CHASING SQUIRRELS IN THE ENERGY TRANSITION

BY
HEATHER PAYNE*

Due to the global lack of action to address emissions that cause climate change, more extreme options such as geoengineering, direct air capture, and carbon capture and sequestration (CCS) are being touted as both necessary and a way to enable the world to continue utilizing fossil fuels into the future. While all of these extreme options are economically prohibitive, technologically, CCS is the furthest developed, with pilot projects and some commercialization activities occurring. In addition to cost, the uncertain legal liability for CCS in the United States has so far hindered wide-scale adoption and development.

This Article argues that due to the nature of the potential harms of CCS projects—asphyxiation, releases to the atmosphere that contribute to climate change, and degradation of water quality—the United States should adopt a strict liability regime. Inadvertent releases of carbon dioxide stored in CCS projects would impact the whole world by increasing the amount of carbon dioxide in the atmosphere. However, the local impacts could be much more pronounced. As demonstrated by spontaneous releases of supersaturated carbon dioxide in Africa and the gassing of a small Mississippi town due to a rupture of the carbon dioxide pipeline that runs through it, a large release of carbon dioxide can sicken or kill. Given the technology currently envisioned, there is also a potential for water contamination, which could be especially problematic in the arid West. The push by some would-be CCS project developers is to dramatically limit liability. However, harms might not be discovered or occur until decades after the initial injection. But those harms are currently foreseeable, and catastrophic.

After discussing the current experience with CCS, this Article discusses the technology, its limitations, harms and their foreseeability, and how the risks caution for the affirmative adoption

*Associate Professor, Seton Hall University School of Law; J.D., University of North Carolina School of Law, BChE Georgia Institute of Technology. Thanks to Victor Flatt and Edward P. Richards for comments and encouragement and Aspen-Jade Tucker for research assistance. As a student in his last class, I especially wish to thank Professor Robert G. "Bob" Byrd, a truly remarkable professor whose love of the law (and, for me, of teaching) was infectious. I know with certainty I would not be teaching today but for him.

of strict liability. While this Article focuses on the CCS, it could just as easily be written about hydrogen, coal gasification, or small module nuclear reactors. Using legal paradigms, we can stop chasing squirrels in the energy transition.

I. INTRODUCTION

> Carbon dioxide has long been used to euthanize laboratory rodents and other small animals, a practice animal welfare organizations now consider inhumane due to the suffering the gas inflicts on the animals. . . . As CO2 concentrations get higher and exposure times longer, the gas causes a range of effects from unconsciousness to coma to death.[1]

[1] Dan Zegart, *The Gassing of Satartia*, HUFFINGTON POST (Aug. 26, 2021), https://perma.cc/7X6X-RNN6.

There are currently only three places where the natural, spontaneous release of supersaturated carbon dioxide[2] can kill: Lakes Nyos and Monoun in Cameroon and Lake Kivu in Rwanda.[3] In 1984, sudden outgassing[4] killed thirty-seven people at Lake Monoun.[5] Two years later, Lake Nyos released 1.6 million metric tons of CO_2 and killed 1,746 people and 3,500 livestock by asphyxiation.[6] These three locations may be the only places on the planet where death due to carbon dioxide asphyxiation is a natural possibility; however, should the practice and implementation of carbon capture and sequestration (CCS)[7] become widespread, many more locations would have the potential to release large amounts of CO_2, akin to what occurs in these lakes.[8] Accordingly, as CCS is implemented, the number of humans and animals who could suffer from such a release likewise becomes significantly larger.

The risks associated with the release of carbon dioxide from carbon dioxide pipelines are already apparent, as the residents of Satartia, Mississippi found out last year. When the carbon dioxide pipeline running through the town ruptured, "people were inside the cloud, gasping for air, nauseated and dazed. Some two dozen individuals were overcome within a few minutes, collapsing in their homes; at a fishing camp on the nearby Yazoo River; in their vehicles."[9] Forty-nine were hospitalized, and many have continuing health problems because of the event.[10] The local emergency management director claimed that the town "got lucky" and had the rupture occurred with other atmospheric conditions or at another time of day, there "would have [been] deaths."[11]

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[2] Carbon dioxide and CO_2 are used interchangeably in this Article.

[3] *Lake Nyos*, WIKIPEDIA, https://perma.cc/N3P2-QZ9C (last visited Feb. 22, 2022). Lake Kivu is the largest of the three lakes, and while it has not had a large release, a release there could have very large human consequences; even without a major release, an estimated nearly 100 people die there each year. Josh Kron, *Deadly Gas Flows Add to a Lake's List of Perils*, N.Y. TIMES, Nov. 6, 2009, at A8.

[4] "Outgas" is defined as "to remove absorbed or occluded gases from." *Outgas*, WEBSTER'S THIRD NEW INTERNATIONAL DICTIONARY, 1601 (3d ed. 2002).

[5] George W. Kling, *Using Science to Solve Problems: The Killer Lakes of Cameroon*, UNIV. OF MICH. (Nov. 19, 2016), https://perma.cc/BDP8-PLKD.

[6] *Lake Nyos*, *supra* note 3. For clarification, a tonne is equivalent to a metric ton in the United States system of measurement. *See* James O. Maloney, *Conversion Factors and Mathematical Symbols*, *in* PERRY'S CHEMICAL ENGINEERS' HANDBOOK, 1-1, 1-17 (Robert H. Perry & Don W. Green eds., 7th ed. 1997) (showing one metric ton equals 2,204.6 pounds).

[7] The author intentionally uses the terminology of sequestration. *See infra* Part II.

[8] Possible CCS locations, and therefore these possible threats, exist all over the world. *See* Sally M. Benson, *IPCC Special Report on Carbon Dioxide Capture and Storage: Storage in Deep Underground Geological Formations*, LAWRENCE BERKELEY NAT'L LAB'Y (unpublished presentation) (on file with author) (explaining potential CCS storage locations around the world and release pathways from storage). This Article, however, is only focused on the liability paradigm that should be adopted for the United States.

[9] Zegart, *supra* note 1.

[10] *Id.*

[11] *Id.*

The counterpoint to this risk, of course, is climate change. Due to the global lack of action on emissions that cause climate change,[12] more extreme options such as geoengineering, direct air capture, and CCS are being touted as both necessary and a way to enable the world to continue utilizing fossil fuels into the future. The policy rationale is beguilingly simple: we cannot transition away from fossil fuels fast enough, and therefore we must find a way to minimize the carbon that is released into the atmosphere.

The most recent U.N. Intergovernmental Panel on Climate Change report amply demonstrates that we have much more to do to minimize the impacts of climate change.[13] The science is clear: human activity, and specifically the burning of fossil fuels, is responsible for the atmospheric changes we are all experiencing.[14] There is broad agreement that we must act; the disagreements are around what to do, who should do what, and who should pay for those actions (or lack of action, in some cases).

The lack of consensus and definitive action to address climate change allows various actors to support pathways that maximize the continuing commercial viability or minimize adverse impacts on their business, regardless of whether that "preferred" pathway is a meaningful way to reduce the planetary crisis or is simply a distraction to delay consequential action. Scholars have provided different rationales to support the use of CCS and, therefore, what type of legal regime should exist.[15] However, while needing to take action to minimize climate change is often the reason given for the use of CCS, these discussions typically lack specificity around three questions: 1) How does CCS compare to other options for achieving the same goals? 2) What liability regime should govern the use of CCS? And 3) what conflicts of interest and moral hazards should we address when determining that liability?

To more fully answer these questions, this Article first discusses the engineering behind CCS, including current projects and the potential for CCS adoption. It then discusses the risks of widespread CCS deployment,

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[12] *'Climate Commitments Not on Track to Meet Paris Agreement Goals' as NDC Synthesis Report is Published*, U.N. FRAMEWORK CONVENTION ON CLIMATE CHANGE (Feb. 26, 2021), https://perma.cc/4GNB-5HUS.

[13] RICHARD P. ALLAN ET AL., INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2021: THE PHYSICAL SCIENCE BASIS, at SPM-36 (Aug. 7, 2021), https://perma.cc/GY8Y-KYLE; *see* Mitchell Beer, *No More Excuses: 'Unimaginable, Unforgiving World' Without Drastic Emissions Cuts, IPPC Warns*, ENERGY MIX (Aug. 9 2021), https://perma.cc/Z4GN-X4FV ("It is still possible to forestall many of the most dire impacts, but it really requires unprecedented transformational change.").

[14] RICHARD P. ALLAN ET AL., *supra* note 13, at SPM-5 to SPM-6; *The Causes of Climate Change*, NASA, https://perma.cc/AJG8-39MQ (last updated Mar. 4, 2022).

[15] *See, e.g.*, Victor B. Flatt, *Paving the Legal Path for Carbon Sequestration from Coal*, 19 DUKE ENV'T L. & POL'Y F. 211, 218, 220 (2009) (arguing for centralized federal control of CCS and a predictable, cost-benefit sensitive liability regime); Alexandra B. Klass & Elizabeth J. Wilson, *Climate Change and Carbon Sequestration: Assessing a Liability Regime for Long-Term Storage of Carbon Dioxide*, 58 EMORY L. J. 103, 108–09 (2008) (questioning the efficacy of limiting liability for CCS developers and proposing federal controls that take the place of common law liability).

specifically to human health and the environment. Part III discusses the most likely uses for CCS and how CCS compares to other options for achieving the same goals, especially the replacement of fossil fuels in electricity generation and the impact on ratepayers. Part IV introduces various liability paradigms that could be used for CCS, as well as the moral hazard considerations that should be understood as part of any policy and why a Price-Anderson-type of liability-limiting scheme should not be adopted. Part V concludes that strict liability will strike the best balance and minimize the use of CCS to only those instances where it is truly cost-effective while maintaining the appropriate focus on long-term sequestration.

II. ENGINEERING AND RISK

CCS has been defined as "a process consisting of the separation of CO_2 from industrial and energy-related sources, transport to a storage location and long-term isolation from the atmosphere."[16] While three terms are typically used interchangeably—CCS; carbon capture and storage (also referred to as CCS); and carbon capture, utilization, and storage (CCUS)—they do imply different things. For the purposes of this Article, the author uses carbon capture and sequestration intentionally. Sequestration identifies something to be withdrawn. If CCS is to be meaningful for climate purposes, we must sequester the carbon—withdraw it permanently from the atmosphere. Storage, on the other hand, means "the putting and keeping of things in a special place for use in the future."[17] There can be no doubt that in certain applications—like enhanced oil recovery—carbon dioxide is indeed captured and stored. But the carbon dioxide is then used to produce more fossil fuels, and this "enhanced oil recovery produces more emissions than it sequesters."[18] Storage—and later use—is not what the climate needs. The climate needs sequestration of carbon. Similarly, CCUS proponents would argue against the permanent sequestration of carbon, rather supporting utilizing the carbon and storing it until it is ready to be released as it suits the entity controlling it.

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16 BERT METZ ET AL., IPCC SPECIAL REPORT ON CARBON DIOXIDE CAPTURE AND STORAGE 3 (2005). This definition, and this Article, deal with geologic carbon storage. "Terrestrial carbon sequestration," defined as "the net removal of CO_2 from the atmosphere by plants during photosynthesis and its fixation in vegetative biomass and in soils," is not discussed in this Article. *Carbon Sequestration: Storage*, NAT'L ENERGY TECH. LAB'Y, https://perma.cc/89Q8-7ZVQ (last visited Feb. 16, 2022). Based on this definition, CCS has uses outside of the energy sector. However, based on the thesis of this Article, the author has limited the discussion to electricity generation. As noted, other sectors which might be candidates for CCS implementation include cement production, the manufacture of iron and steel, and petroleum refining.

17 *Storage*, CAMBRIDGE DICTIONARY, https://perma.cc/AM55-NZ6H (last visited Feb. 16, 2022).

18 Zegart, *supra* note 1.

These may seem like semantic differences, but given the current uses of carbon dioxide, they are not. This Part, therefore, discusses how CCS works, current CCS projects, global CCS potential, and risks associated with CCS technology.

A. How Carbon Capture and Sequestration Works

CCS works the same way regardless of which industry the carbon dioxide has been produced within. Because electricity generation is one major industry where CCS is being contemplated, this discussion will use electricity generation as an example of how CCS works.

Carbon dioxide is produced during the electricity generation process when fuel containing carbon is burned.[19] The process of electricity generation from fossil fuels is as follows: fuel (coal, natural gas, or oil) is burned, releasing carbon dioxide, hydrogen (or water), other by-products, and heat.[20] The heat generated converts water to steam in a boiler, and that steam then turns a steam turbine.[21] The turning steam turbine is connected to a generator, which generates the electric current.[22] The steam from the turbine is condensed back into liquid water, and, as it exists within a closed-loop system, it returns to be heated and turned into steam again.[23]

Before the carbon can be sequestered, it must be separated from other components and captured. There are three possible ways to capture carbon during the electricity generation process: post-combustion, oxy-fuel, and pre-combustion sequestration.[24] Post-combustion is best suited for currently-operating plants, as this process removes the CO_2 after the fossil fuel is burned; it can therefore be more easily added onto existing facilities.[25] Oxy-fuel technology ensures no by-products, leaving only water vapor and CO_2 after the combustion process, thereby allowing

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[19] *How Much Carbon Dioxide is Produced When Different Fuels are Burned?*, U.S. ENERGY INFO. ADMIN. (Oct. 28, 2021), https://perma.cc/HDR2-FG39 (outlining the amount of carbon dioxide emitted for different fuel types).

[20] U.S. DEP'T OF ENERGY, COMBINED HEAT AND POWER TECHNOLOGY: FACT SHEET SERIES 1–2.

[21] *Id.*

[22] *Id.*

[23] *Id.*

[24] *Carbon Sequestration: CO_2 Capture*, NAT'L ENERGY TECH. LAB'Y, https://perma.cc/RCT2-Y37L (last visited Feb. 16, 2022). CCS has the ability to remove up to 90% of CO_2 from coal and gas-fired energy production. METZ ET AL., *supra* note 16, at 168. *See* GLOBAL CCS INST., STRATEGIC ANALYSIS OF THE GLOBAL STATUS OF CARBON CAPTURE AND STORAGE: SYNTHESIS REPORT 48 (2009) (providing a schematic showing the three different capture locations).

