Injecting Earthquakes into the Energy Debate

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I. Introduction

Beneath the earth are natural forces with the potential to cause damage to things resting above the surface. Throughout history, human progress has always been servient to the physical laws of nature, but through technological improvement and innovation our ability to shape the world is increasingly blurring the lines between events caused by nature and those initiated by acts of man.[1] The ability of the oil and gas industry to extract ancient deposits of energy is one of the greatest examples of this phenomenon, and through the advent of unconventional drilling techniques, "the orbit of humanity's reach has enlarged itself dramatically" in the past decade.[2]

Our ability to harness energy is what makes possible our understanding of what it means to live in modern society.[3] The development of unconventional sources of oil and gas using horizontal drilling and hydraulic fracturing offers the potential for a more secure energy supply, geopolitical stability, and a boost to the industrial economy.[4] At the same time, unconventional production has become increasingly controversial as new environmental and social concerns emerge in the wake of shale development.[5] Induced earthquakes are perhaps the "most unexpected phenomenon" of America's energy boom.[6]

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[1] Adam F. Scales, *Man, God, and the Serbian Bog: The Evolution of Accidental Death Insurance*, 86 IOWA L. REV. 173, 269–270 (2000). (explaining that accidents lie in the middle of a spectrum between human and natural events, and occur "when the gravitational pull of neither pole is strong enough to dominate.").
[2] *Id*.
[3] DANIEL YERGIN, THE QUEST, 719 (2012) (explaining that "the bounty can be measured in terms of virtually everything we do in the course of a day.").
[4] Monika Ehrman, *The Next Great Compromise: A Comprehensive Response to Opposition Against Shale Gas Development Using Hydraulic Fracturing in the United States*, 46 Tex. Tech. L. Rev. 423, 460 (2014).
[5] Keith B. Hall, *Recent Developments in Hydraulic Fracturing Regulation and Litigation*, 29 J. Land Use & Envtl. L. 29, 30 (2013).
[6] Ehrman, *supra* note 4, at 460.

The frequency and occurrence of seismic activity in the central and eastern United States has increased dramatically since the boom took off around 2009.[7] This has led many to suspect that the connection between unconventional production and induced seismicity is far from coincidence. Plenty of myths and inaccurate reporting surround the connection, but the consensus from the scientific community is that the injection of wastewater fluids is the most likely culprit of the increasing rates of seismicity.[8] While hydraulic fracturing itself is unlikely to result in any significant levels of seismicity felt at the surface, the rapid development of unconventional formations using this technique has increased the need for disposal capacity, sometimes in areas where disposal has not previously occurred.[9]

The "exponential growth patterns of seismicity" in some parts of the country has prompted a varied response from concerned citizens, regulators, and the industry.[10] The following analysis discusses how the oil and gas industry induces earthquakes, primarily in the context of wastewater disposal from Class II injection wells. It outlines the existing regulatory framework through a comparative survey of the response of state officials in Oklahoma and Colorado. It then offers several non-regulatory strategies that companies can employ to mitigate the incidence damaging earthquakes. This article suggests that the best approach to mitigate seismic risk involves proactive regulatory measures adopted in states like Colorado, in conjunction with voluntary efforts from the industry itself.

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[7] Seismicity in parts of the central and eastern U.S. increased dramatically since 2009, from an average of approximately 20 per year (1970-2000) to over 100 per year (2010-2013). Peter Folger & Mary Tiemann, CONG. RESEARCH SERV., R43836, HUMAN-INDUCED EARTHQUAKES FROM DEEP-WELL INJECTION: A BRIEF OVERVIEW 4-6 (2015).
[8] Justin L. Rubinstein & Alireza B. Mahani, *Myths and Facts on Wastewater Injection, Hydraulic Fracturing, Enhanced Oil Recovery, and Induced Seismicity*, 86:4 Seismological Research Letters 2-3 (2015).
[9] U.S. Environmental Protection Agency, *Minimizing and Managing Potential Impacts of Injection-Induced Seismicity from Class II Disposal Wells: Practical Approaches*, Underground Injection Control National Technical Workgroup, ES-2 (2015).
[10] Rubinstein, *supra* note 8, at 2–3.

II. Recent Increase and Interest in Induced Seismicity

A. Basic Mechanics of Inducing Earthquakes

Induced earthquakes occur when anthropogenic activity "causes a rate of energy release, or seismicity, which would be expected beyond the normal level of historical seismic activity."[11] Over the decades scientists have recognized an array of human activities known to cause earthquakes.[12] Induced seismicity has been observed in the oil and gas industry since at least the 1930s[13] and can be attributed to three types of large-scale fluid injection: wastewater disposal, hydraulic fracturing, and enhanced recovery.[14] While each process is capable of triggering seismicity,[15] wastewater disposal is attributed to the "vast majority" of the recent increase, "including the largest and most damaging quakes."[16] For this reason, the following analysis is primarily concerned with addressing seismicity from wastewater disposal.[17]

The basic understanding of how wastewater disposal causes earthquakes is relatively well understood.[18] Injecting fluids deep into a geologic fault can lubricate the formations and caused them slip (i.e. suddenly release stored energy).[19] This release of energy is felt at the surface in the

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[11] U.S. Dept. of Energy-Lawrence Berkeley National Laboratory, *What is Induced Seismicity?*, http://esd1.lbl.gov/research/projects/induced_seismicity/.
[12] Human activities known to induce seismic events include: impoundment of reservoirs, mining, withdrawal of fluids such as oil and gas, and injection of fluids into subsurface formations. Folger, *supra* note 7, at 1.
[13] U.S. Dept. of Energy-Lawrence Berkeley National Laboratory, *Induced Seismicity-Oil & Gas*, http://esd1.lbl.gov/research/projects/induced_seismicity/oil&gas/.
[14] Rubinstein, supra note 8, at 2.
[15] Enhanced Oil Recovery (EOR) involves production techniques (e.g. water flooding) that sweeps more oil and gas toward wells than would come out on its own. *Id*. at 4.
[16] *Id*. at 5.
[17] The magnitude of potential harm is greatest with wastewater disposal wells because they can raise fluid pressures "more, over longer periods of time, and over larger areas, than either of the other injection methods." Id. at 6.
[18] Earthquakes are induced when: "human perturbation changes the amount of stress in the earth's crust, and the forces that prevent faults from slipping become unequal." Folger, *supra* note 7, at 3.
[19] U.S. Dept. of Energy-Lawrence Berkeley National Laboratory, *Induced Seismicity-Oil & Gas*, http://esd1.lbl.gov/research/projects/induced_seismicity/oil&gas/.

