us/Press/2011/050211.html.

[207] Biello, *supra* note 178.

The emissions sources are numerous at a hydraulic fracturing site and include off-gassing of methane, compressors, generators, drill rigs, pumps, and trucks.[208] As part of its plan to study the environmental impacts of hydraulic fracturing, however, air quality effects will not be evaluated during the study.[209]

3. Sufficiency of Current Federal Approach to Hydraulic Fracturing

Put simply, the current federal regulatory approach is insufficient to protect human health and the environment from the risks associated with hydraulic fracturing. Indeed, while CCS is regulated under the Safe Drinking Water Act, hydraulic fracturing is expressly exempt from the reach of that statute.[210]

Federal policymakers have completely ignored one of the fundamental regulatory considerations in deciding to exempt hydraulic fracturing from the underground injection control regulations of the Safe Drinking Water Act and that is to first do no harm.[211] That is, policymakers failed to consider the precautionary principle in determining whether to exempt hydraulic fracturing from Safe Drinking Water Act regulation.[212]

An illustration of the precautionary principle in environmental regulation is the Clean Air Act, where Congress directed the EPA to develop primary and secondary national ambient air quality standards if the administrator determined that emissions of an air pollutant "cause or contribute to air pollution which may reasonably be anticipated to endanger public health or welfare."[213] Thus, under the Clean Air Act, scientific certainty of harm is not a prerequisite to regulation;[214] rather, the precautionary principle applies.[215] The regulatory philosophy expressed by policymakers in the Clean Air Act is that if there is a reasonable

---

[208] *See* DRAFT STUDY PLAN, *supra* note 169, at 55.
[209] *See id.* at viii ("EPA recognizes that there are important potential research areas related to hydraulic fracturing other than those involving drinking water resources, including effects on air quality. . . . These topics are outside the scope of the current study, but should be examined in the future.").
[210] *See* 42 U.S.C. § 300h(d)(1)(B)(ii) (2006).
[211] *See* David Sirota, *America's Energy Ethos: Do, Regardless of Harm*, CREATORS.COM (June 10, 2011), http://www.creators.com/opinion/david-sirota/america-s-energy-ethos-do-regardless-of-harm.html.
[212] For a more detailed discussion of the precautionary principle see *infra* Part III.
[213] 42 U.S.C. § 7408(a)(1)(A) (2006).
[214] *See id.*
[215] For a more detailed discussion of the precautionary principle see *infra* Part III.

expectation of potential harm, the EPA may regulate and is not required to wait for harm to materialize.[216]

With respect to hydraulic fracturing, policymakers have turned the precautionary principle on its head, and are only now planning to undertake a study of the environmental consequences of hydraulic fracturing.[217] As an approach to regulation, this after-the-fact study is questionable because it is taking place years after expressly exempting hydraulic fracturing from the key federal statute that could have regulated the practice of injecting millions of gallons of water laced with chemicals under high pressure into the subsurface—and did so without fully understanding the impact on drinking water sources. The study is not only after-the-fact, but it is also limited in scope; it is not a comprehensive evaluation of the environmental impacts of hydraulic fracturing and will only consider potential impacts to drinking water, leaving consideration of wastewater discharge, air pollution, soil contamination, ecosystem impacts, and seismic risk for another, yet to be determined day.[218] Such an after-the-fact, piecemeal approach to regulation is inefficient, ineffective, and will not likely result in a regulatory regime governing hydraulic fracturing that sufficiently protects human health and the environment.[219] It is precisely such a lackadaisical approach to regulation that resulted in the BP Deepwater Horizon catastrophe.[220]

C. Geoengineering

The term geoengineering generally refers to a variety of techniques that are under contemplation to cool the earth's temperature as a way to mitigate the global warming arising from the emissions of GHGs into the

---

[216] *See* H.R. REP. NO. 95-294, at 3, 49 (1977) (Conf. Rep.), *reprinted in* 1977 U.S.C.C.A.N. 1077, 1081, 1127.
[217] *See* DRAFT STUDY PLAN, *supra* note 169, at vii.
[218] *See id.*, *supra* note 169, at vii, 54–56.
[219] *See* Osborn et al., *supra* note 187, at 8175–76 (remarking that "[c]ompared to other forms of fossil-fuel extraction, hydraulic fracturing is relatively poorly regulated at the federal level. Fracturing wastes are not regulated as a hazardous waste under the Resource Conservation and Recovery Act, fracturing wells are not covered under the Safe Drinking Water Act, and only recently has the Environmental Protection Agency asked fracturing firms to voluntarily report a list of the constituents in the fracturing fluids based on the Emergency Planning and Community Right-to-Know Act.").
[220] *See* REPORT TO THE PRESIDENT, *supra* note 1, at 115 (mentioning that "the Macondo blowout was the product of several individual missteps and oversights . . . which government regulators lacked the authority, the necessary resources, and the technical expertise to prevent.").

atmosphere.[221] As the effects of climate change become more and more apparent,[222] and as the developed world fails to take decisive action to dramatically reduce GHG emissions,[223] geoengineering techniques are receiving considerable attention as a realistic policy response.[224]

1. Geoengineering Overview

Several geoengineering options are under serious consideration by scientists, but these options generally fall within two categories. One category of geoengineering techniques involves efforts to increase "the reflectivity, or albedo, of the Earth's atmosphere or surface," which would "direct more solar radiation back towards space thus limiting temperature increases."[225] Specific techniques to increase reflectivity can be very

---

[221] *See* ENGINEERING THE CLIMATE, *supra* note 4, at 1 ("Climate engineering, or geoengineering, can be defined as the deliberate large-scale modification of the earth's climate systems for the purpose of counteracting and mitigating anthropogenic climate change.").

[222] *See* Victor et al., *supra* note 5, at 64:

> Each year, the effects of climate change are coming into sharper focus. Barely a month goes by without some fresh bad news: ice sheets and glaciers are melting faster than expected, sea levels are rising more rapidly than ever in recorded history, plants are blooming earlier in the spring, water supplies and habitats are in danger, birds are being forced to find new migratory patterns.
>
> The odds that the global climate will reach a dangerous tipping point are increasing.

