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FRACTURED FAIRYTALES: THE FAILED SOCIAL LICENSE FOR UNCONVENTIONAL OIL AND GAS DEVELOPMENT

*Evan J. House**

Abstract

Few people had heard of "fracking" ten years ago. Today, it is ubiquitous, especially in the media. But, despite our growing familiarity with the term fracking and its companion process, horizontal drilling, they remain poorly understood. Fracking has also become a shorthand term used by various stakeholders to describe a variety of processes related to unconventional oil and gas development that are connected to, but distinct from fracking. Moreover, and to a significant extent, the term has been co-opted by opponents of oil and gas development to encapsulate all of the problems that can arise from such development. To be sure, many of those problems are real, although most might be reasonably addressed. But, because the surge of new unconventional development outpaced a complete discussion of the problems and potential solutions, industry lacks the public's support to fully develop unconventional oil and gas resources.

This article does not advocate for or against the development of unconventional oil and gas deposits; nor does it seek to resolve whether fracking and horizontal drilling are, in all cases, environmentally benign. Rather, this article attempts to demystify unconventional oil and gas development, including hydraulic fracturing, by providing an in-depth explanation of the processes involved. It also suggests a framework to help the public, industry, and decision makers engage in a meaningful social discourse on unconventional oil and gas development generally, and fracking in particular. Further, a foundation is offered for understanding how unconventional gas development can be carried out to best protect affected public and private interests.

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I. INTRODUCTION

Everyone knows what "fracking"[1] is, right? If you read newspapers, blogs, or listen to the evening news you have heard of it. And for energy independence, it appears to be the key to a fairytale dream come true. But how well is fracking understood? Do you know what its environmental consequences are, or even how various stakeholders might be using that term to mean very different things? For

[1] There are several spellings for "fracking," a shorthand term describing the hydraulic fracturing process (e.g., fracking, fraccing, fracing, hydrofracking), all of which are interchangeable. *See infra* Section III(C) for a detailed discussion of the fracking process.

instance, the environmental community often uses the term fracking as shorthand for all negative aspects of oil and gas development activities, and particularly for unconventional oil and gas development.[2] Industry, on the other hand, tends to use fracking as a term to describe one specific process, distinct from an array of other development activities. Additionally, the information gap among members of industry, the public, the media, and even among regulators regarding fracking is vast. And until quite recently, the oil and gas industry has failed to address this gap, let alone to proactively engage affected communities in meaningful discourse on the environmental and social impacts of horizontal drilling and hydraulic fracturing.

Various stakeholders all share some responsibility for this public-industry disconnect. The public, for one, could do more to inform itself about the true consequences of oil and gas development. Unfortunately, hyperbolic, too often simplified, or sometimes inaccurate reporting on the subject significantly impedes the public's ability to self-educate. But industry, which arguably has the most at stake, bears the brunt of the blame: by withholding critical information from the public, especially during the early days of the shale gas boom, industry bred years of public mistrust. Consequently, industry's social license to operate[3] is now under threat.

In order for our society to forge a successful solution to the current social unease related to unconventional oil and gas development and for industry to earn a social license to operate,[4] two things must happen. First, the public must become better informed about unconventional oil and gas development and its attendant risks and consequences. This requires understanding the hydraulic fracturing and horizontal drilling processes and how they have precipitated the boom in the development of globally ubiquitous shale plays. Second, industry must continue to improve its operations: it must increase operational transparency; address the social anxieties caused by impacts to communities; develop cooperative working relationships with affected communities; and it must commit to using more environmentally and socially responsible business practices.

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[2] *See infra* notes 75–108 and accompanying text (discussing conventional and unconventional oil and gas development, generally).

[3] *See generally*, JANE A. GRANT, THE NEW AMERICAN SOCIAL COMPACT: RIGHTS AND RESPONSIBILITIES IN THE TWENTY-FIRST CENTURY (2008). Much like seventeenth and eighteenth century liberalism and the idea of the social compact, the social license stems from the idea of citizens having certain rights guaranteed by their society. While oversimplified, in this case it is the right to a healthful environment that is imperiling the social license to operate unconventional oil and gas development activities.

[4] A company earns the license by conforming to "jointly construct[ed] norms of legal compliance and standards for appropriate business conduct" that are trusted and accepted by the public. *See* Jennifer Howard-Grenville et al., *Construing the License to Operate: Internal Factors and Their Influence on Corporate Environmental Decisions*, 30 LAW & POL'Y 73, 77 (2008). For a discussion on obtaining a social license for unconventional gas development, see *infra* Section VI(A).

The article proceeds in five sections. Section II begins with a concise look at the rise of unconventional gas development. Section III offers an in-depth explanation of the processes involved in unconventional gas development. Section IV introduces the environmental and social impacts associated with these processes. Section V reviews the failed social discourse surrounding unconventional oil and gas development and why industry and permitting agencies bear a duty to facilitate the flow of information. Finally, Section VI outlines how industry and government agencies can meet these obligations to ensure that oil and gas development is conducted in a socially and environmentally responsible manner.

II. UNDERSTANDING THE PHENOMENON OF UNCONVENTIONAL GAS DEVELOPMENT IN SHALE PLAYS

While hydraulic fracturing (fracking) is not a newly invented technique,[5] modern technologies and the advancement of horizontal drilling have opened up significant new opportunities for unconventional oil and gas development. As a result, a domestic energy revolution has developed over the past decade. The North American shale gas phenomenon also appears poised to erupt into a global phenomenon in coming years,[6] with Canada and China[7] reportedly sitting atop the largest shale gas deposits in the world.[8] "A gasified American economy would [also] have profound effects on both international politics and the battle against climate change."[9]

In 2001, shale[10] gas reservoirs, which are classified as unconventional gas plays,[11] accounted for only two percent of the United States' natural gas

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[5] *See* Jennifer L. Miskimins et al., *The Technical Aspects of Hydraulic Fracturing*, HYDRAULIC FRACTURING, Paper No. 1, 1–4 (Rocky Mt. Min. L. Fdn. 2012). The first intentional fracture treatment took place in 1947 in western Kansas and has been a technique used worldwide since then. The first testing of hydraulic fracturing, however, took place as early as 1903. *See* Thomas E. Kurth et al., *American Law and Jurisprudence on Fracing*, HYDRAULIC FRACTURING, Paper No. 3A, 3A-3 (Rocky Mtn. Min. L. Fdn. 2012).

[6] *See* Susan L. Sakmar, *The Global Shale Gas Initiative: Will the United States be the Role Model for the Development of Shale Gas Around the World?*, 33 HOUS. J. INT'L L. 369, 371 (2011) ("Because shale formations exist in almost every region of the world, the potential for shale gas development is enormous and global in scope.").

[7] *See* ENERGY INFO. ADMIN., INTERNATIONAL ENERGY OUTLOOK 2011, 44 (2011), http://www.eia.gov/forecasts/ieo/pdf/0484(2011).pdf.

[8] *See* Leslie Hook, *PetroChina Finds Shale Gas Reserves*, FIN. TIMES (Dec. 7, 2011, 7:01 PM), http://www.ft.com/intl/cms/s/0/b76c54d6-20d5-11e1-816d-00144feabdc0.html#axzz1liRRZlNT.

[9] *An Unconventional Glut: Newly Economic, Widely Distributed Sources are Shifting the Balance of Power in the World's Gas Markets*, ECONOMIST, Mar. 11, 2010, *available at* http://www.economist.com/node/15661889.

[10] For a discussion of the geological characteristics of shale gas reservoirs and the reasons for its now widespread accessibility, see *infra* notes 75–108 and accompanying text.

[11] U.S. DEPT. OF ENERGY, MODERN SHALE GAS DEVELOPMENT IN THE UNITED STATES: A PRIMER, 7 (2009), *available at* http://www.netl.doe.gov/technologies/oil-gas/publications/EPreports/Shale_

production.[12] According to the Energy Information Administration (EIA), from 2000 to 2006, natural gas production from shale formations increased seventeen percent per year.[13] As substantial as this increase might seem, it was eclipsed by the forty-eight percent increase in shale gas production seen between 2006 and 2010.[14] Overall, "during the last decade, U.S. shale gas production has increased fourteen-fold."[15] Today, shale gas reservoirs account for thirty percent of domestic natural gas production.[16] By 2035, the unconventional gas yield is predicted to increase to 13.6 tcf,[17] or nearly half of all United States dry gas[18] production.[19] Depending on technological advances, however, tight gas recovery could yield up to 20.5 tcf by 2035.[20] Increasing natural gas production might even allow the United States to transition from a net importer to a net exporter of natural gas within a few decades.[21]

While several factors have contributed to the recent explosion of shale gas development, the chief catalysts have been the refinements of cost-effective high-pressure hydraulic fracturing and horizontal drilling processes.[22] Because of these technological advancements, natural gas production is more economical today than ever before.[23] The influx of inexpensive natural gas has resulted in other

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Gas_Primer_2009.pdf. The term "play" is used to describe an area where oil or gas development can take place due to hydrocarbon accumulations. *See Play Definition*, SCHLUMBERGER OILFIELD GLOSSARY, http://www.glossary.oilfield.slb.com/Display.cfm?Term=play (last visited Nov. 17, 2012). For a detailed discussion of unconventional plays, see *infra* notes 75–108 and accompanying text.

[12] *See* Joe Nocera, Op-Ed., *How to Extract Gas Responsibly*, N.Y. TIMES, Feb. 27, 2012, at A25, *available at* http://www.nytimes.com/2012/02/28/opinion/nocera-how-to-frack-responsibly.html.

[13] ENERGY INFO. ADMIN., ENERGY OUTLOOK 2011 WITH PROJECTIONS TO 2035, 37 (2011), *available at* http://www.eia.gov/forecasts/aeo/pdf/0383(2011).pdf.

[14] *Id.*

[15] U.S. DEP'T OF ST., *Unconventional Gas Technical Engagement Program (UGTEP)*, http://www.state.gov/s/ciea/gsgi/index.htm (last visited Nov. 17, 2012).

[16] SEC'Y OF ENERGY ADVISORY BD., Shale Gas Production Subcommittee Ninety-Day Report 6 (2011), http://www.shalegas.energy.gov/resources/081111_90_day_report.pdf.

[17] Trillion cubic feet is a common value measurement for natural gas.

[18] "Natural gas is considered 'dry' when it is almost pure methane, having had most of the other commonly associated hydrocarbons removed. When other hydrocarbons are present, the natural gas is 'wet.'" *Background*, NATURALGAS.ORG, http://www.naturalgas.org/overview/background.asp (last visited Nov. 17, 2012).

[19] ENERGY INFO. ADMIN., ANNUAL ENERGY OUTLOOK 2012: WITH PROJECTIONS TO 2035, 3 (2012), http://205.254.135.7/forecasts/aeo/pdf/0383(2012).pdf.

[20] *Id.*

[21] *Id.*

[22] U.S. DEPT. OF ENERGY, *supra* note 11, at ES-3.

[23] According to the Department of Energy, "[t]hree factors have come together in recent years to make shale gas production economically viable: 1) advances in horizontal drilling, 2) advances in hydraulic fracturing, and, perhaps most importantly, 3) rapid increases in natural gas prices in the last several years as a result of significant supply and demand pressures." *Id.* at ES-1. However, since the Energy Information Administration report in 2009, gas prices have decreased and are not expected to return to the pre-2009 recession levels. *See* ENERGY INFO. ADMIN., *supra* note 13, at 78.

forms of fossil hydrocarbon-based electric power generation no longer being cost-competitive.[24] The levelized costs of natural gas generation, for example, are predicted to be lower than all forms of coal generation, even when comparing conventional coal plants with natural gas plants that incorporate costly carbon capture and sequestration technologies.[25] The current glut of natural gas and warmer than average winter temperatures have, however, driven natural gas prices to historically low levels, disincentivizing new natural gas production in favor of oil, which remains highly profitable.[26] Nonetheless, because oil produces comparably prodigious amounts of pollution, it is not a contender for new electric generation.[27] Thus, despite production companies' current reluctance to drill new gas wells, electricity generators continue to shift electricity production to natural gas.[28]

While the focus of this article is on natural gas development, the same basic techniques (viz. horizontal drilling and hydraulic fracturing) that have spurred the shale gas phenomenon and driven down natural gas prices have also been used to greatly enhance shale oil[29] and other liquid petroleum production.[30] The Bakken

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[24] *See Levelized Cost of New Generation Resources in the Annual Energy Outlook 2011*, ENERGY INFO. ADMIN, (Nov. 2010), http://www.eia.gov/oiaf/aeo/electricity_generation.html.

[25] *See id.* (The levelized costs of conventional coal generation (2009$/MWh) are 94.8, compared to natural gas with CCS at 89.3).

[26] *See, e.g.*, Floyd Norris, *Two Directions for the Prices of Natural Gas and Oil*, N.Y. TIMES, Feb. 25, 2011, at B3, *available at* http://www.nytimes.com/2011/02/26/business/global/26charts.html (in February of 2011, the price of natural gas was less than one-quarter that of oil on an energy-equivalent basis).

[27] *See Natural Gas*, U.S. EPA, http://www.epa.gov/cleanenergy/energy-and-you/affect/natural-gas.html (last updated Oct. 17, 2012) ("At the power plant, the burning of natural gas produces nitrogen oxides and carbon dioxide, but in lower quantities than burning coal or oil . . . . Emissions of sulfur dioxide and mercury compounds from burning natural gas are negligible.").

[28] *Cf.* ENERGY INFO. ADMIN., *supra* note 19, at 3 ("In the Reference case, the natural gas share of electric power generation increases from 24 percent in 2010 to 28 percent in 2035, while the renewables share grows from 10 percent to 15 percent. In contrast, the share of generation from coal-fired power plants declines.").

[29] *Colorado's New Oil Boom—the Niobrara*, COLO. DEPT. OF NAT. RES., 13 ROCK TALK 1 (Spring 2011), http://geosurvey.state.co.us/pubs/Documents/rtv13n1%204-15-11%20B.pdf.

> Shale oil should not be confused with the perhaps [better-known] 'oil shale' found in [places like] western Colorado. Shale oil and related shale gas occur in reservoirs where oil already exists as a liquid in very small openings between grains of rock. Oil shale, on the other hand, is an inorganic rock reservoir containing no liquid petroleum. It must be heated to high temperatures in order to convert solid organic material (kerogen) into a liquid or gas hydrocarbon.

Id. Fracking and horizontal drilling technologies are not used to develop oil shale, but are used for enhanced recovery in shale oil formations. *See also Oil Shale*, U.S. DEPT. OF THE INTERIOR, http://www.blm.gov/wy/st/en/field_offices/Rock_Springs/minerals/oil_shale (last updated Jan. 13, 2011).

[30] Other natural gas liquids (NGLs) include "propane, butane, pentane, hexane and heptane, but not methane [or] ethane, since these hydrocarbons need refrigeration to be liquefied." *See Natural Gas Liquids Definition*, SCHLUMBERGER OILFIELD GLOSSARY, http://www.glossary.oilfield.slb.com/Display.cfm?Term=natural%20gas%20liquids (last visited Nov. 17, 2012).

Shale serves as a prominent example of the unconventional oil boom.[31] Thanks largely to horizontal drilling, which accounted for ninety percent of the total volume of Bakken production in 2010, North Dakota is now the fourth largest oil producing state.[32] Other plays exploding in recent years, such as the Niobrara Formation in the Denver-Julesburg Basin, are sources of shale oil, natural gas, and natural gas liquids,[33] which are all often found in the same geological formations.

Together, fracking and horizontal drilling have been hailed as revolutionary and "game changing," greatly expanding the potential scope of shale gas development throughout the United States and in global plays.[34] In fact, due to the extremely low permeability and flow capacities characteristic of unconventional plays, without these two processes industry could not economically develop shale gas formations.[35] Nevertheless, although technological innovations have largely been driving the recent shale gas boom, other important factors have facilitated the shale gas revolution. One such factor is domestic energy policy.