form of a vibration, or earthquake. Scientists at the United States Geological Survey (USGS) explain that most injection operations "do not appear to induce earthquakes," and when they do, the damage is often minimal.[20] Most of the earthquakes have been aseismic (i.e. not causing any appreciable seismic activity for quakes over Magnitude (M) 3).[21] However, induced seismicity associated with wastewater disposal "will become an increasingly important issue" as domestic energy resources continue to be developed.[22]

B. Hydraulic Fracturing ("Fracking") & Induced Seismicity

The role that hydraulic fracturing[23] plays in the increased rate of seismic activity has been misrepresented by the media and interest groups on both sides of the fracking debate.[24] Fracking opponents sometimes assert that the fracking process itself is the cause of the recent trend in damaging earthquakes. Industry loyalists counter by stating that fracking plays no role since the injections are of a short duration and use much lower volumes of water than other types of injection activities.[25] Both sides miss the point by focusing on the fracking process itself, rather than its connection to the overall capacity of wastewater requiring disposal. Although a few

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[20] Rubinstein, *supra* note 8, at 1; Damaging earthquakes are usually greater than magnitude 5 U.S. Dept. of Energy-Lawrence Berkeley National Laboratory, *About Induced Seismicity?* http://esd1.lbl.gov/research/projects/induced_seismicity/. Folger, *supra* note 7, at 1(explaining that "only a small fraction of the more than 30,000 US wastewater disposal wells appears to be associated with damaging earthquakes.").

[21] Folger, *supra* note 7, at 9.

[22] U.S. Dept. of Energy-Lawrence Berkeley National Laboratory, *About Induced Seismicity?* http://esd1.lbl.gov/research/projects/induced_seismicity/.

[23] Hydraulic fracturing, or "fracking," is the process of injecting a cocktail of mostly water, sand, and chemicals at high pressure into deep geologic strata to fracture hydrocarbon-bearing source rocks in order to provide permeable pathways to extract the oil and gas. RUSSELL GOLD, THE BOOM, 30 (2014). GOLD, *supra* note 23, at

[24] Keith B. Hall, *Recent Developments in Hydraulic Fracturing Regulation and Litigation*, 29 J. Land Use & Envtl. L. 29, 30 (2013). (explaining that "some media reports have inaccurately suggested that the injection disposal wells were wells in which hydraulic fracturing was being conducted, but those reports given an erroneous impression."); see also Rubinstein, *supra* note 8, at 1 (noting that "there remains confusion in the popular press beyond this basic level of understanding" that oil and gas fluid injection contributes to seismic activity).

[25] Rubinstein, supra note 8, at 6.

instances of fracking-related earthquakes have been observed,[26] hydraulic fracturing "does not typically induce felt earthquakes" and "does not play a key role" in the overall increase in seismicity.[27] In other words, the process of injecting high pressure liquids does not itself contribute greatly to the recent uptick in induced seismic activity, but there is a connection: the exploitation of unconventional formations—made possible by fracking and other production techniques—"has contributed significantly to a growing volume of wastewater requiring disposal."[28] As a result of unconventional drilling, some of these disposal wells are also "located in geographic areas where disposal has not previously occurred."[29] Sometimes disposal wells are "bored into unmapped faults," and this occurrence has "proliferated" since the domestic energy boom.[30] When it comes to addressing induced seismicity, the first mechanism that comes to mind is the direct regulation of wastewater disposal wells. These operations are regulated to varying degrees at the federal, state, and local level.[31]

III. Federal Regulatory Framework and Response

The primary federal legal authority to address induced seismicity comes from the Safe Drinking Water Act (SDWA), which directs the EPA to "promulgate regulations for state

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[26] There are several locations worldwide (OK, OH, England, and Canada) where there is "substantial suspicion that hydraulic fracturing itself, rather than the operation of an injection well, caused induced seismic activity." Hall, *supra* note 24, at 50–51. Rubinstein, supra note 8, at 4 (clarifying that "in these cases, total injected volumes (630,000) were remarkably high."); Folger, *supra* note 7, at 11 (OH state officials said that the fracking process "may have produced tremors in Poland Township in March 2014.).

[27] Rubinstein, supra note 8, at 6.

[28] *Id*. at 1. This is especially true in places like CO and TX, where production yields large volumes of produced water that must be put back underground. U.S. Dept. of Energy-Lawrence Berkeley National Laboratory, *Induced Seismicity-Oil & Gas*, http://esd1.lbl.gov/research/projects/induced_seismicity/oil&gas/. However, it should be noted that in OK, the location of the largest increase, "spent hydraulic fracturing liquid does not represent a large percentage of the fluids compromising disposed wastewater." Rubinstein, supra note 8, at 6.

[29] U.S. Environmental Protection Agency, *Minimizing and Managing Potential Impacts of Injection-Induced Seismicity from Class II Disposal Wells: Practical Approaches*, Underground Injection Control National Technical Workgroup, ES-2 (2015).

[30] *Id*.

[31] Darlene A. Cypser, *Colorado Law and Induced Seismicity*, 47 (1996) (unpublished manuscript) (on filed with author), http://www.researchgate.net/publication/273789334_Colorado_Law_and_Induced_Seismicity.

underground injection control (UIC) programs to prevent underground injection that endangers drinking water sources."[32] Of the more than 800 billion gallons of fluid generated annually by the oil and gas industry, over one-third is injected into Class II disposal wells.[33] The SDWA authorizes the EPA to delegate primary enforcement authority over the UIC program to states if they meet certain requirements.[34] If a state chooses not to assume primacy, or its plan is not approved, EPA implements the UIC program in that state.[35] Most oil and gas producing states, including Colorado and Oklahoma, have assumed primacy for Class II disposal wells.[36] For this reason, and because the SDWA was not designed to address seismicity, the federal government's ability to remedy induced earthquakes is relatively limited.