[25] DAVID J. ABOOD ET AL., ACCENTURE, CARBON CAPTURE AND STORAGE: ACTIONS TO ACHIEVE HIGH PERFORMANCE IN A LOW-CARBON ECONOMY 6 (2009). The standard composition of flue gas from an existing facility is 12-18% CO_2 by volume, exhausted at 10-15 psi. *Carbon Sequestration: CO_2 Capture*, *supra* note 24. "Regenerable glycol solvents can capture CO_2 from these systems to produce pure CO_2 at 50-300 psi." *Id.*

efficient separation of CO_2.[26] The final technology is pre-combustion, which pre-treats the fuel to pure CO_2 and hydrogen, and separation occurs before the hydrogen is burned.[27]

Once the carbon dioxide has been captured, it must be transported and then permanently sequestered.[28] Three main geologic formations have been identified as theoretically possible storage locations: depleted oil and gas fields, saline aquifers, and coal bed seams.[29] Using depleted oil and gas fields would entail filling the spaces left vacant from pumping oil and gas with liquid, pressurized carbon dioxide.[30] Carbon dioxide has been used in oil and gas fields to aid in enhanced oil recovery, but the carbon dioxide escapes into the atmosphere after injection.[31] Methods that allow carbon dioxide to escape may qualify as carbon capture and storage and CCUS but do not qualify as CCS, which requires long-term isolation of carbon dioxide from the atmosphere. However, should adequate sequestration technology be developed, these "depleted oil and gas fields . . . have already undergone extensive geological mapping," so the possibilities for migration are better understood than with the other two potential geological options.[32]

Saline aquifers are "geological formations . . . of porous rocks pocked by tiny holes filled with saltwater[and] capped by nonporous rock."[33] This

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[26] The fuel stock is burned with enriched oxygen levels. *Id.* "The CO_2 is then captured by condensing the water in the exhaust stream." *Id.* However, because this method requires an air separation unit, it is unlikely that this will be adopted for existing plants. ABOOD ET AL., *supra* note 25.

[27] As this requires a specific plant design, this option would likely only be chosen for new construction going forward. ABOOD ET AL., *supra* note 25. "[F]uel is converted into gaseous components by applying heat under pressure in the presence of steam. CO_2 can be captured from the synthesis gas that emerges from the coal gasification reactor before it is mixed with air in a combustion turbine." *Carbon Sequestration: CO_2 Capture*, *supra* note 24. However, these plants require a coal gasification unit, which make them more costly to construct. ABOOD ET AL., *supra* note 25.

[28] *See* GLOBAL CCS INST., ACCELERATING CCS 6 (2009) (depicting a schematic of the value chain of carbon dioxide, including CO_2 capture, transport, and storage). There are additional policy issues associated with the development of pipelines, e.g., whether eminent domain should be allowed for fossil fuel infrastructure. However, while some risks will be addressed, the specific liability that should attach to pipeline development and operation are not the subject of this Article. The author also does not opine in this Article on the ownership of any underground property. For a discussion on subsurface property rights, see generally Joseph Schremmer, *A Unifying Doctrine of Subsurface Property Rights*, HARV. ENV'T L. REV. (forthcoming 2022); Tara Righetti et al., *The Carbon Storage Future of Public Lands*, 38 PACE ENV'T L. REV. 181 (2021); Legal Pathways to Deep Decarbonization, Introductory Memorandum and Annotated Model State Legislation for the Geologic Storage of Carbon Dioxide (2019), available at https://perma.cc/4TKP-X82Z.

[29] *Technologies: Carbon Sequestration*, NAT'L ENERGY TECH. LAB'Y, https://perma.cc/VE53-M829 (last visited Feb. 20, 2022). *See also* Benson, *supra* note 8 (schematic showing different storage options).

[30] *Carbon Sequestration: Storage*, *supra* note 16.

[31] Benson, *supra* note 8.

[32] ABOOD ET AL., *supra* note 25, at 7.

[33] *Id.* The process works by "pumping saltwater containing bubbles of CO_2 through the aquifers. The porous rock acts like a sieve, trapping CO_2." *Id.*

technology has been used in the Sleipner oil field in Norway to allow Statoil to avoid paying "$55 million per year in taxes."[34] While the Sleipner oil field is an example of offshore use, saline aquifers can exist either on-shore or off-shore. Due to the theoretical stability where the carbon dioxide is bound chemically and therefore is less likely to escape, those hesitant about the proliferation of CCS installations tend to focus on this application as one that could be safe.

The last possible storage location, coal bed seams, involves coal deposits that are too deep or too narrow to be mined economically.[35] The process works because "[w]hen CO_2 is injected into the formation, it is absorbed onto the coal surfaces, and methane gas is released and produced in adjacent wells."[36] This method of storage, therefore, could easily produce more emissions and cause more climate change since methane (the main component of natural gas) is far more heat-trapping than carbon dioxide.[37] To have any chance of being carbon neutral, the CO_2 generated by burning the methane would then also require injection into a CCS location. Efficient capture of the released methane would be critical[38]— releasing any methane into the atmosphere during this process would have a negative effect on global climate change and greenhouse gas emissions rather than a positive one. Given the documented methane leaks that exist from both production wells and

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[34] Katie Walter, *A Solution for Carbon Dioxide Overload*, LAWRENCE LIVERMORE NAT'L LAB'Y, https://perma.cc/GH47-B3HB (last visited Feb. 15, 2022). While Statoil has said that it has tested monitoring and verification, as the saline aquifer is under the ocean, it would be difficult to independently verify that none of the carbon dioxide had migrated into the ocean. *Id.* Photographic depictions are available of the carbon dioxide plume of the Sleipner field. *Carbon Sequestration: Monitoring, Verification, and Accounting (MVA)*, NAT'L ENERGY TECH. LAB'Y, https://perma.cc/F6C9-J36C (last visited Feb. 20, 2022). The National Energy Technology Laboratory (NETL) also acknowledges that the "[c]urrent on-the-ground" technology to measure sequestered carbon is "accurate to within plus or minus 5-30 percent." *Id*.

[35] PA. DEP'T OF CONSERVATION & NAT. RES., GEOLOGIC CARBON SEQUESTRATION OPPORTUNITIES IN PENNSYLVANIA 9, 12 (2009).

[36] *Carbon Sequestration: Storage*, *supra* note 16.

[37] Gavin Schmidt, *The Definitive CO_2/CH_4 Comparison Post*, REALCLIMATE, (Sept. 19, 2021), https://perma.cc/5JR3-SRLL.

[38] Additionally, coal bed seam injection can cause swelling; fracturing is being used to attempt to correct this problem. *Carbon Sequestration: Storage*, *supra* note 16. The contents of fracture fluid do not need to be disclosed and are specifically exempt from the Safe Water Drinking Act. 42 U.S.C. § 300h(d)(1)(B)(ii) (2018). Coal bed methane producers used diesel fuel as fracturing fluid, until voluntarily agreeing to stop in 2004 while the issue was being studied by the EPA. U.S. ENV'T PROT. AGENCY, EVALUATIONS OF IMPACTS TO UNDERGROUND SOURCES OF DRINKING WATER BY HYDRAULIC FRACTURING OF COALBED METHANE RESERVOIRS, EPA 816-R-04-003, at ES-2 (2004). Fracturing fluid has been implicated in benzene contamination in Wyoming and Colorado. Abrahm Lustgarten, *Buried Secrets: Is Natural Gas Drilling Endangering U.S. Water Supplies?,* PROPUBLICA, (Nov. 13, 2008), https://perma.cc/7YMP-U9DL. EPA has done a literature review looking at fracturing fluid used in eleven major coal basins to determine the extent of contamination in drinking water. U.S. ENV'T PROT. AGENCY, EVALUATIONS OF IMPACTS TO UNDERGROUND SOURCES OF DRINKING WATER BY HYDRAULIC FRACTURING OF COALBED METHANE RESERVOIRS, EPA 816-R-04-003, at ES-1, 5-1 (2004).

throughout the natural gas distribution system, it is certainly debatable that any carbon decrease would occur from this method.

B. Global Potential, Current Projects, and Challenges

1. Global Potential and Current Projects

As burning fossil fuels is a worldwide phenomenon, the development of CCS as a potential enabler is also global. The potential to sequester with CCS has been listed by physical science scholars as substantial: "3,093 carbon clusters and 432 sinks in 85 countries and regions are selected to achieve 92 G[igatonnes of]CO_2 mitigation" with around two-thirds being sequestered.[39] According to the same study, available sinks are "located in China, the United States, the European Union, Russia and India."[40] Looking at CCS potential more locally, "North America has enough geochemical storage capacity for over 900 years of CO_2 at current production rates" per the American National Energy Technology Laboratory (NETL).[41]

However, the reality has—at least to date—not matched the potential. As of 2019, there were nineteen CCS facilities in operation, with an additional four under construction.[42] This is not a dramatic increase from over a decade earlier when nine were operational or under construction.[43] The four largest CCS facilities listed as of 2019 all utilize their captured carbon dioxide for enhanced oil recovery.[44] Since then, the fourth largest CCS facility, Petra Nova, "suffered chronic mechanical problems and routinely missed its targets" and shut down.[45] Claiming a design capability to capture 90%, the "plant cut emissions 55% the first year and 70% after three years. . . . The picture worsened when the emissions from coal mining and other activities were taken into account," leading to an overall reduction of 12%.[46] Another CCS facility, a retrofit of Unit 3 at the Boundary Dam plant owned by Sask Power, "has been

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39 Yi-Ming Wei et al., *A Proposed Global Layout of Carbon Capture and Storage in Line with a 2 °C Climate Target*, 11 NATURE CLIMATE CHANGE 112, 112 (2021). The remainder would be used in enhanced oil recovery. *Id.*

40 *Id.*

41 Ellie Pritchard, *Boundary Dam Project: Hopes Versus Reality in Capturing Carbon*, VALVE WORLD, https://perma.cc/TC2D-FT7D (last visited Feb. 19, 2022).

42 *New Wave of CCS Activity: Ten Large-Scale Projects Announced*, GLOBAL CCS INST. (Oct. 29, 2019), https://perma.cc/32E3-39N5.

43 ABOOD ET AL., *supra* note 25, at 8.

44 Shankar Besta, *What are the Top Carbon Capture and Storage Projects Around the World?*, NS ENERGY (July 19, 2019), https://perma.cc/5PMM-3GX3.

45 Nichola Groom, *Problems Plagued U.S. CO2 Capture Project before Shutdown: Document*, REUTERS (Aug. 6, 2020), https://perma.cc/RDJ3-24PJ. The plant "suffered outages on 367 days" between starting up in 2017 and shutting down in 2020 and "also missed its carbon capture targets by about 17%." *Id.*

46 Donnelle Eller, *Some Iowa Farmers Who Fought Dakota Access are in the Path of World's Largest Carbon Capture Pipeline*, DES MOINES REG., (Sept. 24, 2021), https://perma.cc/T9R9-NMFC.

producing mixed results" since it "came online in 2014."[47] Rather than one million tonnes per year of CO_2 captured, less than four million tonnes total were captured between 2014 and February 2021.[48] At its best, it has recovered less than 75% of its target, with the majority of the captured carbon dioxide going towards enhanced oil recovery.[49] Indeed, the vast majority of projects globally are involved in enhanced oil recovery.[50]

But CCS "ha[s] a poor track record. . . . More than 80 percent of the 39 CCS projects attempted in the U.S. have ended in failure."[51] Even for CCUS projects that do start up, success is anything but guaranteed. "[M]ost CCUS projects initiated in the past three decades have failed."[52] As one commenter noted, "the bigger the project, more likely failure is."[53] Certainly, Chevron's Gorgon project in Australia seems to demonstrate that—the plant "was supposed to lock away 80 percent of Gorgon's gas field emissions over its first five years, a period that ended in July 2021. But at that point, the CCS facility, which only began operating two years ago, had captured just 5 million metric tons of CO_2."[54] The project has been criticized for receiving large subsidies and becoming clogged with sand.[55]

Kemper, the coal plant developed by Mississippi Power, also illustrates failure. Originally designed to gasify local lignite coal and remove 65% of the carbon dioxide for sale to a third party to use in enhanced oil recovery, the plant was estimated to cost $1.8 billion and be online by 2013.[56] Instead, the plant cost $7.5 billion, and equipment was still in need of costly repairs.[57] Hundreds of millions of dollars had to be

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47 Pritchard, *supra* note 41.

48 *Id.*

49 *Id.*

50 *See* Darrell Stonehouse & Deborah Jaremko, *A Look at the World's 21 Large-Scale Carbon Capture and Storage Projects*, JWN ENERGY (Mar. 10, 2017), https://perma.cc/R2CC-Z9C5 (listing sixteen out of twenty two projects as enhanced oil recovery with two projects in Norway, one in Algeria, one in Canada, one in Australia and one in the United States for sequestration only).

51 Jason Deign, *The Carbon Capture Project That Couldn't: Chevron Misses Target for its Huge Australia Facility*, CANARY MEDIA (Oct. 1, 2021), https://perma.cc/AU7M-5H2E.

52 Nan Wang et al., *What Went Wrong? Learning From Three Decades of Carbon Capture, Utilization and Sequestration (CCUS) Pilot and Demonstration Programs*, ENERGY POL'Y, Nov. 2021, at 1, 1.

53 David Roberts (@drvolts), TWITTER (Sept. 13, 2021, 11:20 AM), https://perma.cc/Q7K4-K8SM.

54 Deign, *supra* note 51. "By one analyst's calculations, it should have captured approximately another 4.6 million metric tons to meet its commitments, meaning it had a shortfall of around 48 percent." *Id.*

55 Lisa Cox, *Western Australia LNG Plant Faces Calls To Shut Down Until Faulty Carbon Capture System is Fixed*, GUARDIAN (Jan. 14, 2021), https://perma.cc/8NNL-VC2W.

56 Darren Samuelsohn, *Billions over Budget. Two Years after Deadline. What's Gone Wrong For the 'Clean Coal' Project That's Supposed to Save an Industry?*, POLITICO (May 26, 2015), https://perma.cc/M9V3-SWJN.

57 Robert Walton, *Cost Settlement for Failed $7.5B Kemper 'Clean Coal' Project Heads to Finish Line*, UTIL. DIVE (Jan. 24, 2018), https://perma.cc/4G6J-2NYD; Sharon Kelly, *How America's Clean Coal Dream Unravelled*, GUARDIAN (Mar. 2, 2018), https://perma.cc/PB2U-QBFB.

repaid to ratepayers,[58] the third party who never received any carbon dioxide for enhanced oil recovery operations sued for breach of contract,[59] the dome where coal was to be stockpiled started crumbling to the point that it had to be razed and rebuilt, and the coal gasifiers never worked (with cracks in multiple critical parts).[60] A whistleblower was illegally fired.[61] With escalating costs, Mississippi regulators decreed the plant to run as a combined-cycle natural gas plant, not capturing any carbon dioxide at all and having produced electricity from "coal for only about 100 hours."[62] As a final blow, the gasification part of the plant was recently imploded, at least physically erasing the evidence of failure.[63] A litany of failures, indeed.

2. Challenges

The non-legal challenges around CCS broadly fall into three categories: issues with site selection, challenges around measurement and verification, and infrastructure.

Responsible site selection is critical but difficult: "The degree to which a specific underground formation is amenable to CO_2 storage can be difficult to discern."[64] Site selection is important because carbon dioxide is "buoyant in the subsurface."[65] Carbon dioxide is not a liquid at

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[58] Samuelsohn, *supra* note 56; Ian Urbina, *Piles of Dirty Secrets behind a Model 'Clean Coal' Project*, N.Y. TIMES (July 5, 2016), https://perma.cc/LH8L-Q3TG.

[59] Kendra Ablaza, *Mississippi Power Sued for Kemper Plant Delays*, MISSISSIPPI TODAY (June 21, 2016), https://perma.cc/4M6N-WQAA.