[223] *See id.* at 65 (noting that "[h]olding global warming steady at its current rate would require a worldwide 60–80 percent cut in emissions, and it would still take decades for the atmospheric concentration of carbon dioxide to stabilize."). On this point, the authors conclude that "[m]ost human emissions of carbon dioxide come from burning fossil fuels, and most governments have been reluctant to force the radical changes necessary to reduce those emissions." *Id.*

[224] *See id.* at 65–66 ("The world's slow progress in cutting carbon dioxide emissions and the looming danger that the climate could take a sudden turn for the worse require policymakers to take a closer look at emergency strategies for curbing the effects of global warming. These strategies, often called 'geoengineering,' envision deploying systems on a planetary scale, such as launching reflective particles into the atmosphere or positioning sunshades to cool the earth."); *see also* ENGINEERING THE CLIMATE, *supra* note 4, at 2 (noting that "in recent years a growing number of credible scientific bodies have engaged in more serious deliberation to the concept of climate engineering.").

[225] BRACMORT ET AL., *supra* note 12, at 2, 16. Manipulating the earth's albedo "could have an effect on the climate system large enough to offset the gross increase in warming that is likely over the next century as a result of a doubling of the amount of carbon dioxide in the atmosphere." Victor et al., *supra* note 5, at 67.

low tech, "such as painting roofs and paved areas white" instead of the much more typical heat absorbing black.[226] Other techniques to increase reflectivity are more controversial because they involve directly manipulating the earth's climate.[227]

For instance, seeding clouds with sea salt on a continuous basis to increase their whiteness and reflectivity is one such geoengineering technique under consideration.[228] Another example of geoengineering to enhance reflectivity is to add sulfur dioxide to the atmosphere where it would be converted into particles that would reflect sunlight, and thereby reduce the earth's temperature.[229] This geoengineering effort would attempt to mimic the global cooling effect that has been observed following the eruption of large volcanoes such as Mount Pinatubo.[230] Yet another geoengineering approach contemplated is to reflect sunlight and cool the earth by launching reflectors into space that would orbit between the earth and the sun.[231]

A second general category of geoengineering involves efforts to remove carbon dioxide from the atmosphere or prevent its emission in the first instance.[232] One example of a carbon dioxide removal process has been previously discussed and that is CCS, which removes carbon dioxide from the emission stream of a power plant or other GHG-emitting facility and then transports it to a site for sequestration deep beneath the surface of the earth.[233]

---

[226] BRACMORT ET AL., *supra* note 12, at 16; *see also* Max G. Bronstein, *Readily Deployable Approaches to Geoengineering: Cool Materials and Aggressive Reforestation*, 10 SUSTAINABLE DEV. L. & POL'Y 44, 45 (2010) (explaining that "[t]he theory underlying this solution is quite simple; lighter colors reflect more sunlight and therefore increase the planet's reflectivity, which, on a large scale, can result in global cooling."). The author also notes the other additional benefits of white roofs: "white roofs keep buildings cooler. Cooler buildings reduce energy costs and in turn lower CO_2 emissions. Lower energy costs and a smaller carbon footprint help to minimize the 'heat island' effect." *Id.*

[227] *See* Albert C. Lin, *Geoengineering Governance*, 8 ISSUES IN LEGAL SCHOLARSHIP 1, 2–4 (2009).

[228] *See* BRACMORT ET AL., *supra* note 12, at 17.

[229] *See* Lin, *supra* note 227, at 4.

[230] *See* BRACMORT ET AL., *supra* note 12, at 18; *see also* Victor et al., *supra* note 5, at 68 (remarking that "[m]ost schemes that would alter the earth's albedo envision putting reflective particles into the upper atmosphere, much as volcanoes do already.").

[231] *See* Victor et al., *supra* note 5, at 69 ("More ambitious projects could include launching a huge cloud of thin refracting discs into a special space orbit that parks the discs between the sun and the earth in order to bend just a bit of sunlight away before it hits the planet.").

[232] *See* BRACMORT ET AL., *supra* note 12, at 10.

[233] *See id.* at 10–11.

Afforestation, the use of trees and other plants to reduce the levels of carbon dioxide,[234] is another carbon dioxide removal method that does not trigger any of the environmental concerns that CCS raises. This is because afforestation merely requires the planting of trees in an area where none have been for at least a decade.[235] However, it is worth considering that while afforestation may not be controversial from an environmental perspective, a related difficulty is deforestation, which is occurring at a rapid rate, and results in the release of carbon dioxide and eliminates a natural carbon dioxide sequestration source.[236]

A more controversial carbon dioxide removal geoengineering technique is the concept of ocean fertilization.[237] The idea here is to add "nutrients such as iron to the ocean" to spark an increase in phytoplankton, which naturally take up and sequester carbon dioxide.[238]

2. Risks of Geoengineering

Tinkering with the climate through geoengineering is rife with uncertainty and risk. The number of questions posed by geoengineering raised by Michael C. MacCracken, chief climate change scientist for the Climate Institute, bear repeating verbatim:

> Is geoengineering really possible? Can all or most adverse impacts from combustion of fossil fuels really be cancelled out? What confidence does the scientific community have in its understanding of all of this? How much would doing this cost up front and over time? Who would pay for geoengineering and actually do it? Are there any side

---

[234] *See* Robert B. Jackson & James Salzman, *Pursuing Geoengineering for Atmospheric Restoration*, ISSUES SCI. & TECH. Summer 2010, at 67, 73 ("Plants and other photosynthetic organisms provide one of the oldest and most efficient ways to remove CO_2 from air.").

[235] *See* BRACMORT ET AL., *supra* note 12, at 13. Afforestation is a particularly potent carbon dioxide removal mechanism because "forest communities can store about 10 times more carbon . . . than non-forest communities and for longer time periods (decades to hundreds of years)," with added benefits of "erosion control, recreational value, wildlife habitat, and production of forest goods." *Id.*

[236] *See* Bronstein, *supra* note 226, at 46 (recognizing that "every year a forest area the size of Panama is lost. Deforestation can occur naturally through wildfires—which have been increasing in number with global warming—but deforestation is more commonly driven by the need for agricultural and grazing space.").

[237] *See* BRACMORT ET AL., *supra* note 12, at 12–13.

[238] *Id.* at 12.