A. Limited Federal Jurisdiction

The Obama administration, through the EPA, has mostly stayed out of the issue in terms of direct regulation or federal rulemaking.[37] This is primarily due to the fact that the EPA's jurisdiction to regulate induced earthquakes "remains unclear" and it lacks the authority to do so in places where the seismic risk is the most amplified.[38] Instead, the EPA and other federal agencies have played more of an investigative role and encouraged states to adopt certain mitigation measures.

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[32] Folger, *supra* note 7, at 12.
[33] *Id*. at 11. There are 6 classes of UIC wells. *Id*. at 14.
[34] *Id.*
[35] *Id.*
[36] *Id.*
[37] Mathew Philips, *Oklahoma Earthquakes Are a National Security Threat*, Bloomberg Energy and Climate Report (BNA), Oct. 23, 2015, http://www.bloomberg.com/news/articles/2015-10-23/oklahoma-earthquakes-are-a-national-security-threat.
[38] Emery G. Richards, *Finding Fault: Induced Earthquake Liability and Regulation*, 40 COLUM. J. ENVTL. L. FIELD REPORTS, (2015).

In states like Pennsylvania where EPA implements the UIC program, it evaluates seismicity risk factors through the permitting process.[39] However, in most states where increased seismicity has been observed, primacy was obtained under SDWA Section 1425.[40] This means the EPA regulations "provide limited avenues for deterring" the most damaging potential threats from induced earthquakes.[41]

B. Limited Statutory Application

The SDWA is hampered in its ability to address induced earthquakes for several reasons. First off, the statute's UIC provisions do not mention seismicity for Class II wells.[42] Even though regulations covering two categories of wells[43] do require some level of seismic evaluation in terms of siting and testing, these regulations do not apply to Class II wells.[44] Another reason why the SDWA is not well tailored to address induced seismicity has to do with the statute's primary aim: protecting drinking water.[45] The UIC provisions authorize the EPA or state overseeing the program to regulate the underground injection of fluids in order to abate hazards to aquifers and other subterranean sources of drinking water.[46] While it is "conceivable" that an induced earthquake could threaten the structural integrity of infrastructure or geologic formations that provide the public with drinking water, using this hypothesis as a justification for federal oversight is tenuous at best.[47] The regulations do give UIC Directors considerable discretion in

[39] Folger, *supra* note 7, at 14.
[40] Richards, *supra*, note 38, at 11.
[41] *Id*. at 10.
[42] Folger, *supra* note 7, at 14.
[43] EPA regulations for Class I (hazardous waste disposal), and Class VI (CO2 sequestration) wells "specifically address evaluation of seismicity risks with siting and testing requirements." *Id*. at 15.
[44] *Id*.
[45] Richards, *supra*, note 38, at 10.
[46] Folger, *supra* note 7, at 14.
[47] Richards, *supra*, note 38, at 11; Folger, *supra* note 7, at 14.

how to protect these underground sources of drinking water, but as mentioned, it is mostly at the state level where this discretion is exercised.[48] Therefore, given the limited reach of the SDWA and EPA jurisdiction to regulate seismicity under the UIC framework, the regulation of induced seismicity will occur primarily at the state-level.[49]

III. State Regulatory Response

Unlike the federal framework, authority at the state level "rests on a strong legal foundation" to address induced seismicity because its regulations are passed under state enabling statutes.[50] State-level regulation also has the ability to account for various factors unique to the individual state, such as "local geology, environmental concerns, and economic priorities."[51] In their attempts to address the risks associated with increased seismicity, states have responded in a variety of ways: requiring seismic analysis through the well permitting process; moratoriums or orders to scale back on wastewater injection (and hydraulic fracturing); and legislation affecting wastewater disposal.[52]

In states that administer the UIC program under Section 1425, such as Colorado and Oklahoma, the scope of authority to regulate induced earthquakes depends on the legislative

[48] Folger, *supra* note 7, at 15.
[49] Barclay R. Nicholson, *Induced Seismicity Legal Issues Break New Ground*, Law360, May 15, 2015, http://www.law360.com/articles/654837/induced-seismicity-legal-issues-break-new-ground.
[50] Richards, *supra*, note 38, at 11.
[51] *Id.*
[52] Colorado, Oklahoma, Texas, California, Ohio, Pennsylvania, South Dakota, New York, New Mexico, Louisiana, Mississippi, and West Virginia are among the states that have made changes to their Class II well requirements. *Id*. Arkansas and OH have imposed moratoria on wastewater injection in areas where earthquakes have occurred. *Id.* at 6.

authority of the entity charged with administering Class II wells in that state.[53] Since these regulatory bodies are generally provided with a "broad mandate to protect public safety and regulate oil and gas production activities," it is likely that officials have adequate authority to address the risks of induced seismicity.[54] This broad mandate to protect health and safety combined with the discretionary authority under the UIC program allows states to add conditions to the permit process on a case-by-case basis, in addition to "requirements for construction, corrective action, operation, monitoring, or reporting" as necessary to protect sources of drinking water.[55] The next section surveys the different regulatory responses from two states with the potential for induced seismicity.

A. Colorado Regulatory Response

There are currently around 885 active class II wells in Colorado, and none of these injection wells have been implicated in the recent spate of earthquakes being observed east of the Rockies.[56] However, the state has a rich and familiar history with induced seismicity.