[60] Kelly, *supra* note 57 ("The first hint of the real trouble for Kemper came on 15 December 2011 when meeting notes mention the discovery of small 'air bubble cracks' in the thick heat-resistant lining inside the power plant's twin hearts, its gasifiers – the units that convert coal into flammable gas in a feat of chemistry requiring temperatures over 1,800F and pressures higher than those at 1,500ft deep in the ocean. To keep that hellish heat and pressure inside, it was vital for the concrete-like insulation lining the steel tank walls to be solid. Then in February 2012, engineers discovered that the concrete lining inside the gasifer was suffering from 'explosive spalling' – laced with tiny pockets of moisture that turned to steam under high heat, causing the concrete shell to pop and crack – and no one could say what had caused the bubbling.").

[61] Urbina, *supra* note 58.

[62] Kelly, *supra* note 57; Walton, *supra* note 57.

[63] Kristi E. Swartz, *The Kemper Project Just Collapsed. What it Signifies for CCS*, E&E NEWS (Oct. 26, 2021), https://perma.cc/D64R-83KL. Additionally, "[t]he adjacent coal mine once intended to feed into the carbon capture system is now covered in grass and has trees starting to grow on top." *Id. See also*, Ian Urbina, *Piles of Dirty Secrets behind a Model 'Clean Coal' Project*, N.Y. TIMES (July 5, 2016), https://perma.cc/8BTR-K93E. ("In the end, the Kemper project is a story of how a monopoly utility, with political help from the Mississippi governor and from federal energy officials who pressured state regulators in letters to support the project, shifted the burden of one of the most expensive power plants ever built onto the shoulders of unwitting investors and some of the lowest-income ratepayers in the country.").

[64] *Carbon Sequestration: Storage*, *supra* note 16.

[65] Elizabeth J. Wilson et al., *Research for Deployment: Incorporating Risk, Regulation, and Liability for Carbon Capture and Sequestration*, 41 ENV'T SCI. TECH. 5945, 5945 (2007).

standard atmospheric temperature and pressure; it is a gas.[66] When liquified at high pressure and forced underground, it will continuously attempt to return to its gaseous state and find any lower pressure pathway that enables this transition.

"There is no empirical method to definitively prove the safety of very long-term CO_2 storage."[67] There are frequent references to the need for suitable site selection or responsible development to minimize the possible harm from CCS.[68] However, serious questions remain about "the geological validation of safe and secure long-term storage sites for CO_2. . . . This will require both high-level seismological assessments and case-by-case detailed surveys to understand the degree of heterogeneity among reservoirs."[69] Some have predicted low leakage risks at well-chosen locations;[70] however, the accuracy of such predictions relies on the ability to characterize different locations to determine suitability for site development and the availability of necessary information.

There are some material deficiencies in measuring and validating the effectiveness of geological sites to contain carbon dioxide. The first is simply the lack of accurate technology: the federal government is still attempting to develop technologies that can detect leakage rates of less than 5%. NETL concludes that the "[c]urrent on-the-ground measurements are accurate to within plus or minus 5-30 percent."[71] The reliability and measurement of leakage rates become more sharply focused when discussed with the corresponding volumes: "[A] 1,000 Megawatt power plant produces 4 to 6 million tons [of carbon dioxide] per year."[72] This rate corresponds to "1.5 billion tons of CO_2 produced from U.S. coal-fired power plants."[73] With an undetected 30% leakage rate possible with current measurement technology, and assuming a 90% capture rate at generation, this equates to a release of at least 405 million tons per year. Leaks from CCS injection sites could far outweigh the emission reductions achieved with capture technology, and no one will even realize that is occurring if there are no improvements in measurement and verification technology. Additionally, after injections have ceased, there are uncertainties surrounding not only dispersion and leakage but also with the properties of containment materials.

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[66] *See* Peter E. Liley et al., *Physical and Chemical Data*, *in* PERRY'S CHEMICAL ENGINEERS' HANDBOOK, *supra* note 6, at 2-12 (showing carbon dioxide has a sublimation point of -78.5°C).

[67] ABOOD ET AL., *supra* note 25, at 11. "Safety" in this context refers to the harms of "CO_2 leakage into the atmosphere or underground." *Id.*

[68] Benson, *supra* note 8 ("Well [s]elected and [m]anaged [s]ites [a]re the [k]ey to [s]uccess."); Wilson et al., *supra* note 65, at 5945–46 ("Deployment will require development of a comprehensive risk characterization and management strategy.").

[69] ABOOD ET AL., *supra* note 25, at 11.

[70] Benson, *supra* note 8.

[71] *Carbon Sequestration: Storage*, *supra* note 16. NETL concludes that measurement and verification capability is necessary to "ensure safe permanent storage." *Id.*

[72] Klass & Wilson, *supra* note 15, at 117.

[73] *Id.*

"Containment potential over hundreds of years is affected by unknowns and uncertainties, some of them currently hotly debated and with no available analogs – such as cement degradation rates."[74]

This is not good enough. Any carbon dioxide production will still create planetary issues from the amount not captured. Leakage in the short term will add more carbon dioxide to the atmosphere and continue to create planetary problems. Reliance on CCS will not delay climate change for long enough, or reduce it enough, to matter. Diffusing for ten years simply is not good enough. CCS—like hydrogen,[75] small modular reactors,[76] and coal gasification[77]—is just a delay tactic, and one that has been used to ensure continuing reliance on fossil fuels for decades.[78] Infinite delay and promise, with no success and no accountability. Squirrel!

There are also other infrastructure challenges:

> CO2 is corrosive and will eat through the carbon steel used in petroleum pipelines if contaminated with even small amounts of water, CO2 pipelines have to be manufactured to a higher standard and the purity of the gas carefully monitored. And research shows that CO2 from a commonly used carbon capture technique is particularly likely to have water in it. CO2 pipelines also run at significantly higher pressures than natural gas

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74 Claudia Vivalda et al., *Building CO2 Storage Risk Profiles with the Help of Quantitative Simulations*, 1 ENERGY PROCEDIA 2471, 2472 (2009).

75 GLOBAL WITNESS, HYDROGEN'S HIDDEN EMISSIONS 2 (2022). Of course, "[h]ydrogen's main selling point is that it emits no greenhouse gases at the point of consumption. But this only tells part of the story, as at present hydrogen is commonly produced from fossil gas, which causes high climate heating emissions." *Id.* The Shell Quest plant demonstrates this well. Designed to create hydrogen from natural gas and use CCS, the plant has "created *more* emissions in its five years of operation than it's captured." Molly Taft, *Shell CCS Plant Emits More Greenhouse Gases Than it's Captured*, GIZMODO (Jan. 21, 2022), https://perma.cc/LA2X-TQZK. "[T]he plant cost $1 billion to build, with more than $650 million of that money coming from Canadian government subsidies." *Id.* Just 48% of the plant's carbon emissions are captured, we found, falling woefully short of the 90% carbon capture rate promised by industry for fossil hydrogen projects. GLOBAL WITNESS, *supra*. This rate drops to only 39% when including other greenhouse gas emissions from Shell's project. *Id.*

76 Paul Brown, *Analysis: Small Modular Reactors are Decades Away. That Suits the Fossil Lobby Just Fine.*, ENERGY MIX (Dec. 1, 2021), https://perma.cc/7JE9-72RW ("Nor did campaigners at Glasgow miss the fact that Britain, Canada, and the United States, the three countries with most enthusiasm for small modular reactors, have something else in common: Their wish to go on extracting oil and gas that scientists say needs to be kept in the ground if the 1.5°C limit is not to be breached. Perhaps it is no coincidence that the fossil fuel lobby in all three countries is keen to support nuclear power as 'one of the answers to climate change.' Unlike renewables that can be deployed quickly, new nuclear power is decades away, providing breathing space for a dying industry to go on exploiting fossil fuels while nuclear power plants are built.").

77 Swartz, *supra* note 63.

78 Urbina, *supra* note 58 ("Carbon capture has been considered a holy grail for decades. For Ronald Reagan, it was a solution to acid rain; for Bill Clinton, an alternative to nuclear power. George W. Bush billed his FutureGen project as the world's first zero-emissions coal plant but mothballed it when it became too expensive.").

> pipelines, which in turn requires more energy-gobbling compressor stations along the line to keep the CO2 in a liquid state.[79]

C. Risks

Unfortunately, the risks to human health and the environment from ill-suited CCS sites have not been well quantified. Methods have been proposed for modeling these geologic systems and the risk of using them for storage,[80] but realistically the risk from each site will need to be individually calculated and determined. Additionally, much of the possible storage capacity in the United States is underneath inhabited land[81]—and, if a large buildout is to take place, pipelines will be developed in heavily populated areas.[82]

The failure modes associated with CCS are threefold: 1) failure can happen catastrophically with a large release; 2) failure can happen through migration in the subsurface; and 3) failure can happen with any slow escape. All three can lead to the sequestration being ineffective from a climate perspective, resulting in either no benefit or reduced benefits, along with additional harms.

1. Asphyxiation and Other Health Risks

Carbon dioxide is more dense than air[83] and thus collects at ground level. A carbon dioxide pipeline rupture like the one in Mississippi "sends CO2 gushing out in a dense, powdery white cloud that sinks to the ground and is cold enough to make steel so brittle it can be smashed with a sledgehammer."[84] This weight and the corresponding displacement of air enables harmful concentrations to exist until adequately dispersed by wind or other atmospheric conditions.[85] "A leak at a moment when there is no wind is the most dangerous because the vapor that forms as the

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[79] Zegart, *supra* note 1.

[80] Vivalda et al., *supra* note 74. Unfortunately, these models deal with slow leakages over time, either into the atmosphere or into groundwater; they do not take a catastrophic release into account.

[81] *See Carbon Sequestration: Storage*, *supra* note 16 (showing maps developed by NETL that demonstrate where saline formations, coal basins, and oil and gas reservoirs exist that could be used for CCS within North America).

[82] Zegart, *supra* note 1.

[83] The specific gravity of carbon dioxide is 1.53 with reference to air at a specific gravity of 1.0. The higher the number above 1.0, the more dense the gas. Liley et al., *supra* note 66.

[84] Zegart, *supra* note 1.

[85] *See, e.g.*, Louis Theodore et al., *Waste Management*, *in* PERRY'S CHEMICAL ENGINEERS' HANDBOOK, *supra* note 6, at 25-34 (discussing methods to calculate maximum ground level concentrations); Stanley M. Englund et al., *Process Safety*, *in* PERRY'S CHEMICAL ENGINEERS' HANDBOOK, *supra* note 6, at 26-78 (discussing parameters affecting gas dispersion); *see also id.* at 26-82 (demonstrating a continuous release example calculation). Dispersal models show how little gas needs to be released to affect a large geographic area. *Id.*

liquid evaporates won't disperse. It will gather in a cloud that grows until the leak stops or all the liquid spills."[86]

Topography is also important. Carbon dioxide released into valleys is especially dangerous to human and animal inhabitants, as the terrain will minimize the mechanical mixing of the carbon dioxide with air, increasing the dispersion time and distance required to regain a non-depleted level of oxygen.[87]

The effects of decreased oxygen on humans are well documented. The Occupational Safety and Health Administration recommends oxygen levels of between 19.5% and 23.5%.[88] As the level of oxygen in the atmosphere decreases and is replaced by carbon dioxide, the effects depend on the concentration. "Exposure to a 1% to 5% atmospheric CO_2 mixture can result in physical effects including increased breathing; loss of consciousness usually occurs from exposure to greater than 10% atmospheric CO_2; and most CO_2 concentrations above 30% are lethal."[89] One or two breaths of pure CO_2 can kill, as oxygen in the lungs is replaced with gas with no oxygen.[90] An intoxicating agent, carbon dioxide "causes the development of hypercapnia and respiratory acidosis" even at concentrations that do not kill immediately, "resulting in a depression of the respiration and the circulation."[91]

The possibility also exists that leakage could occur into confined spaces, like cellars and basements,[92] which might have more direct harmful effects on humans due to the confined space and the lack of adequate dispersion by natural airflow.[93] The fast onset of impacts from concentrated exposure—loss of consciousness can occur in seconds—rarely allows those exposed to act and save themselves.[94]

The CO_2 can also be contaminated with other compounds, making its impact on human health even worse. The gas cloud that the residents of Satartia experienced "[wa]s contaminated with hydrogen sulfide, a deadly

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[86] Will Englund, *Engineers Raise Alarms Over the Risk of Major Explosions at LNG Plants*, WASH. POST (June 3, 2021), https://perma.cc/AX2F-WX6E.

[87] *Volcanic Gases Can Be Harmful to Health, Vegetation and Infrastructure*, U.S. GEOLOGICAL SERV., https://perma.cc/S5JZ-VYVS (last visited Mar. 7, 2022).

[88] Englund et al., *supra* note 86, at 26-76.

[89] Victor B. Flatt, *Paving the Legal Path for Carbon Sequestration from Coal*, 19 DUKE ENV'T L. & POL'Y F. 211, 221 (2009).

[90] Englund et al., *supra* note 86, at 26-76 ("Within five seconds of inhaling only a few breaths of oxygen-free gas, there can be mental failure and coma. . . . Death follows in two to four minutes.").

[91] Kris Permentier et al., *Carbon Dioxide Poisoning: A Literature Review of an Often Forgotten Cause of Intoxication in the Emergency Department*, INT'L J. EMERGENCY MED., 2017, at 1, 2.

[92] Klaus S. Lackner & Sarah Brennan, *Envisioning Carbon Capture and Storage: Expanded Possibilities Due to Air Capture, Leakage Insurance, and C-14 Monitoring*, 96 CLIMATE CHANGE 357, 370 (2009).

[93] *See* Permentier et al. *supra* note 91, at 1 (reviewing harms associated with "confined space hypoxic syndrome" and CO_2 buildup).

[94] *Id.* at 2 ("CO_2 levels of more than 30% act rapidly leading to loss of consciousness in seconds. This would explain why victims of accidental intoxications often do not act to resolve the situation (open a door, etc.).").

gas that likely worsened residents' symptoms."[95] "CO2 is often contaminated with hydrogen sulfide [H2S], and . . . not only does H2S increase the corrosiveness of CO2, but it has serious health effects that can include damage to the nervous system, lungs, liver and heart."[96]

2. Climate Change

As noted above when characterizing the different formations that could host CCS, carbon dioxide is already in use in oil and gas fields to aid in enhanced oil recovery. However, the goal should be not to allow any of the carbon captured to escape again. We also will need to stop using liquid fossil fuels, so using carbon dioxide to aid in crude production is not moving us to a carbon-free future. As with coal bed seam storage, there is ample evidence that additional natural gas production is also not what would be useful for the planet.

Additionally, any leaks or ruptures of a carbon dioxide pipeline or storage location are bad for the climate. In at least one case, a carbon dioxide pipeline rupture "lasted for more than six weeks and contaminated the air with unsafe levels of both CO2 and methane."[97] As noted earlier, the scientific consensus is clear; we must reduce quickly and then completely eliminate our release of carbon dioxide and carbon dioxide equivalents. Saying that we are "solving" climate change by using CCS, only to have that carbon not sequestered but rather released into the atmosphere, is creating a far worse problem because we are deluding ourselves into thinking that more stringent actions do not need to be taken, that delaying a move away from fossil fuels and maintaining a habitable planet without intense suffering is possible. It is not.