Even though energy policies are not primarily responsible for natural gas's increasing importance, they have created a favorable climate for unconventional development activities. Of particular importance is Congress's clear goal of furthering the United States' energy independence,[36] which implicitly involves increasing domestic energy production. Enter natural gas: a domestic source of energy so plentiful that the United States might ultimately *export* it.[37] Recent studies estimate that, with horizontal drilling and hydraulic fracturing, the domestic natural gas supplies are between 1,836 tcf[38] and 2,247 tcf.[39] The latter number indicates that, at the 2007 production rate, there is enough natural gas in

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[31] "Since the beginning of 2008, the number of active oil rigs has increased [in the Bakken] 242%, reaching a 24-year high in October of [2011]." *See* SIERRA CLUB ET AL., COMMENTS ON PROPOSED NEW SOURCE PERFORMANCE STANDARDS: OIL AND NATURAL GAS SECTOR; REVIEW AND PROPOSED RULE FOR SUBPART 0000 10 (Nov. 30, 2011).

[32] *See Bakken Formation Oil and Gas Drilling Activity Mirrors Development in the Barnett*, ENERGY INFO. ADMIN., (Nov. 2. 2011), http://www.eia.gov/todayinenergy/detail.cfm?id=3750.

[33] *See* COLO. DEPT. OF NAT. RES., *supra* note 29, at 1.

[34] *See* Sakmar, *supra* note 6, at 370–71, 380–82 (citing Tom Fowler, *Energy Game-Changer?*, HOUS. CHRON., Nov. 1, 2009, at A1).

[35] *See* Miskimins et al., *supra* note 5, at 1–9.

[36] *See* Energy Independence and Security Act of 2007, Pub. L. No. 110–140 (2007) ("An Act to move the United States toward greater energy independence and security.").

[37] *See* ENERGY INFO. ADMIN., *supra* note 19 (projecting that between 2010 and 2035 natural gas production will increase to the point that the United States becomes a net exporter of natural gas).

[38] *Potential Gas Committee Reports Unprecedented Increase in Magnitude of U.S. Natural Gas Resource Base*, COLO. SCHOOL OF MINES (June 18, 2009), http://www.mines.edu/Potential-Gas-Committee-reports-unprecedented-increase-in-magnitude-of-U.S.-natural-gas-resource-base.

[39] NAVIGANT CONSULTING, ADDRESS AT 32ND IAEE INTERNATIONAL CONFERENCE: THE DYNAMICS OF ABUNDANCE OF NORTH AMERICAN DOMESTIC NATURAL GAS SUPPLY (2009), *available at* http://www.usaee.org/usaee2009/submissions/presentations/Pickering.pdf.

the United States to sustain production for 118 years.[40] Other estimates are more conservative, however, with the EIA opining in 2011 that technically recoverable[41] United States shale gas reserves sit between 423 tcf and 1,230 tcf.[42] The discrepancies among these estimates are due, in part, to the considerable uncertainty regarding the acreage of recoverable gas within each play, technological advancements, and the productivity levels of the producing reservoirs.[43] Notwithstanding such uncertainties and the obvious improvidence of exploiting the entire domestic gas reserve,[44] natural gas has become a realistic, economical domestic energy source.[45]

Another way shale gas development complements current United States energy initiatives is its ability to facilitate renewable integration.[46] Because of the inherently intermittent nature of renewable energy sources, conventional power plants can help make up for unexpected energy shortfalls by ramping up quickly.[47] And natural gas-fired power plants are capable of being ramped up quicker,[48] burning cleaner,[49] and generally have better operational flexibility than coal-fired plants.[50] Consequently, newly constructed baseload[51] electric power plants are

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[40] *Id.*

[41] For a discussion of the metric, technically recoverable resource (TRR), see ENERGY INFO. ADMIN., *supra* note 19, at 56.

[42] ENERGY INFO. ADMIN., *supra* note 13, at 38.

[43] *Id.*; *See also* Mark Zoback, *Producing Natural Gas From Shale—Opportunities and Challenges of a Major New Energy Source*, HYDRAULIC FRACTURING, Paper No. 4B, 4B–7 (Rocky Mt. Min. L. Fdn. 2012) (showing decreasing production rates over time).

[44] ENERGY INFO. ADMIN., *supra* note 13, at 79.

[45] *See* Dialogue, *Nuts and Bolts of Marcellus Shale Drilling and Hydraulic Fracturing*, 41 ENVTL. L. REP. NEWS & ANALYSIS 10587, 10587 (July 2011) ("Abundant, inexpensive, and lower in emissions than traditional coal power sources, natural gas is expected to play an enormous role in our energy future.").

[46] *See* U.S. EPA, *supra* note 27.

[47] *See FlexEfficiency 50 Combined Cycle Power Plant*, GEN. ELECTRIC, http://www.ge-energy.com/content/multimedia/_files/downloads/FlexEfficiency%2050%20Plant%20eBrochure.pdf (last visited Nov. 18, 2012) ("In support of fluctuations in renewables, fossil fuel prices, and energy demand, fewer plants will be operating in baseload mode.").

[48] *See* Symposium, *The MIT Energy Initiative's Symposium on Managing Large-Scale Penetration of Intermittent Renewables*, MASS. INST. OF TECH., 10 (Apr. 20, 2011), *available at* http://web.mit.edu/mitei/research/reports/intermittent-renewables-findings.pdf.

[49] *See* ENERGY INFO. ADMIN., NATURAL GAS 1998: ISSUES AND TRENDS, 49 (1999), *available at* http://www.eia.gov/pub/oil_gas/natural_gas/analysis_publications/natural_gas_1998_issues_trends/pdf/chapter2.pdf ("Natural gas, when burned, emits lower quantities of greenhouse gases and criteria pollutants per unit of energy produced than do other fossil fuels.").

[50] *See generally Simple Cycle Power Plants*, GEN. ELECTRIC, http://www.energy.siemens.com/hq/en/power-generation/power-plants/gas-fired-power-plants/simple-cycle-power-plant-concept/#content=Benefits (last visited Nov. 18, 2012); *see also* Symposium, *supra* note 48.

[51] A baseload plant is:

> [a] plant, usually housing high-efficiency steam-electric units, which is normally operated to take all or part of the minimum load of a system, and which consequently

almost entirely natural gas-fired, which is also expediting the retirement of older coal-fired power plants.[52]

Apart from coal, natural gas, and renewable sources of energy, the other major player in electric power generation is nuclear. While nuclear energy does not emit greenhouse gases (GHGs), a large-scale nuclear build-out in the United States remains highly unlikely. The recent disaster at Fukushima Daiichi has forced the United States and other countries, such as Germany, to reevaluate nuclear as a "safe" energy source.[53] Further, the continued high capital costs of building a conventional nuclear power plant[54] significantly limit the future prospects for nuclear power.[55] Consequently, for a near-term, reliable supplement to renewable energy, natural gas has emerged as the clear frontrunner.[56]

In addition to complementing United States energy policies, the recent boom in shale gas development can also be attributed to a friendly regulatory environment for oil and gas industries. While states have begun to fill the gap in regulations for unconventional oil and gas development, the federal government has, until recently, remained largely absent from the regulatory scene.[57] During the 1930s, President Roosevelt created a Petroleum Code with an approach similar to that taken in the National Industrial Recovery Act (NIRA).[58] But, as Professor Bruce

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> produces electricity at an essentially constant rate and runs continuously. These units are operated to maximize system mechanical and thermal efficiency and minimize system operating costs.

Baseload Definition, EIA ELECTRICITY TERMS AND DEFINITIONS, http://www.eia.gov/cneaf/electricity/page/glossary.html (last visited Nov. 18, 2012).

[52] *See generally*, UNION OF CONCERNED SCIENTISTS, EPA POWER PLANT STANDARDS: A POWERFUL CATALYST FOR MODERNIZING OUR ELECTRIC SYSTEM (2012), *available at* http://www.ucsusa.org/assets/documents/clean_energy/EPA-standards-and-electricity-reliability.pdf.

[53] *See* Judy Dempsey & Jack Ewing, *Germany, In Reversal, Will Close Nuclear Plants by 2022*, N.Y. TIMES, May 30, 2011, at A4, *available at* http://www.nytimes.com/2011/05/31/world/europe/31germany.html?_r=1 (explaining the German government's plan to close all seventeen nuclear reactors in Germany by 2022).

[54] *See generally* ENERGY INFO. ADMIN,, *supra* note 24.

[55] *See* ENERGY INFO. ADMIN., ANNUAL ENERGY OUTLOOK 2012 EARLY RELEASE OVERVIEW 2 (2012), *available at* http://www.eia.gov/forecasts/aeo/er/pdf/0383er%282012%29.pdf (predicting nuclear energy production to remain stagnant through 2035).

[56] *See* ENERGY INFO. ADMIN., *supra* note 19, at 87 (forecasting natural gas and renewables to, in part, supplant coal-fired generation, with natural gas making up sixty percent of capacity additions between 2011 and 2035).

[57] *See, e.g.*, Permitting Guidance for Oil and Gas Hydraulic Fracturing Activities Using Diesel Fuels—Draft, 77 Fed. Reg. 40354-02 (July 9, 2012); Oil and Gas; Well Stimulation, Including Hydraulic Fracturing, on Federal and Indian Lands, 77 Fed. Reg. 27691-01 (May 11, 2012) (to be codified at 43 C.F.R. pt. 3160). *See also* Emily C. Powers, *Fracking and Federalism: Support for an Adaptive Approach that Avoids the Tragedy of the Regulatory Commons*, 19 J. L. POLY. 913, 939–941 (2011); Hannah Wiseman, *Untested Waters: The Rise of Hydraulic Fracturing in Oil and Gas Production and the Need to Revisit Regulation*, 20 FORDHAM ENVTL. L. REV. 115, 142–46 (2009).

[58] *See* Bruce M. Kramer, *A Short History of Federal Statutory and Regulatory Concerns Relating to Hydraulic Fracturing*, HYDRAULIC FRACTURING, Paper No. 2, 2-2 (Rocky Mtn. Min. L. Fdn. 2012).

Kramer explains, after *A.L.A. Schechter Poultry Corp. v. United States* found Title I of NIRA unconstitutional, federal oil and gas regulation effectively ended.[59] This is not to say, however, that industry is not regulated at all. During the 1930s and 1940s, "states responded to the lack of federal regulation with the enactment of state oil and gas . . . conservation statutes" and the establishment of agencies with broad regulatory powers.[60]

It seems fair to surmise that many agencies were unprepared for the boom in development driven by fracking and horizontal drilling operations. Indeed, Nobel Laureate Paul Krugman makes a convincing argument "that far from being hobbled by eco-freaks, the energy industry has been given a largely free hand to expand domestic oil and gas production."[61]

A third motivating factor behind unconventional oil and gas development is the potential boon to local economies during difficult economic times:[62] The words 'new oil boom' "stir excitement in the hearts of landmen, landowners, geologists, engineers, regulators, environmentalists, tax collectors, the unemployed and charlatans."[63] In Northern Colorado's 400-foot-thick Niobrara formation, Noble Energy plans to invest an additional eight billion dollars into further exploration and development.[64] Others, like Anadarko, have committed to drilling thousands of more wells in the Niobrara in coming years.[65] According to the Colorado Department of Natural Resources, the Niobrara Formation alone "has the potential to bring billions of dollars to the state of Colorado. The direct monetary benefits, as well as the creation of jobs and infrastructure, [could] have a substantially positive impact for [the] state."[66]

In 2008, an economic and financial analysis firm, the Perryman Group, conducted a study for the Fort Worth Chamber of Commerce on the economic impacts of the Barnett Shale development on the Fort Worth area. The report

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[59] *See generally id.*

[60] *Id.* at 2-2.

[61] Paul Krugman, Op-Ed., *Natural Born Drillers*, N.Y. TIMES, Mar. 16, 2012, at A27, *available at* http://www.nytimes.com/2012/03/16/opinion/krugman-natural-born-drillers.html?_r=1&src=me&ref=general.

[62] *See, e.g.*, Neal Conan, *Fracking Brings Jobs and Pollution to Town*, NAT'L PUB. RADIO (June 2, 2011), http://www.npr.org/templates/story/story.php?storyId=136895815.

[63] COLO. DEPT. OF NAT. RES., *supra* note 29, at 11; *see also* Bobby Magill, *Niobrara: The Upcoming Oil Boom*, THE COLORADOAN (Jan. 4, 2012), http://www.coloradoan.com/article/20120104/NEWS01/201040347/Niobrara-upcoming-oil-boom.

[64] *See* Cathy Proctor, *Noble Energy Joins Anadarko in Plans to Spend Billions in Niobrara*, DENV. BUS. J. (Nov. 16, 2011, 2:43 PM), http://www.bizjournals.com/denver/news/2011/11/16/noble-energy-joins-anadarko-in-plans.html.

[65] *See* Magill, *supra* note 63 (stating that Anadarko plans to drill an additional 2,700 wells in the Wattenberg Field in the Niobrara Shale).

[66] COLO. DEPT. OF NAT. RES., *supra* note 29, at 11.

concluded that activities surrounding the Barnett Shale play accounted for "$8.2 billion in annual output (8.1% of total output in the regional economy), and 83,823 jobs (8.9% of total jobs)."[67] An updated report in 2011 estimated that the "total effect of Barnett Shale activity [amounts to] $11.1 billion in annual output and 100,268 jobs in the region."[68] "For [Texas] as a whole, Barnett Shale-related activity leads to estimated 2011 gains in output (gross product) of almost $13.7 billion as well as 119,216 jobs."[69] These numbers become more significant when considering "the Barnett Shale region predominantly is an urban area, which already had a large and extensive economy."[70] The Shale Gas Subcommittee of the Secretary of Energy Advisory Board (SEAB) also expects shale gas development will create tens of thousands of additional jobs in the coming years.[71] Additionally, in communities with shale development, "many [other] sectors in the economy will benefit from natural gas exploration and drilling, as businesses and employees spend money locally."[72]

Others are more skeptical. Paul Krugman, for example, notes that "[e]mployment in oil and gas extraction has risen more than 50 percent since the middle of the last decade, . . . [which] amounts to only 70,000 jobs, around one-twentieth of 1 percent of total U.S. employment."[73] Krugman is quick to point out that the recent drilling boom in North Dakota, which has helped lower unemployment rates there to 3.2 percent, is not likely to translate into significantly lower unemployment rates in areas with higher populations. As Krugman notes: "The comparable-sized fracking boom in Pennsylvania has had hardly any effect on the state's overall employment picture, because, in the end, not that many jobs are involved."[74] Nonetheless, in the current economic environment, the allure of even some economic benefit from fracking operations is appealing.

The current circumstances for a shale gas boom are thus ideal. Unconventional gas development not only furthers United States energy policies as a relatively abundant and economical source of domestic energy, but it can also help to integrate renewables into the grid. And although unconventional gas development

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[67] Timothy W. Kelsey, *Potential Economic Impacts of Marcellus Shale in Pennsylvania: Reflections on the Perryman Group Analysis from Texas*, PENN STATE COOP. EXTENSION, http://naturalgaslease.pbworks.com/f/Potential+Economic+Impacts+of+Marcellus+Shale.pdf (last visited Nov. 18, 2012).

[68] THE PERRYMAN GROUP, A DECADE OF DRILLING: THE IMPACT OF THE BARNETT SHALE ON BUSINESS ACTIVITY IN THE SURROUNDING REGION AND TEXAS: AN ASSESSMENT OF THE FIRST DECADE OF EXTENSIVE DEVELOPMENT 3 (2011), *available at* http://www.fortworthchamber.com/BarnettShaleStudy11.pdf.