(i) Rocky Mountain Arsenal

One of America's most infamous cases of injection-induced seismicity involved a series of quakes that struck near Denver in the 1960-70s.[57] The most damaging earthquake weighed in at M5.3 and was considered the to be the largest recorded induced earthquake in history until the M5.7 tremor that rocked Oklahoma in 2011.[58] The seismic events were eventually linked to the

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[53] *Id*. at 11.
[54] *Id*. at 40. States that administer the UIC program under Section 1422 also probably have authority to address seismicity since the SDWA allows these states to implement requirements more stringent than the minimum standards set by the EPA. *Id*. *See also* Folger, *supra* note 7, at 18.
[55] This includes the power to close an injection well. U.S. Environmental Protection Agency, *Minimizing and Managing Potential Impacts of Injection-Induced Seismicity from Class II Disposal Wells: Practical Approaches*, Underground Injection Control National Technical Workgroup, ES-2 (2015).
[56] Richards, *supra*, note 38, at 20.
[57] *Id*. at 4.
[58] USGS, Colorado Earthquake History, http://earthquake.usgs.gov/earthquakes/states/colorado/history.php.

disposal well injection of hazardous chemical wastes at the Rocky Mountain Arsenal defense plant.[59] There are many similarities between the Rocky Mountain Arsenal earthquakes and recent events taking place in the central U.S.[60] The legacy of the Rocky Mountain Arsenal is exemplified in Colorado's proactive approach to managing induced seismicity.

(ii) Rangeley Experiments

In response to the Rocky Mountain Arsenal events, USGS scientists conducted a field experiment at the Rangeley oil field in Colorado to test their suspicions regarding earthquakes and the manipulation of underground fluid pressures.[61] They pumped water into a well and monitored seismic activity as they varied the amount of fluid and injection pressure.[62] The studies revealed that humans could induce earthquakes "by varying fluid pressure in a seismically active zone."[63]

(iii) COGCC Authority to Address Induced Seismicity

The Colorado Oil & Gas Conservation Commission (COGCC) regulates all aspects of oil and gas production within the state, including the disposal of production and exploration wastes.[64] Since it was granted primacy from EPA in 1984, the COGCC has enforced the provisions of the UIC program for Class II injection wells.[65] This broad authority includes the power to set maximum injection pressures and condition permits on certain monitoring and siting

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[59] *Id.*
[60] Folger, *supra* note 7, at 4.
[61] Darlene A. Cypser & Scott D. Davis, *Liability for Induced Earthquakes*, 9 J. ENVTL. L & LITIG. 551, 566 (1994). See also Raleigh, C.B. et al., *An experiment in Earthquake Control at Rangely*, Colorado, SCIENCE, 191(4233), 1230-1237. (1976).
[62] Alexandra Witze, *Artificial Quakes Shake Oklahoma*, 520 Nature 418 (2015).
[63] J. Thomas Lane et al., *Carbon Sequestration: Critical Property Rights and Legal Liabilities*, 32 E. Min. L. Found. §23.05 (2011).
[64] *COGCC Underground Injection Control and Seismicity in Colorado*, CO Dept. Nat. Resources, Jan. 19, 2011, http://www.oilandgasbmps.org/docs/cogcc_seismicity_co.pdf.
[65] *Id.*

requirements that can be used to mitigate seismic risk.[66] The COGCC has historically regulated seismicity indirectly through its regulations on maximum injection pressures even though there has been relatively little incidence of induced earthquakes since Rocky Mountain Arsenal. Its regulations have also evolved in response to the increased concern related to oil and gas wastewater disposal.[67]

In 2011, the injection of produced wastewater from a coalbed methane field in the Raton Basin triggered a large earthquake (M5.3) near Trinidad, Colorado.[68] The COGCC responded a month later by expanding the UIC permit review process to specifically include a seismicity review for Class II oil and gas wastewater disposal.[69] The COGCC now works in conjunction with the Colorado Geological Service (CGS) and USGS to conduct an initial report analyzing the potential of inducing seismicity.[70] If historic seismicity or certain preexisting conditions are identified near a proposed disposal site, the agency requires the well operator "to define the seismicity potential and the proximity to faults through geologic and geophysical data prior to any permit approval."[71]

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[66] Darlene A. Cypser, *Colorado Law and Induced Seismicity*, 47 (1996) (unpublished manuscript) (on filed with author), http://www.researchgate.net/publication/273789334_Colorado_Law_and_Induced_Seismicity.

[67] Richards, *supra*, note 38, at 21.

[68] *Id*. *See also* Barnhart, W. et al. (2014), *Seismological and geodetic constraints on the 2011 Mw5.3 Trinidad, Colorado earthquake and induced deformation in the Raton Basin*, J. Geophys. Res., 119, doi:10.1002/2014JB011227.

[69] Folger, *supra* note 7, at 11; Richards, *supra*, note 38, at 20.

[70] The permit process also involves review and approval of: well construction; isolation of ground water aquifers; maximum injection pressure; maximum injection volume; and injection zone water quality. COGCC, *Class II Underground Injection Control Wells*, Gov. Task Force on State & Local Oil & Gas Operations, 1 (2015) http://cogcc.state.co.us/documents/about/TF_Summaries/GovTaskForceSummary_Engineering%20UIC%20Wells.pdf.

[71] *Id*. at 2.

Outside the permit review process, COGCC utilizes a "stoplight system"[72] to shut down injection wells if certain levels of seismicity are observed.[73] Further, the agency has partnered with the CGS, USGS, and state universities to establish an "induced seismicity advisory group" in order to foster a more comprehensive monitoring and guidance network.[74] Colorado's proactive measures also include financial assurance requirements imposed on well operates in order to compensate persons or property injured by earthquakes.[75] However, these requirements are "likely insufficient to fully compensate" the damage since they were originally designed to protect against "more garden-variety forms of environmental damage" like water contamination.[76] Nonetheless, since the COGCC implemented these requirements, the state has not experienced significant seismicity connected to anthropogenic activity.[77]

B. Oklahoma Response to Induced Earthquakes

Nowhere has the uptick in seismic activity been more evident than in Oklahoma.[78] In 2014, Oklahoma was the most seismically active state in the continental U.S., enduring more earthquakes than it experienced in the previous thirty years combined.[79] The Sooner State is on