3. Water Quality and Quantity

One of the main concerns around water quality in relation to CCS is the lack of geological mapping.[98] This is true even when dealing with depleted oil and gas reservoirs which have been more extensively mapped than either coal bed seams or saline aquifers.[99]

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95 Zegart, *supra* note 1.

96 *Id.*

97 *Id.*

98 J.J. DOOLEY ET AL. CARBON DIOXIDE CAPTURE AND GEOLOGIC STORAGE 26, 55 (2006) (noting that "[r]egulations must contain accepted protocols and standards for geologic site characterization and selection and for the safe and effective operations of CCS systems, including the frequency of measurement and monitoring for stored CO_2. Computer models and simulation tools will need to be developed and accepted by industry, regulators, and other stakeholders as valid means for qualifying prospective CO_2 storage sites and for predicting the movement of stored CO_2.").

99 *Id.* at 18 ("A key mechanism for storing CO_2 in deep geologic formations and ensuring that it stays there is a system of layered, deeply buried, permeable rock formations that serve as the CO_2 storage reservoir, overlain by impermeable caprocks which serve to keep the injected CO_2 in place. A thorough evaluation of these formations and their ability to accept and retain injected CO_2 must be an essential component of site assessment before

An extra consideration, especially with off-shore saline aquifer applications, is the possibility of pronounced acidification if a large release were to occur.[100] The average pH of the world's oceans has already decreased due to the natural equilibrium of carbon dioxide between the water and the atmosphere, and any releases would continue the acidification process.[101]

Around more traditional water quality issues, leaks could discharge into "drinking water aquifers or operational gas and oil reservoirs. This could occur via man-made potential leakage routes such as abandoned injection wells, adjacent drilling or undetected fractures in the rock formation due to seismic activity."[102] These fractures can occur when drilling the injection well or from previous wells driven into the same non-porous layer.[103]

Additionally, while there is research into whether carbon dioxide can be trapped by reaction within other layers of rock,[104] carbon dioxide can also have the opposite effect, eating away geologic features and enabling it to move farther from the injection point.[105] There is also the possibility that, if the depth of the geologic storage varies, someone might unwittingly drill into the storage strata.

On the water quantity front, "implementation of today's CO_2 capture technologies would significantly increase freshwater consumption by

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any CO_2 is injected."); *see generally* Hussein Hoteit et al., *Assessment of CO_2 Injectivity During Sequestration in Depleted Gas Reservoirs*, GEOSCIENCES, May 2019, at 1, 1 (discussing use of gas reservoirs for CCS due to reservoir characterization).

[100] ANDY CHADWICK ET AL., BEST PRACTICE FOR THE STORAGE OF CO_2 IN SALINE AQUIFERS 67 (2008). The pressure at the ocean floor bed presents both a positive and a negative. The positive is that, due to the higher pressure, carbon dioxide is easier to keep in its liquid form. Amy Coombs, *An Ocean Trap for Carbon Dioxide*, TECH. REV., (May 14, 2009), https://perma.cc/2D4F-TXFK. The negative is that monitoring and verification become more difficult; due to the water pressure, it is more challenging for instruments to accurately measure pressure differences, which is one of the ways that monitoring can verify that the liquid pressurized carbon dioxide is not being released.

[101] LENNY BERNSTEIN ET AL., INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2007: SYNTHESIS REPORT 52 (2008). *See also Ocean Acidification,* SMITHSONIAN INST., https://perma.cc/6XYD-JYC3 (last visited Mar. 9, 2022) (describing the science behind ocean acidification).

[102] ABOOD ET AL., *supra* note 25, at 11. Another issue that could become practically problematic is if "cracking" fluid has been previously pushed into these wells and continues to exist there. If so, there might be a possibility that these solutions will end up in drinking water aquifers as well, pushed there by the additional pressure of the injected CO_2. Also, this demonstrates that even well-done mapping does not disclose all locations into which solutions can seep, as cracking solutions migrated into ground water when, at least publicly, it was not expected to. *See also* JOEL B. EISEN ET AL., ENERGY, ECONOMICS AND THE ENVIRONMENT 201 (5th ed. 2020) (discussing how natural fractures can go undetected in underground operations and allow for a release).

[103] *See Carbon Sequestration: Storage*, *supra* note 16 (describing various geological formations that are generally drilled for resources—leaving the potential for manmade fractures—but can then serve as potentially ideal subsurface sequestration areas).

[104] *Id.*

[105] U.S. ENV'T PROT. AGENCY, EPA PROPOSES NEW REQUIREMENTS FOR GEOLOGIC SEQUESTRATION OF CARBON DIOXIDE, EPA 816-F-08-032, at 1 (2008).

fossil-based power plants."[106] "[U]sing current . . . technologies . . . would more than double the amount of water consumed per unit of electricity generated."[107] Water shortages are already shutting down fossil-fueled plants.[108] As the freshwater projections under realistic climate change scenarios demonstrate,[109] water will likely become more scarce in many of the locations where CCS may be utilized, leading to even more challenges for its use. Carbon dioxide also becomes corrosive with water present,[110] which may lead to unforeseen consequences for the geologic formations meant to encase the pressurized liquid carbon dioxide.[111]

4. Land Use, Soil Fertility, and Other Challenges

Other impacts on land use and soil fertility are also likely from the use of CCS. As farmers found, "land that Dakota Access trenched through to bury its pipeline continues to produce fewer bushels of corn and soybeans than before the pipeline."[112] With the potential buildout of carbon dioxide pipelines, some of those same farms may now be asked to house additional pipelines with likely similar results.[113] Decreased crop production is not part of our current conversation around the buildout of the "nearly 710 miles of pipeline" that would reach into more than 30% of Iowa counties for a pipeline network that would stretch more than 2000 miles across five agriculturally-significant states.[114] According to one farmer: "We're destroying thousands of acres of productive farmland that will eventually affect food security here in the United States."[115]

This also ignores significant environmental justice concerns that exist with the location of potential CCS installations.[116] Logically, potential storage locations closest to industrial facilities that emit the carbon dioxide would be used to minimize energy, transportation, and pipeline costs. But these same communities are the ones already overburdened by industrial pollution. The other air pollutants and toxics emitted by these plants will not go away just because the carbon dioxide is removed from the flue gas; these communities will continue to be overburdened. Adding another facility will only continue the injustice

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106 *Energy-Water Nexus: Hearing Before the Comm. On Energy & Nat. Res. U.S. S., 111th Cong.* 5 (2009) (statement of Carl O. Bauer, Director, National Energy Technology Laboratory).

107 *Id.* at 6.

108 Esther Whieldon & Taylor Kuykendall, *Climate Change Poses Big Water Risks for Nuclear, Fossil-Fueled Plants*, S&P GLOBAL (Oct. 21, 2020), https://perma.cc/64D9-RHRH.

109 BERNSTEIN ET AL., *supra* note 101, at 2, 11, 49.

110 U.S. ENV'T PROT. AGENCY, *supra* note 105.

111 *See, e.g.*, Vivalda et al., *supra* note 74, at 2472–74, 2477 (calculating CO_2 leakage rates and pathways from geological CO_2 storage).

112 Eller, *supra* note 46.

113 *Id.*

114 *Id.*

115 *Id.*

116 KATLYN SCHMITT ET AL., THE FALSE PROMISE OF CARBON CAPTURE AS A CLIMATE SOLUTION IN LOUISIANA AND BEYOND 3–5, 8 (2021).

that already exists. Moving completely off fossil fuels is the best way to remove the air pollution burden from these communities.[117]

III. COSTS AND IMPACTS ON CONSUMERS

Any development of CCS should be rightly viewed in relation to other options of achieving the same goal. Viewing broad decarbonization of the world economy as the goal leads to the question of whether the use of CCS to enable the continued burning of fossil fuels is the best way to achieve that goal. Given that CCS may only be applied to the burning of fossil fuels by stationary sources, its use is limited to specific applications. For example, the emissions from the use of fossil fuels for transportation, which accounts for 72% of petroleum and 3% of natural gas, would not be capable of being captured using CCS and would need to be decarbonized in a different way.[118]

A. Alternatives for Electricity Generation

Based on one estimate, CCS will add approximately three cents per kilowatt-hour (kWh) to the price of coal-based electricity.[119] And that is without considering any carbon price assessed on any released carbon that is either not captured originally or escapes from sequestration. While this calculation was not determined based on a particular liability scheme being adopted, what the electricity generation industry needs most is certainty on what the liability paradigm will be. "Unambiguous messages are certainly what the energy sector wants. . . . 'Business needs messages that have the long-term clarity needed to secure investment, loud enough to be heard across a wide variety of boardrooms and legally underpinned to create the new framework for delivery that will be needed.'"[120]

However, CCS would need to make financial sense. Looking at the current unweighted levelized cost, the Energy Information Administration (EIA) anticipates that the cheapest resources to bring online in 2026 will be solar, geothermal, and onshore wind, even without tax credits.[121] All three are predicted to be cheaper than any fossil-fueled

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[117] David Roberts, *Air Pollution is Much Worse than We Thought*, VOX (Aug. 12, 2020), https://perma.cc/W9QJ-4WN6.

[118] EISEN ET AL., *supra* note 102, at 3.

[119] This is based on a retrofitted pulverized coal plant at 85% capture efficiency. ABOOD ET AL., *supra* note 25, at 10. Other estimates put the increase at 40-80%. Richard K. Morse et al., *The Real Drivers of Carbon Capture and Storage in China and Implications for Climate Policy* 14 (Stanford Freeman Spogli Inst. For Int'l Studies., Working Paper No. 88, 2009).

[120] Roger Milne, *Heated Debate*, UTILITY WEEK, Dec. 4, 2009, at 16, 17 (quoting David Green) (on file with author).

[121] U.S. ENERGY INFO. ADMIN., LEVELIZED COSTS OF NEW GENERATION RESOURCES IN THE ANNUAL ENERGY OUTLOOK 2021 8 (2021) (giving a price of $32.78 per megawatt-hour (MWh) for solar, $36.40 for geothermal, and $36.93/MWh for onshore wind).

generator, even without CCS.[122] Factoring in current tax credits will make renewable resources even cheaper.[123]

Although the EIA did not evaluate the levelized cost of resources with CCS in their most recent report, it has in the past. In the 2019 Annual Energy Outlook, the EIA estimated costs for a coal plant with 30% CCS, a coal plant with 90% CCS, and an advanced natural gas combined cycle with CCS.[124] Including tax credits, these resources were estimated to cost $104.30 per megawatt-hour (MWh), $98.60/MWh, and $67.50/MWh, respectively.[125] These were all estimated to be significantly more than geothermal ($38.30/MWh), hydroelectric ($39.10/MWh), solar PV ($45.70/MWh), and onshore wind ($49.80/MWh).[126] And the costs for solar and wind continue to decrease. Even the most recent bids for offshore wind are comparable to estimates provided by the EIA of an advanced natural gas combined cycle with CCS—the levelized cost of US Wind's project off Ocean City, Maryland, is $54.17/MWh.[127] Other analyses, however, put the cost of CCS even higher.[128]

Importantly, at least some utilities have already concluded that combined-cycle natural gas units with CCS are not cost-competitive compared with other options.[129] The rapid cost declines of renewables completely erode the value of CCS.[130] There are no plans for any new coal plants in the United States. Utilities and regulators should acknowledge that renewable sources of energy are cheaper, especially if a carbon price exists at the market or federal level.

B. Costs to Ratepayers

There is no doubt that implementing CCS will make electricity production more expensive. There are substantial continuing efficiency penalties associated with CCS.[131] "Separation and compression of CO_2 are themselves both energy-intensive processes and result in more fuel being

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122 *Id.*

123 *Id.*

124 U.S. ENERGY INFO. ADMIN., LEVELIZED COST AND LEVELIZED AVOIDED COST OF NEW GENERATION RESOURCES IN THE ANNUAL ENERGY OUTLOOK 2019 8 (2019).

125 *Id.*

126 *Id.*

127 *See* Order at 151, Skipjack Offshore Energy, LLC and US Wind, Inc.'s Offshore Wind Applications (2021) (MD Order No. 90011) (showing price in 2012 dollars, which roughly equates to about $67.83/MWh today).

128 Mark Z. Jacobson (@mzjacobson), TWITTER (Nov. 25, 2021, 10:09 AM), https://perma.cc/3SBS-BN4F.

129 Ben Inskeep (@Ben_Inskeep), TWITTER (Oct. 27, 2021, 5:46 PM), https://perma.cc/DK5E-FACL.

130 Neil Grant et al., *Cost Reductions in Renewables Can Substantially Erode the Value of Carbon Capture and Storage in Mitigation Pathways*, 4 ONE EARTH 1588, 1589 (2021).

131 The thermal efficiency penalty ranges from 6% to 20%, depending on the estimates and assumptions used. INT'L ENERGY AGENCY, CO_2 CAPTURE AND STORAGE: A KEY CARBON ABATEMENT OPTION 45 (2008) (noting 6% to 12%); Morse et al., *supra* note 119, at 4 (noting 20%).

required to achieve the same energy output."[132] To satisfy this increased power demand, more electricity would have to be generated, probably using a fossil fuel that carbon also needs to be sequestered from.[133] The electricity used in the sequestration process would otherwise go onto the grid and to consumers,[134] making the electricity that they do receive more expensive.

Unlike renewable technologies, there are societal costs associated with burning fossil fuels that are not currently accounted for in rate comparisons. In addition to climate change impacts, this mainly includes increased health costs;[135] and these societal costs would not all go away with the implementation of CCS. Factoring in these additional costs would increase coal-generated electricity by an average of 3.2 cents per kWh and up to 12 cents per kWh for the most polluting plants.[136]

As noted above, the costs of CCS are prohibitive and unlikely to come down. As recently noted regarding CCS:

> i) it is currently a very small, low growth sector, ii) it has exhibited no promising cost improvements so far in its 50 year history, and iii) the cost of fossil fuels provides a hard lower bound on the cost of providing energy via fossil fuels with CCS. This means that within a few decades electricity produced with CCS will likely not be competitive even if CCS is free.[137]

But CCS is currently not free, and CCS has been found by at least one government entity to be "'currently inconceivable' without government support."[138] As the Kemper example showed, even when subsidized generally by taxpayers, utility customers can still be left picking up costs for failed projects for decades into the future.[139]

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132 ABOOD ET AL., *supra* note 25, at 10. Estimates range between 6% and 12% more electricity is needed when using CCS to produce the same amount of electricity for use on the grid, thereby requiring that much more coal and that much more carbon dioxide to be generated. *Id.*

133 Regardless of which fossil fuel this might be, there are environmental damages associated with its production. For example, if coal is coming from mountaintop removal mining then water quality, habitat, and recreation, among other things, are damaged. *See* MICHAEL SHNAYERSON, COAL RIVER, 291–92 (2008) (detailing the struggles of Joe Lovett to address the environmental and community damages from mountaintop removal coal mining).