[69] *Id.* at 4.

[70] Kelsey, *supra* note 67.

[71] *See* SEC'Y OF ENERGY ADVISORY BD., *supra* note 16, at 7.

[72] Kelsey, *supra* note 67.

[73] Krugman, *supra* note 61.

[74] *Id.*

remains mostly regulated by state agencies, companies have historically been able to avoid federal bureaucratic regulatory entanglements thanks to a federal regulatory void that existed for many years. Unconventional gas development is also likely to be economically beneficial to surrounding communities, even if only indirectly. The confluence of these factors, in addition to the refinement of hydraulic fracturing and horizontal drilling practices, technologies, and processes, has created a climate where unconventional gas development could flourish—and indeed has flourished.

III. THE PROCESSES: AN EXPLANATION OF HORIZONTAL DRILLING AND HYDRAULIC FRACTURING

Although the focus of this article is on the law and policy issues associated with unconventional oil and gas development, understanding the scientific and technical underpinnings of the horizontal drilling and hydraulic fracturing processes is a prerequisite for evaluating their full ramifications. Only by understanding these processes can regulators and the public advance strategies and solutions to allow shale gas development to continue safely. And even though the recent rise in shale development has garnered considerable media attention, the environmental, public health, and social issues raised by natural gas production remain poorly understood. Understanding unconventional oil and gas development, and specifically fracking, will help bridge the public-industry disconnect that has developed.

A. *Unconventional Plays and the Need for New Technologies*

In order to economically develop unconventional plays, new techniques beyond vertical well drilling were needed.[75] Conventional plays are the low-hanging fruit of the oil and gas world. They are high-to-medium quality reservoirs generally found nearer to the earth's surface, but are usually found in small quantities[76] and "exist in discrete petroleum accumulations related to a localized geographic feature."[77] Conventional host formations tend to have reasonable permeability and thus high flow capabilities[78] making them comparably easy to develop because they require less stimulation to economically extract the gas or oil.[79] The underground reservoir pressure and higher permeability force the oil

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[75] *See* Kent Perry & John Lee, *Unconventional Gas Reservoirs—Tight Gas, Coal Seams, and Shales*, NPC Global Oil and Gas Study, Topic Paper No. 29, 6–7 (Feb. 21, 2007) (describing the "resource triangle").

[76] *See* STEPHEN A. HOLDITCH, THE INCREASING ROLE OF UNCONVENTIONAL RESERVOIRS IN THE FUTURE OF THE OIL AND GAS BUSINESS 6 (2003), *available at* http://www.aboutoilandgas.com/jpt/print/archives/2003/11/JPT2003_11_management.pdf.

[77] Miskimins et al., *supra* note 5, at 1–9.

[78] *See id.*

[79] *See* HOLDITCH, *supra* note 76, at 6.

and gas up the wellbore without much assistance.[80] Consequently, developing conventional reservoirs is comparably less expensive and requires lower levels of technology.[81]

On the other hand, unconventional plays, despite their typically large volumes, require much greater cost and more technology to economically develop.[82] These reservoirs "exist in petroleum accumulations that are pervasive throughout a large [geographic] area and that are not affected by hydrodyamic influences."[83] These resources have extremely low permeability—six to nine orders of magnitude less than conventional systems[84]—and low flow capacities.[85] Tight reservoirs typically have a permeability of less than 0.1 md, with porosities[86] of six to fourteen percent.[87] In other words, the gas or oil trapped in unconventional, tight formations cannot migrate through the nearly impermeable rock and can only flow along preexisting fractures.[88] Thus, when a well is drilled in an unconventional reservoir without stimulation, the tight "rock formations . . . do not allow passage of oil and gas through and up a well."[89] Moreover, without artificial stimulation, the naturally occurring fractures in unconventional systems do not often permit economical development because the cost of drilling would outweigh the value of the extractable gas.[90]

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[80] Kurth et al., *supra* note 5, at 3A-2.

[81] *See* HOLDITCH, *supra* note 76, at 6.

[82] *See id.*

[83] Miskimins et al., *supra* note 5, at 1–9. Also, "[a]n unconventional gas reservoir can be deep or shallow; high pressure or low pressure; high temperature or low temperature; blanket or lenticular; homogeneous or naturally fractured; and containing a single layer or multiple layers." Perry et al., *supra* note 75, at 5.

[84] Miskimins et al., *supra* note 5, at 1–9. "Orders of Magnitude" is defined as "a number assigned to the ratio of two quantities; two quantities are in the same order of magnitude if one is less than ten times as large as the other; the number of magnitudes that the quantities differ is specified to within a power of ten." *Order of Magnitude Definition*, WORDNETWEB.PRINCETON.EDU, http://wordnetweb.princeton.edu/perl/webwn?s=order+of+magnitude&sub=Search+WordNet&o2=&o0=1&o8=1&o1=1&o7=&o5=&o9=&o6=&o3=&o4=&h= (last visited Nov. 21, 2012).

[85] Miskimins et al., *supra* note 5, at 1–9.

[86] Permeability is the measure of a rock's ability to transmit a fluid, and is based on the pore space and interconnectivity of the pores. The shape and arrangement of the geologic particles, on the other hand, relates to the porosity of the rock. The porosity of the geologic materials is the ratio of the volume of pore space in a unit of material to the total volume of material. *See Soil and Aquifer Properties and Their Effect on Groundwater*, PORTAGE CNTY. WIS., http://www.co.portage.wi.us/groundwater/undrstnd/soil.htm#Porosity (last visited Nov. 18, 2012).

[87] STEVE SONNENBERG, CORE ANALYSIS AND UNCONVENTIONAL RESERVOIRS, *available at* http://www.tight-oil-shale-plays.com/media/downloads/inline/steve-sonnenberg-colorado-school-of-mines.1295453329.pdf .

[88] *See* Kurth et al., *supra* note 5, at 3A-2.

[89] *Id.*

[90] *Id.*

The three forms of unconventional natural gas plays are tight gas sands, coalbed methane,[91] and shale gas.[92] Tight gas sands reservoirs are found in low-porosity sandstones and carbonates. "The natural gas is sourced (formed) outside the reservoir and migrates into the reservoir over time (millions of years)."[93] Tight sands have accounted for the largest proportion of unconventional natural gas production to date, amounting to nearly one-third of all domestic natural gas production.[94] Although production from tight sands is not predicted to outpace shale gas production,[95] modern advancements in directional drilling and fracking can be used to develop tight sands formations, as can be seen in Colorado's Wattenberg Field.[96]

Coalbed methane (CBM), also known as coalbed natural gas, is "produce[d] from . . . coal seams [that] act as [the] source and reservoir of the natural gas . . . . [These] wells are mostly shallow as the coal matrix does not have the strength to maintain porosity under the pressure of significant overburden thickness."[97] Some CBM reservoirs are also sources of drinking water, which makes CBM problematic for fracking and horizontal drilling operations.[98] As a result, CBM production is expected to remain fairly stagnant in the coming years.[99] And even though shale gas is predicted to outgrow both tight sands and CBM production, tight sands and CBM are still predicted to account for twenty-nine to forty percent of total United States gas production from 2009 to 2035.[100]

The third type of unconventional gas is found in low-permeability shale reservoirs, known as shale gas. Shale is a fissile and laminated sedimentary rock formed from the compaction of silt and clay particles.[101] Within shale gas formations, "[t]he natural gas volumes can be stored in a local macro-porosity system (fracture porosity) within the shale, or within the micro-pores of the shale, or it can be adsorbed onto minerals or organic matter within the shale."[102] Even

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[91] While the consumer-grade natural gas is composed almost entirely of methane, prior to refinement, natural gas still contains approximately seventy to ninety percent methane. *See* NATURAL GAS.ORG, *supra* note 18.

[92] *See* U.S. DEPT. OF ENERGY, *supra* note 11, at 15. *See also* Sakmar, *supra* note 6, at 375–76.

[93] U.S. DEPT. OF ENERGY, *supra* note 11, at 15 (footnote omitted).

[94] ENERDYNAMICS: THE ENERGY INSIDER, THE RISE OF UNCONVENTIONAL GAS 2 (2007), *available at* http://www.enerdynamics.com/documents/Insider91807_000.pdf.

[95] *See* ENERGY INFO. ADMIN., *supra* note 13, at 3.

[96] *See Tight Gas*, ANADARKO, http://www.anadarko.com/Operations/Pages/TightGas.aspx (last visited Nov. 18, 2012).

[97] U.S. DEPT. OF ENERGY, *supra* note 11, at 15 (footnote omitted).

[98] *See id.*

[99] *See* ENERGY INFO. ADMIN., *supra* note 13, at 79.

[100] *See id.*

[101] *See What is Shale?*, GEOLOGY.COM, http://geology.com/rocks/shale.shtml (last visited Nov. 18, 2012).

[102] U.S. DEPT. OF ENERGY, *supra* note 11, at 15 (footnotes omitted).

using a modest assumed technically recoverable estimate of 827 tcf, the EIA predicts that the meteoric growth of shale gas development will continue through 2035, accounting for nearly all domestic dry gas production growth.[103]

The recent improvements in horizontal drilling and fracking were borne of necessity as precursors for the economic development of unconventional resources.[104] By creating artificial fractures in the shale,[105] "oil or natural gas [can] move more freely from the rock pores to production wells that bring the oil or gas to the surface."[106] Horizontal drilling further facilitates economic development of unconventional systems by allowing operators to drill one surface well and horizontally access multiple reservoirs, maximizing the extractable volume of gas.

Without horizontal drilling and hydraulic fracturing, the economic development of unconventional resources would not be possible. Today, in some areas of production, more than ninety-five percent of wells are fracked;[107] and in the next five to ten years, it is estimated that an additional 100,000 wells will be drilled, and one to two million hydraulic "frack jobs" will take place.[108] Understanding both of these processes is a critical step towards proper social discourse on the benefits and environmental and social risks associated with fracking, as well as all unconventional gas development activities, generally.

B. Well Drilling

Although they have not garnered the same media attention as fracking, properly drilling and casing a well are perhaps the most important aspects of shale gas development for protecting water resources.[109] Today, wells can be drilled vertically or directionally in an s-curve or on a horizontal plane.[110] Directional drilling is often used when vertical wells would otherwise be financially

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[103] *See* ENERGY INFO. ADMIN., *supra* note 13, at 79.

[104] *See Nuts and Bolts of Marcellus Shale Drilling and Hydraulic Fracturing*, *supra* note 45, at 10590.

[105] Kurth et al., *supra* note 5, at 3A-2.

[106] *Hydraulic Fracturing Background Information*, U.S. EPA, http://water.epa.gov/type/groundwater/uic/class2/hydraulicfracturing/wells_hydrowhat.cfm (last updated May 9, 2012).

[107] Miskimins et al., *supra* note 5, at 1-5.

[108] Zoback, *supra* note 43, at 4B-2.

[109] *See* Mark K. Boling, *Working with Stakeholders—Separating Fact from Myth*, HYDRAULIC FRACTURING, Paper No. 5, 5-4 to 5-5 (Rocky Mtn. Min. L. Fdn. 2012).

[110] Horizontal drilling and directional drilling are not one in the same, although drilling a horizontal well requires directional drillings. "S-Curve" wells, for example, can be used to drill a vertical well under an area not directly accessible at the surface by curving the wellbore. Horizontal wells may also use S-Curve wells to maximize efficient use of surface area drilling restrictions or drilling lease areas.

unsuccessful.[111] For example, in low-permeability shale formations, horizontal drilling can generate 2.5 to seven times the flow rate and reserves of vertical wells. Thus, directional drilling may make more economic sense, even at three times the cost of vertical drilling.[112] Directional drilling is also useful when the area directly above the target formation is not accessible.[113]

Horizontal drilling is a technique that has advanced considerably in the last decade.[114] It is beneficial for two main reasons: one, only a single well pad is needed to drill multiple wellbores on one parcel of land; and two, it allows for more efficient development of the resource as compared to vertical drilling.[115] The increased efficiency comes from the ability to drill multiple directional wells in close proximity to one another. For instance, the surface area of the Apache 34 pad in the Horn River Development of British Columbia totals 6.3 acres, with twelve multi-fractured horizontal wells that recover gas from an area of approximately 5,000 subsurface acres.[116] The number of individual pads required can thus be dramatically reduced using horizontal drilling. The ancillary surface impacts from road construction and vehicle traffic are also reduced.[117] However, with increased success from unconventional plays comes the increased occurrence of drilling, and consequently the creation of more well sites, offsetting the otherwise reduced surface impacts from multi-well pads.[118]

But, surface impacts notwithstanding, there is no doubt that directional wells are vastly more efficient than vertical wells. Since shale reservoirs are much more expansive laterally than vertically, the increased efficiency stems from directional

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[111] Lynn Helms, *Horizontal Drilling*, N. DAK. GEOLOGICAL SURV., 1 (Jan. 2008), https://www.dmr.nd.gov/ndgs/newsletter/NL0308/pdfs/Horizontal.pdf.

[112] *Id.*

[113] *See Directional and Horizontal Drilling*, NATURALGAS.ORG, http://www.naturalgas.org/naturalgas/extraction_directional.asp (last visited Nov. 18, 2012) (e.g., when a body of water or housing development overlies the producing formation).

[114] U.S. DEPT. OF ENERGY, *supra* note 11, at 9.

[115] *See infra* text accompanying notes 158–59.

[116] *See* Zoback, *supra* note 43, at 4B-18.

[117] *See Intermountain Oil and Gas BMP Project: The Development Process*, NAT. RES. LAW CENTER, http://www.oilandgasbmps.org/resources/development.php (last visited Nov. 21, 2012).

[118] *See* INT'L ENERGY AGENCY, GOLDEN RULES FOR A GOLDEN AGE OF GAS: WORLD ENERGY OUTLOOK SPECIAL REPORT ON UNCONVENTIONAL GAS 19 (2012), *available at* http://www.worldenergyoutlook.org/media/weowebsite/2012/goldenrules/WEO2012_GoldenRulesReport.pdf .

> One feature of the greater scale of operations required to extract unconventional gas is the need for more wells. Whereas onshore conventional gas fields might require less than one well per ten square kilometers, unconventional fields might need more than one well per square kilometer . . . , significantly intensifying the impact of drilling and completion activities on the environment and local residents.

Id.

wells exposing more of the wellbore to a greater length of the producing formation than vertical wells.[119]

Quite unlike the cartoonish images of a hapless pioneer unleashing a "gusher" well with a pickaxe or errant rifle shot, successful natural gas drilling today requires complex and technically advanced processes.[120] After a drilling pad is prepared and the drilling rig is erected, a vertical wellbore is drilled using a roller-cone bit or auger.[121] A "drill string" connects the bit to the surface rig, which is composed of the drill bit itself, "drill collars (heavy weight pipe to put weight on the bit), and drill pipe"[122] that is added as the bit progresses downward.[123] The surface hole is usually drilled with freshwater to prevent shallow aquifer contamination, and extends below the deepest occurrence of groundwater resources.[124]

Further drilling operations use drilling fluid, or "mud, which is either water- or oil-based,"[125] and typically contains additives such as bentonite, barite, and polymers[126] to facilitate the drilling process. Generally, high-velocity fluid jets on the drill bit remove the crushed rock and carry it up the annulus,[127] which is the area between the drill string and surrounding rock.[128] The drilling mud also serves to "lubricate the drilling assembly, . . . maintain pressure control of the well, and stabilize the hole being drilled."[129]

A critical step in well construction is well casing design and implementation. In fact, as is discussed in more detail below, a likely culprit in aquifer contamination is actually poor well integrity, not the fracking process.[130] The general process of

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119 Helms, *supra* note 111, at 1 ("By drilling a well which intersects such a reservoir parallel to its plane of more extensive dimension, horizontal drilling exposes significantly more reservoir rock to the well bore than would be the case with a conventional vertical well penetrating the reservoir perpendicular to its plane of more extensive dimension.").