[72] Like a traffic light, the regulations greenlight injection disposal activities "when observed seismicity levels are low, slow operations when seismicity reaches a certain threshold, and cut operations off entirely above a point." Barclay R. Nicholson, *Induced Seismicity Legal Issues Break New Ground*, Law360, May 15, 2015, http://www.law360.com/articles/654837/induced-seismicity-legal-issues-break-new-ground.
[73] Trent Jacobs, *Searching for Solutions to Induced Seismicity*, J. Petroleum Tech., Sept. 1, 2014, http://www.spe.org/jpt/article/7139-searching-for-solutions-to-induced-seismicity/. *See also* Bridgett Weaver, *COGCC Has a Plan For Future Earthquakes*, Greeley Tribune, Feb. 10, 2015, http://www.greeleytribune.com/news/14763491-113/cogcc-has-a-plan-for-future-earthquakes.
[74] Folger, *supra* note 7, at 19.
[75] 6 Colo. Code. Regs. § 404-1 (Rules 706, 707, and 712)
[76] Richards, *supra*, note 38, at 22.
[77] Id.
[78] Arkansas, Texas, and Ohio have also experienced damaging quakes with suspected links to wastewater from oil and gas operations. Richards, *supra* note 14, at 3.
[79] Bustillo, *supra* note 30.

pace to double that amount in 2015,[80] as "the frequency and severity of these earthquakes are both on the rise."[81] The explanation for these events appears to be induced seismicity.[82]

In 2011, a M5.6 earthquake struck near the town of Prague, damaging roads and destroying at least fourteen homes.[83] The seismic event was the largest recorded earthquake in Oklahoma history, and one of many unprecedented tremors that have hit the region in recent years.[84] Scientists concluded that the massive tremor was facilitated by the operations of nearby oil and gas wastewater disposal wells.[85]

(i) Denial and Delayed Response from State Officials

Oklahoma regulators have been slow to address their problems of induced seismicity, but in the face of increasing outside pressure and studies warning of the risk, state officials have started to implement similar mechanisms to those employed in Colorado.

Like the COGCC, the Oklahoma Corporation Commission (OCC) is vested with exclusive jurisdiction over oil and gas Class II UIC disposal wells.[86] Given the state's historically low seismicity, the OCC traditionally did very little to address potential risks from induced seismicity. Yet, despite being the focus of the current upswing in earthquake activity, Oklahoma

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[80] Mathew Philips, *Oklahoma Earthquakes Are a National Security Threat*, Bloomberg Energy and Climate Report (BNA), Oct. 23, 2015, http://www.bloomberg.com/news/articles/2015-10-23/oklahoma-earthquakes-are-a-national-security-threat.

[81] Blake Watson & Catrina Rorke, *Should Oil Firms Be Held Liable in Earthquake Lawsuits?* WALL St. J., Nov. 15, 2015, http://www.wsj.com/articles/should-oil-firms-be-held-liable-in-earthquake-lawsuits-1447643517.

[82] USGS began warning in 2012 that a "remarkable" surge in earthquakes in OK was likely linked to disposal operations (or paying attention since) Mike Soraghan, *Sierra Club Threatens to Sue Drillers to Stop Okla. Shaking*, E&E, Nov. 3, 2015, http://www.eenews.net/stories/1060027316.

[83] Bustillo, *supra* note 30.

[84] *Id.*

[85] *Id*. Several lawsuits have been filed against the companies seeking damages under common law tort theories. Ladra v. New Dominion, LLC, 353 P.3d 529 (Okla. 2015) (seeking damages for personal injury); Cooper v. New Dominion, LLC, No. CJ-2015-0024 (D. Lincoln Ct. Okla., Feb. 10, 2015) (seeking class-action for people whose property was damaged by the 2011 Prague earthquake).

[86] 52 Okla. Stat. §139 (D). The OCC is an independent agency with three elected commissioners. *See also* Craig D. Sundstrom, *Oklahoma Regulators Implement Evolving Regulatory Directives in Response to Earthquakes*, 46 No. 6 ABA Trends 4 (2015).

did not enact permit requirements or other regulations until very recently.[87] The delayed response may have something to do with petroleum politics.[88]

Remember, "Oil is the Oklahoma business,"[89] the state's largest employer, and interfering with the industry is highly unpopular.[90] Oil and gas officials have been slow to acknowledge the link connecting seismicity to injection wells, and they successfully lobbied the state legislature to pass laws limiting the ability of municipalities to regulate wells within their communities.[91] OCC officials explain that they are "struggling to devise a plan that would curb earthquakes without hamstringing" the oil and gas industry.[92]

Scientists at the Oklahoma Geological Survey (OGS) have also been pressured to deemphasize the evidence linking wastewater disposal to induced seismicity.[93] The OGS's chief seismologist stepped down in the fall of 2015 after relentless pressure from the industry to minimize the impact of injection wells on earthquakes in the area.[94] OCC officials had been "waffling" about the science for years until finally succumbing in April 2015 in the face of

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[87] Richards, *supra*, note 38, at 11.
[88] *Id*. at 30; Alexandra Witze, *Artificial Quakes Shake Oklahoma*, 520 Nature 418 (2015). (emphasizing that oil and gas companies wield great power in Oklahoma).
[89] GOLD, *supra* note 23, at 170 (explaining that it is a "point of pride for many Oklahomans to be invested in a well or two.")
[90] Mike Soraghan, *Okla. Officials May Lack Authority on Seismicity Issues*, E&E News, Oct. 9, 2015, http://www.eenews.net/stories/1060026113. (noting that "as many as one in five jobs are tied to the industry, and most politicians rely on industry executives for campaign contributions.").
[91] Richard A. Oppel, *Oklahoma Court Rules Homeowners Can Sue Oil Companies Over Quakes*, NEW YORK TIMES, June 30, 2015, http://www.nytimes.com/2015/07/01/us/oklahoma-court-rules-homeowners-can-sue-oil-companies-over-quakes.html.
[92] Maria Gallucci, *Oklahoma Earthquake Swarm: Groups Start Legal Process To Sue Oil Companies Over Wastewater Injections*, International Business Times, Nov. 2, 2015, http://www.ibtimes.com/oklahoma-earthquake-swarm-groups-start-legal-process-sue-oil-companies-over-2165858 (emphasizing that the industry is a major driver of state revenues).
[93] Michael Wines, *New Concern Over Quakes in Oklahoma Near a Hub of U.S. Oil*, NEW YORK TIMES, Oct. 14, 2015, http://www.nytimes.com/2015/10/15/us/new-concern-over-quakes-in-oklahoma-near-a-hub-of-us-oil.html.
[94] The OCC's enforcement budget was also cut by about 45% in July 2015. Id.