> effects of doing this? What if geoengineering is started and it does not work as we expect—what is irreversible and what is not? Are there winners and losers from undertaking geoengineering? Who would get to decide what is done? What are the optimal conditions for the Earth—and, if they exist, would they simultaneously be optimal for all peoples, for society, for plants and wildlife? Once geoengineering started, how long would it have to continue? How soon would decisions about geoengineering have to be made? Is it appropriate to take additional actions to modify the climate, even if the intent is to moderate what are negative impacts for at least some nations? Beyond the scientific, engineering, and economic aspects, what are the moral and ethical aspects of geoengineering, for us today and for future generations?[239]

Answering these questions is difficult because geoengineering as a response to anthropogenic climate change is in its nascent stages, and furthermore there is a dearth of solid scientific research in the field.[240]

The research that has been done, however, is not particularly comforting about geoengineering's potential adverse consequences. Increasing the reflective capabilities of clouds, for instance, might disrupt regional weather patterns in unpredictable ways.[241] Whitening clouds through geoengineering technology could also adversely affect the marine ecosystem.[242]

Research also strongly suggests that intentionally reducing the amount of sunlight to counteract a warming planet could have dramatic adverse consequences for the hydrological cycle, potentially leading to catastrophic droughts especially in areas that are already water stressed.[243]

---

[239] MICHAEL C. MACCRACKEN, WORLD BANK, BEYOND MITIGATION: POTENTIAL OPTIONS FOR COUNTER-BALANCING THE CLIMATIC AND ENVIRONMENTAL CONSEQUENCES OF THE RISING CONCENTRATIONS OF GREENHOUSE GASES, BACKGROUND PAPER TO THE 2010 WORLD DEVELOPMENT REPORT 5–6 (2009), *available at* http://www.climate.org/PDF/World-Bank_Beyond-Mitigation_MacCracken.pdf.

[240] *See* Victor et al., *supra* note 5, at 73 ("Despite years of speculation and vague talk, peer-reviewed research on geoengineering is remarkably scarce. . . . [T]he entire scientific literature on the subject could be read during the course of a transatlantic flight. Geoengineering continues to be considered a fringe topic.").

[241] *See* MACCRACKEN, *supra* note 239, at 21.

[242] *See Cloud Whitening*, HANDS OFF MOTHER EARTH, http://www.handsoffmotherearth.org/learn-more/what-is-geoengineering/cloud-whitening/ (last visited Oct. 13, 2011).

[243] *See* G. Bala et al., *Impact of Geoengineering Schemes on the Global Hydrological Cycle*, 105 PROC. NAT'L ACAD. SCI. 7664, 7664 (2008), *available at* http://www.pnas.org/content/105/22/7664.full.pdf.

This concern is based on the observed effect that large volcanic eruptions have had on rainfall.[244] Other researchers using sophisticated modeling have also voiced the concern that reducing the amount of sunlight reaching the earth could have dire negative consequences on the hydrological cycle resulting in widespread droughts.[245] Yet another difficulty presented by reflecting sunlight away from the earth is that it would have some negative consequences for the feasibility of reducing GHG emissions through the increased use of solar energy as a viable alternative to fossil fuel–derived energy production.[246]

Use of sulfates to reflect sunlight is also a problematic geoengineering option because of the adverse impacts that adding additional sulfates to the atmosphere entails.[247] These adverse impacts include destruction of the ozone layer,[248] acid rain,[249] and the inability to counteract or retrieve the sulfates from the atmosphere once they are released.[250] Of course, adversely impacting the ozone layer has demonstrable negative consequences for human health since the ozone layer shields us from the sun's harmful ultraviolet radiation.[251] Similarly, increased acidity in precipitation has negative consequences for ecosystems, such as the forest die-offs that occurred in the northeastern United States as a result of the so-called acid rain phenomenon, triggered by sulfur dioxide emissions from midwestern coal-fired power plants.[252]

---

[244] Following the eruption of Mount Pinatubo in 1991 some researchers noted "large hydrological responses, including reduced precipitation, soil moisture, and river flow in many regions." Alan Robock, *20 Reasons Why Geoengineering May Be a Bad Idea*, BULL. OF THE ATOMIC SCIENTISTS, May/June 2008, at 14, 15. Similar disruptions to the hydrological cycle adversely affecting rainfall have been observed following other volcanic eruptions. *Id.*

[245] *See, e.g.*, Bala et al., *supra* note 243, at 7668 (concluding based on modeling that geoengineering techniques aimed at reducing the amount of sunlight striking earth "will lead to a reduction in global mean precipitation and evaporation."); Robock, *supra* note 244, at 15 (recalling that at the 2007 meeting of the American Geophysical Union "researchers presented preliminary findings from several different climate models that simulated geoengineering schemes and found that they reduced precipitation over wide regions, condemning hundreds of millions of people to drought.").

[246] *See* Robock, *supra* note 244, at 16 (noting that even "as little as a 1.8 percent reduction in incoming solar radiation . . . would significantly affect the radiation available for solar power systems—one of the prime alternative methods of generating clean energy.").

[247] *See* Lin, *supra* note 227, at 4.

[248] *See id.*

[249] *See* Robock, *supra* note 244, at 16.

[250] *See id.* at 17.

[251] *See* MACCRACKEN, *supra* note 239, at 18–19.

[252] *See id.* at 20 (remarking that atmospheric addition of "sulfates would also be likely to have adverse health consequences, reduce visibility, and increase acidic deposition ('acid

Ocean fertilization, which is another geoengineering technique under consideration, too, presents risks. One risk is that fertilizing the ocean with iron or other chemical substances will unintentionally affect the marine ecosystem with disastrous results, given the critical importance of phytoplankton in the food chain.[253] Another risk is that ocean fertilization may not lead to a reduction in GHGs through increased uptake by phytoplankton, but may actually increase GHG emissions.[254] Increased ocean acidification is also one the observed negative consequences of climate change,[255] and it is already having a demonstrated impact on the world's oceans.[256] Consequently, there is also a concern that ocean fertilization could exacerbate the acidity problem that is already taking place as a result of climate change.[257]

In addition to the specific risks attendant to certain geoengineering techniques under consideration, there are risks in general associated with geoengineering technologies that are worthy of contemplation. The technologies themselves, for example, may have inherent adverse environmental consequences.[258] Further, what would occur if a geoengineering technology suddenly failed or malfunctioned? Some scientists believe that if such an event occurred then potentially catastrophic rapid warming would result.[259]

---

rain') that would need to be considered in comparison to the impacts of the warming that is averted.").

[253] *See* Lin, *supra* note 227, at 7 (recognizing that "ocean fertilization schemes risk significant alteration of marine ecosystems. Phytoplankton form the foundation of marine food webs, and changes in their populations could lead to unpredictable changes in ecosystems.").

[254] *See* Lin, *supra* note 227, at 7 (noting that ocean fertilization could increase the release of methane, which is a potent GHG); BRACMORT ET AL., *supra* note 12, at 13.

[255] *See* Victor et al., *supra* note 5, at 69 (noting with respect to GHG emissions that "much of that carbon dioxide ends up in the oceans, where it forms carbonic acid."); *see also* Robock, *supra* note 244, at 15 (stating that approximately fifty percent of excess atmospheric carbon dioxide is removed by the oceans).

[256] *See* Victor et al., *supra* note 5, at 69.