134 Pritchard, *supra* note 41.

135 The total cost is estimated at $120 billion per year, mostly from air pollution. Matthew L. Wald, *Fossil Fuels' Hidden Cost Is in Billions, Study Says*, N.Y. TIMES (Oct. 19, 2009), https://perma.cc/2563-EEWC.

136 *Id.* Professor Victor Flatt has posited that clean air should be a right, an entitlement, with no grandfathered rights for those whose use "interferes with the air as right." Victor B. Flatt, *Let Us Drink Our Fill: The History of Water and Its Impact on Resource and Environmental Management*, 18 YALE J. L. & HUMAN. 122, 131 (2006).

137 Rupert Way et al., *Empirically Grounded Technology Forecasts and the Energy Transition* 9 (University of Oxford, Inst. for New Econ. Thinking, Working Paper No. 2021-01, 2021).

138 Deign, *supra* note 51.

139 *See supra* text accompanying notes 57–63.

The proposed Build Back Better Act included an additional tax credit for CCS that, on top of the existing 45Q tax credit, would result in an $85/ton credit,[140] making current coal plants with CCS much cheaper to operate. However, this credit would exact a horrible cost from ratepayers. One analysis found "a 1,000 MW coal plant with CCS pegged at $85/ton would consume nearly $7 billion in taxpayer dollars, and have a net capacity of just 660 MW."[141] The tax credit would enable the plant to bid a negative price into the market, enabling it to constantly run while continuing to pollute.[142] Since the existing 45Q credit is a production tax credit, "[t]he more you burn, the more you earn."[143] This would incent continued fossil fuel development without minimizing emissions—with taxpayers potentially paying as much as $30 billion in the short term.[144] This is on top of the hundreds of millions of dollars that taxpayers have already squandered on CCS.[145] Setting the appropriate liability scheme can ensure whether that investment does as intended and permanently sequesters carbon, or whether it puts in motion actions that taxpayers will have to pay more to clean up later.

C. Industrial Processes

CCS is often touted as "a solution for [decarbonizing] hard-to-abate sectors such as cement, steel, and chemicals manufacturing, which have limited other options for reduction."[146] However, this projection is turning out to be incorrect.

Rather than count on CCS, steel plants are using hydrogen made from renewable energy.[147] Fertilizer is being produced just from water,

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[140] Nicole Pollack, *Carbon Capture May Not be Coal's Savior. But it Could Spawn an Industry All its Own.*, CASPER STAR TRIB. (Nov. 21, 2021), https://perma.cc/94BG-FHDB.

[141] Jeremy Fisher (@j_I_Fisher), TWITTER (Oct. 15, 2021, 3:11 PM), https://perma.cc/Q8AP-ACCM.

[142] *See* Joshua Rhodes, *The New Federal Carbon Credits Might Bring Back *Some* Coal*, FORBES (Mar. 9, 2018), https://perma.cc/K5VJ-LC9N (explaining how tax credits reduce the marginal cost of electricity that is used to bid into wholesale markets and how these negative bids ensure that coal plants with CCS clear the market and run more often).

[143] Jeremy Fisher (@j_I_Fisher), TWITTER (Oct. 15, 2021, 5:27 PM), https://perma.cc/542T-ZK64.

[144] Jeremy Fisher (@j_I_Fisher), TWITTER (Oct. 16, 2021, 12:16 PM), https://perma.cc/5GBN-838U; *see* Mitchell Beer, *New Carbon Capture Tax Credit Would Drive Higher Emissions, Could Mislead Investors*, ENERGY MIX (Dec. 29, 2021), https://perma.cc/382Y-TW5X ("The economics of those failing power plants, coupled with a volume-based tax credit that pays up to US$50 per tonne for any carbon an operator can capture, turn Section 45Q into an incentive to burn and emit more carbon, not less.").

[145] Jeff St. John, *US Government Squandered Hundreds of Millions on 'Clean Coal' Pipe Dream*, CANARY MEDIA (Jan. 5, 2022), https://perma.cc/J6TY-3RLC.

[146] Pritchard, *supra* note 41.

[147] Christian Roselund, *Green Steel Is Picking up Steam in Europe*, CANARY MEDIA (June 23, 2021), https://perma.cc/5FFZ-73AK. *See also Building Demand for Net Zero Steel*, CLIMATE GRP. STEELZERO, https://perma.cc/YF5W-B9MV (last visited Feb. 22, 2022) ("SteelZero is a global initiative that brings together leading organisations to speed up the transition to a net zero steel industry.").

renewable energy, and air.[148] Maritime transport is being addressed, mainly due to a push by large retailers.[149] Trucking is finding electrification solutions.[150] Industrial decarbonization is occurring using technologies that are cheaper than CCS.[151]

IV. LIABILITY, MORAL HAZARD, AND LESSONS FROM PRICE-ANDERSON

Regardless of whether utilized for electricity generation or in industrial processes, "[i]f the private sector won't invest in the technology unless construction and accident liability shifts to the public, including through excessive subsidies, it sends a strong signal not to approve these projects."[152] Based on the risks and costs discussed above, there is a need for CCS operators to be accountable when releases happen, regardless of which type of release (catastrophic or slow) or who or what is harmed. Therefore, one of the goals of the liability scheme that is chosen should be to ensure that only locations best suited for long-term storage (based on geology and geography) are developed and that use of the technology is minimized.[153]

A. Potential Liability Paradigms

Six possible liability paradigms could determine liability for a CCS release: 1) negligence; 2) trespass; 3) nuisance; 4) the Environmental Protection Agency's (EPA's) Underground Injection Permit program; 5) a

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148 Pique (@PiqueAction), TWITTER (Oct. 26, 2021, 6:59 AM), https://perma.cc/2DMM-ULYM.

149 *Major Companies Commit to Zero-Carbon Fueled Vessels by 2040, Sending Clear Market Signal to Fuel Producers*, CLEAN AIR TASK FORCE (Oct. 19, 2021), https://perma.cc/CHW6-2R9C; *see* Maria Gallucci, *Sailing into 2022 with Wind-Powered Cargo Ships*, CANARY MEDIA (Jan. 3, 2022), https://perma.cc/85H2-DD4D (explaining green shipping measures different shipping companies are implementing in 2022).

150 Jeff St. Johns, *Electric Trucks Could Handle Millions of Short-Haul Routes Across North America*, CANARY MEDIA (Sept. 23, 2021), https://perma.cc/6M8X-YZYM.

151 Julian Spector, *2021: When the Hard Climate Stuff Started Looking Doable*, CANARY MEDIA (Dec. 20, 2021), https://perma.cc/78N7-9NUD.

152 Grant Smith, *Energy Equity: Reforming Utilities' Business Plans by Rebalancing Ratepayers' Financial Risks*, UTIL. DIVE (Sept. 7, 2021), https://perma.cc/Y9Q5-3HUG.

153 Another issue, not discussed in this Article, is the ability of the federal government to make leases for the time periods that CCS requires. It has been acknowledged that the effect of CCS will be "using the subsurface property in perpetuity." Klass & Wilson, *supra* note 15, at 108. Many of the locations suitable are owned by the federal government, or the federal government owns and controls the subsurface rights. For most fossil-fuel exploration or extraction activities, the work takes place under a long-term lease. This would be a challenge for CCS, as the federal government would essentially be selling a long-term lease meant to exist into perpetuity. It would therefore be difficult to call this a lease and handle it the same way; the subsurface rights would need to be sold, as it is envisioned as the citizens should never make use of that land. Using a lease mechanism might also be more of a challenge for liability reasons, also not discussed, because the federal government would maintain an ownership right in the property. This is also an issue when dealing with off-shore storage, especially within the 200-mile Exclusive Economic Zone.

liability cap, similar to Price-Anderson; and 6) strict liability. Like the oil that once was in the most likely CCS locations, "CO_2 is a 'fugitive' substance," and "it will naturally migrate throughout the pore space."[154] Dispersion will therefore be critical, from a legal perspective as well as a practical one.

1. Negligence

"In order to prove a negligence claim, a plaintiff would have to prove four elements: duty, breach, causation, and damages."[155] Typically that duty will arise from a requirement "to conform to a certain standard of conduct, for the protection of others against unreasonable risks."[156] The standard of duty is based on a reasonably prudent person with the same knowledge; a duty arises when a reasonably prudent person would foresee the harm and would avoid the conduct that creates the risk.[157] Obviously, the harm associated with CCS is foreseeable; the question of duty then becomes whether a reasonably prudent person would avoid the conduct that creates the risk. For negligence, this essentially becomes a balancing test. "As the gravity of the possible harm increases, the apparent likelihood of its occurrence need be correspondingly less to generate a duty of precaution. Against this probability, and gravity, of the risk, must be balanced in every case the utility of the type of conduct in question."[158] Given the gravity of global climate change,[159] it is likely that those who support CCS will stress the utility of CCS and, therefore, will attempt to show that no duty exists above what all operators in the area are doing to provide for the general public health and welfare.[160] So even while life is more important than property and CCS operators are operating their sites to make money, using a negligence cause of action may lead to the determination that many of the harms are either unforeseeable with sufficient exactness or the utility of the conduct is sufficiently great enough that no duty exists.

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[154] Flatt, *supra* note 15, at 221.

[155] *Id.* at 222.

[156] W. PAGE KEETON ET AL., PROSSER AND KEETON ON THE LAW OF TORTS 164 (5th ed. 1984).

[157] *Id.* at 169.

[158] *Id.* at 171.

[159] BERNSTEIN ET AL., *supra* note 101, at 7–8.

[160] As long as some basic standards are met in terms of safety devices or monitoring, there would be no liability. This follows the general rule that manuals and proof of general custom are admissible as they tend to establish a standard by which ordinary care may be judged; and even though these do not replace the reasonably prudent person standard of care, a jury will likely have little other experience with CCS on which to base a judgment. This mimics the rule for doctors—customary practice—or the professional standard, which applies to other professional groups. DAN B. DOBBS & PAUL T. HAYDEN, TORTS AND COMPENSATION: PERSONAL ACCOUNTABILITY AND SOCIAL RESPONSIBILITY FOR INJURY 396–97 (5th ed. 2005) (discussing rule for customary practice).

Even if the injured plaintiff gets a determination that a duty does exist, a breach of the duty must also be proven.[161] For a breach to have taken place, specific actions must be found to be unreasonable.[162] Again, this could be difficult based on the state of technology or the specific foreseeability of the incident.

Causation has two elements: 1) actual causation and 2) proximate causation.[163] Actual causation may also be difficult to prove, depending on the harm caused. If the area has a number of CCS injection points with different operators, it may be impossible to determine which injection site caused the problem, especially without extensive underground mapping. Also, if the harm is a problem that can occur with either active oil and gas drilling or CCS injection,[164] it may be impossible to determine which activity, and therefore which actors, caused the harm. While joint and several liability may exist for indivisible harms, causation must be proven for each of these actors in the absence of statutorily derived liability.[165] Proximate causation may also be difficult to prove, as proximate cause again requires foreseeability of the specific harm, where the risk that led to the finding of a breach of duty is the same risk that led to the plaintiff's injury.[166]

"Damages could be in the form of either property damage or damage to plaintiff's health."[167] However, as the consequences of the negligence are likely to be considered permanent, the plaintiff would have only one

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161 *Id.* at 114.

162 *Id.*

163 *Tort Law: Causation*, Law.Jrank.org, https://perma.cc/GJL2-DV82 (last visited May 1, 2022).

164 One example would be drinking water contaminated with fracturing fluid. If there are active extractions taking place in the area, fracturing fluid might have migrated from there; however, it might also have existed in the CCS injection location and simply have been pushed into other areas where it then contacted drinking water based on the flow of carbon dioxide pushing into the pore space.

165 An example of this statutorily derived liability without true actual causation is the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). 42 U.S.C. § 9607(a) (2006). CERCLA requires three conditions for liability:

> 1. That there has been a release or threatened release of a hazardous substance from a facility; 2. That the government or other authorized party incurred response costs because of the release or threatened release; and 3. That the party being sued falls into one of the four classes of P[otentially Responsible Partie]s under § 107.

CRAIG N. JOHNSTON ET AL., LEGAL PROTECTION OF THE ENVIRONMENT 680 (4th ed. 2018). The four factors needed for a generator to be liable are that the generator "has (1) disposed of its hazardous substances (2) at a facility which now contains hazardous substances of the sort disposed of by the generator (3) if there is a release of that or some other type of hazardous substance (4) which causes the incurrence of response costs." U.S. v. Wade, 577 F. Supp. 1326, 1333 (E.D. Pa. 1983).

166 DOBBS & HAYDEN, *supra* note 160, at 234 ("Even when the defendant was negligent and in fact caused harm to the plaintiff, courts refused to impose liability when the harm actually resulting was not the kind of harm that led to a finding of negligence in the first place.").

167 Flatt, *supra* note 15, at 222.

possible chance at proving all damages.[168] Given the fugitive nature of carbon dioxide, it is certainly possible that later damages on the same property might become apparent, either in the form of environmental damage or damage to human health, which would then not be recoverable. Additionally, proving the value of environmental damage or damage to the property is likely to be seriously contested, and lengthy judicial proceedings will be advantageous to those accused of the environmental or property harm, leaving the real possibility that those harmed will not receive adequate compensation for the harm caused.

Another issue with relying on negligence as the primary liability scheme for CCS-caused harms is that negligence damages must be at least in part based on pecuniary harm.[169] Therefore, even with gross negligence, there would be no monetary reward for emotional distress or harm if that anguish was not attached to either property damage or a quantifiable damage to human health that could be the basis for a claim.[170]

However, even when punitive damages are awarded in conjunction with quantifiable damage to property or human health, extended litigation allows the harm to go uncompensated for an extended period, even if the plaintiff finally prevails.[171] A negligence cause of action

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[168] A CCS property claim for pore space occupied below ground would likely be considered permanent, as it is unlikely that the invasion could be terminated. Even if all CO_2 injection was stopped, as CO_2 is a fugitive emission, it will move into the remaining pore space. The cost of termination might also be considered oppressive, and depending on the state of global climate change, there might be a public policy that favors continuing contamination and essentially granting the right to continue the invasion for one set amount. The landowner would then be barred from suits for future damages by res judicata. *See* CHARLES ALAN WRIGHT & ARTHUR R. MILLER, FEDERAL PRACTICE AND PROCEDURE § 4402 (3d ed. 2021) (explaining how claims can be prevented from being re-litigated through the doctrine of res judicata).

[169] *See* Mariia Synytska, *Suing for Emotional Distress*, LAWRINA (Sept. 14, 2021), https://perma.cc/9AMV-LSVU (noting that most states require physical harm to bring a case for non-pecuniary harm like emotional distress).

[170] *See id.* (noting the need for some of measurable harm).