mounting evidence showing a link between the earthquakes and injection well disposal.[95] The OCC's shift in stance was unexpected, and state leaders released a statement citing a determination by the OGS that "the majority of recent earthquakes in central and north-central OK are very likely triggered" by wastewater disposal wells.[96] Since then, the OCC has developed a slowly evolving regulatory response.[97]

(ii) OCC Recent Efforts & Challenged Authority

The OCC has used authority to "persuade" companies in seismic sensitive areas to limit the amount of wastewater they inject.[98] After a series of quakes started hitting near the Cushing Oil Hub complex[99]—one of the largest crude storage hubs in the world and critical to America's energy security in terms of supply—the OCC "ordered wells within three miles to shut down entirely" and a little further out to reduce their volume by 25 percent.[100] The OCC has also

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[95] Mike Soraghan, *Okla. Officials May Lack Authority on Seismicity Issues*, E&E News, Oct. 9, 2015, http://www.eenews.net/stories/1060026113.

[96] Richard A. Oppel, *Oklahoma Court Rules Homeowners Can Sue Oil Companies Over Quakes*, NEW YORK TIMES, June 30, 2015, http://www.nytimes.com/2015/07/01/us/oklahoma-court-rules-homeowners-can-sue-oil-companies-over-quakes.html.

[97] OCC, Latest Developments, http://earthquakes.ok.gov/what-we-are-doing/oklahoma-corporation-commission/.

[98] For example, in August 2015 the OCC ordered a 38% cut in the amount of wastewater injected underground by operators of 23 injection wells located within a 40-mile stretch northeast of Oklahoma City. Michael Wines, *New Concern Over Quakes in Oklahoma Near a Hub of U.S. Oil*, NEW YORK TIMES, Oct. 14, 2015, http://www.nytimes.com/2015/10/15/us/new-concern-over-quakes-in-oklahoma-near-a-hub-of-us-oil.html.

[99] The Cushing Hub is often considered "ground zero" for the world price since is serves as the "gathering point for light, sweet crude known as West Texas Intermediate (WTI)" that provides a reference point for futures traded on the New York Mercantile Exchange. YERGIN, *supra* note 6, at 161. After 9/11, U.S. government officials highlighted Cushing as a potential terrorist target, labeling the hub as "critical national infrastructure." See also Philips, *supra* note 80 (arguing that "if even a couple of Cushing's tanks had to shut down, or a pipeline were damaged the impact could ripple through the market.").

[100] The largest quake (M4.5) hit within a few miles of town and rattled the complex's massive tanks. Mathew Philips, *Oklahoma Earthquakes Are a National Security Threat*, Bloomberg Energy and Climate Report (BNA),

instituted a stoplight system for UIC well permitting similar to the framework adopted by Colorado.[101]

Entities subject to the new regulations can appeal the OCC's actions and request a hearing before an administrative law judge.[102] However, the success of these isolated efforts hinges on voluntary compliance from the industry, and concerns are mounting as to whether the OCC has the legal authority to limit the shaking.[103] In October 2015 a Tulsa-based energy company filed the first challenge to the OCC's efforts to rein in seismic inducing operations, particularly the agency's controversial volume restrictions adopted in August.[104] Rules enacted under the UIC program are focused on "cleaning up pollution, not preventing earthquakes," and more companies might jump on the bandwagon to rein in the OCC's efforts.[105] In a recent review of Oklahoma's UIC program, EPA urged the OCC to "implement additional regulatory actions."[106] However, even with the OCC stepping up its enforcement efforts, they might not have the power

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Oct. 23, 2015, http://www.bloomberg.com/news/articles/2015-10-23/oklahoma-earthquakes-are-a-national-security-threat.

[101] The traffic light regulations apply to both new and existing wells in seismically active areas. An important component is OCC's "delineation of areas of interest, which are determined by proximity to recent seismic swarms or groups of seismic events." Murray KE, *Class II Underground Injection Control Well Data for 2010–2013 by Geologic Zones of Completion, Oklahoma*. Oklahoma Geological Survey Open-File Report (OF1-2014), 32, (2014), http://www.ogs.ou.edu/pubsscanned/openfile/OF1_2014_Murray.pdf.

[102] Sundstrom, supra note 86, at 6.

[103] *Id*.; Mike Soraghan, *Okla. Officials May Lack Authority on Seismicity Issues*, E&E News, Oct. 9, 2015, http://www.eenews.net/stories/1060026113. However, OCC might "prevail under its public safety backstop authority" though this argument has not yet been tested with regards to seismicity concerns. Murray *supra* note 101.

[104] Michael Wines, *New Concern Over Quakes in Oklahoma Near a Hub of U.S. Oil*, NEW YORK TIMES, Oct. 14, 2015, http://www.nytimes.com/2015/10/15/us/new-concern-over-quakes-in-oklahoma-near-a-hub-of-us-oil.html (arguing that its wells are not contributing to the problem). However, OCC might "prevail under its public safety backstop authority" though this argument has not yet been tested with regards to seismicity concerns. Murray *supra* note 101.

[105] Mike Soraghan, *Okla. Officials May Lack Authority on Seismicity Issues*, E&E News, Oct. 9, 2015, http://www.eenews.net/stories/1060026113. *See also* Murray, *supra* note 101 (explaining that the current regulatory controls "were designed to protect potable-water resources from contamination.").