120 For a list of well drilling and completion activities, see AM. PETROLEUM INST., HYDRAULIC FRACTURING OPERATIONS—WELL CONSTRUCTION AND INTEGRITY GUIDELINES 2-3 (2009), *available at* http://www.api.org/policy/exploration/hydraulicfracturing/upload/API_HF1.pdf.

121 More than a thousand kilowatts of generation are needed to operate this type of drilling rig.

122 AM. PETROLEUM INST., *supra* note 120, at 4.

123 *See Introduction to Shale Gas Development*, ENERGY IN DEPTH (2009), http://www.energy-indepth.org/category/media/.

124 *See* Kurth et al., *supra* note 5, at 3A-5.

125 *See id.* at 3A-3 to 3A-4.

126 Miskimins et al., *supra* note 5, at 1-20.

127 *See Roller-Cone Bit Definition*, SCHLUMBERGER OILFIELD GLOSSARY, http://oilfieldglossary.com/Display.cfm?Term=roller-cone%20bit (last visited Nov. 17, 2012).

128 Kurth et al., *supra* note 5, at 3A-4.

129 AM. PETROLEUM INST., *supra* note 120, at 4.

130 *See, e.g.*, Boling, *supra* note 109, at 5-4 to 5-5. It should be noted, however, that other sources of groundwater contamination still exist. For example, orphan vertical wells that are not cemented properly or frack jobs that take place too close to the surface are also potential contributors to contamination.

well construction is to run casing, which is steel pipe used for well construction, and then to cement the casing in place to ensure the well is completely isolated.[131] This is repeated multiple times for the shallow portions of the well.[132] The largest pipe is the conductor pipe, which keeps out loose sediment towards the surface and isolates "groundwater zones from the drilling fluids."[133] Following the conductor pipe is the surface casing. "[N]early all states requir[e] the surface casing to be set below the deepest freshwater aquifer."[134] The oil and gas trade association, the American Petroleum Institute (API), goes even further, recommending "that the surface casing be entirely cemented to completely isolate freshwater aquifers."[135]

Once the casing is in place, cement slurry is pumped down the casing and is circulated up the wellbore and casing annulus. "Typical cement tops range from 1000 [feet] over the pay interval to cement back into the surface casing."[136] The cement used is not concrete, i.e., it does not contain sand, gravel or rock; rather, it is composed of specially formulated small particles designed to build compressive strength very quickly.[137]

After the surface casing has been installed and cemented, an intermediate casing may be installed if geologic conditions so require. "The purpose of drilling the intermediate hole and running casing is to isolate subsurface formations that may cause borehole instability and to provide protection from abnormally pressured subsurface formations."[138] If the surface casing is protecting all potentially exposed groundwater aquifers, the intermediate casing is not often cemented back to the surface. It is prudent, however, to cement below any underground source of drinking water (USDW)[139] or hydrocarbon-bearing zone, e.g., a non-target producing zone located above the target zone.[140]

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[131] *See* AM. PETROLEUM INST., *supra* note 120, at 4.

[132] *See id.*

[133] Kurth et al., *supra* note 5, at 3A-4 to 3A-5.

[134] *See id.* at 3A-5.

[135] *Id.* at 3A-6.

[136] Miskimins et al., *supra* note 5, at 1-20.

[137] *See id.* at 1-23.

[138] AM. PETROLEUM INST., *supra* note 120, at 12.

[139] Under the Underground Injection Control Program:

> Underground source of drinking water (USDW) means an aquifer or its portion: (a)(1) Which supplies any public water system; or (2) Which contains a sufficient quantity of ground water to supply a public water system; and (i) Currently supplies drinking water for human consumption; or (ii) Contains fewer than 10,000 mg/l total dissolved solids; and (b) Which is not an exempted aquifer.

40 C.F.R. § 144.3.

[140] AM. PETROLEUM INST., *supra* note 120, at 12.

Once the surface and intermediate casings are installed and the well is logged,[141] the production hole is drilled down to the well's total depth (TD) and production casing is run to the TD and cemented in place.[142] The rationale for cementing the entire production casing is to create "zone integrity" whereby the producing zone is isolated from other subsurface formations.[143] It also protects subsurface areas from exposure to fracking fluids, later to be injected into the well.[144] "Packers" are also installed, which are expanding rings used to seal off the producing formation.[145]

Ideally at this point in the drilling process, there are conductor, surface, production, and potentially intermediate casings installed and cemented where needed to ensure that zone integrity is maintained. The result, if implemented correctly, is "a completed borehole where the freshwater aquifers[] are separated from communication with fluids in the wellbore" by multiple layers of casing and cement.[146]

As a final step after the production casing is cemented, tests are often conducted to determine whether the well will withstand the pressure conditions expected during production.[147] Different methods can be employed, including pressure, acoustic, temperature, and hydraulic testing.[148] Well design is dictated largely by expected pressure conditions and is based on three major criteria: one, "[b]urst due to internal pressure from pumping conditions"; two, "[c]ollapse due to external pressure acting on an evacuated hole"; and three, "[j]oint strength due to [tensile strength] and weight of the pipe."[149] If the well gives way to pressure or the casing has voids, gas from shallow producing zones can escape and possibly contaminate aquifers.[150] Thus, maintaining zone integrity is key. As the API explains:

> Placement of the cement completely around the casing and at the proper height above the bottom of the drilled hole (cement top) is one of the primary factors in achieving successful zone

[141] "Well logging chronicles the depths, subsurface formations and events encountered while drilling. Well logs can include visual observations or be made by instruments lowered into the well during drilling." *How Does Well Logging Work*, RIGZONE, http://www.rigzone.com/training/insight.asp?insight_id=298&c_id=1 (last visited Nov. 18, 2012).

[142] *See* Miskimins et al., *supra* note 5, at 1-20.

[143] *See* AM. PETROLEUM INST., *supra* note 120, at 12.

[144] *See id.*

[145] *See* Kurth et al., *supra* note 5, at 3A-6.

[146] *Id.*

[147] AM. PETROLEUM INST., *supra* note 120, at 12.

[148] *See* Miskimins et al., *supra* note 5, at 1-24.

[149] *Id.* at 1-23.

[150] *See* Boling, *supra* note 109, at 5-4 to 5-5.

> isolation and integrity. Good isolation requires complete annular filling and tight cement interfaces with the formation and casing. Complete displacement of drilling fluid by cement and good bonding of the cement interfaces between the drilled hole and the casing immediately above the hydrocarbon formation are key parts of well integrity and seal integrity. The absence of voids and good bonding of cement at these interfaces prevent migration paths [from producing zones to aquifers] and establish zone isolation.[151]

In addition to ensuring that the well is properly constructed, continued monitoring is essential to confirm that the fracking, or other stimulation procedure, is entirely contained within the producing reservoir.[152]

A vertical wellbore is drilled to varying depths from several hundred to several thousand feet, depending on the depth of the target producing formation.[153] Most tight shale gas formations are found deep in the earth. In Pennsylvania's Marcellus Shale, for example, reservoirs are found between 5,000 and 8,000 feet below the surface.[154]

For a horizontal well, vertical drilling ends at the "kickoff point," where a directional bit is used to steer the bit horizontally into the target zone.[155] Today, operators can make the ninety-degree turn from vertical to horizontal in less than a quarter of a mile. The well can then bore up to two miles laterally into the producing zone to maximize well exposure to the reservoir.[156] The directional downhole drilling instruments are referred to as "measurement-while-drilling" instruments, and their modern permutations allow operators to calculate the precise location of the drill bit at all times.[157]

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[151] AM. PETROLEUM INST., *supra* note 120, at 7.

[152] *See* Adam S. Cohen & Shannon Stevenson, *Hydraulic Fracturing—Regulatory and Litigation Update for the Rocky Mountain States*, HYDRAULIC FRACTURING, Paper No. 3C, 3C-7 (Rocky Mtn. Min. L. Fdn. 2012) (citing Statement of Basis, Specific Statutory Authority and Purpose, New Rules and Amendments to Current Rules of the Colorado Oil and Gas Conservation Commission, 2 C.C.R. 404-1 at 36).

[153] *See The Process of Hydraulic Fracturing*, U.S. EPA, http://www.epa.gov/hydraulicfracturing/process.html (last updated Oct. 18, 2012).

[154] *See* SUSQUEHANNA RIVER BASIN COMM'N, GAS WELL DRILLING AND DEVELOPMENT MARCELLUS SHALE 7 (2008), http://www.srbc.net/whatsnew/docs/Marcellusshale61208ppt.PDF.

[155] *See* Helms, *supra* note 111, at 1.

[156] *See* SEC'Y OF ENERGY ADVISORY BD., *supra* note 16, at 13.

[157] Helms, *supra* note 111, at 2.

C. *Hydraulic Fracturing*

After the well is entirely constructed and pressure tested, the shale formation can then be stimulated. Due to the impermeability of tight sands, CBM, and shale gas formations, the gas trapped within these reservoirs will not flow freely to the newly constructed wellbore. The resources must therefore be stimulated, often by hydraulic fracturing. Fracking is "generally viewed as a completion technique that is a practical necessity to promote development of unconventional . . . reservoirs" that would otherwise be uneconomical to develop.[158] Although the media and public often use the term fracking to describe the entire completion processes of drilling, well construction, stimulation, and production, hydraulic fracturing is a necessary and connected, but nonetheless discrete process. Typically, the fracking process consists of perforating the casing and shale formation, fracturing the reservoir by pumping large amounts of pressurized fluids into the well, and propping the formation open, allowing the operators to ultimately extract the petroleum liquids and natural gases.

Before the rock can be fractured, the inside of the casing must be exposed to the producing formation to facilitate communication between the gas and the casing. If only the end of the wellbore were exposed, the impermeability of the producing formation would allow only a small area of rock to be in communication with the wellbore. On the other hand, creating holes throughout the horizontal wellbore exponentially increases the communication with the producing formation, and therefore the amount of gas recoverable by that well. For example, while a traditional vertical well in a 100-foot formation would have only 160 ft^2 of contact with the producing formation, a 2,000-foot horizontal well would have 3,207 ft^2 of contact. A multi-stage frack job would yield even more impressive results: a 2,000-foot horizontal well with *ten* 150-foot fractures would have an astounding 153,207 ft^2 of contact with the producing formation.[159]

The process of perforating the casing and the reservoir is called "perfing."[160] Two common methods for this are "perf-and-plug" and the use of graduated seated balls. The plug-and-perf technique involves the use of jet perforating guns and shaped explosive charges.[161] "The shaped charge is detonated and a jet of very hot, high-pressure gas vaporizes the steel pipe, cement, and formation in its path. The result is a tunnel that connects the inside of the production casing to the formation" that is isolated by the cement.[162] If the formation will be fracked

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[158] Kurth et al., *supra* note 5, at 3A-1.

[159] *See* WILLIAM FLECKENSTIEN, COLO. SCHOOL OF MINES, SHALE DRILLING AND COMPLETIONS 5 http://www.colorado.edu/law/nrlc/events/documents/shaleplays/5%20-%20Flekenstein%20-%20Shale%20Plays%20Drilling%20and%20Completions%20Talk.pptx.

[160] *See* AM. PETROLEUM INST., *supra* note 120, at 14.

[161] *See id.*

[162] *Id.*

in multiple sections, the second step is to plug the perforations to isolate the previously perfed and fracked sections. Generally, this technique involves placing a bridge plug above the perforation, a sand plug below the perforation, or the use of inflatable packers[163] or ball sealers.[164] If bridge and sand plugs are used, the plugs must be drilled or circulated out. After perfing, the formation can then be fracked to enhance production. "In order for natural gas or oil to be produced from low permeability reservoirs [like shale gas and tight sands], individual molecules of fluid must find their way through a tortuous path to the well."[165] "[Fracking] increases the exposed area of the producing formation, creating a high conductivity path that extends from the wellbore through a targeted hydrocarbon bearing formation for a significant distance, so that hydrocarbons and other fluids can flow more easily from the formation rock, into the fracture, and ultimately to the wellbore."[166] Essentially, fracking creates artificial cracks in the producing formation in order to produce enough gas or oil to make development economical.

Fracking takes place in three basic stages: first, hydraulic fluids are pumped into the wellbore without proppants, which, as discussed forthwith, hold or "prop" the fractures open; second, additional fracking fluids are pumped into the wellbore, this time with the addition of proppants; and third, the reservoir is flushed to clear proppant from the borehole and to push it further into the target formation.[167]

The first phase involves injecting fracking fluid into the wellbore at very high pressures through the perforations to fracture the rock, known as the "breaking down"[168] or "pad" phase.[169] The rock's fracture orientation is dictated by rock stresses, which open perpendicular to minimum stress lines.[170] Quite astonishingly, the fractures created are generally only a quarter of an inch thick.[171]

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[163] *See, e.g.*, *Well Completions*, BAKER HUGHES, http://www.bakerhughes.com/products-and-services/completions/well-completions (last visited Nov. 18, 2012).

[164] *See Ball Sealers Definition*, SCHLUMBERGER OILFIELD GLOSSARY, http://www.glossary.oilfield.slb.com/Display.cfm?Term=ball%20sealer (last visited Nov. 17, 2012).

[165] AM. PETROLEUM INST., *supra* note 120, at 15.

[166] *Id.*

[167] Kurth et al., *supra* note 5, at 3A-7.

[168] AM. PETROLEUM INST., *supra* note 120, at 15.

[169] Kurth et al., *supra* note 5, at 3A-7.

[170] Miskimins et al., *supra* note 5, at 1-7.

[171] *See* GEORGE E. KING, APACHE CORP., ESTIMATING FRAC RISK AND IMPROVING FRAC PERFORMANCE IN UNCONVENTIONAL GAS AND OIL WELLS 30 (2012), *available at* http://gekengineering.com/Downloads/Free_Downloads/Estimating_and_Explaining_Fracture_Risk_and_Improving_Fracture_Performance_in_Unconventional_Gas_and_Oil_Wells.pdf; *see also* Miskimins et al., *supra* note 5, at 1-5.

As the injections continue the fractures propagate, and surface pressure must be increased accordingly to the propagation pressure, or extension pressure. Fracking surface pressures can exist at 15,000 psi,[172] created by a handful of several-thousand horsepower engines.[173] As fractures continue to grow, proppants are added to hold the fractures open; otherwise, the natural pressures exerting on the rock would collapse the newly made artificial fractures.[174] The "sand" often used as a proppant can be natural or artificial, the latter of which is usually ceramic or sintered bauxite.[175]

To sustain such high pressures, a very large volume of fluid is needed—between 2.4[176] to twelve million gallons[177] of water per frack job, with some wells being fracked multiple times.[178] Large frack jobs may require 1,260 to 3,000 gallons per minute to be pumped for forty to 100 hours over a two- to five-day period.[179]

The two main forms of fracking fluids are slickwater and gel. Sometimes very fast pumping is needed to clear sand out of the cracks within the formation; this is where the slickwater method is preferred.[180] Slickwater designs are also more simplistic and less expensive than gels, and consist mostly of water, sand, and friction reducers.[181] Surfactants, which reduce the surface tension of the fluid, clay stabilizers, and scale inhibitors are also used as necessary.[182]

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172 *See* Miskimins et al., *supra* note 5, at 1-4.

173 *See, e.g.*, N.Y. DEP'T OF ENVTL. CONSERVATION, REVISED DRAFT SUPPLEMENTAL GENERIC ENVIRONMENTAL IMPACT STATEMENT ON THE OIL, GAS AND SOLUTION MINING REGULATORY PROGRAM, 6-99 to 6-102 (2011), *available at* http://www.dec.ny.gov/energy/75370.html (follow "full 2011 Revised Draft SGEIS document (PDF)" hyperlink).