[171] The case of the Exxon Valdez is a prime example where there was obviously a duty: broadly, not to harm the environment, as that would cause economic harm to those who depend upon the environment; more narrowly defined, to ensure a single-hull supertanker was not under the command of a "lapsed alcoholic." Exxon Shipping Co. v. Baker, 128 S. Ct. 2605, 2638 (2008) (Stevens, J., dissenting). A breach of that duty (running aground, allowing the oil spill), causation (there was no other location that crude oil was coming from in Price William Sound, both actual and proximate cause was proven), and damages (to property, subsidence fishing, commercial fishing, marine mammals and birds) were also present. The Exxon Valdez spilled a minimum of 10.8 million gallons of crude oil into the water on March 24, 1989. *Exxon Valdez*, WIKIPEDIA, https://perma.cc/4LKP-DJL3 (last visited Feb. 18, 2022). Exxon was sued by 38,000 people claiming harm. *Id.* Unfortunately, 6,000 of those harmed died before the 2008 Supreme Court decision. Robert Barnes, *Finally Closure in Exxon Oil Spill Case?*, NBC NEWS (Feb. 24, 2008), https://perma.cc/466U-SBT9. The jury awarded $287 million for actual damages and $5 billion for punitive damages (equal to Exxon's profit for one year at the time). *Exxon Valdez*, WIKIPEDIA, https://perma.cc/4LKP-DJL3 (last visited Feb. 18, 2022). That was 1994. *Id.* By 2002, the punitive damages were reduced to $4 billion. After more appeals by Exxon, punitive damages were reduced to $2.5

therefore does not work to dissuade irresponsible behavior in certain cases, *i.e.*, when an actor has a profit motive as an incentive.[172] Negligence also does not truly compensate non-pecuniary harms caused by those activities in the same cases.[173]

The statute of limitations also creates a challenge for negligence claims, as the statute of limitations starts running as soon as the injury occurs; there is no tolling for not discovering the injury unless that specific jurisdiction follows the discovery doctrine.[174] While the injury may be classified as carbon dioxide moving into the pore space beneath a home, it is likely difficult for the homeowner to identify this injury until after the statute of limitations has run.[175] Additionally, because CCS is projected to store CO_2 underground "for hundreds to thousands of years,"[176] the original corporate entity that would have been liable might no longer be around or may be judgment proof due to bankruptcy or merger.[177]

billion in 2006. Exxon then took the case to the Supreme Court, where the punitive damages were reduced to $500 million in 2008. So 19 years later, the punitive damages in a clear case of negligence where a jury had made an award were reduced by 90%; Exxon's profit, meanwhile, increased from $5 billion per year in 1994 to $45 billion per year in 2008. Steve Hargreaves, *Exxon 2008 Profit: A Record $45 Billion*, CNN MONEY (Jan. 30, 2009), https://perma.cc/D3V3-JH3U. Therefore, paying the entire punitive damage claim would have been 11.1% of one year's profits; instead, those harmed have waited 19 years for one-tenth of what a jury thought was appropriate, with commensurate increases in legal fees for the length of time involved.

172 David E. Adelman & Ian J. Duncan, *The Limits in Promoting Safe Geologic Sequestration of CO2*, 22 DUKE ENV'T L. & POL'Y F. 1, 6, 37 (2011). If an actor with a profit motive acting negligently can make more than any actual harm plus the cap for non-pecuniary damages that exist in that jurisdiction, a rational financial actor would do so.

173 *See* Barnes, *supra* note 171 (noting that 6,000 plaintiffs died between the negligent accident and final resolution of the case). Lack of adequate compensation for non-pecuniary harms is especially true where caps have been legislatively mandated. *See* JOHN FLEMING, THE LAW OF TORTS 278, 280 (10th ed. 2011) (discussing limits and caps on non-pecuniary damages).

174 DOBBS & HAYDEN, *supra* note 160, at 320. Additionally, the discovery doctrine also requires "reasonable inquiry" in most cases; this could further bar claims even if the discovery doctrine is followed in a particular jurisdiction. *Id.* at 323. Limiting liability further, some states have also passed generally applicable statutes of repose. Mark Anthony de Figueiredo, The Liability of Carbon Dioxide Storage 52 (Jan. 12, 2007) (unpublished Ph.D. dissertation, Massachusetts Institute of Technology), https://perma.cc/JED3-YZDG. These ensure that the time limitations start "run[ning] at the conclusion of the defendant's activities which gave rise to the injury. Thus a plaintiff's cause of action could potentially be time-barred by a statute of repose before the injury has even been suffered." *Id.*

175 *See, e.g.*, N.C. GEN. STAT. § 1-52(16) (2019) ("Within three years an action . . . for personal injury or physical damage to claimant's property, the cause of action . . . shall not accrue until bodily harm to the claimant or physical damage to his property becomes apparent or ought reasonably to have become apparent to the claimant, whichever event first occurs.").

176 Klass & Wilson, *supra* note 15, at 107.

177 Various bankruptcy proceedings or mergers could be used to strand liabilities while moving assets to going concerns. While these might end up being deemed fraudulent, given the time periods under discussion, it is unlikely that they would be reversed. THOMAS LEE HAZEN & JERRY W. MARKHAM, CORPORATIONS AND OTHER BUSINESS ENTERPRISES: CASES

2. Trespass

Trespass on land is an intentional tort, and therefore requires an intent to commit the action which causes the harm.[178] To demonstrate intent, either purpose or substantial certainty must be shown.[179]

Damages must also be shown.[180] Damages from carbon dioxide moving into the pore space would typically be that the invading carbon dioxide "prevented . . . use of that pore space."[181] However, unlike negligence, trespass only applies to property damage; it does not cover human health damages.[182] "The remedy for trespass is usually an injunction, payment for the loss of property value, and/or costs of restoration."[183] However, each of these has specific problems when applied to CCS. First, if the carbon dioxide is moving throughout the pore space where the operator did not intend or expect, it is unlikely for a court to grant an injunction because to remedy the harm, the court would have to order the CCS operator to remove all carbon dioxide already injected. While a court might order no additional carbon dioxide injected until a measure is found that would stop the fugitive carbon dioxide from moving into that pore space, this will not compensate for the damage caused. Second, as noted in Part IV.A.1, payment of the lost property value can be problematic and highly contentious, with extensive judicial proceedings. Last, restoration is also not a practical solution as this would require the removal of the carbon dioxide; again, unlikely, especially as the world works to reduce the amount of carbon dioxide being released; the carbon dioxide removed for the "restoration" would go into one of two locations: either the atmosphere or another CCS location.

As with most torts, damages for trespass claims do not generally include mental or emotional distress unless there is proven pecuniary damage.[184] "[P]unitive damages may be awarded if the trespass is

AND MATERIALS 172 (2d ed. 2009) (discussing fraudulent conveyance laws). Additionally, insurance companies rely on the statute of limitations and/or statutes of repose to gain certainty for potential losses. Anthony de Figueiredo, *supra* note 174, at 53. Therefore, even if insurance had been purchased originally for the CCS injection site, insurers may assert that the claim is time-barred.

178 DOBBS & HAYDEN, *supra* note 160, at 68.

179 *Id.*

180 *Id.* at 69.

181 Flatt, *supra* note 15, at 223; *see also* Anthony de Figueiredo, *supra* note 174, at 55 (explaining that a trespass cause of action can result from migrating CO_2 in subsurface property if the plaintiff can show that the unauthorized entry of the defendant's CO_2 resulted in harm in the form of loss of use of subsurface space).

182 STEVEN N. GEISE & HOLLIS R. PETERSON, TOXIC TRESPASS: LEAD US NOT INTO LITIGATION 8 (2009); DOBBS & HAYDEN, *supra* note 160, at 68.

183 Flatt, *supra* note 15, at 223.

184 DOBBS & HAYDEN, *supra* note 160, at 69.

deliberate or 'malicious.'"[185] Proving deliberate or malicious intent can be difficult and requires truly egregious conduct.[186]

Additionally, as with negligence, the statute of limitations may bar claims, depending on when the trespass was discovered and if it could be ascertained when it started.[187] The statute of limitations starts running at the time of the trespass, so if it continues without being noticed, the date of discovery is not important so long as the jurisdiction does not follow the discovery doctrine.[188] Additionally, the same issues with mergers and bankruptcy limiting liability would be present.[189]

And finally, depending on the depth of the pore space infiltrated, a court may find no cause of action whatsoever—instead determining that the surface property owner has no (or very limited) ownership interest.[190] If that is the case, then no trespass action can be found.

3. Nuisance

Nuisance claims must be based on a substantial interference with the reasonable use of property.[191] While carbon dioxide moving in the pore space may be a nuisance if it interferes with something else in the subsurface,[192] the nuisance may be larger than just what occurs in the subsurface. The interference must reach the level of a substantial and unreasonable invasion to qualify as a nuisance.[193] For the policy reasons listed in Part IV.A.1, courts might not find migrating carbon dioxide a substantial and unreasonable invasion and therefore rule that no nuisance exists. Depending on the state, the state will apply either the gravity of the harm test, looking purely at the impact to the reasonable, expected use of the land or the Restatement, which balances the utility and the harm to determine whether a nuisance exists.[194]

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185 *Id.*

186 *Id.* Malicious behavior has been demonstrated when the defendant used a plaintiff's property after the plaintiff had refused permission. Jacque v. Steenberg Homes, Inc., 563 N.W.2d 154, 156 (Wis. 1997).

187 The statute of limitations for trespass actions in North Carolina, for example, is three years. N.C. GEN. STAT. § 1-52(3) (2019). "When the trespass is a continuing one, the action shall be commenced within three years from the original trespass, and not thereafter." *Id.*

188 DOBBS & HAYDEN, *supra* note 160, at 320, 323.

189 *See supra* text accompanying note 177.

190 *See e.g.*, Chance v. BP Chems., Inc., 670 N.E.2d 985, 992 (Ohio 1996) (holding that "property owner[s] must accept some limitations on . . . subsurface [ownership] rights").

191 DOBBS & HAYDEN, *supra* note 160, at 672–74.

192 Mark Anthony de Figueiredo gives the example of saltwater contaminating a well and how this could be analogized to carbonation of well water. Anthony de Figueiredo, *supra* note 174, at 56.

193 KEETON ET AL., *supra* note 156, at 629. Carbon dioxide would likely be classified as an intangible nuisance for surface nuisance claims, as it is most analogous to historical intangibles such as odors, music, and light.

194 *See, e.g.*, Boomer v. Atlantic Cement Co., 257 N.E.2d 870, 872 (N.Y. 1970) (applying the gravity of the harm test); RESTATEMENT (SECOND) OF TORTS § 826 (AM. L. INST. 1977).

If a nuisance is determined to exist, the remedies for property damage available are often similar to those for trespass.[195] However, as discussed in Part IV.A.2, none of those remedies are suitable for dealing with carbon dioxide. Unlike trespass, the harm in a nuisance claim of action could either be to health or property.[196] As with strict liability, "even lawful operations that result in harm . . . can be enjoined or subject to damages."[197] This might allow nuisance to serve an important function without another liability paradigm being statutorily imposed; however, causation and the balance between the harm and the utility of CCS storage to the planet may limit its effectiveness.[198]

As with negligence and trespass, the statute of limitations may also prove a difficulty for recovery of damages in a nuisance cause of action.[199] Additionally, the same issues with mergers and bankruptcy limiting liability would be present.[200]

4. Underground Injection Permit Program

EPA adopted a rule which regulates CCS through the Underground Injection Permit program,[201] as CCS injection meets the definition of underground injection.[202] The Underground Injection Permit program regulates the construction, operation, permitting, and closure of injection wells.[203] The goal is to protect underground drinking water supplies; a new class of well (Class VI) was developed for CCS.[204] This rule modifies the rules for underground injection specifically for CCS, including attempting to ensure that CCS only takes place in appropriate locations.[205]

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[195] Flatt, *supra* note 15, at 223.

[196] *See, e.g.*, Thomsen v. Greve, 550 N.W.2d 49, 55 (Neb. Ct. App. 1996) ("We have no trouble concluding that . . . to have the use and enjoyment of one's home interfered with by smoke, odor, and similar attacks upon one's senses is a serious harm.").

[197] Klass & Wilson, *supra* note 15, at 139.

[198] *See id.* at 140–41 ("Even if a nuisance claim for such harm is possible . . . most courts would balance carefully the benefits of CCS and CO_2 storage against the nature of the harm before finding either that a nuisance exists or determining the appropriate remedy for the nuisance.").

[199] In North Carolina, the statute of limitations for nuisance is the same as trespass. James v. Clark, 454 S.E.2d 826, 830 (N.C. Ct. App. 1995). This would set the statute of limitations at three years. *See* N.C. GEN. STAT. § 1-52(3) (2019) (establishing that an action for trespass must commence within three years).

[200] *See supra* text accompanying note 177.

[201] 40 C.F.R. §§ 146.81–146.95 (2020); *see Class VI - Wells Used for Geologic Sequestration of Carbon Dioxide*, U.S. ENV'T PROT. AGENCY, https://perma.cc/R3A9-B6B4 (last visited Feb. 20, 2022) ("In December 2010, EPA published the Federal Requirements Under the Underground Injection Control (UIC) Program for Carbon Dioxide.").

[202] *See* Safe Drinking Water Act, 42 U.S.C. § 300h(d)(1) (2018) (defining "underground injection" as "the subsurface emplacement of fluids by well injection").

[203] 40 C.F.R. §§ 146.81, 146.82, 146.86, 146.93.

[204] U.S. ENV'T PROT. AGENCY, *supra* note 105, at 2.

[205] *Id.* The full list of factors includes:

- Geologic site characterization to ensure that GS wells are appropriately sited;

CCS operators should ensure compliance with the financial responsibilities, including using trust funds, letters of credit, surety bonds, insurance, self-insurance, or an escrow account.[206] While these are similar to the types of financial instruments used now to ensure that underground injection well operators do not pollute groundwater (or have the financial resources available if a clean-up is required), self-bonding has proved problematic in other instances such as coal mining, where companies using self-bonding for reclamation costs have gone bankrupt and little if anything is left for environmental clean-ups.[207] Abandoned oil and gas wells also provide an idea for how these types of regulations have failed in the past—a recent analysis found "that there are 81,283 documented orphan wells across the country that were drilled and then improperly abandoned by oil and gas companies."[208]

Even acknowledging the issues with financial mechanisms, one of the largest challenges with this paradigm is the closure mechanism and post-closure liability. Currently, after a set period, as long as the closure procedures determined by EPA are followed, liability transfers from the operator of the underground injection well to the federal government.[209] It has been suggested that possible federal involvement in compensating for harms could be mitigated by "a post-closure care program of graduated responsibility" implemented in two phases: operator liability for a set period of time, followed by a third party public or private organization

- Requirements to construct wells with injectate-compatible materials and in a manner that prevents fluid movement into unintended zones;
- Periodic re-evaluation of the area of review around the injection well to incorporate monitoring and operational data and verify that the CO_2 is moving as predicted within the subsurface;
- Testing of the mechanical integrity of the injection well, ground water monitoring, and tracking of the location of the injected CO_2 to ensure protection of underground sources of drinking water;
- Extended post-injection monitoring and site care to track the location of the injected CO_2 and monitor subsurface pressures; and
- Financial responsibility requirements to assure that funds will be available for well plugging, site care, closure, and emergency remedial response.

Id.