[257] *See* BRACMORT ET AL., *supra* note 12, at 13.

[258] *See* Robock, *supra* note 244, at 16–17 (asserting that "[a]ny system that could inject aerosols into the stratosphere . . . would cause enormous environmental damage. The same could be said for systems that would deploy sun shields.").

[259] *See* Bala et al., *supra* note 243, at 7664 (noting that studies have found that "a failure of the geoengineering scheme could lead to rapid climate change, with warming rates up to 20 times greater than present-day rates."); Robock, *supra* note 244, at 17 ("Such an abrupt shift would result in rapid climate warming, which would produce much more stress on society and ecosystems than gradual global warming.").

While currently there is mounting pressure for developing countries in particular to reduce GHG emissions,[260] what happens to that growing sense of urgency if geoengineering becomes a reality and successfully serves to mitigate against the harmful effects of climate change? Some fear that successfully implementing geoengineering technology would eliminate much of the incentive to dramatically reduce GHG emissions, and the world's energy demands would remain fossil fuel–based.[261] This is a problematic general risk because even if geoengineering were successful at ameliorating many of the adverse consequences associated with a warming planet, the continued emissions of GHGs would result in further ocean acidification.[262] This in and of itself is an evolving environmental disaster for the marine ecosystem.[263]

What are the unintended consequences of geoengineering? Much like we have since discovered from emitting billions of tons of GHGs annually into the atmosphere, resulting in the unintended consequences we call climate change,[264] there very likely will be unintended consequences associated with geoengineering.[265] No matter how much research is conducted by scientists at preeminent research centers, and no matter how much funding is directed towards geoengineering, these unintended consequences will simply remain unknown until we embark on what is essentially a massive experiment on a global scale, if geoengineering is seriously pursued as a climate change remedy.[266] The global climate and all of its

---

[260] *See* Ambuj D. Sagar et al., *Climate Change, Energy, and Developing Countries*, 7 VT. J. ENVTL. L. 71, 91 (2006).

[261] *See* Robock, *supra* note 244, at 17 (recognizing that "[i]f humans perceive an easy technological fix to global warming that allows for 'business as usual,' gathering the national (particularly in the United States and China) and international will to change consumption patterns and energy infrastructure will be even more difficult."). The author goes on to state that "[t]his is the oldest and most persistent argument against geoengineering." *Id.*

[262] *See* Bala et al., *supra* note 243, at 7668 ("Geoengineering of this kind will not mitigate the harmful effects of ocean acidification because the geoengineered world would still have higher concentration of atmospheric CO_2.").

[263] *See* Victor et al., *supra* note 5, at 69 (noting that "[o]cean acidification is a catastrophe for marine ecosystems, for the 100 million people who depend on coral reefs for their livelihoods, and for the many more who depend on them for costal protection from storms and for biological support of the greater ocean food web.").

[264] *See id.* at 76 (commenting that we "have already engaged in a dangerous geophysical experiment by pumping massive amounts of carbon dioxide and other greenhouse gases into the atmosphere."). Unfortunately, since we have not taken the steps necessary to dramatically curb GHG emissions, this grand experiment continues today unabated.

[265] *See id.* at 76; *see, e.g.*, Lin, *supra* note 227, at 4–5.

[266] *See* Robock, *supra* note 244, at 17 ("Scientists cannot possibly account for all of the complex climate interactions or predict all of the impacts of geoengineering. . . . With so much at stake, there is reason to worry about what we don't know.").

interconnections form a phenomenally complex, highly intertwined web that, as climate change illustrates, we struggle to understand.[267] In light of this complexity and interconnectedness, precisely what intentional manipulation of the climate will unleash is pregnant with uncertainty and remains to be seen.[268]

Lastly, what if geoengineering technology fell into the wrong hands? Could it become a new weapon of war by a hostile regime or the latest threat of mass destruction offered by some terrorist organization? Indeed, the first forays into geoengineering were not focused on protecting humankind from the ravages of climate change.[269] Rather, during the Cold War the United States and the Soviet Union looked to geoengineering as a possible component of warfare.[270] If appropriate safeguards are not in place, it is not farfetched to believe that geoengineering could be put to intentionally harmful uses, such as inflicting a prolonged heat wave or drought on a country or region with devastating effects.[271]

3. Regulation of Geoengineering

Presumably because the sophisticated geoengineering technologies are far from ready for full-scale deployment, there are no federal statutes or regulations that specifically govern their use.[272] Policymakers have held hearings to discuss federal research needs and governance issues that geoengineering necessitates;[273] however, if and when any federal legislation will be enacted remains to be seen.

The one-time focus by the Soviet Union and the United States on geoengineering as a possible adjunct to warfare did result in the adoption by the United Nations of a treaty that requires consideration here.[274] This treaty, *The Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques*, was adopted by the United

---

[267] *See id.*
[268] *See id.*
[269] *See* Victor et al., *supra* note 5, at 66.
[270] *See id.*
[271] *See id.* at 72 (recognizing that some geoengineering technologies could be utilized by individuals). Thus given the times that we live in, where airplanes have been used as a weapon of mass destruction, it is certainly conceivable that geoengineering has the potential to serve as a tool of sophisticated terrorists.
[272] *See* Jackson & Salzman, *supra* note 234, at 71 ("Indeed, there are no regulatory mechanisms in place, domestically or internationally, that explicitly address geoengineering.").
[273] *See, e.g.*, ENGINEERING THE CLIMATE, *supra* note 4.
[274] *See* Victor et al., *supra* note 5, at 66–67.

Nations in 1976.[275] It explicitly prohibits "military or any other hostile use of environmental modification techniques having widespread, long-lasting or severe effects as the means of destruction, damage or injury to any other State Party."[276] The Convention defines "environmental modification technique" as "any technique for changing—through the deliberate manipulation of natural processes—the dynamics, composition or structure of the Earth, including its biota, lithosphere, hydrosphere and atmosphere, or of outer space."[277]

It has been suggested that the Convention might serve as a legal impediment to the implementation of geoengineering technology, especially if widespread international agreement is not reached concerning its deployment.[278] The Convention does, however, allow for the use of so-called environmental modification techniques for peaceful purposes.[279] It thus should not serve as an insurmountable hurdle to the implementation of geoengineering technology to combat climate change, assuming broad-based international consensus is reached concerning its implementation.[280]