174 *See* AM. PETROLEUM INST., *supra* note 120, at 15.

175 *See id.* at 18. Ceramic sand has an intermediate crushing strength compared to sintered bauxite, which has an extremely high crushing strength and is more consistently shaped to enhance gas recovery. The consistent circular shapes of artificial proppants allow the gas to flow more easily through it once production begins, just as a gas or liquid can travel more easily through a ball pit than a gravel pit. *See* Miskimins et al., *supra* note 5, at 1-14.

176 *See* N.Y. DEP'T OF ENVTL. CONSERVATION, *supra* note 173, at 5-93 to 5-94 (noting the pumped fluid estimates used in Marcellus Shale development).

177 *See* King, *supra* note 171, at 30. EnCana and Apache have used up to twelve million gallons of saline water for fracking operations. *Id.*

178 *See Water Use in the Barnett Shale*, TEX. RAILROAD COMM'N, http://www.rrc.state.tx.us/barnettshale/wateruse_barnettshale.php (last updated Jan. 24, 2011).

179 *See* N.Y. DEP'T OF ENVTL. CONSERVATION, *supra* note 173, at 5-94.

180 *See* Miskimins et al., *supra* note 5, at 1-11.

181 *See id.*

182 *See id.*

Generally, 99.5% of the fluid is freshwater[183] and sand. Chemical additives comprise the remaining 0.5%.[184] However, the small percentage of chemicals in fracking fluids translates into a significant amount of chemicals used because of the enormous volumes of fluids involved. For instance, if a frack job uses five million gallons of water, roughly 25,000 gallons of chemicals will be injected into the well. Moreover, many of the chemicals are toxic in concentrations below five parts per thousand—the total percentage of chemicals typically used in fracking fluids.[185] Take, for example, benzene and ethylbenzene, which are chemical compounds used in fracking fluids. The maximum contaminant level goals[186] of benzene and ethylbenzene are 0.0 mg/L and 0.7 mg/L, respectively.[187] But even at 0.02% of the concentration of the fracking fluid by mass, such a concentration of petroleum distillate chemicals would equate to roughly 200 mg/L—well above safe drinking levels.

Of particular concern to the public is the use of diesel in fracking fluids. "[B]etween 2005 and 2009, oil and gas service companies injected 32.7 million gallons of diesel fuel or hydraulic fracturing fluids containing diesel fuel [into] wells in 20 states."[188] In 2003, an agreement was reached among fracking service companies that diesel fuel would not be used in development of CBM wells, which are typically closer to the surface than other unconventional reservoirs, and are therefore often close to underground aquifers.[189] While the Energy Policy Act of 2005 exempted most hydraulic fracturing fluids from compliance with the Safe Drinking Water Act's (SDWA) Underground Injection Control (UIC) permitting requirement, an exception was made for diesel used in oil and gas recovery, which still requires UIC permitting.[190] The EPA has also recently issued proposed permitting guidance for fracking activities still using diesel.[191]

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[183] *See id.* Millions of gallons of freshwater are still used for drilling and fracturing operations, but industry has been moving toward using more saline sources of water, including produced water. King, *supra* note 171, at 39–43. And, as George King notes, the "[u]se of large volumes of fresh water for fracs in arid areas causes severe problems." *Id.* at 44.

[184] *See* Miskimins et al., *supra* note 5, at 1-11.

[185] *See id.*

[186] The maximum contaminant level goals reflect the level of a contaminant in drinking water below which there is no known or expected risk to health. *See Drinking Water Contaminants*, U.S. EPA, http://water.epa.gov/drink/contaminants/index.cfm#1 (last visited Nov. 18, 2012).

[187] *See id.*

[188] House of Representatives Democratic Committee on Energy and Commerce, Letter to Lisa Jackson 2 (Oct. 25, 2011), http://democrats.energycommerce.house.gov/sites/default/files/documents/Jackson%20hydraulic fracturing%202011%2010%2025.pdf.

[189] *See* U.S. EPA, EVALUATION OF IMPACTS TO UNDERGROUND SOURCES OF DRINKING WATER BY HYDRAULIC FRACTURING OF COALBED METHANE RESERVOIRS; NATIONAL STUDY FINAL REPORT (2004), *available at* http://www.epa.gov/ogwdw/uic/pdfs/cbmstudy_attach_uic_final_fact_sheet.pdf.

[190] *See Natural Gas Extraction—Hydraulic Fracturing*, U.S. EPA, http://www.epa.gov/hydraulicfracture/#diesel (last updated Oct. 2, 2012).

[191] *See* Permitting Guidance for Oil and Gas Hydraulic Fracturing Activities Using Diesel Fuels—Draft: Underground Injection Program Guidance #84, 77 Fed. Reg. at 27451-02 (May 10, 2012).

The last fracking stage is displacement. Here, the sand is flushed out to a depth just above the perforations, known as clean-up. Displacement is done to ensure the production pipe is not clogged with sand and that the proppant will end up in the newly created fractures.[192]

A significant portion of the fracking fluid returns to the surface—an event aptly described as "flowback."[193] The compositions of the fluids dictate whether the flowback must be disposed of or reclaimed.[194] The amount of water recovered from flowback varies significantly, from five to fifty percent in many cases,[195] but can be as high as eighty percent.[196] "Most fracturing fluid additives used in a well can be expected in the flowback water, although some are expected to be consumed in the well (e.g., strong acids) or react during the fracturing process to form different products (e.g., polymer precursors)."[197] Under-saturated shale will act like a sponge by trapping and holding water in its pores and microfractures. Such water remains underground and will not return to the surface during production. The residual underground water will, however, help prop open smaller fissures where it is trapped by natural capillary forces.[198]

"Some portion of the proppant may [also] return to the surface with flowback, but operators strive to minimize proppant return: the ultimate goal of hydraulic fracturing is to convey and deposit the proppant within fractures in the shale to maximize gas flow."[199] Returning fluids may also contain barium, strontium, bromine, as well as heavy metals that are naturally radioactive, known as naturally occurring radioactive materials, or NORM.[200] The levels of radioactivity are "usually low . . . and do not usually encroach on the EPA threshold unless they are concentrated by formation of mineral scale . . . or intentional trapping mechanisms."[201]

Flushing the reservoir (viz., the new perforations) and wellbore ultimately prepares the well for production. Traditionally this involved "producing the well

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192 AM. PETROLEUM INST., *supra* note 120, at 18.

193 *See* N.Y. DEP'T OF ENVTL. CONSERVATION, *supra* note 173, at 5-99.

194 *See* AM. PETROLEUM INST., FREEING UP ENERGY: HYDRAULIC FRACTURING: UNLOCKING AMERICA'S NATURAL GAS RESOURCES (2010), *available at* http://www.api.org/~/media/files/policy/exploration/hydraulic_fracturing_primer.ashx

195 *See* King, *supra* note 171, at 11.

196 *See* Charles G. Groat & Thomas W. Grimshaw, *Fact-Based Regulation for Environmental Protection in Shale Gas Development*, THE ENERGY INST., Section 1, 20 (Feb. 2012), http://energy.utexas.edu/images/ei_shale_gas_regulation120215.pdf.

197 N.Y. DEP'T OF ENVTL. CONSERVATION, *supra* note 173, at 5-100.

198 King, *supra* note 171, at 11.

199 N.Y. DEP'T OF ENVTL. CONSERVATION, *supra* note 173, at 5-101.

200 King, *supra* note 171, at 11.

201 *Id.* at 12.

to open pits or tankage where sand, cuttings, and reservoir fluids are collected for disposal and the produced natural gas is vented to the atmosphere."[202] While this venting process continues today, it has been supplanted in some cases by "green completions," or reduced emission completions (RECs). REC operations emit less methane, a potent greenhouse gas, into the atmosphere, as well as fewer volatile organic compounds (VOCs), and increase the recovery of salable gas.[203]

The basic premise of green completions is to capture or reduce the emissions of gas—mainly methane—discharged in the traditional clean-up process. Surfacing gas is separated from fluids and solids using a series of heavy-duty separators, or flowback units. Water and sand are then discharged to tanks for reuse or storage, and the gas is either cycled back through the well bore or sent to a pipeline for production rather than vented or flared.[204]

If the gas can be captured and sent into a pipeline immediately, green completions would produce an immediate revenue stream from the produced natural gas and gas liquids, coupled with less solid waste and water pollution, and a safer operating practice.[205] If a pipeline is not available, wells can control VOCs by "pit flaring" when it safe to do so. Pit flaring involves passing frack fluid flowback through "a continuous ignition source as it is discharged from a pipe into a pit."[206] And while flaring gas is preferable to simply venting it, there are still drawbacks from an environmental perspective.[207] Piping the gas directly from

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[202] U.S. EPA, REDUCED EMISSIONS COMPLETIONS FOR HYDRAULICALLY FRACTURED NATURAL GAS WELLS 1 (2011), *available at* http://www.epa.gov/gasstar/documents/reduced_emissions_completions.pdf.

[203] *See Proposed Rules for "Green Completions,"* COLO. OIL AND GAS CONSERVATION COMM'N, 3 (June 27, 2008), http://cogcc.state.co.us/rulemaking/HearingDocuments/Green%20Completion%20Presentation.pdf.

[204] *Flareless Completions*, EARTHWORKS, http://www.earthworksaction.org/issues/detail/flareless_completions (last visited Nov. 18, 2012).

[205] *See id.*; U.S. EPA, *supra* note 202, at 11.

[206] *U.S. EPA Proposes Stricter Regulation of Air Emissions From Hydraulic Fracturing and Other Oil and Gas Operations*, HOLLAND & HART (Aug. 4, 2011), *available at* http://www.martindale.com/natural-resources-law/article_Holland-Hart-LLP_1325740.htm. *See also* Proposed Rule: Oil and Natural Gas Sector: New Source Performance Standards and National Emission Standards for Hazardous Air Pollutants Reviews, 76 Fed. Reg. 52738-01, 52756, (Aug. 23, 2011) (to be codified at 40 C.F.R. pts. 60 & 63) [hereinafter Proposed NSPS].

[207] *See* Proposed NSPS, 76 Fed. Reg. at 52758.

> For category 1 well completions, we estimated that 0.02 tons of NO_X are produced per event. This is based on the assumption that 5 percent of the flowback gas is combusted by the combustion device. The 1.2 tons of VOC controlled during the pit flaring portion of category 1 well completions is approximately 57 times greater than the NO_X produced by pit flaring. Thus, we believe that the benefit of the VOC reduction far outweighs the secondary impact of NO_X formation during pit flaring.

Id.

the wellhead is ideal for the environment, and even production companies, as green completions have recovered as much as eighty-nine percent of gas produced during well completions and workovers.[208]

Unfortunately, green completions do require additional equipment and expenses. In order to start production without venting or flaring, several pieces of permanent equipment are needed: piping from the wellhead to the sales line; a dehydrator; a lease meter; and stock tanks for wells producing a significant amount of condensate.[209] Additional portable equipment is also required, such as skid- or trailer-mounted equipment to capture gas during cleanup, and "portable desiccant dehydrator[s] for workovers requiring glycol dehydrator maintenance."[210]

Whether or not the monetary costs associated with implementing RECs are offset by their economic benefits, largely through sale of gas and condensates, is debatable. In 2004, EPA concluded that, "[a]t a natural gas price of $3 per Mcf and condensate price of $19 per barrel, green completions will pay back the costs in about 1 year."[211] In 2010, however, EPA presented a study on RECs that estimated companies could recoup their costs of doing green completions in just three to five months based on a twenty-five well-per-year program.[212] Sub-three dollar gas prices might further complicate the REC cost-benefit debate, but data suggest that RECs will help production companies in the long-term. Consider EPA's presentation: the *average* revenue *per flowback* was $139,941, resulting in average net savings of $129,510 per flowback.[213] Thus, even if capital costs of $500,000 are required for REC equipment, most producers should be able to recover well in excess of their costs. In its New Source Performance Standards and National Emissions Standards for Hazardous Air Pollution Reviews in the Oil and Gas Sector, EPA "estimate[d] that REC will result in an overall net cost savings in many cases."[214] Additionally, through federal natural gas leases, the United States

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[208] *See* U.S. EPA, REDUCING METHANE EMISSIONS FROM PRODUCTION WELLS: REDUCED EMISSION COMPLETIONS: LESSONS LEARNED FROM THE NATURAL GAS STAR PROGRAM 5 (2010), *available at* http://epa.gov/gasstar/documents/workshops/farmington-2010/08_recs_farmington_nm_final.pdf (ranging from two to eighty-nine percent, with an average of fifty-three percent total gas recovery).

[209] *See id.* at 3.

[210] *Id.* at 4.

[211] U.S. EPA, *supra* note 202.

[212] *See* U.S. EPA, *supra* note 208, at 5. One of the EPA's "REC Partners" for the report, British Petroleum, saw actual payback on its green completion costs in eighteen months. *Id.* at 6.

[213] *See id.* at 10.

[214] Proposed NSPS, 76 Fed. Reg. at 52758.

> The emission reductions for a hydraulically fractured well are estimated to be around 22 tons of VOC. Based on an average incremental cost of $33,237 per completion, the cost effectiveness of REC, without considering any cost savings, is around $1,516 per ton of VOC (which we have previously found to be cost effective on average). When the value of the gas recovered (approximately 150 tons of methane per completion)

government stands to gain an estimated twenty-three million dollars per year in royalties from the sale of captured natural gas that would otherwise be vented or flared.[215]

The final step in well construction is to replace the blow out preventer, which sealed the well hole at the surface, with a wellhead "Christmas tree," which is a wellhead with control valves and connections to production facilities.[216] Once in place, production from the well can commence.

The horizontal drilling and hydraulic fracturing processes require an orchestrated effort by many people and pieces of equipment. Before production begins, a well pad must be prepared, the rig erected, and a slew of equipment put into place, including "fluid storage tanks, proppant transport equipment, blending equipment, pumping equipment, and all ancillary equipment such as hoses, piping, valves, and manifolds."[217] The drilling process alone requires multiple stages requiring precise execution and careful monitoring to ensure that production is maximized while risks of contamination are minimized.[218] Only then does hydraulic fracturing begin—one facet of the convoluted unconventional oil and gas development process.

IV. Identifying and Understanding the Environmental Impacts Associated with Unconventional Shale Gas Development

In addition to understanding the processes involved, a second critical step in engaging in a meaningful discourse is acknowledging the known and unknown social and environmental risks of such developmental activities.[219] While it is unreasonable to claim that unconventional gas development never causes environmental harm, it is equally unreasonable to stigmatize all such development absent evidence that it causes such harm. A complete assessment of the environmental impacts from hydraulic fracturing and horizontal drilling is beyond the scope of this article, but an overview of those impacts is important in understanding how the public views fracking and how industry has responded to the public's concerns.

> is considered, the cost effectiveness is estimated as an average net savings of $99 per ton VOC reduced, using standard discount rates. We believe that these costs are very reasonable, given the emission reduction that would be achieved.

Id.

[215] *See* U.S. Gov't Accountability Off., Opportunities Exist to Capture Vented and Flared Natural Gas, Which Would Increase Royalty Payments and Reduce Greenhouse Gases, 25 (2010), http://www.gao.gov/assets/320/311826.pdf.

[216] *See* King, *supra* note 171, at 7.

[217] Am. Petroleum Inst., *supra* note 120, at 18.

[218] *See id.*

[219] *See, e.g.*, Powers, *supra* note 57, at 952–53 ("Deciding whether to encourage or limit hydro-fracking requires a highly subjective analysis that relies on uncertain and incomplete information.").