206 40 C.F.R. § 146.85(a)(1); *see* Klass & Wilson, *supra* note 15, at 160–62 (discussing the mixed success of using bonds with CCS projects).

207 Dylan Brown, *Mine Cleanup Concerns Spike as Industry Sputters*, E&E NEWS: GREENWIRE (Mar. 1, 2016), https://perma.cc/W67Y-7SKX; *see* Jason Deign, *Will the Dying Coal Industry Leave its Mess for Others to Clean Up?*, CANARY MEDIA (May 19, 2021), https://perma.cc/74VB-KQH4 (stating that allowing self-bonding created little regulatory oversight and likely led to underfunding).

208 Maxine Joselow, *Abandoned Wells are a Huge Climate Problem*, WASH. POST. (Oct. 15, 2021), https://perma.cc/UYA5-LTRQ.

209 "[I]n the vast majority of cases no long-term monitoring is required and the bond is released upon well closure." Klass & Wilson, *supra* note 15, at 162.

tasked with stewardship and remediation.[210] The funding of the third party would be covered by pooled funds from operators.[211]

CCS locations will require long-term stewardship—and allowing the ownership of these locations to transfer to a third party with limited funding to monitor and remediate in perpetuity without any further operator liability could lead to the development of ill-suited locations when leakages would not occur until after the first post-closure period. This could lead to either the federal government directly compensating for harms or infusing the third party stewardship provider with funding. As with the liability cap, the federal government, and through it the taxpayers, might be left paying for any large accident that occurs. It is precisely the need for perpetual stewardship of CCS injection locations that requires long-term liability. The same issues with mergers and bankruptcy might also apply to liability under the EPA's Underground Injection permit program. Under EPA's permitting, there is currently only one active permitted Class VI well where carbon dioxide is being injected.[212] However, multiple states have been granted primacy where they can approve Class VI permits,[213] and North Dakota became the first to issue a Class VI permit in October 2021.[214]

5. Liability Cap (Price-Anderson-like Paradigm)

The most comprehensive example of a liability cap in the energy sector is the Price-Anderson Act,[215] passed to help develop the nuclear industry.[216] This liability paradigm establishes three tiers of liability depending on the severity of the incident: 1) primary individual liability insurance; 2) an industry fund; and 3) federal government indemnification.[217] The first tier is private liability insurance, which is obtained by each individual nuclear owner/operator and covers claims up to a set amount—the current amount of insurance required per reactor is $300 million.[218] The second tier creates a liability fund when an incident

[210] *Id.* at 172.
[211] *Id.* at 174.
[212] *Class VI Wells Permitted by EPA*, U.S. ENV'T PROT. AGENCY, https://perma.cc/A4H2-BJ45 (last visited Feb. 19, 2022). Nine more are pending approval. *Id.*
[213] *Primary Enforcement Authority for the Underground Injection Control Program*, U.S. ENV'T PROT. AGENCY, https://perma.cc/6CPJ-5UST (last visited May 1, 2022).
[214] Gov. Doug Burgum (@DougBurgum), TWITTER (Oct. 19, 2021, 4:41 PM), https://perma.cc/J2MC-NXCW. Wyoming is also hoping to issue a permit for a Class VI injection well soon. Pollack, *supra* note 140.
[215] 42 U.S.C. §§ 2210, 2282 (2018).
[216] Pub. L. No. 85-256, § 1, 51 Stat. 576, 576 (1957).
[217] 42 U.S.C. § 2210(a)–(b).
[218] *Backgrounder on Nuclear Insurance and Disaster Relief*, U.S. NUCLEAR REGUL. COMM'N, https://perma.cc/WT39-BS8E (last updated Apr. 11, 2022). All of this insurance is provided by a single insurance company, American Nuclear Insurers. PUB. CITIZEN, PRICE-ANDERSON ACT: THE BILLION DOLLAR BAILOUT FOR NUCLEAR POWER MISHAPS 2 (2004). One must wonder how this cap is set when ExxonMobil's annual profit can be as high as $45

occurs; at the time of the incident, the entire industry starts paying into the fund on a prorated basis, based on all other nuclear reactors being assigned a portion of the liability for the accident over the $300 million.[219] Currently, the entire fund is almost $13 billion.[220] The federal government then indemnifies any damages above this amount, regardless of how high the damages go.[221]

While this liability scheme provides certainty for nuclear owners and operators regarding the financial risks they would face when liable, the government has faced this open-ended financial risk since 1957.[222] This liability scheme provides a subsidy to the nuclear industry in two ways: 1) by having a primary cap, it does not require nuclear owners and operators to outlay for primary liability insurance that would cover the liability associated with an accident; and 2) the indemnification mechanism provides for the direct transfer of liability of a serious nuclear incident to the federal government.[223] This distorts the market by not internalizing the risks of the activity into the price of electricity generated by nuclear reactors.[224]

The statute of limitations should not be an issue with a nuclear incident in the way it might be with CCS injection. However, the perpetuity issue becomes clear: as a nation, we have yet to find a way to deal with nuclear waste.[225] As with nuclear waste, CCS is another attempt to find a way to deal with a by-product of non-renewable energy.

The same issues that exist with bankruptcy and mergers in assigning tort liability could hamper effective compensation for those injured under the Price-Anderson fund paradigm. However, learning from the nuclear industry, the government may need to limit foreign ownership of those who control CCS locations to ensure sufficient funds for damages.[226]

billion; the energy sector obviously has the ability to pay for more. Hargreaves, *supra* note 171.

219 *Backgrounder on Nuclear Insurance and Disaster Relief*, *supra* note 218.

220 *Id.*

221 42 U.S.C. § 2210(c)–(e).

222 *Id.* § 2210.

223 PUB. CITIZEN, *supra* note 218. The contention is that if reactors are truly as safe as the nuclear industry asserts, private liability insurance should be available for the full amount of a possible incident, as the likelihood would be so small. *Id.* at 4.

224 *Id.* at 1.

225 42 U.S.C. § 10131. The Nuclear Waste Policy Act of 1982 "establishes both the Federal government's responsibility to provide a place for the permanent disposal of high-level radioactive waste and spent nuclear fuel, and the generators' responsibility to bear the costs of permanent disposal." *Governing Legislation*, U.S. NUCLEAR REGUL. COMM'N, https://perma.cc/547G-Y2AD (last updated Sept. 10, 2021).

226 One relatively recent purchase was for 49.99% of Constellation's nuclear assets by EDF. *EDF, Constellation Review Maryland Nuclear Deal Ruling*, MKT. WATCH (Oct. 30, 2009), https://perma.cc/P3S2-AMTN. There is a statutory limit that a nuclear license will not be granted to "[a]ny person who is a citizen, national, or agent of a foreign country, or any corporation, or other entity which the Commission knows or has reason to believe is owned, controlled, or dominated by an alien, a foreign corporation, or a foreign government." Final Standard Review Plan on Foreign Ownership, Control, or Domination, 64 Fed. Reg. 52,355, 52,358 (Sept. 28, 1999). "The Commission has not determined a specific threshold

There is no reason to assume that United States subsidiaries of global entities would be left with more than the statutory minimum of assets, as a global company would prefer to limit that liability as much as possible. Therefore, in the case of an accident, the subsidiary would be deemed sufficiently capitalized,[227] but the assets would be far fewer than those necessary to compensate for the harms caused. Additionally, many of the nuclear operators in Europe, now making investments in the United States, are at least partially government owned, which could also limit the ability of United States nationals to sue in the home country of the global company for injury.[228]

6. Strict Liability

Strict liability is the usual liability paradigm for abnormally dangerous activities[229] and product liability, which requires the operator

above which it would be conclusive that an applicant is controlled by foreign interests through ownership of a percentage of the applicant's stock." *Id.* "An applicant that is partially owned by a foreign entity, for example, partial ownership of 50% or greater, may still be eligible for a license if certain conditions are imposed, such as requiring that officers and employees of the applicant responsible for special nuclear material must be U.S. citizens." *Id.* Therefore, even with this statutory limitation on ownership, a controlling position dealing with asset capitalization may be controlled by a foreign entity, and this controlling position may occur with less than 50%. *See* HAZEN & MARKHAM, *supra* note 177, at 572 (citing 44.4% as effective control). 28.3% share control has been sufficient to find control. *Id.* at 580.

[227] The subsidiary would be deemed to have sufficient capital as it met the statutory minimum, so there would be no justification for piercing the corporate veil to gain access to the rest of the company's assets to compensate for the harms of the subsidiary. *See* HAZEN & MARKHAM, supra note 177, at 164 (noting that the undercapitalization would need to be "gross" in order to pierce the corporate veil).

[228] Europe has a framework to deal with transboundary harms associated with nuclear accidents, the Vienna Convention on Civil Liability for Nuclear Damage. *Vienna Convention on Civil Liability for Nuclear Damage*, WIKIPEDIA, https://perma.cc/3NWK-4L7A (last visited Feb. 22, 2022). The EU has also started discussing a more comprehensive liability paradigm for environmental harms. EUROPEAN COMM'N, DIRECTORATE-GEN. FOR THE ENV'T, WHITE PAPER ON ENVIRONMENTAL LIABILITY 7 (2000).

[229] Abnormally dangerous activities create a significant risk of serious harm even if reasonable care is used. Other activities deemed abnormally dangerous are the transportation, storage, and use of explosives; atomic energy; and oil drilling in a dense residential part of LA. Whether something is deemed an ultra-hazardous activity and therefore subject to strict liability may change based on the jurisdiction. CCS is analogous to the "broad range of activities" that have been classified abnormally dangerous activities

> including the release of petroleum or oil that contaminated groundwater, the seepage of salt water from an oil and gas well that contaminated a water supply, the release of toxic and hazardous wastes from industrial operations and disposal facilities, the release of P[olychlorinated Biphenyl]s from a natural gas pipeline that contaminated neighboring property, the release of pollutants during the blowout of an oil well during drilling, and the pollution of water wells caused by percolation of oil-well-formation waters ponded on neighboring property.

Klass & Wilson, *supra* note 15, at 142. Similar sorts of harms are certainly possible with CCS.

or manufacturer to ensure that the activity or product is safe.[230] The factors used to determine if an activity is abnormally dangerous are:

> (a) existence of a high degree of risk of some harm to the person, land or chattels of others; (b) likelihood that the harm that results from it will be great; (c) inability to eliminate the risk by the exercise of reasonable care; (d) extent to which the activity is not a matter of common usage; (e) inappropriateness of the activity to the place where it is carried on; and (f) extent to which its value to the community is out-weighed by its dangerous attributes.[231]

With strict liability, the liability does not depend completely on the foreseeability of the harm or the precautions taken; there must be harm and a causal connection between that harm and the activity or product.[232] CCS injection could be deemed an abnormally dangerous activity and, therefore, be subjected to strict liability by either a legislature or the judiciary. However, as noted in several places, adopting a strict liability paradigm by passing federal legislation would be preferable. This would allow for one uniform law to apply to all jurisdictions instead of a possible patch-work liability scheme that might result from judicial holdings.[233] Also, differing liability paradigms—where strict liability applies in some states but not in others—might create an incentive for CCS locations to develop not where there is the least geographic or geologic risk but rather where it is least likely that operators will be subject to strict liability.[234] Indeed, states may attempt to draw CCS locations to their state by enacting favorable liability laws.[235] For these reasons, a uniform federal standard should be adopted.

CCS injection is also analogous to product liability. Strict liability is applied to product liability due to a profit motive; as the manufacturer has made a profit on the product, the manufacturer must also accept the

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[230] DOBBS & HAYDEN, *supra* note 160, 698–700; *see also* KEETON ET AL., *supra* note 156, at 692–695 (noting strict liability is used to assign liability for abnormally dangerous activities and product liability).

[231] RESTATEMENT (SECOND) OF TORTS § 520 (AM. L. INST. 1977). While a Restatement of Torts, Third, for products liability has been published, it has not been widely adopted.

[232] DOBBS & HAYDEN, *supra* note 160, at 691–93.

[233] "Texas and Wyoming, two states that may play a big role in future CO_2 storage, disfavor the doctrine of strict liability or have rejected it entirely." Klass & Wilson, *supra* note 15, at 142. A judicially-developed strict liability regime could emerge, as "twenty-one out of twenty-seven jurisdictions that have squarely considered the issue have applied the doctrine of strict liability to activities resulting in environmental contamination." *Id.* However, a federal statutory scheme providing strict liability would be better because relying on a judicially-developed scheme leaves too large a gap between states and too much uncertainty regarding whether harms would be compensated.

[234] The author disagrees with the suggestion that all CCS operators, if possibly subject to strict liability in one jurisdiction, would simply "conduct their operations accordingly" in all jurisdictions. *Id.* at 143.

[235] This was demonstrated by the fact that both Texas and Illinois passed legislation limiting liability in an attempt to entice FutureGen to come to their state. *Id.* at 150–51.

liability associated with the risks that product creates.[236] CCS injection is similar in that it is driven by profit and will, if the correct liability paradigm is chosen, only continue so long as the profit outweighs the risks associated with the liability. Strict liability will again ensure that the profit motive does not lead to the development of ill-suited locations and takes the costs of risks into account.

As with every other type of liability paradigm, causation still needs to be proven with a strict liability paradigm. As noted earlier, this could be challenging if more than one injection location was possibly the source of the harm or if the harm could be the result of more than one activity.[237] This could be made easier, however, with the adoption of a Comprehensive Environmental Response, Compensation, and Liability Act [238]-like statutory provision that could ease proving causation-in-fact by adopting proof requirements within a regulatory scheme.[239]

However, the statute of limitations issue might still be a challenge for those seeking recovery for an injury under a strict liability paradigm. "For example, in the case of a defective product, a statute of repose might specify that a cause of action must be brought within ten years from the date of purchase."[240] This is because both insurers and manufacturers want some certainty with how long they may be liable. However, given the periods at issue with CCS, this is unrealistic. To perfect the goals associated with strict liability, the statute of limitations or statute of repose associated with CCS needs to be lengthened to be commensurate with the anticipated storage period.[241]

Strict liability will best allow a movement from fossil-fuel based electricity generation to a future with renewable sources of electricity, based on internalizing the risk associated with CCS. Given the challenges with the other legal paradigms, carbon dioxide migration could be seen as a "license to pollute"; only strict liability will send the appropriate market signals to ensure that CCS is developed responsibly. As we need to incent behavior that moves toward a carbon-free future, the development of CCS should be limited, and strict legal liability is one method that can be used to ensure that occurs.

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236 *See The Product Liability Torts*, Cozen O'Connor, available at https://perma.cc/9BNT-MCBN ("The purpose behind the strict product liability doctrine is to spread the risk of loss caused by defective products away from the innocent consumer and to the entities in the chain of distribution for the defective product that profit from the sale of the product.").

237 *See supra* text accompanying note 164.

238 Comprehensive Environmental Response, Compensation, and Liability Act of 1980, 42 U.S.C. § 9601–9675 (2018).

239 Klass & Wilson, *supra* note 15, at 159. CERCLA also allows for joint and several liability, putting the burden on defendants to demonstrate they are not the cause of a specific harm once associated with a site. Additionally, CERCLA provides for retroactive liability, which has been upheld as constitutional. CCS liability should also adopt these provisions from CERCLA (strict, causation-free, retroactive, and joint and several liability).