III. GUIDELINES TO CONSIDER FOR THE ENVIRONMENTAL REGULATION OF EMERGING TECHNOLOGIES

Discerning how to better regulate emerging technologies from an environmental perspective, in order to minimize the risk of another catastrophe similar in magnitude to the BP Deepwater Horizon oil spill that raged for several months, raises a number of questions. For instance, what assurances do we have that the risks associated with CCS, hydraulic fracturing, geoengineering, and other yet to be heard of technologies that will follow are adequately understood? How sure are we that appropriate

---

[275] Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques, Dec. 10, 1976, 31 U.S.T. 333.
[276] *Id.* at art. I.
[277] *Id.* at art. II.
[278] *See* MACCRACKEN, *supra* note 239, at 27 (asserting that "it would not be far-fetched to argue that this treaty might well not permit geoengineering schemes to be used for the purpose of climate change . . . (indeed, not changing climate patterns is specifically mentioned as being covered in one of the understandings of the treaty).").
[279] *See* Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques, *supra* note 275, at art. III, § 1 ("The provisions of this Convention shall not hinder the use of environmental modification techniques for peaceful purposes and shall be without prejudice to the generally recognized principles and applicable rules of international law concerning such use.").
[280] For other international agreements that geoengineering may implicate, see BRACMORT ET AL., *supra* note 12, at 30–35.

measures have or will be taken to address those risks? How do we balance the need for technological innovation as a remedy for climate change and other environmental risks, while at the same time adequately regulating to protect human health and the environment without overly burdening technological innovation and creativity? Similarly, how do we effectively regulate technological innovations, such as deepwater drilling, and at the same time assure that our current energy needs are met? How much risk are we willing to accept in an effort to combat the adverse consequences of climate change?

Such questions allow for no easy, readily available answers. Simply banning the technologies discussed above as a response to the risks they pose is not an adequate answer for multiple reasons.[281] Considering hydraulic fracturing as an example, a ban would be difficult to impose because hydraulic fracturing has, in a few short years, become a widespread practice in the natural gas industry.[282] It also provides gainful employment for over one million people who would likely join the rolls of the unemployed if a ban were imposed.[283] That makes prohibition a quite distasteful option in this era of persistently greater than nine percent unemployment in the United States.[284] Another practical difficulty with a ban is that the natural gas provided by hydraulic fracturing provides a substantial part of our energy needs.[285] Furthermore, as a fuel, natural gas emits less carbon dioxide and other GHGs, so its use is perceived as a beneficial alternative to other fossil fuels.[286] Finally, and more generally, these technologies either exist or are under serious consideration as viable responses to combat the ravages of climate change and thus merit proactive contemplation of how to best go about regulating them.

What is needed is a thoughtful regulatory approach to CCS, hydraulic fracturing, geoengineering, and similar technologies that may

---

[281] *See* Victor et al., *supra* note 5, at 75 (remarking with respect to geoengineering that "[f]iddling with the climate to fix the climate strikes most people as a shockingly bad idea").
[282] *See* Urbina, *supra* note 3 (noting that around ninety percent of the 493,000 active natural gas wells in 2009 utilized hydraulic fracturing).
[283] *See FracInDepth*, ENERGY IN DEPTH (Sept. 1, 2001, 11:12 AM), http://web.archive.org/web/20110704131804/http://www.energyindepth.org/in-depth/frac-in-depth/energy-and-economic-benefits/ (stating that the natural gas industry directly employs over 1.2 million people).
[284] *See* News Release, Bureau of Labor & Statistics, U.S. Dep't of Labor, The Employment Situation—July 2011 (Aug. 5, 2011), *available at* http://www.bls.gov/news.release/pdf/empsit.pdf (containing a graph depicting unemployment rates persistently above nine percent since July 2009).
[285] *See* Manuel, *supra* note 162, at 199 (stating that "[n]atural gas provides almost 25% of the U.S. energy supply and could provide 50% by 2035").
[286] *See* IHS CAMBRIDGE ENERGY RESEARCH ASSOCS., *supra* note 158, at 5.

emerge and carry with them significant environmental risks. As a society, we should not want to see another BP Deepwater Horizon magnitude environmental disaster arising from the use of sophisticated technologies. To that end, I offer several guiding regulatory principles for contemplation below.

A. *The Precautionary Principle*

First, policymakers must keep in the forefront as they develop environmental regulatory regimes governing these emerging technologies the precautionary principle. This bedrock principle of environmental regulation, much akin to medicine's Hippocratic Oath that commands physicians to first do no harm,[287] requires policymakers to "[a]void steps that will create a risk of harm. Until safety is established, be cautious . . . In a catchphrase: better safe than sorry."[288]

With this core regulatory principle in mind, major efforts are required by policymakers and regulators to understand knowable risk.[289] While risk cannot be completely eliminated, it could be that some technologies may simply present too much risk and are suitable only for unpopulated areas, or areas that already suffer from environmental degradation such as brownfield sites,[290] or if the risks are such that we should either judicially or legislatively subject the parties who utilize them to strict liability if harm ensues,[291] or perhaps the risks are so great that

---

[287] *See Greek Medicine—The Hippocratic Oath*, NAT'L INST. OF HEALTH (Sept. 1, 2011), http://www.nlm.nih.gov/hmd/greek/greek_oath.html.

[288] Cass R. Sunstein, *Beyond the Precautionary Principle*, 151 U. PA. L. REV. 1003, 1003–04 (2003); *see also* Frank B. Cross, *Paradoxical Perils of the Precautionary Principle*, 53 WASH. & LEE L. REV. 851, 851 (1996) ("Few principles are better ensconced in the law and philosophy of environmentalism than is the 'precautionary principle.'").

[289] *See, e.g.*, Ragnar E. Löfstedt et al., *Precautionary Principles: General Definitions and Specific Applications to Genetically Modified Organisms*, 21 J. POL'Y ANALYSIS MGMT. 381, 386–87 (2002).

[290] *See Brownfields and Land Revitalization*, U.S. ENVTL. PROT. AGENCY, http://epa.gov/brownfields/ (last visited Oct. 13, 2011) (defining brownfields as "real property, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant. Cleaning up and reinvesting in these properties protects the environment, reduces blight, and takes development pressures off greenspaces and working lands.").