Although numerous studies have assessed the impacts of shale gas development, not all of the environmental effects are clear. Complicating matters further is the fact that horizontal drilling and fracking are sometimes conflated, with environmental impacts occasionally being overstated or misattributed.[220] However, unconventional gas development still raises serious environmental concerns that must be more fully appraised.

A. Water Related Concerns

At the heart of the public's fears about fracking are water impacts. Oil and gas development impacts ground and surface water, including both the quality and quantity of water. While a great deal of public consternation regarding shale gas development revolves around drinking water contamination in underground aquifers, industry arguably faces even bigger challenges on the surface, both in finding adequate water supplies and identifying safe methods for water disposal.

The seeming mantra of the natural gas industry is that there have been "zero confirmed cases of groundwater contamination connected to the fracturing operation in one million wells hydraulically fractured over the last 60 years."[221] One might ponder, "how could this be true given the wealth of claims to the contrary?" An EPA draft report suggests it might not be. In its Superfund groundwater investigation report on the water in Pavillion, Wyoming, EPA concluded that hydraulic fracturing was the likely cause of contaminated groundwater there.[222] However, many interested parties, including the state of Wyoming, have hotly criticized the scientific integrity of the report.[223] Those opposed to EPA's conclusion remain steadfast adherents to the claim that fracking has *never* contaminated groundwater aquifers.

Assessing the validity of this statement ultimately lies within the province of the scientific community, and might well still be open to debate; but regardless of whether or not fracking has contaminated any aquifers, industry has certainly failed to assuage the public's trepidations surrounding shale gas development. It

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[220] Professor Mark Zoback makes a compelling argument that fracking has become a "bumper sticker" for everything bad associated with the fracking process, including well drilling and casing; however, a great deal of evidence suggests that fracking itself may be fairly benign. *See* SEC'Y OF ENERGY ADVISORY BD., *supra* note 16, at 13.

[221] AM. PETROLEUM INST., *supra* note 194, at 7.

[222] *See* U.S. EPA, DRAFT INVESTIGATION OF GROUNDWATER CONTAMINATION NEAR PAVILLION, WYOMING, xiii (2011), *available at* http://www.epa.gov/region8/superfund/wy/pavillion/EPA_ReportOnPavillion_Dec-8-2011.pdf ("Alternative explanations were carefully considered . . . . However, when considered together with other lines of evidence, the data indicates likely impact to ground water that can be explained by hydraulic fracturing.").

[223] *See* Danielle Venton, *EPA Grilled over Pavillion Report*, HIGH COUNTRY NEWS (Feb. 2, 2012), http://www.hcn.org/blogs/goat/epa-grilled-over-pavillion-report.

is one thing to simply state that "no confirmed case of contamination exists"—itself containing a legal qualifier in "confirmed" that some might find difficult to digest—and quite another to provide explanations of the processes taking place in their backyards. At a minimum, industry should acknowledge the inherent risks of the drilling and fracking processes. As SEAB noted, "[a]n industry response that hydraulic fracturing has been performed safely for decades rather than engaging the range of issues concerning the public will not succeed."[224]

The public's apprehension regarding water contamination is not entirely unwarranted, either. More than ninety percent of public drinking water comes from underground sources.[225] And, while fracking fluids are composed of 0.5% chemical additives, the injection of millions of gallons equates to a large volume of chemicals being used.[226] A House Committee on Energy and Commerce Minority Staff report concluded that, "[b]etween 2005 and 2009, the 14 [leading] oil and gas service companies used more than 2,500 hydraulic fracturing products containing 750 chemicals and other components . . . [and] 780 million gallons of hydraulic fracturing products—*not including water*."[227] Where these potentially hazardous chemicals end up is therefore a legitimate concern to those who drink water from wells near fracking operations.

Among the hazardous chemicals are "BTEX" compounds and other aromatic hydrocarbons.[228] BTEX is an abbreviation for benzene, tolulene, ethylbenzene, and xylene,[229] which are compounds found in petroleum products.[230] The main concern with BTEX compounds is prolonged and acute exposure, which can result in "skin and sensory irritation, central nervous system depression, and effects on the respiratory system," can affect kidney, liver, and blood systems, and are also carcinogenic.[231] Petroleum distillates, which "can be found in a variety of additive products including corrosion inhibitors, friction reducers

224 SEC'Y OF ENERGY ADVISORY BD., *supra* note 16, at 13.

225 *See* U.S. EPA, UNDERGROUND INJECTION CONTROL 101: PERMITTING GUIDANCE FOR HYDRAULIC FRACTURING USING DIESEL FUELS TECHNICAL WEBINARS 4 (2011), *available at* http://water.epa.gov/type/groundwater/uic/class2/hydraulicfracturing/upload/uic_101_webinar_presentation.pdf.

226 *See supra* notes 183–87 and accompanying text.

227 HOUSE OF REPRESENTATIVES DEMOCRATIC COMM. ON ENERGY AND COM., CHEMICALS USED IN HYDRAULIC FRACTURING (2011), *available at* http://democrats.energycommerce.house.gov/sites/default/files/documents/Hydraulic%20Fracturing%20Report%204.18.11.pdf (emphasis added).

228 *See* King, *supra* note 171, at 8.

229 Poe Leggette, *Federal Developments Affecting Hydraulic Fracturing*, *Hydraulic Fracturing*, Paper No. 4, 4A-3 (Rocky Mtn. Min. L. Fdn. 2012).

230 TOSC ENVIRONMENTAL BRIEFS FOR CITIZENS, BTEX CONTAMINATION 1, *available at* http://www.egr.msu.edu/tosc/akron/factsheets/fs_btexpdf.pdf (last visited Nov. 19, 2012). While benzne, tolulene, and xylene are naturally occurring in petroleum compounds, ethylbenzene is an additive. *Id.*

231 *Id.* at 2.

and solvents," can, depending on exposure levels, affect the gastrointestinal and central nervous systems, and can cause skin irritation, blistering, or peeling.[232] Other fracking additives[233] have adverse health impacts that include increased cancer risks, nervous system impacts, kidney function, red blood cell formation, and reproductive complications.[234] Another source of public concern is the secrecy associated with fracking fluid constituents. One organization, FracFocus.org, provides a venue where companies can voluntarily disclose the chemicals added to fracking fluids.[235] However, the registry on FracFocus.org includes only chemicals that would appear on a Material Safety Data Sheet under OSHA.[236] As a result, numerous chemicals used in fracking are, in fact, unreported on the FracFocus.org registry.[237]

Surface water contamination is yet another source of public apprehension. After being injected, some fracking fluids return to the surface. The amount of water returned can vary significantly among wells, with the amount of water recovered ranging from five[238] to eighty percent.[239] The composition of flowback water is also quite dynamic: "[t]he quality and composition of flowback from a single well can also change within a few days after the well is fractured."[240] Among the flowback components of greatest environmental concern are gelling agents, surfactants and chlorides, but other components can include dissolved solids, metals, biocides, lubricants, organics, and radionuclides.[241]

Surface water contamination can also stem from surface spills resulting from chemicals used in production operations seeping into groundwater aquifers from above. There have also been numerous incidents of state regulation violations resulting from storing flowback on site, in pits, or in tanks, which have resulted

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232 N.Y. DEP'T OF ENVTL. CONSERVATION, *supra* note 173, at 5-75.

233 The categories of compounds identified by the New York Department of Environmental Conservation include: petroleum distillates; aromatic hydrocarbons; glycols; glycol ethers; alcohols and aldehydes; amides; amines; organic acids, salts, esters and related chemicals; microbiocides; and other non-disclosed chemicals. *Id.* at 5-75 to 5-79. The effects of these chemicals on human health depends on the level and length of exposure, as well as the type of exposure (e.g., ingestion, skin contact, or inhalation). *See generally* N.Y. DEP'T OF ENVTL. CONSERVATION, *supra* note 173.

234 *See id.* at 5-75 to 5-79.

235 *See generally What Chemicals are Used*, FRACFOCUS.ORG, http://fracfocus.org/chemical-use/what-chemicals-are-used (last visited Nov. 19, 2012); *Find a Well*, FRACFOCUS.ORG, http://www.hydraulicfracturingdisclosure.org/fracfocusfind/ (last visited Nov. 19, 2012).

236 *See Chemicals & Public Disclosure*, FRACFOCUS.ORG, http://fracfocus.org/chemical-use/chemicals-public-disclosure; *see also* SEC'Y OF ENERGY ADVISORY BD., *supra* note 16, at 23–24.

237 *See* FRACFOCUS.ORG, *supra* note 236.

238 *See* King, *supra* note 171, at 11.

239 *See* Groat et al., *supra* note 196, at Section 1, 20.

240 N.Y. DEP'T OF ENVTL. CONSERVATION, *supra* note 173, at 6-18.

241 *Id.* at 6-17.

in spills.[242] Spills can occur in various ways, such as storage leaks or spills at well pads of unmixed, concentrated chemicals. Additionally, "[t]rucks hauling hydraulic fracturing chemicals, flowback, and produced water can be involved in accidents resulting in spills."[243] The transportation of flowback or produced water to injection or treatment sites, either by pipeline or tanker truck, can similarly result in spills.[244] And once fracking fluids or flowback arrive at the well site, they are usually stored in lined, open-air pits, which themselves create possibilities of spills.[245]

Some spills are particularly worrisome.[246] Risks of spills to shallow aquifers are particularly acute because of the close proximity of the chemicals to large sources of drinking water. In New York, for example, the groundwater table in the Primary and Principal Aquifers is fairly shallow, generally ranging from zero to twenty feet in depth.[247] Because these aquifers are largely located and contained in unconsolidated sands and gravel, "the high permeability of soils that overlie these aquifers and the shallow depth to the water table make these aquifers particularly susceptible to contamination from surface activity."[248] Consequently, surface spills could result in rapid contamination of a primary water supply aquifer.[249] And, once shallow aquifers are contaminated, it is very difficult and expensive to reclaim them as sources of drinking water.[250]

Evidence exists that surface contaminations are occurring far more than other types of potential pollutions. An interdisciplinary Massachusetts Institute of Technology (MIT) study on the future of natural gas provided examples of forty-three reported incidents related to natural gas development, of which fourteen resulted from on-site surface spills, with another four resulting from off-site disposal issues.[251] The report also noted that "no incidents of direct invasion of shallow water zones by fracture fluids during the fracturing process [were] recorded."[252] A February 2012 study by the Energy Institute of the University

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[242] *See* Hannah Wiseman, *Fracturing Regulation Applied*, 22 DUKE ENVT'L L. & POL'Y FORUM 361, 374 (2012) (noting the common violations at shale gas and tight sands sites).

[243] Groat et al., *supra* note 196, at Section 4, 35.

[244] *Id.* Pipeline leaks can be particularly problematic because they are difficult to discover, and thus might exist for long periods of time. *See id.*

[245] *See id.* at Section 4, 36. *See also* Venton, *supra* note 223.

[246] *Cf.* Wiseman, *supra* note 242, at 376 ("Of perhaps more concern than leaking pits are the high percentage of violations in several states associated with surface spills.").

[247] N.Y. DEP'T OF ENVTL. CONSERVATION, *supra* note 173, at 6-37.

[248] *Id.* at 6-37.

[249] *Id.* at 6-36.

[250] *Id.* at 6-39.

[251] *See* MIT, 2011 MIT STUDY ON THE FUTURE OF NATURAL GAS App. 2E, 2, http://web.mit.edu/mitei/research/studies/documents/natural-gas-2011/NaturalGas_Appendix2E.pdf.

[252] *Id.*

of Texas arrived at a similar conclusion, finding that "[h]ydraulic fracturing chemicals and flowback water present . . . more significant risk[s] above ground than they do in the deep sub-surface."[253]

To date, there remains a relative dearth of information about how many spills take place and to what extent they are contained or remediated.[254] Nonetheless, the risks of further adverse effects to the environment and human health are real, given the number of frack jobs expected to occur in coming decades: if *millions of gallons* of fluids will be used in *each* frack job, of which an estimated one to two million will take place in the next five to ten years,[255] the chance of *some* liquids spilling onto the ground is a near certainty.

The quantity of water used in fracking operations is yet another area of public disquiet, especially in the arid and semi-arid western states.[256] As Leslie Savage, chief geologist for the Texas Railroad Commission, explains: "[W]hile the amount of water being used for fracking doesn't make up a large percentage of overall use statewide or nationwide, it can make up a large portion of the water use in certain localized areas, having a big impact on water supplies."[257] And in years of drought, fracking operations only further strain water supplies.[258]

Although the amount of water needed varies depending on the shale formation being drilled and fracked, the quantities currently required are significant.[259] The volume of water used in shale gas development is difficult to conceptualize. One

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[253] Groat et al., *supra* note 196, at Section 4, 35. And, although the debate about the validity of EPA's results persists, it is worth noting that that EPA Draft Report on Pavillion, Wyoming also concluded that "samples from shallow monitoring wells near pits indicate[] that pits are a source of shallow ground water contamination." U.S. EPA, *supra* note 222, at xi.

[254] *See, e.g.*, Groat et al., *supra* note 196, at Section 4, 37 ("The key question is how often do surface spills occur and what is the nature of the environmental consequences of these spills (and the result of remediation efforts). Regulatory agencies either do not collect this information or do not make it publicly available in a form readily accessible.").

[255] *See* Zoback, *supra* note 43, at 4B-2.

[256] *See, e.g.*, Kiah Collier, *Railroad Commission, Halliburton Officials Say Amount of Water Used for Fracking is Problematic*, ABILENE REPORTER NEWS, July 15, 2011, *available at* http://www.reporternews.com/news/2011/jul/15/railroad-commission-halliburton-officials-say-of/?print=1 ("'Frankly, in my opinion, it is not the well casing, it is not the hydraulic fracturing chemicals that are a problem in hydraulic fracturing,' . . . '[i]t is the use of water, particularly in drought.'").

[257] *Id.*

[258] *See* Jim Magill, *South Texas Worries Over Gas Industry's Water Use During Drought*, PLATTS (July 5, 2011), *available at* http://www.platts.com/RSSFeedDetailedNews/RSSFeed/NaturalGas/3555776 ("Although the drought does not have a direct impact on water levels in the underground aquifers, the drought results in greater demand on the aquifers from users, such as farmers irrigating their parched fields, which in turn can lower water levels.").

[259] *See* Groat et al., *supra* note 196, at Section 2, 24 (on average, the amount of water used per well is (in millions of gallons): 4.0 in the Barnett; 5.6 in the Haynesville; 4.9 in the Fayetteville; 5.6 in Marcellus; and 6.1 in the Eagle Ford).

way to do so is to compare it to residential usage. In Colorado, for example, the volume of water, including recycled water, used every year for new oil and gas development could serve up to 118,400 homes, or just short of 300,000 people.[260] Another way is through an examination of water transportation. Roughly 200 trucks are required to deliver one million gallons of water,[261] weighing a total of 8,340,000 pounds.[262] Therefore, to service a large frack job of eight million gallons, 1,600 trucks would be required to deliver that water.[263] As an extreme example, 38,400 trucks would be required to deliver the 192 millions gallons to Apache Corporation's K pad in Canada's Horn River Basin that has sixteen wells, each consuming twelve million gallons of water.[264] Truck traffic has consequential air quality issues, as well, which are discussed below. Some wells, however, use sources of water where no trucks are needed, such as pipelines and in situ pumping from a groundwater aquifer or surface impoundment.

The potential good news[265] for western water users is that, even with the expected increase of fracking operations in the region, there have been considerable advancements regarding water recycling and the use of alternative liquids.[266] Water recycling and reuse "involves either straight dilution of the flowback water with fresh water or the introduction on-site of more sophisticated treatment options prior to flowback reuse."[267] Unfortunately, considerable portions of injected fluids remain underground, and returned water is entirely consumptive, meaning it cannot be returned to streams.[268] Thus, massive quantities of freshwater are still needed for unconventional oil and gas development, even with recycling efforts.