[106] Mathew Philips, *Oklahoma Earthquakes Are a National Security Threat*, Bloomberg Energy and Climate Report (BNA), Oct. 23, 2015, http://www.bloomberg.com/news/articles/2015-10-23/oklahoma-earthquakes-are-a-national-security-threat.

to "seriously curb waste disposal, and politicians in a state dominated by the energy industry have made no move to give it to them."[107] The best mechanism to mitigate seismicity might instead lie with voluntary efforts from the industry itself.

IV. Voluntary Industry Efforts in Response to Induced Seismicity: Corporate Social Responsibility & Social License to Operate

Mitigating the most damaging effects from induced seismicity will require "detailed seismic monitoring, careful selection of injection locations, variation of injection rates and pressures in response to ongoing seismicity, and a clear management plan."[108] Regulators have limited resources and information to address seismicity.[109] Due to their superior geophysical knowledge and capacity to address seismic issues as they unfold, it is voluntary mitigation efforts from individual companies that will likely have the greatest impact.[110]

Addressing seismicity head-on is important to mitigating the effects of potentially damaging earthquakes, but is also important to gain public acceptance and alleviate conflicts with the surrounding community.[111] Indeed, the mere presence of a potential seismic hazard "creates a stigma of harm," regardless of the fact that the threat of induced earthquakes is relatively low.[112] Rather than responding "only after the risk manifests into a full-brown crisis," companies should engage in more proactive measures to address induced seismicity.[113]

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[107] Michael Wines, *New Concern Over Quakes in Oklahoma Near a Hub of U.S. Oil*, NEW YORK TIMES, Oct. 14, 2015, http://www.nytimes.com/2015/10/15/us/new-concern-over-quakes-in-oklahoma-near-a-hub-of-us-oil.html.
[108] Rubinstein, *supra* note 8, at 6.
[109] Murray, *supra* note 101 (explaining that "there is an urgent need to quantify volumes and pressures" and obtain additional data "to develop best management practices" for wastewater disposal).
[110] Barclay R. Nicholson, *Induced Seismicity Legal Issues Break New Ground*, Law360, May 15, 2015, http://www.law360.com/articles/654837/induced-seismicity-legal-issues-break-new-ground.
[111] U.S. Dept. of Energy-Lawrence Berkeley National Laboratory, *About Induced Seismicity?* http://esd1.lbl.gov/research/projects/induced_seismicity/ (providing "access to high quality, state of the art seismic information will be important for both public acceptance and industry response.").
[112] Don C. Smith & Jessica M. Richards, *Social License to Operate: Hydraulic Fracturing-Related Challenges Facing the Oil & Gas Industry*, 1:2 Oil & Gas, Nat. Resources, & Energy J. 81, 3 (2015).
[113] Reilly Goodwin, *Risk Mitigation Through CRS and Sustainability*, 4 (2015).

The oil and gas industry is "being scrutinized more than ever,"[114] and technology has enabled citizens to demand greater accountability from operators than in the past.[115] This is especially true in places like Colorado where population growth and urban sprawl collides with unconventional shale development.[116] Modern societies expect oil and gas companies to self-regulate, to take efforts beyond merely complying with the law.[117] Sometimes expressed as an "ongoing social contract with society" or a "social license to operate," companies should manage the risks of induced seismicity in terms of social political risk, not just in terms of actual physical damage resulting from the quakes.[118] This process involves engaging in early and "ongoing communication at the community level, transparency, and engagement in decision making, and the establishment of effective conflict resolution mechanisms."[119] Besides addressing community issues and earning trust prior to the occurrence of a seismic event, what other strategies can companies deploy to mitigate the impact?[120]

These efforts might involve taking the operation management steps quoted at the beginning of this section.[121] In the absence of an insurance market and in addition to the financial assurance requirements like those imposed by the COGCC, the industry can create their own compensation pool to pay damages to those injured by induced earthquakes.[122] Disposal wells could be placed

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[114] GOLD, *supra* note 23, at 26.
[115] Goodwin, supra note 113, at 4 (explaining that "[t]he collision of globalization, the internet, social media, and a growing consciousness of human impacts on the natural environment is empowering stakeholders and creating greater expectations of accountability and transparency from the world's corporate citizens.").
[116] Smith, *supra* note 112, at 1.
[117] Spence, infra note 134, at 60 (arguing that citizens demand CSR from oil and gas companies, "[perhaps more so than in any other industry.").
[118] Smith, *supra* note 112, at 6–7.
[119] *Id*. at 3.
[120] *Id*. at 40.
[121] *supra* note 108.
[122] Blake Watson & Catrina Rorke, *Should Oil Firms Be Held Liable in Earthquake Lawsuits?* WALL St. J., Nov. 15, 2015, http://www.wsj.com/articles/should-oil-firms-be-held-liable-in-earthquake-lawsuits-1447643517.

further apart or located in areas that are less populated.[123] It might also involve coming up with more creative ways of handling and disposing of oil and gas wastewater.

Because the wastewater is hazardous, disposing it deep underground is currently considered the "environmentally preferred option" for managing produced and other wastewater associated with oil and gas production.[124] One alternative disposal method involves the discontinuation of injecting into the traditional geologic formations that have resulted in seismic activity, and instead sending the produced water back into the formation from which it was extracted.[125] Another option includes re-using some of the wastewater to create new frack fluids or to re-fracture the production wells. Water is the "hydraulic heart"[126] of the fracking process, and recycling the produced and flowback water has the potential to cut down on the load of underground disposal wells while conserving precious water resources at the same time.[127] However, this relatively new practice may not be the most cost-effective option for oil and gas producers.[128]

Re-using wastewater or utilizing other alternative disposal methods entails significant transportation costs, in addition to the task of treating the water and removing hazardous pollutants.[129] To reduce their injection volumes, companies have to cut production or spend money to the ship waste further away for disposal.[130] This might be particularly burdensome for