[291] *See* Teresa A. Berwick, *Responsibility and Liability for Environmental Damage: A Roadmap for International Environmental Regimes*, 10 GEO. INT'L ENVTL. L. REV. 257, 264 (1997) (explaining the endorsement of strict liability for an international liability standard).

use of a particular technology should be banned altogether,[292] despite the difficulties previously mentioned regarding such severe regulatory action. Alternatively, keeping true to the precautionary principle as a guide may mean that certain technologies may be put to use only if the risks of climate change or some other environmental calamity outweigh the risks attendant to a potential mitigating technology, such as geoengineering.[293]

Admittedly, as Cass Sunstein and others have pointed out, there are inherent difficulties in applying the precautionary principle since "it offers no guidance—not that it is wrong, but that it forbids all courses of action, including regulation. Taken seriously, it is paralyzing, banning the very steps that it simultaneously requires."[294] Although the precautionary principle has been criticized for its elegant simplicity among other reasons,[295] its basic lesson remains valid and applicable to regulating in the face of uncertainty. That is, it teaches us to proceed with caution, especially in the face of potential catastrophic risks.[296]

If this basic precautionary principle lesson were applied in the context of hydraulic fracturing, as an example, it would require Congress to direct the EPA to first conduct a comprehensive, thorough study of the risks to human health and the environment associated with the hydraulic fracturing process.[297] Following the completion and digestion of the study

---

[292] *See, e.g.*, Protection of Stratospheric Ozone, 58 Fed. Reg. 69,675, 69,676 (Dec. 30, 1993) (to be codified at 40 C.F.R. pt. 82) (as an example of the United States banning a particular substance and practice for its environmental risks pursuant to the Clean Air Act).

[293] *See* Cross, *supra* note 288, at 852.

[294] Cass R. Sunstein, *Irreversible and Catastrophic*, 91 CORNELL L. REV. 841, 850 (2006). As an illustration of this difficulty with the precautionary principle, Sunstein discusses the dilemma posed by drug regulation, where strict adherence to the precautionary principle may protect people from the unknown harms associated with new drugs but at the same time prevent access to disease-curing or life-saving drug therapies. *See id.* at 851.

[295] *See, e.g.*, *id.* at 848 (noting that one such difficulty is defining with precision exactly what the precautionary principle is, since "there are twenty or more definitions . . . and they are not all compatible with one another."); Jonathan Remy Nash, *Standing and the Precautionary Principle*, 108 COLUM. L. REV. 494, 498–501 (2008) (summarizing some of the criticism that the precautionary principle has been subjected to over time).

[296] *See* Sunstein, *supra* note 294, at 892 (arguing that "a Catastrophic Harm Precautionary Principle . . . is a coherent and defensible part of environmental policy" which would take into account appropriate safety margins, and asserting that "[i]ndeed, such a principle might well be the best understanding of the Precautionary Principle itself. It has many uses, not only in environmental policy but in health and safety regulation as a whole, including the war on terrorism.").

[297] *Cf.* Cross, *supra* note 288, at 862 (stating "policymakers should confront the scientific uncertainty and act prudently . . . with the best possible scientific understanding . . . but only after considering the potentially substantial risks attendant to precaution.").

results, then the EPA would develop appropriate regulations specific to the risks established by the study.[298] Assuming that the risks were manageable and deemed not too great, only then would the activity be allowed.

Instead, federal policymakers have cast aside the precautionary principle by expressly exempting hydraulic fracturing from the Safe Drinking Water Act.[299] Only now is the EPA moving to undertake a study of the effects of hydraulic fracturing, after thousands of hydraulic fracturing operations have taken place and the concerns about the environmental and human health effects have mounted.[300] Moreover, the planned study that the EPA will undertake is flawed from the perspective of the precautionary principle because the primary focus is on the impact hydraulic fracturing may have on drinking water supplies.[301] The other adverse consequences of hydraulic fracturing are not included, but perhaps they will be the subject of further study at some undetermined point in the future.[302] This backwards regulatory approach to hydraulic fracturing—first allowing the activity to proceed, then years after the fact determining the risks presented, and then only on a limited basis—flies in the face of the precautionary principle. By the time the EPA completes its study, the potential harm to groundwater, other media, and possibly to human health will continue throughout the country where natural gas is produced through hydraulic fracturing and may be difficult to reverse.[303]

This "wait and see what happens" approach to regulation is unfortunate in the context of hydraulic fracturing and cannot suffice for a regulatory framework for CCS or geoengineering. The risks are too great, and this is especially true regarding geoengineering.[304] It may involve promising technologies; however, those technologies come with the uncertain potential to catastrophically transform the global environment.

---

[298] *See, e.g.*, Sunstein, *supra* note 288, at 1014 (discussing levels of regulation that could be implemented based on the level of risk due to unknown adverse effects).
[299] *See* 42 U.S.C. § 300h(d)(1)(B)(ii) (2006).
[300] *See generally* DRAFT STUDY PLAN, *supra* note 169.
[301] *See id.* at vii, 54–56 (defining the scope of the study as "the relationship between hydraulic fracturing and drinking water resources" and further determining that any impact on air quality, whole ecosystems, seismic activity, and public safety are outside the scope of the study).
[302] *See id.* at 54.
[303] *See* EPA, *supra* note 202 (stating that the goal deadline of the hydraulic fracturing study is 2014). *See generally* Urbina, *supra* note 3 (discussing the potential harms to groundwater and human health by the hydraulic fracturing practice).
[304] *See generally* Fogarty & McCally, *supra* note 104 (discussing the health and safety risks of CCR); Victor et al., *supra* note 5 (discussing the risks of geoengineering).

It very well may be that the cure turns out to be far worse than the disease unless, before allowing for CCS or geoengineering to occur, adequate research is undertaken to establish the knowable range of risks followed by appropriate regulations to manage the most significant threats presented.

B. International Cooperation

Because these emerging technologies can potentially have cross-border adverse impacts,[305] a substantial degree of international cooperation is required to develop broad understanding of the risks posed and effective regulation in response to those risks.[306] It is not inconceivable that a CCS project located in upstate New York could adversely impact a source of drinking water shared with Canada. Similarly, hydraulic fracturing operations conducted in southern Texas could conceivably impact northern Mexico. Certainly any negative consequences of geoengineering could reach around the globe if this effort to mitigate climate change were to come to fruition and go awry.[307] Only a collective, coordinated international approach, involving shared expertise from around the world, can achieve the best possible understanding of the risks and serve as a basis for sound policy approaches responsive to the environmental risks of these emerging technologies.[308] The importance of a coordinated international approach is especially relevant when it comes to much-needed scientific research regarding these emerging technologies.[309]

---

[305] *See* David Ellyard, *Geoengineering: Can It Help Our Planet Keep Its Cool?*, AUSTRALIAN ACADEMY OF SCIENCES, http://www.science.org.au/nova/123/123print.html (last visited Oct. 13, 2011).

[306] *See* Richard Benedick, *Considerations on Governance for Climate Remediation Technologies: Lessons from the "Ozone Hole,"* 4 STAN. J.L. SCI. & POL'Y 6, 7 (2011).