240 Anthony de Figueiredo, *supra* note 174, at 54.

241 Another option is, like CERCLA, to have the statute of limitations start running when cleanup begins. Klass & Wilson, *supra* note 15, at 131.

B. Moral Hazard and Lessons from the Price-Anderson Act

Laws and regulations perpetuate "a 'moral hazard' when citizens do not bear the full consequences of their risk-taking and thus have an incentive to take more risks and engage in less preventive effort."[242] This is exactly what anything less than a strict liability scheme for CCS would accomplish.

It is unsurprising, therefore, who is pushing for CCS and for alternative liability schemes. In addition to support from federal governmental actors, "most utilities; the coal industry and the governments of several coal states; ExxonMobil, the rest of Big Oil and other major industrial corporations; several climate NGOs; the AFL-CIO" all support expanded use of CCS and the build-out of the associated infrastructure which would support it.[243] "The fossil fuel industry has gotten behind CCS as a technology that, it hopes, would allow continued production so long as the emissions are buried underground."[244] Minimizing cost—regardless of the potential for harm that might cause—has been a focus of those supporting CCS.[245] CCS equipment has even been exempted from property taxes in one state.[246]

Insurance could also become a part of the solution for CCS operators. Once the risks are understood based on geologic and geographic data, private insurers may be willing to quantify and insure the risk associated with an accident. However, if private insurers are unwilling to assume the liability associated with a CCS release, then that also sends a needed signal to the market in regards to the safety of this technology. This signal should be heeded, not dismissed.[247] If private insurers are unwilling to accept the risk or unable to quantify the cost, the federal government should not intercede. An intercession at this junction would persist in skewing the market towards CCS for an indefinite period.

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[242] Stephanie M. Stern, *Climate Transition Relief: Federal Buyouts for Underwater Homes* (forthcoming 2022) (manuscript at 28), https://perma.cc/9HHR-DM2Q (quoting Steven Shavell, *On Moral Hazard and Insurance*, 93 Q. J. ECON. 541, 544 (1979)).

[243] Zegart, *supra* note 1.

[244] *Id.*

[245] *See id.* (noting that there are significant concerns with using existing pipeline infrastructure, but using the existing pipelines for CCS is being pushed to minimize the costs associated with CCS).

[246] H.B. 394, 67th Leg., Reg. Sess. (Mont. 2021).

[247] The best example of where it was dismissed is the Price-Anderson Act, dealing with the nuclear industry. Private insurance was unwilling to insure reactors resulting in the cap, which has, in essence, transferred liability of a nuclear accident to the federal government and has turned into an ongoing subsidy to the nuclear industry. PUB. CITIZEN, *supra* note 218, at 1–2. It was anticipated that this liability scheme would only exist as long as private insurers were unable to quantify the risks associated with nuclear power; it has, in fact, lasted 52 years. *Id.* Additionally, Price-Anderson has been extended for new reactors built until 2025. Energy Policy Act of 2005, Pub. L. No. 109-58, 119 Stat. 594 (codified in scattered sections of 42 U.S.C.).

Some have suggested that the liability paradigm for CCS parallel the liability scheme set up by Price-Anderson.[248] However, this would allow another industry with deadly potential to transfer the risk to the federal government for an extended period and distort the price of electricity from non-renewable sources.[249] The Price-Anderson Act was originally designed to be in place for fewer than ten years,[250] as it was meant to correct a market failure of insufficient information. It was assumed this was enough time to prove the technology and for the private insurance markets to develop pricing that would adequately reflect the risk of nuclear power.[251] As amply demonstrated, the United States suffers from legislative inertia; once a particular liability paradigm is passed and the industry develops around it, it is unlikely that that liability paradigm will change. In actuality, as there is a vested interest on the part of the government based on the previous subsidies, other legislative provisions favoring the industry can be added. In the nuclear industry, after Price-Anderson was enacted, the federal government assumed responsibility for long-term storage locations of nuclear waste.[252]

Additionally, the government indemnifies even in cases of recklessness or gross negligence.[253] Given that the indemnification applies to reckless or negligent operation as well, this liability paradigm certainly could encourage ill-suited CCS locations to be developed, as liability would be limited to a set, known amount, with the remainder transferred to the federal government. This would encourage the use of CCS far into the future, at riskier locations, when other alternatives would be both cheaper and less risky to human health and the environment if the costs were calculated without the liability cap and the transfer of liability to the federal government.

The federal law, in this case, also preempts state laws of liability, disallowing more favorable state laws to be used by those injured in the case of an incident.[254] Additionally, the federal law "protects nuclear operators from punitive damages that are not covered under their private insurance coverage."[255] This assures that, with an incident of even minor magnitude, no punitive damages will be paid to those injured.

A hybrid solution to CCS liability might include a liability cap similar to Price-Anderson coupled with regulations[256] that control siting decisions. However, these regulations are apt to be less rigorous and allow

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248 Klass & Wilson, *supra* note 15, 167–68.

249 *Id.* at 166–68.

250 PUB. CITIZEN, *supra* note 218, at 3.

251 *Id.*

252 Nuclear Waste Policy Act of 1982, 42 U.S.C. § 10131 (2018); *see supra* text accompanying note 196.

253 PUB. CITIZEN, *supra* note 218, at 4.

254 *Id.* at 3.

255 *Id.*

256 This could occur either under the EPA, using the Underground Injection Permit system or another permitting mechanism, or a separate agency like the Nuclear Regulatory Commission could be formed. Klass & Wilson, *supra* note 15, at 167–68.

for the development of more ill-suited locations than if the private market determined what risks are acceptable and which locations should be utilized—provided that a liability paradigm is chosen that internalizes all the external risk. Additionally, regulations are likely to accept more unknowns when making the development decision than the private market, again leading to the possibility of ill-suited locations being developed. "[E]ven if regulatory safeguards are created, unforeseen long-term problems associated with the storage of CO_2 in large amounts raise significant uncertainty with regard to the success of any regulatory structure."[257] The private market would require enough information to be able to adequately quantify the risk before development, as long as the chosen paradigm internalized the external risks, leading to better decisions around risk quantification than under a liability cap/regulatory hybrid model.

We must be honest: The continued use of fossil fuels, even with CCS, makes no sense. Take, for example, one project recently proposed in Louisiana.[258] To continue using fossil fuels, it was proposed to create a hydrogen manufacturing complex and use the hydrogen as a "clean" fuel elsewhere.[259] But think about how this would actually work. First, natural gas is produced, likely using fracking, with a significant percentage of that methane directly escaping into the atmosphere and contributing to global warming. The process then uses energy to remove all impurities. Then the process uses more energy to crack the methane apart, isolating the hydrogen and carbon. Carbon then mixes with oxygen (also having used energy to isolate that oxygen from air) to make a pure carbon dioxide stream. More energy is used to pressurize and inject CO_2 (along with energy to run any compressor stations along with way). Hydrogen is then mixed with nitrogen, which also had been developed using another process that used even more energy to isolate N_2 (and only N_2) from the air. Then ammonia is formed. More energy is used to pump ammonia to ships. Shipping the ammonia then uses more energy (in the form of bunker fuel, which is especially dirty) to transport the ammonia to wherever the hydrogen is going to be used. Then more energy is used to offload and pump the ammonia to where it is going to be used. Then even more energy is used to split the ammonia, getting back to H_2. Finally the H_2 is used.

A potential solution that is more energy efficient: use renewable energy that would otherwise be curtailed to produce H_2 via electrolysis at the same location that it will be used; that way, tank storage will only be required for buffering needs.[260] There are very few places where H_2 will be useful, cost effective, or needed; and it will be far better to create it

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[257] *Id.* at 132.

[258] *Gov. Edwards Announces $4.5B in New Clean Energy Plant*, WAFB-9 (Oct. 14, 2021), https://perma.cc/TNG3-3MRF.

[259] *Id.*

[260] *Green Hydrogen Production from Curtailed Wind and Solar Power*, CARNEGIE SCI. (July 20, 2021), https://perma.cc/Z56K-YL2N.

onsite from water and renewable energy and for purposes that it is the best suited for.[261] But hydrogen is not the optimal decarbonization strategy for most industrial processes, electricity generation, or transportation.[262]

But this situation is very telling about why CCS is such a distraction and why so many are willing to continue to chase it rather than the more simple, elegant solution: money. That entire chain of fossil fuel production, chemical transitions, energy use, and transportation allows for corporate profits and additional employment at every step. The simpler solution, while far better for the planet, will be less enriching to entrenched interests.

V. ADOPTION OF STRICT LIABILITY

Strict liability is the one liability scheme that would minimize both the use of CCS and the release of greenhouse gases from CCS activities as well as avoid potential moral hazard. It would ensure the highest level of protection of human and animal life. Strict liability puts the requirements to ensure safety onto the operator or manufacturer. This encourages development only where the profits are large enough to mitigate the liability risks in perpetuity.

Strict liability would be advantageous as the liability paradigm for CCS for several reasons. First, all the cost of the risk of CCS operation is internalized; therefore, the cost of electricity generated with the help of CCS can adequately be priced by the market. This would allow for true cost comparisons with alternate technologies as we move into a carbon-neutral scheme for electricity generation and other industrial activity. Second, allowing the private insurance market to determine the risk will give a valuable data point on how risky individual locations are and will help ensure that ill-suited locations will not be developed.[263] Third, with statutorily-enacted strict liability, there is a lower likelihood that the federal government would pay the costs of harm and a higher likelihood that those injured by harms will be compensated.[264] Finally, CCS will only continue as long as market forces deem it to be economically advantageous with the risk costs inherent in that pricing. This will best

[261] *See* Michael Barnard, *Hydrogen Is as Broadly Useful as Hemp, and Will Be Used Just as Much*, CLEANTECHNICA (Oct. 13, 2021), https://perma.cc/3NMH-P4XC ("Using electricity directly or through batteries is almost always more effective, efficient, and cheaper than using hydrogen.").

[262] Hype, L.A. Times (Mar. 24, 2022), https://perma.cc/CP64-FVXB (stating that making green hydrogen is not efficient and that direct electrification is preferable in most situations). E.g., French City Cancels Hydrogen Bus Order, Finds Electric Fleet 6x Cheaper to Operate, Energy Mix (Jan. 18, 2022), https://perma.cc/HWB5-K7SE (transportation).

[263] INT'L RISK GOVERNANCE COUNCIL, POLICY BRIEF: REGULATION OF CARBON CAPTURE AND STORAGE 8, 9 (2008). While this might be an issue if insurers start to fail, other regulations will be needed to address that problem.

[264] *Id.* at 20.

ensure that CCS use is minimized; useful while needed, but limited in scope and number of locations.

It has been acknowledged by industry that "liability has the potential to prove a sizable risk for potential operations in this industry."[265] However, this risk can be minimized by only choosing locations where the risk of a release is small. This can optimally be determined based on geology and geographic constraints. Developing this information will not be inexpensive; however, without this information, ill-suited locations could be developed, and without a strict liability paradigm, the owners and operators of these poorly chosen locations would have multiple legal avenues under which to shirk their responsibilities and liabilities for the harm caused. Therefore, responsible operators of CCS should welcome the adoption of a strict liability regime; if a location is truly as safe and the risk as small as argued, then the imposition of strict liability will not be a hindrance.

Strict liability, however, may not be enough without additional measures. Having effective monitoring systems that ensure leaks are detected quickly and with specificity will limit the risks to humans, animals, and the environment.[266] As with location selection, well-designed monitoring and response systems and processes may limit this risk for those owners and operators willing to invest to ensure responsible operation. As with poor site selection, owners and operators without monitoring or adequate response could avoid legal liability without strict liability.

While strict liability can help to limit the development of CCS to where it is safest, a strict liability regime does not fully internalize the environmental harms of release. This will likely only occur by mandating sovereign durability—requiring those who injected the carbon dioxide to maintain the site in perpetuity, including requiring the site/corporate entity to be maintained in any sale with the part of the business that has a larger balance sheet and by not allowing any discharge of legal liability in bankruptcy. As bonding for mines and wells has amply demonstrated, bonding requirements are not set high enough to manage environmental harms and ensure responsible corporate behavior. A functioning economy-wide carbon market—where any leakage would need to be paid for based on a global social cost of carbon—would also aid in encouraging corporate responsibility for CCS sites.

Accidents and harms will happen if CCS is developed; the choice is how they will be handled when they occur. While CCS operators

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[265] ABOOD ET AL., *supra* note 25 at 12.

[266] The Global CCS Institute, an organization founded to promote CCS, concedes that "the possibility of CO_2 escaping the reservoir is negligible, *provided the storage site has been well characterised*." GLOBAL CCS INSTITUTE, *supra* note 28, at 5 (emphasis added); *Carbon Sequestration: Monitoring, Verification, and Accounting (MVA)*, supra note 34; Flatt, *supra* note 15, at 220. Unfortunately, due to a lack of technology and corresponding empirical data, it is simply unclear how efficient even a well-designed monitoring and response system would be.

internalizing the cost of risk may be expensive and increase the cost of certain goods (including electricity), a strict liability paradigm will also allow for true cost comparisons with other technologies and will drive innovation towards a carbon-free future. At best, CCS is a minimal distraction; at worst, "a scam, just a big scheme to get funding subsidies" while delaying needed action on climate change.[267]

> [T]he climate models upon which everyone bases their hope for decarbonization include []gigatons[] of CCUS -- an industry that will capture [and] bury an amount equal to what the entire global fossil fuel industry now digs up -- by 2030. We[a]re utterly deluding ourselves. . . . The reason those gigatons of CCUS are tucked away in the models a few decades hence is that, if they were[no]t, it would be nakedly [and] unavoidably apparent that the only way to avoid catastrophic [global] warming is an immediate full-scale wartime decarb[onization] effort.[268]

VI. CONCLUSION

Even more true now than when expressed by President Kennedy, "[t]he supreme reality of our time is . . . our common vulnerability on this planet."[269] Instead of subsidies, including those created by limiting liability, the operators of CCS should bear the full cost. Only then can the external risks be internalized.

By protecting fossil-fuel use into the future by enabling CCS, we incent the status quo, hindering the widescape adoption of deployable renewable solutions to the issues associated with global climate change. With all such distractions, whether CCS, hydrogen, small modular reactors, or similar technologies that will solve all our problems ten years from now, we must recognize we can do far more for the planet by minimizing their use. Implementing legal paradigms allows us to do that—to stop chasing squirrels in the energy transition.

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267 Deign, *supra* note 51.

268 David Roberts (@drvolts), TWITTER (Sept. 13, 2021, 11:22 AM), https://perma.cc/6ZVD-LPV6; David Roberts (@drvolts), TWITTER (Sept 13, 2021, 11:24 AM), https://perma.cc/Y4MU-FQE9.

269 GEOFFREY WILLIAMS, THE PERMANENT ALLIANCE: THE EUROPEAN-AMERICAN PARTNERSHIP 1945-1984, at 221 (1977) (quoting President Kennedy's speech to the Irish Parliament on June 28, 1963).