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[260] *See* W. RES. ADVOC., FRACKING OUR FUTURE: MEASURING WATER AND COMMUNITY IMPACTS FROM HYDRAULIC FRACTURING 6 (2012), http://www.westernresourceadvocates.org/frackwater/fracking_our_future_july_2012.pdf.

[261] *See* RADISAV VIDIC, UNIV. OF PITT., SUSTAINABLE WATER DEVELOPMENT FOR MARCELLUS SHALE DEVELOPMENT (2010), *available at* http://www.temple.edu/environment/NRDP_pics/shale/presentations_TUsummit/Vidic-Temple-2010.pdf.

[262] *A Million Gallons of Water—How Much Is It?*, U.S. GEOLOGICAL SURV., http://ga.water.usgs.gov/edu/mgd.html (last visited Nov. 19, 2012).

[263] *See* VIDIC, *supra* note 261.

[264] *See* King, *supra* note 171, at 30. It is worth noting that water usage varies among plays, and even wells within a certain play depending on, *inter alia*, well length, depth, porosity, and type of fracking fluid used. *See, e.g.*, *id.* at 40.

[265] It should be kept in mind that even a reuse of eighty percent of flowback is only eighty percent of whatever is returned and reusable at all (five to eighty percent of total water injected). Thus, reducing the total amount used and returned is still critical to conserve water resources in the west.

[266] *See supra* notes 177–83 and accompanying text.

[267] N.Y. DEP'T OF ENVTL. CONSERVATION, *supra* note 173, at 5-118.

[268] *See* W. RES. ADVOC., *supra* note 260, at 6.

B. Air Impacts

A second major environmental impact of unconventional gas development is the emission of pollutants and other airborne substances. While national media attention has gravitated toward water quality concerns, there are some areas where air quality impacts from fracking and drilling have become particularly problematic.[269] And, on a global scale, a debate has sparked over whether the lifecycle emissions of natural gas production, transportation, and consumption are any better than coal, and whether natural gas is a good choice for a "bridge fuel" to a green energy future.

Concern regarding air emissions created by drilling and fracking operations can be separated into two categories of pollutants. The first are criteria pollutants, including potentially noxious VOCs, and hazardous air pollutants (HAPs) that can pose direct threats to human health. The second are greenhouse gases (GHGs) emitted in the lifecycle of natural gas production, distribution, and consumption.

A wide variety of shale gas development activities, processes, and mechanisms produce emissions that fall under at least one of these two broad categories. These include emissions from: dehydrators, condensate tanks,[270] pneumatic pumps, construction activities, heaters, drill rigs,[271] flaring, venting, pits, and blowouts; exhaust and particulate matter from on-site engines as well as vehicles coming and going from the well site; fugitive emissions from production wells, completions, and workovers;[272] and leaks in production and pipeline operations.[273]

Among the pollutants that natural gas development and related activities create is ground-level ozone pollution. Ozone (O_3) "is created by chemical reactions between oxides of nitrogen (NOx) and [VOCs] in the presence of sunlight,"

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[269] According to SEAB, "[s]ignificant air quality impacts from oil and gas operations in Wyoming, Colorado, Utah and Texas are well documented, and air quality issues are of increasing concern in the Marcellus region (in parts of Ohio, Pennsylvania, West Virginia and New York)." SEC'Y OF ENERGY ADVISORY BD., *supra* note 16, at 15 (footnote omitted). Unlike GHGs that warm the planet, certain emissions, namely criteria and hazardous air pollutants, from shale gas development pose more direct and immediate health and environmental harms.

[270] *See Source of Oil and Gas Air Pollution*, EARTHWORKS, http://www.earthworksaction.org/issues/detail/sources_of_oil_and_gas_air_pollution (last visited Nov. 19, 2012).

[271] JOHN CORRA, EMISSIONS FROM HYDROFRACKING OPERATIONS AND GENERAL OVERSIGHT INFORMATION FOR WYOMING 5 (2011), *available at* http://www.shalegas.energy.gov/resources/071311_corra.pdf.

[272] *Id.* at 5–7.

[273] *See generally* FORT WORTH AIR QUALITY COMM., POINT SOURCES ON TYPICAL GAS FACILITIES (2010), *available at* http://fortworthtexas.gov/uploadedFiles/Gas_Wells/Gas%20Point%20Sources%203-31-10.pdf.

and is the "primary constituent of smog."[274] While ozone is considered good in the stratosphere because it helps protect the earth from ultraviolet rays, ozone is harmful to people and the environment in the troposphere.[275] Breathing ozone can lead directly to respiratory problems such as chest pain, coughing, throat irritation, and congestion.[276] It can also exacerbate bronchitis, emphysema, and asthma.[277] Ground-level ozone can even reduce lung function and inflame the linings of the lungs, with repeated exposure permanently scaring lung tissue.[278]

Ground-level ozone has become problematic in several of the producing regions in the Rocky Mountains; and while the causal connection between natural gas production and increased ozone levels is still less than perfect, the evidence is mounting. One area that has experienced significant ozone increases is Sublette County, Wyoming, home to the Green River Basin, the Jonah Field, and the Pinedale Anticline.[279] One day in 2011, ozone levels there rose to 124 parts per billion (ppb),[280] well above the National Ambient Air Quality Standard (NAAQS) level of 75 ppb.[281] Two other days saw levels of 116 and 104 ppb.[282] As a point of comparison, the highest ozone levels recorded in Los Angeles in all of 2010 was 114 ppb.[283] In April of 2012, the EPA designated Sublette County and parts of two other counties as nonattainment areas for ozone.[284] Even the rural,

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[274] *Ground-Level Ozone*, U.S. EPA, http://www.epa.gov/glo/ (last updated Nov. 1, 2012); *Ground-Level Ozone: Basic Information*, U.S. EPA, http://www.epa.gov/glo/basic.html (last updated Nov. 1, 2012).

[275] *See Ozone—Good Up High Bad Near By*, U.S. EPA, http://www.epa.gov/airquality/gooduphigh/ozone.pdf (last updated July 21, 2011). EPA manages ozone's effects to vegetation as a secondary air quality standard to protect public welfare. *See Ground-Level Ozone: Health Effects*, U.S. EPA, http://www.epa.gov/glo/health.html (last updated Nov. 1, 2012).

[276] *See Ground-Level Ozone: Health Effects*, *supra* note 275.

[277] *See id.*

[278] *See id.*

[279] Ann Chambers Noble, *The Jonah Field and Pinedale Anticline: A Natural-Gas Success Story*, WYOHISTORY.ORG, http://www.wyohistory.org/essays/jonah-field-and-pinedale-anticline-natural-gas-success-story (last visited Nov. 19, 2012).

[280] Mead Gruver, *Wyoming Air Pollution Worse than Los Angeles Due to Gas Drilling*, ASSOCIATED PRESS, Mar. 8, 2011, *available at* http://www.huffingtonpost.com/2011/03/08/wyoming-ait-pollution-gas-drilling_n_833027.html.

[281] *See National Ambient Air Quality Standards*, U.S. EPA, http://www.epa.gov/air/criteria.html (last updated July 16, 2012) (the eight hour primary and secondary NAAQS for ozone are 0.075 ppm, or 75 ppb).

[282] Gruver, *supra* note 280.

[283] *Id.*

[284] *See* Letter from Lisa Jackson, U.S. EPA, to Honorable Matt Mead, Governor of Wyoming, (Apr. 30, 2012) (on file with author), *available at* http://deq.state.wy.us/aqd/downloads/Non attainmentletter4_30_12.pdf. An area is designated as being in nonattainment for a particular pollutant when it fails to meet the NAAQS for that pollutant. *See* 42 U.S.C. § 7501(2); 42 U.S.C. § 7407(d).

sparsely populated Uintah basin—with an average of seven people per square mile—*periodically* experienced an eight-hour ozone average of 140 ppb in the winter of 2011.[285]

Colorado has also experienced increased ozone-forming pollutants along its Front Range. One National Oceanic and Atmospheric Administration (NOAA) study revealed that actual measured ozone precursor emissions in Colorado's Front Range were "up to twice the amount that government regulators . . . calculated should exist."[286] The NOAA study of the Denver-Julesburg Basin pinpointed "oil and gas development as the main source" of those emissions, finding that oil and gas operations released twice the methane[287] into the atmosphere in 2008 than the state had anticipated.[288]

Other criteria pollutants, particularly NOx, VOCs, particulate matter (PM) (including dust), and carbon monoxide (CO), are also emitted by oil and gas operations, with engines and turbines used in the field being the major sources. As EPA acknowledges, "[s]ignificant emissions of [NOx] . . . occur at oil and natural gas sites due to the combustion of natural gas in reciprocating engines and combustion turbines used to drive the compressors that move natural gas through the system, and from combustion of natural gas in heaters and boilers."[289] These sources are, however, somewhat unique in oil and gas development for two reasons. First, they are "not [included] in the Oil and Natural Gas source category,"[290] and therefore fall under different sections of the Clean Air Act.[291] Second, mobile engines and turbines are necessarily transitory and their emissions are consequently ephemeral. Nonetheless, the emissions can be intense, especially

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[285] *Utah's Winter Air Quality Mystery: NOAA Study Targets High Ozone Pollution Events in Western Oil and Gas Fields*, NAT'L OCEANIC AND ATMOSPHERIC ADMIN., (Feb. 7, 2012), http://researchmatters.noaa.gov/news/Pages/utah.aspx.

[286] Mead Gruver, *Air Pollution Levels Along Colorado Front Range Higher than Predicted*, ASSOCIATED PRESS, Feb. 10, 2012, *available at* http://rlch.org/news/air-pollution-levels-along-colorado-front-ranger-higher-predicted.

[287] Studies have shown that methane is a precursor to background tropospheric ozone. *See, e.g.*, U.S. EPA, REGULATORY IMPACT ANALYSIS: PROPOSED NEW SOURCE PERFORMANCE STANDARDS AND AMENDMENTS TO THE NATIONAL EMISSIONS STANDARDS FOR HAZARDOUS AIR POLLUTANTS FOR THE OIL AND NATURAL GAS INDUSTRY, 4–27 (2011), *available at* http://www.epa.gov/ttnecas1/regdata/RIAs/oilnaturalgasfinalria.pdf ("Studies have shown that reducing methane can reduce global background ozone concentrations.").

[288] *See* Gayathri Vaidyanathan, *Study Ignites Fresh Concerns About Drilling Emissions*, RED LODGE CLEARINGHOUSE (Feb. 16, 2012), http://rlch.org/news/study-ignites-fresh-concerns-about-drilling-emissions.

[289] Proposed NSPS, 76 Fed. Reg. at 52756.

[290] *Id.*

[291] According to EPA, "[t]he NO[x] emissions from engines and turbines are covered by the Standards of Performance for Stationary Spark Internal Combustion Engines (40 CFR part 60, subpart JJJJ) and Standards of Performance for Stationary Combustion Turbines (40 CFR part 60, subpart KKKK), respectively." *Id.*

in local communities that experience a sudden explosion of truck traffic and turbine engine use. Consider that well over one thousand truck trips *per frack job* are required to transport water to and from the pad site; and the number of truck trips is further compounded by multiple frack jobs taking place in relatively the same geographic area. The dust, noise, and emissions generated by traffic alone raise significant environmental and health concerns,[292] with rig engines and turbines only exacerbating the problem.

The lifecycle emissions of natural gas development have also become an area of contentious public and scientific debate. The main GHGs associated with natural gas production and consumption are carbon dioxide (CO_2) and methane (CH_4). Carbon dioxide is generally produced by combustion, from both engines used in the production of the gas and the combustion of the gas itself by the end user.[293] Methane is mostly released from natural production and distribution, known as "fugitive emissions."[294]

Although CO_2 and CH_4 are both problematic compounds vis-à-vis global climate change, methane has a significantly higher global warming potential (GWP)[295] than carbon dioxide.[296] According to the Intergovernmental Panel on Climate Change (IPCC), methane has a GWP of seventy-two over a twenty-year time horizon, and twenty-five over a 100-year time horizon.[297] In essence, the same amount of methane has a much higher radiative efficiency than carbon

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[292] *See* NAT. RES. LAW CENTER, *supra* note 117.

[293] "Despite the high level of industrial activity involved in developing shale gas, the indirect emissions of CO_2 are relatively small compared to those from the direct combustion of the fuel." *See* ROBERT W. HOWARTH ET AL., METHANE AND THE GREENHOUSE-GAS FOOTPRINT OF NATURAL GAS FROM SHALE FORMATIONS (2011), *available at* http://www.sustainablefuture.cornell.edu/news/attachments/Howarth-EtAl-2011.pdf (citation omitted). Unconventional gas production does, nonetheless, emit CO_2 in amounts that cannot be considered de minimis. The two main sources of CO_2 emissions in production activities are engine emissions and combustion during flow-back operations.

[294] Methane makes up seventy to ninety percent of unrefined natural gas. *See* NATURALGAS.ORG, *supra* note 18.

[295] The GWP is a metric used to compare the effect that different pollutants have on global warming over a certain time horizon, with CO_2 often being given a value of one. *See* INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, IPCC FOURTH ASSESSMENT REPORT: CLIMATE CHANGE 2007, 2.10.1 (2007), http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-10.html#2-10-1 (full publication *available at* http://www.ipcc.ch/publications_and_data/publications_and_data_reports.shtml#.UJnH8Rwhrx4). Radiative efficiency, which is a component of the GWP calculation, describes how strongly the pollutant affects the radiative balance at the tropopause. *See* ROBERT PORTMAN, RADIATIVE FORCING OF CLIMATE BY NON-CO_2 ATMOSPHERIC GASES, (2007), *available at* http://www.esrl.noaa.gov/research/themes/forcing/FutureForcing.pdf.

[296] *See* INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, *supra* note 295, at 2.10.2.

[297] *Id.*

dioxide.[298] Once emitted, however, methane has a shorter atmospheric lifetime[299] than carbon dioxide.[300]

Much like NOx, which is "a triple threat because it forms haze, ozone and acidic precipitation,"[301] methane is environmentally harmful on multiple fronts. Above all else, methane is a potent greenhouse gas, with a GWP of twenty-five to seventy-two times that of CO_2.[302] The emission of methane into the atmosphere thus contributes directly and significantly to climate change. Additionally, methane is a precursor to ozone, which is not only a "major public health threat, linked to a wide range of maladies," and a threat to "vegetation, agricultural productivity, and cultural resources," but also contributes to climate change.[303] A recent study by the United Nations Environment Program placed ozone as the third most significant contributor to human-caused climate change, behind only carbon dioxide and methane.[304]

There are also new studies showing disturbing data that natural gas might have a more significant impact on global climate change than previously thought.[305] And even though there is not a consensus as to the extent of fugitive methane emissions, natural gas's prospects as a "bridge fuel" to a renewable portfolio has been brought into question. There is, however, the potential for marked lifecycle

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[298] *See id.*

[299] *Lifetime Definition*, ECOLOGY DICTIONARY, http://www.ecologydictionary.org/Lifetime, defines lifetime as:

> The lifetime of a greenhouse gas refers to the approximate amount of time it would take for the anthropogenic increment to an atmospheric pollutant concentration to return to its natural level (assuming emissions cease) as a result of either being converted to another chemical compound or being taken out of the atmosphere via a sink. This time depends on the pollutant's sources and sinks as well as its reactivity. The lifetime of a pollutant is often considered in conjunction with the mixing of pollutants in the atmosphere; a long lifetime will allow the pollutant to mix throughout the atmosphere. Average lifetimes can vary from about a week (sulfate aerosols) to more than a century (chlorofluorocarbons (CFCs), carbon dioxide).

[300] INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, *supra* note 296.