[307] *See* Victor et al., *supra* note 5, at 71–72.

[308] *See id.* at 73.

[309] *See id.* at 73, where the authors note, concerning geoengineering:

> The scientific academies in the leading industrialized and emerging countries—which often control the purse strings for major research grants—must orchestrate a serious and transparent international research effort funded by their governments. Although some work is already underway, a more comprehensive understanding of geoengineering options and of risk-assessment procedures would make countries less trigger-happy and more inclined to consider deploying geoengineering systems in concert rather than on their own.

Although the authors mention the above in the context of geoengineering, the same can be said for CCS and hydraulic fracturing, too.

To some extent this cooperative international approach is underway by policymakers.[310] Such discussions have already occurred, in fact, between the United Kingdom and the United States with respect to geoengineering.[311]

C. *International Governance*

Further, international cooperation is particularly critical with respect to geoengineering in order to develop an appropriate governance structure. This is because these technologies have the potential to adversely impact the entire globe.[312] If for no other reason, some international governance regime is required as a check on countries from acting in their best interests to the possible detriment of others. As MacCracken posits:

> Wanting to sustain its use of fossil fuel derived energy . . . might China act unilaterally if it became convinced that global warming was leading to sharp disruption of the life-sustaining monsoons on which it depends? If the US became convinced that global warming was leading to more and more powerful hurricanes that were devastating its Southeast, might it choose to act unilaterally?[313]

The specter of possible unilateral action in deploying geoengineering technologies is troubling because it "could impose costs on other countries, such as changes in precipitation patterns and river flows or adverse impacts on agriculture, marine fishing, and tourism."[314] Consequently, technologies that possess such planet-altering capabilities must not be unilaterally used. Given that they are capable of inflicting life-altering harms on other nations, international consensus is a required prerequisite to their development and use.[315]

---

[310] *See* Eli Kintisch, *House Science Panel to Lead International Effort on Geoengineering*, SCI. INSIDER (Nov. 5, 2009, 5:24 PM), http://news.sciencemag.org/scienceinsider/2009/11/house-science-p.html.

[311] *See* ENGINEERING THE CLIMATE, *supra* note 4, at 43.

[312] *See, e.g.*, Victor et al., *supra* note 5, at 71–72.

[313] MACCRACKEN, *supra* note 239, at 27.

[314] Victor et al., *supra* note 5, at 71–72.

[315] *See* Lin, *supra* note 227, at 14–15 (stressing that "a system of geoengineering governance should be adopted to oversee geoengineering research efforts, address potential unilateral geoengineering deployment, and establish a mechanism to make collective decisions on any future geoengineering efforts.").

Certainly establishing an acceptable international governance regime that would oversee geoengineering, and other emerging technologies with global environmental risk, presents a recognized challenge. All one needs to do is consider the lack of success among nations in developing a meaningful international consensus in Copenhagen around what actions are necessary by the global community in order to combat climate change.[316] Nonetheless, contemplating the establishment of some international governance mechanism is a critical aspect of an effective regulatory approach to emerging technologies that present global environmental risk, such as geoengineering. This international governance mechanism may be as straightforward as a new treaty specifically governing geoengineering and other similar technologies.[317] Alternatively, from a global governance perspective, it might take the form of a new international body charged with the oversight of these technologies. If such an international body were developed, it could serve as a cooperative clearinghouse for research, development, and deployment of technologies that present substantial global environmental risk, as well as provide a forum to resolve disputes, such as claims of harm arising from the use of these environmentally risky technologies.[318]

D. *The States and the Federal Government*

The classic environmental regulatory approach in the United States currently involves a patchwork of state laws governing emerging technologies, such as CCS and hydraulic fracturing.[319] This approach requires reconsideration in light of the significant potential extraterritorial

---

[316] *See* Navroz K. Dubash, *Copenhagen: Climate of Mistrust*, ECON. & POLITICAL WKLY., Dec. 26, 2009, at 8, 10–11, *available at* http://files.tiggroups.org/92473/get-web/Copenhagen_EPW_Navroz_K_Dubash.pdf.

[317] *See* Lin, *supra* note 227, at 15. The author notes that the possible international governance of geoengineering "seems to fall logically within the purview of the [United Nations Framework Convention on Climate Change]," but also points out that reliance on this key climate change treaty is not problem free. *Id.* at 15–16.

[318] *See* Victor et al., *supra* note 5, at 74–75 ("Although the international scientific community should take the lead in developing a research agenda, social scientists, international lawyers, and foreign policy experts will also have to play a role. Eventually, there will have to be international laws to ensure that globally credible and legitimate rules govern the deployment of geoengineering systems.").

[319] For an overview of some of the state regulations applicable to CCS, see Allan Ingelson et al., *Long-Term Liability for Carbon Capture and Storage in Depleted North American Oil and Gas Reservoirs—A Comparative Analysis*, 31 ENERGY L.J. 431, 441–47 (2010), and for a similar summary of state law applicable to hydraulic fracturing, see Hannah Wiseman, *Untested Waters: The Rise of Hydraulic Fracturing in Oil and Gas Production and the Need to Revisit Regulation*, 20 FORDHAM ENVTL. L. REV. 115, 157–67 (2009).

harm to the environment that is at stake. This was illustrated by the hydraulic fracturing blowout that occurred in Pennsylvania, which prompted the State of Maryland to issue a notice of intent to sue under federal environmental laws.[320] As this showed, the environmental risks associated with CCS, hydraulic fracturing, and geoengineering can certainly cross state lines.[321] Of course, geoengineering presents the possibility of wreaking unintended havoc around the world.[322]

Domestically, this calls for a unified regulatory approach that only the federal government can provide, instead of state-by-state regulation. Thus, as federal regulations evolve to meet the environmental challenges posed by these emerging technologies, Congress should consider expressly preempting inconsistent or less stringent state laws, as it did regarding the regulation of mobile source emissions under the Clean Air Act.[323] Perhaps a more palatable approach, since Congress generally loathes express preemption of state laws, would be based on a cooperative federalism model, which would allow states to seek delegation of federal programs as they emerge to regulate new environmental technologies such as CCS, hydraulic fracturing, or geoengineering. Congress and the states certainly have successfully taken the cooperative federalism route in the implementation of several existing key environmental laws and could adopt a similar approach for hydraulic fracturing, CCS, and some aspects of geoengineering.[324]

As an added benefit, a uniform federal approach governing CCS, hydraulic fracturing, geoengineering, and other emerging technologies of the future will prevent a race to the bottom.[325] That is, it will prevent states from enacting few, if any, regulations governing these technologies in order to reap the economic gains potentially attendant to attracting businesses engaged in high environmental impact industries, including CCS, hydraulic fracturing, and geoengineering.[326] A uniform federal approach