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[123] Chris Faulkner, *Fracking-Related Quakes May Keep Courts Busy*, 32 No. 10 Westlaw J. Toxic Torts 11, 4 (2014).
[124] Folger, *supra* note 7, at 11.
[125] Mark Zoback & F. Rall Walsh III, *Oklahoma's Recent Earthquakes and Saltwater Disposal*, SCIENCE, 1 (2015).
[126] Almost all of the water that makes up the "gelatinous glop" used to frack wells is snowmelt from Rocky Mountains that flows into the Missouri River and into giant reservoirs. GOLD, *supra* note 23, at 51.
[127] Faulkner, *supra* note, 124 at 3.
[128] *Id*.
[129] *Id*.
[130] Mike Soraghan, *Okla. Officials May Lack Authority on Seismicity Issues*, E&E News, Oct. 9, 2015, http://www.eenews.net/stories/1060026113.

smaller companies already struggling to survive since the price of oil fell drama dramatically in 2014.[131] Since prices fell the "mantra" among shale producers is "thrift," and capacity is being cut across the industry, particularly in projects with high production costs.[132] However, experience thus far shows that, while not devoid of financial hurdles, mitigating the risk of seismicity "can be handled in a cost-effective manner."[133]

Engaging in "robust corporate social responsibility" can also "improve competitive value" in addition to mitigating seismic risk.[134] If the industry is passive in its approach, the unmitigated seismic risk can translate into social risks with "the potential to negatively influence the financial success" of industry operations.[135] Many oil and gas companies have reached this conclusion, and recognize that it is in their financial interest to pay "greater attention to the needs and wants of external stakeholders."[136] The industry has begun to develop a set of best practices, and several leading companies now have seismic mitigation policies.[137] If companies embrace this strategy, there will be less of a need for reactionary command-and-control regulation.

V. Conclusion

[131] The energy boom ended abruptly in mid-2014 when the price of oil in America dropped from $100 to $43. *Fractured Finances*, ECONOMIST, July 4th, 2015.
[132] *Id*. *See also*, *There Will be Blood*, ECONOMIST, July 4th, 2015 (explaining that "gone are the days when roughnecks were fed lobster in luxury camps and Texan towns were circled by Learjets").
[133] *Fractured Finances*, ECONOMIST, July 4th, 2015 (emphasizing the shale industry's "entrepreneurial spirit and its skill in both geological and financial engineering.").
[134] Goodwin, *supra* note 113, at 6; David B. Spence, *Corporate Social Responsibility in the Oil and Gas Industry*: The Importance of Reputational Risk, 86 Chi.-Kent. L. Rev. 59, 84 (2010).
[135] Daniel M. Franks et al, *Conflict Translates Environmental and Social Risk Into Business Costs*, (2014) (explaining that social conflict is a "further means through which environmental and social risks are translated into business costs and decision making.").
[136] Spence, supra note 134, at 84.
[137] ExxonMobil has established a protocol and other companies are beginning to follow suit. *See* Richards, *supra*, note 38, at 5. *See also* Barclay R. Nicholson, *Induced Seismicity Legal Issues Break New Ground*, Law360, May 15, 2015, http://www.law360.com/articles/654837/induced-seismicity-legal-issues-break-new-ground. (noting that some companies voluntarily utilize stop light protocols in their injection operations).

State regulation of induced seismicity can have a strong deterrent effect, but if regulators are slow to address induced seismicity in a meaningful way, some operators may ignore the risk.[138] Given its history with damaging induced earthquakes and preventative approach to mitigate potential new threats, Colorado has developed a strong regulatory framework.[139] Its earthquakes ceased after proactive measures were imposed.[140] By contrast, in Oklahoma, where the oil and gas industry makes up a large portion of the economy and has substantial influence over the state's politics, the risk of "inertia against regulation" is particularly high.[141] The OCC's regulatory response was merely reactive, delayed, and the state continues to experience rising levels of induced seismicity.[142] The Colorado approach demonstrates that establishing an affirmative scientific link is not a prerequisite for taking early action to address the potential of induced seismicity.[143]

When it comes to addressing new challenges emerging in the wake of America's energy boom, finding common ground can be elusive.[144] Whether you're an industry lobbyist or an ardent fracktivist, solving the problems associated with seismicity requires constructive dialogue and compromise.[145] Finding the right balance requires continued development of hydrocarbon

[138] Richards, *supra* note 38, at 30.
[139] Id. at 33.
[140] Id. at 30.
[141] Richards, *supra* note 38, at 30. See also GOLD, *supra* note 23, at 26.
[142] Richards, *supra*, note 38, at 30.
[143] U.S. Environmental Protection Agency, *Minimizing and Managing Potential Impacts of Injection-Induced Seismicity from Class II Disposal Wells: Practical Approaches*, Underground Injection Control National Technical Workgroup, ES-3 (2015).
[144] GOLD, *supra* note 23, at 297 (explaining that "the forces arrayed in favor and against don't speak the same language."). *See also* Ehrman, *supra* note 4, at 426–27 (arguing that "environmental issues, industry lobby efforts, and intentional relations have all prevented a comprehensive national energy policy that would address current and potential supply along with corresponding reductions in demand.").
[145] Ehrman, *supra* note 4, at 464(asserting that "without compromise regarding our energy future we may face a decrease in industrial growth and an increase in environmental harm."). YERGIN, *supra* note 3, at 723.

resources, but also judicious regulatory monitoring and community engagement.[146] The best approach is to "broadly align government policy and market forces" in order to facilitate new best practices and mitigation strategies in the context of induced seismicity.[147] Within this collaborative framework, various entities take on different roles: geoscientists act as investigators and demystify false assumptions regarding the science; courts and regulators hold companies accountable when they ignore the risks; and the oil and gas industry can tailor their operations to decrease their role in inducing earthquakes.[148]

[146] Ehrman, *supra* note 4, at 464.
[147] GOLD, *supra* note 23, at 307.
[148] EPA stresses the use of this multidisciplinary approach. U.S. Environmental Protection Agency, *Minimizing and Managing Potential Impacts of Injection-Induced Seismicity from Class II Disposal Wells: Practical Approaches*, Underground Injection Control National Technical Workgroup, ES-2 (2015).