---

[320] *See* Press Release, Maryland Attorney General, *supra* note 206.
[321] *See, e.g.*, *id.*
[322] *See, e.g.*, Victor et al, *supra* note 5, at 72.
[323] *See, e.g.*, 42 U.S.C. § 7543(a) (2006) (expressly preempting states from regulating motor vehicle tailpipe emissions).
[324] *See, e.g.*, Clean Water Act, 33 U.S.C. § 1342(b) (2006) (delegating the national pollutant discharge elimination system permitting system to states); Safe Drinking Water Act, 42 U.S.C. § 300g-2 (2006) (delegating to the states responsibility for enforcing public water supply regulations); Resource Conservation and Recovery Act, 42 U.S.C. § 6926(b) (2006) (delegating to the states authority to create hazardous waste programs).
[325] *See* Joshua D. Sarnoff, *The Continuing Imperative (But Only from a National Perspective) for Federal Environmental Protection*, 7 DUKE ENVTL. L. & POL'Y F. 225, 278 (1997).
[326] *See id.*

to regulation should also be welcome by industry as a matter of administrative and regulatory convenience, instead of a patchwork quilt of fifty potentially inconsistent state-based approaches to regulation.[327]

A high degree of sophisticated technical ability and resources are required to gain an adequate level of understanding of CCS, hydraulic fracturing, and geoengineering.[328] States have fewer resources than the federal government,[329] and the federal government has at its disposal vast bureaucracies populated by a wide range of expertise in many fields.[330] The states simply do not have such a breadth of technical experts readily available, and this is another reason to look for the federal government to lead in the regulation of CCS, hydraulic fracturing, and geoengineering.

Another reason why federal law should predominate in regulating the emerging technologies of CCS, hydraulic fracturing, and geoengineering is because of the high degree of international cooperation that is ideal for successful regulation of these emerging technologies.[331] The states have limited, if any, authority in the international arena, while the federal government's authority over international affairs is essentially boundless.[332]

E. The Fossil Fuel Dilemma

Each of the technologies discussed in this Article is directly related to our highly fossil fuel-dependent energy and transportation systems.[333] We permit exploration and drilling operations for oil in thousands of feet of ocean because we require the oil to heat our homes and fuel our motor vehicles, trains, ships, and planes.[334] Policymakers and scientists are on the brink of finding feasible the injection of billions of tons of carbon dioxide deep under the earth's surface because we rely so heavily around the world

---

[327] *See* Kirsten Engel, *State and Local Climate Change Initiatives: What Is Motivating State and Local Governments to Address a Global Problem and What Does This Say About Federalism and Environmental Law?*, 38 URB. LAW. 1015, 1026–27 (1997).
[328] *See* BRACMORT ET AL., *supra* note 12, at 9–12.
[329] *See* Shari Shapiro, *Who Should Regulate? Federalism and Conflict in Regulation of Green Buildings*, 34 WM. & MARY ENVTL. L. & POL'Y REV. 257, 278 (2009).
[330] *See* Stephen C. Robertson, Note, *State Permitting:* United States v. Smithfield Foods, Inc. *and Federal Overfiling Under the Clean Water Act*, 23 WM. & MARY ENVTL. L. & POL'Y REV. 593, 603 (1999).
[331] *See* Victor et al., *supra* note 5, at 74–75.
[332] *See* U.S. CONST. art. I, § 10; U.S. CONST. art. II, § 2.
[333] *See* Susan A. Schneider, *A Reconsideration of Agricultural Law: A Call for the Law of Food, Farming, and Sustainability*, 34 WM. & MARY ENVTL. L. & POL'Y REV. 935, 954 (2010).
[334] *See id.*

on coal for electricity production.[335] We allow unfettered withdrawal and ultimate high pressure injection of millions of gallons of water tainted with undisclosed chemicals below the earth's surface because we require the natural gas for heat, electricity generation, and fuel or feedstocks for other industrial processes.[336] Finally, we are seriously considering, as emergency mitigation measures, intentional efforts to cool the planet through a variety of technologies to avert the climate crisis that is evolving quickly around us.[337]

If we were to substantially reduce our dependence on fossil fuels, the need for these technologies becomes greatly diminished, or perhaps not necessary at all. If we were to radically transform our transportation sector through the use of electric vehicles, the need for oil from deep beneath the Gulf of Mexico lessens. If we were to radically transform how we generate electricity by increased reliance on solar, wind, and other forms of renewable energy, the urgent need to pump billions of tons of carbon dioxide deep beneath the earth to reduce the buildup of GHGs in the atmosphere may vanish along with mountaintop coal mining, too. The same may be said with the need to fracture the shale deep within the earth to unlock recalcitrant natural gas reserves—the need to do so disappears if we can transform our economies and lives away from fossil fuels. Geoengineering? We pull back from the brink of implementing such a risky last resort mitigation measure and realize the potential folly of attempting to rise to the level of the gods through intentional efforts to manipulate the climate. All of this is possible only if we can only break free from our fossil fuel bondage.

Thus, as a matter of regulatory policy, when scientists, engineers, lawyers, and others who may contemplate regulating the risks attendant to existing and emerging technologies, such as deepwater drilling, CCS, hydraulic fracturing and geoengineering, substantial attention and resources must also be devoted to transforming the world away from fossil fuels. We cannot, as some fear, lose the sense of urgency that climate change presents because some technology looks promising as a means of mitigating the consequences of an inexorably warming planet. When one considers the myriad risks to human health and the environment that our fossil fuel dependency carries with it, moving away from them as our predominate source of fuel is an integral component of any comprehensive public policy response to regulating emerging technologies such as CCS, hydraulic fracturing, or geoengineering.

---

335 *See* Flatt, *supra* note 6, at 213.
336 *See id.*
337 *See* Victor et al., *supra* note 5, at 65–66.

Certainly the technologies that will move us to a less carbon-intensive future will present their own set of environmental risks and challenges. What those risks exactly will be, we do not know; however, what we currently do know is that our centuries-long dependence on fossil fuels has imperiled our planet and has put at risk life on earth as we know it. Consequently, the need to wean ourselves off fossil fuels cannot be forgotten as we consider how best to regulate emerging technologies.[338] To do otherwise is to completely ignore the terrible lesson of the BP Deepwater Horizon disaster, which at its core exposed the substantial risks to human health and the environment that is just beneath the surface of our fossil fuel addiction.

[338] *See* Robock, *supra* note 244, at 17.