[301] Ray Ring, *Oil and Gas Drilling Clouds the West's Air*, HIGH COUNTRY NEWS, Oct. 31, 2005, *available at* http://www.hcn.org/issues/309/15873.

[302] *See* INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, *supra* note 296 (methane has a GWP (compared to CO_2 of 25 over a 100-year time frame and 72 over a 20-year time frame)).

[303] SIERRA CLUB ET AL., *supra* note 31, at 12.

[304] *See id. See also* UNITED NATIONS ENVTL. PROGRAMME AND WORLD METEOROLOGICAL ORG., INTEGRATED ASSESSMENT OF BLACK CARBON AND TROPOSPHERIC OZONE: SUMMARY FOR DECISION MAKERS (2011), *available at* http://www.unep.org/dewa/Portals/67/pdf/Black_Carbon.pdf.

[305] *See, e.g.*, Howarth et al., *supra* note 293; Gabrielle Pétron et al., *Hydrocarbon emissions characterization in the Colorado Front Range: A pilot study*, J. OF GEOPHYSICAL RESEARCH, Vol. 117, 19 (2012).

emission reductions,[306] suggesting that the plan for natural gas to facilitate a low-carbon United States energy future is not entirely dead on arrival.

The precise amount of methane released by unconventional gas production and related activities is uncertain, but the estimates are substantial. Over the last 250 years, atmospheric methane concentrations have increased by 148 percent.[307] According to EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks*, by 2009, natural gas systems were "the largest anthropogenic source category of [methane] emissions in the United States in 2009 with 221.2 [teragrams (or million metric tons) of the CO_2 equivalent (Tg CO_2 Eq.)] of [methane] emitted into the atmosphere."[308] But even the 221.2 Tg CO_2 Eq. figure fails to take into account emissions from tight sand plays, such as the behemoth Marcellus Shale.[309] When added to petroleum systems (excluding refineries) and tight sands, the total methane emissions from petroleum and natural gas systems rises to 328.29 Tg CO_2 Eq.[310] By comparison, enteric fermentation[311] was the second largest source of United States methane emissions in 2009 at 139.8 Tg CO_2 Eq.[312] All told, the oil and gas sectors are responsible for forty percent of all United States methane emissions, or about four percent of all domestic GHG emissions, *not including* end use combustion.[313]

The environmental risks associated with horizontal drilling and hydraulic fracturing are numerous and unique to other forms of oil and gas development.[314] Water resources are challenged above and below ground and must be protected from poor well construction, shallow producing formations, spills, and accidents. Scarce water resources are also pitted against continued slickwater fracking

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306 *See supra* notes 202–09 and accompanying text.

307 *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2009: Executive Summary*, U.S. EPA 2 (Apr. 2011), http://www.epa.gov/climatechange/ghgemissions/usinventoryreport/archive.html (follow "Executive Summery" hyperlink under Inventory April 2011).

308 *Id.* at 11.

309 Proposed NSPS, 76 Fed. Reg. at 52756.

310 *Id.*

311 Enteric fermentation is "fermentation that takes place in the digestive systems of animals." U.S. EPA, SUPPLEMENT D TO COMPILATION OF AIR POLLUTANT EMISSION FACTORS: VOLUME I: STATIONARY POINT AND AREA SOURCES 14.4.1 (1998), http://nepis.epa.gov/EPA/html/DLwait.htm?url=/Exe/ZyNET.exe/200120KW.PDF?ZyActionP=PDF&Client=EPA&Index=1995%20Thru%201999&File=D%3A\ZYFILES\INDEX%20DATA\95THRU99\TXT\00000019\200120KW.txt&Query=&SearchMethod=1&FuzzyDegree=0&User=ANONYMOUS&Password=anonymous&QField=&UseQField=&IntQFieldOp=0&ExtQFieldOp=0&Docs=. 1998)

312 U.S. EPA, *supra* note 307, at 11.

313 *See* DEBRA A. KADEN, HYDROFRACKING: AIR ISSUES AND COMMUNITY EXPOSURE 3 (2012), *available at* http://www.colorado.edu/law/centers/nrlc/events/hottopics/Kaden%20PPT%20(1-27-12_.pdf.

314 *See* Wiseman, *supra* note 242, at 365.

operations in the arid west. Air impacts, while not completely known, are also consequences of widespread unconventional oil and gas development. More data are needed to determine the precise effects from GHGs, VOCs, PM, and other pollutants released from the development processes, as well as ways to reduce these impacts on global and local scales. Other environmental risks from development include increased road construction, truck traffic, and noise and light pollution.[315] Because unconventional oil and gas development is not an environmentally benevolent practice, ways of managing these and other environmental and health risks are necessary, as discussed in subsequent sections of this article.

V. THE FAILED SOCIAL DISCOURSE ON FRACKING

A. *Defining Fracking*

While hydraulic fracturing and horizontal drilling were evolving to allow the economical development of unconventional reservoirs, little work was done to understand and address the unique environmental impacts associated with such development. And as fracking and horizontal drilling began to be used closer to residential communities, the public became justifiably concerned. The then-secretive processes and the industry's reluctance to disclose the chemicals in fracking fluids also fueled the public's increasing alarm. These new fears were further heightened when claims began to surface that fracking was contaminating drinking water aquifers[316] and allowing homeowners to light their tap water on fire.[317] Industry has been accused of failing to provide either evidence to rebut these assertions or reasonable explanations for potential incidents of contamination. To complicate matters more, fracking quickly became a shorthand term for describing a wide range of problems relating to oil and gas development. An informational schism was thus created, with little or no public discourse.

The discourse regarding fracking that has since taken place has been "marked by confusion and obfuscation due to a lack of clarity about the terms used to characterize the [fracking] process."[318] According to a report by the Pacific Institute, even today "[t]here is a general disagreement about what is meant by 'hydraulic fracturing,'"[319] with different stakeholders viewing fracking as a term

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[315] These risks are discussed in greater detail in Section VI(B), *infra*.

[316] *See, e.g.*, Abraham Lustgarten, *Hydrofracked: One Man's Quest for Answers About Natural Gas Drilling*, HIGH COUNTRY NEWS, June 27, 2011, *available at* http://www.hcn.org/issues/43.11/hydrofracked-one-mans-quest-for-answers-about-natural-gas-drilling.

[317] *See, e.g.*, Abraham Lustgarten, *Scientific Study Links Flammable Drinking Water to Fracking*, PROPUBLICA (May 9, 2011), http://www.propublica.org/article/scientific-study-links-flammable-drinking-water-to-fracking.

[318] HEATHER COOLEY & KRISTINA DONNELLY, HYDRAULIC FRACTURING AND WATER RESOURCES: SEPARATING THE FRACK FROM THE FICTION 5 (2012), *available at* http://www.pacinst.org/reports/fracking/full_report.pdf.

[319] *Id.* at 7.

encompassing different processes—all with different environmental impacts. Groups such as the Pacific Institute and the investigative journalism outfit ProPublica tend to define fracking to include the entire production process, including drilling, well construction and completion, hydraulic fracturing, gas production, and well closure.[320] Industry, on the other hand, has consistently used fracking as a term that narrowly describes the process of using fluids to fracture rock formations in isolation.[321]

As a consequence of this definitional disagreement, the discussion regarding fracking's role in causing environmental harm quickly stalled. Public and media outcries causally link aquifer contaminations to fracking when, in fact, the hydraulic fracturing process itself appears to have caused fewer environmental harms compared to the associated production stages. For instance, ProPublica has repeatedly discussed how fracking is contaminating groundwater.[322] But in an article titled, "Setting the Record Straight on Hydraulic Fracturing," even the ProPublica author notes that "it's difficult for scientists to say which aspect of drilling . . . causes [water contamination]."[323]

Additionally, the public-industry disconnect has been both perpetuated and exacerbated because non-industry stakeholders often use fracking as a term encompassing all oil and gas development activities. As industry insider George King explains:

> Environmentalist critics insist that some "fracks" have contaminated ground and surface waters while engineers insist that not one frac has ever contaminated ground waters . . . . Surprisingly, both sides have valid arguments—just a mismatch of definitions. Much of the turmoil concerns how each group defines fracturing. In engineering terms, fracturing concerns a precise stimulation activity, limited to the fluid action in initiating and extending cracks in the rock; while, for many concerned citizens, bloggers and environmentalists, fracturing has come to represent nearly every phase of the well development cycle from drilling to production.[324]

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[320] *See id.*

[321] *See id.*

[322] *See, e.g.*, Abrahm Lustgarten, *Buried Secrets: Is Natural Gas Drilling Endangering U.S. Water Supplies?*, PROPUBLICA (Nov. 13, 2008), http://www.propublica.org/article/buried-secrets-is-natural-gas-drilling-endangering-us-water-supplies-1113; Abraham Lustgarten, *Setting the Record Straight on Hydraulic Fracturing*, PROPUBLICA (Jan. 12, 2009), http://www.propublica.org/article/setting-the-record-straight-on-hydraulic-fracturing-090112.

[323] Lustgarten, *Setting the Record Straight on Hydraulic Fracturing*, *supra* note 322.

[324] King, *supra* note 171, at 4.

Although some might take issue with these seemingly derisory distinctions, they are matters of great importance for industry workers who understand development terms on a technical level. And these distinctions may be more important still for lawyers carefully crafting statements about the risks of fracking. After all, no oil and gas company or service operator wants to admit they contaminate drinking water supplies, let alone to be accused of doing so. Understandably then, industry adheres to the narrow definition of fracking to avoid fracking's connection to other, more environmentally circumspect development processes.

B. *Groundwater Contamination: A Study of the Failed Discourse on Fracking, its Impacts, and Overcoming Semantic and Technical Hurdles*

The debate over whether and to what extent fracking is contaminating aquifers is exemplary of the failed social discourse on fracking. While this article does not purport to resolve whether fracking is causing groundwater contamination, it is nonetheless important to understand the reasons for the potential confusion surrounding fracking and why the public discourse quickly stalled. Ultimately, whether unconventional oil and gas development actually caused aquifer contamination remains uncertain.[325] It is clear, however, that fracking is a distinct process from horizontal drilling, and by most accounts, is not the stage of oil and gas development that is the most environmentally harmful. Rather, the well drilling and construction stages appear to be crucial in ensuring that no underground aquifers are contaminated.[326] Properly cased and cemented wells are, in fact, not only essential for protecting aquifers, but also for efficient production of the hydrocarbon bearing zones.[327] Knowing how to properly construct wells does not guarantee, however, that well construction is done correctly, nor does it prevent mistakes.

Setting accidents aside for the moment, the process of fracking itself, taken as an isolated process, appears to be relatively benign *when properly executed*. As the New York Department of Environmental Conservation concluded, "exposure to fracturing additives [viz., fracking fluid constituents] would not occur absent a failure of operational controls such as an accident, a spill or other non-routine incident."[328] To help understand why this is so, a basic understanding of the subsurface geologic features is necessary.

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[325] The EPA report on Pavillion, Wyoming drew enormous criticism for its data collection process, calling into question the validity of EPA's conclusions. *See* Jodi Peterson, Follow-up on Abraham Lustgarten, *Hydrofracked: One Man's Quest for Answers About Natural Gas Drilling*, HIGH COUNTRY NEWS, June 27, 2011, HIGH COUNTRY NEWS, May 28, 2012, at 5.

[326] *See* Boling, *supra* note 109, at 5-4 to 5-5.

[327] *See* AM. PETROLEUM INST., *supra* note 194, at 7.

[328] N.Y. DEP'T OF ENVTL. CONSERVATION, *supra* note 173, at 5-74.

Below the water table lie sources of drinking water for most public systems. These areas of treatable water are found at varying depths. In a sample of seven shale gas-producing areas, the depth of the base of treatable water resources range from approximately 300 feet to 1,200 feet.[329] These areas of water are separated from target oil and gas production zones by rock columns ranging from only 100 feet to 13,000 feet.[330] Shallow reservoirs, such as the New Albany,[331] undoubtedly deserve special consideration due to the close proximity of the fracked formations to overlying water tables. But such propinquity is not endemic to shale gas plays throughout the United States. For example, the gaps between the tops of the production zones and the bottoms of treatable water columns in the Barnett Shale range from 5,300 to 7,300 feet; 10,100 to 13,100 in the Haynesville; 2,125 to 7,650 in the Marcellus; and 5,600 to 10,600 in the Woodford.[332] The geographic uniqueness of each well site is also precisely why proper well construction and pre-fracking preparations are essential to the development process.

Additionally, the creation of artificial fractures does not create sufficient pathways between the producing formations and overlying aquifers. The roughly quarter-inch fractures are controlled by the amount of pressure applied.[333] If pressure drops to a certain level, the fracture will stop growing.[334] Other rock layers will also stop the vertical growth of a fracture.[335] Micro-seismic monitoring is used to determine and verify the precise[336] fracture growths by "triangulat[ing] the location of sounds made by rock breaking during shear fracturing."[337] The micro-seismic mapping of frack jobs in the Barnett and Marcellus shales reveal, fairly conclusively, that as long as there is measured separation between aquifers and the producing formation, fracture growth does not breach aquifers.[338] A 2011 study confirmed these results, showing that in four shale plays, the Eagle Ford, Barnett, Marcellus, and Woodford, the closest proximity of fracture growths to an

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[329] *See* U.S. DEPT. OF ENERGY, *supra* note 11, at 17.

[330] *Id.*

[331] The New Albany Shale's maximum depth between the producing formations and the bottom of treatable water is 1,600 feet, and the minimum depth is only 100 feet. *See id.* at 17.

[332] *Id.* Even in the controversy-shrouded Wind River Formation, the site of the Pavillion, Wyoming EPA study, production took place at a minimum of 1,220 feet below ground surface. EPA did not, however, provide the minimum distance between production wells and groundwater aquifers. According to EPA's data, even assuming the shallowest production well is found directly under the deepest aquifer, there would still be a 420-foot separation between the two. *See* U.S. EPA *supra* note 222, at 2.

[333] *See* King, *supra* note 171, at 30–31.

[334] *See id.*

[335] *See id.*

[336] Micro-seismic monitoring has been confirmed to be accurate to about fifty feet. *See id.* at 34.

[337] *Id*. at 33.

[338] *See* Zoback, *supra* note 43, at 4B-14; King, *supra* note 171, at 33–34.

aquifer were 6,000, 2,800, 3,800, and 4,000 feet, respectively.[339] Therefore, when wells are properly drilled and constructed, fracking fluid and the hydrocarbon bearing zones will often be sufficiently isolated from groundwater aquifers.

One reason for there being no communication between producing reservoirs and overlying aquifers is due to the exceptionally low permeability of shale in which the oil and gas are located. To wit, tight shale formations do not allow fluid to travel up through the shale, a principle governed by Darcy's law:[340]

> In the subsurface, rock is deposited in layers. Fluid flow within and between the rock layers is governed by the permeability of the rocks. However, to account for permeability, it must be measured in both the vertical and horizontal directions. For example, shale typically has permeabilities that are much lower vertically than horizontally (assuming flat lying shale beds). This means that it is difficult for fluid to flow up and down through a shale bed but much easier for it to flow from side to side.[341]

On a less technical level, most of the unconventional shales being fracked today are less permeable than granite and even "approach the permeability of steel pipe."[342]

Consequently, the gas and fracking fluids in most shale formations are not likely to travel upward and communicate with aquifers thousands of feet overhead. As the SEAB concluded: "Regulators and geophysical experts agree that the likelihood of properly injected fracturing fluid reaching drinking water through fractures is remote where there is a large depth separation between drinking water sources and the producing zone."[343]

To reiterate, shallow wells do deserve special treatment. But well-planned and properly executed well construction and frack jobs generally pose less risk to the environment than early media coverage intimated. But risks still exist in

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339 King, *supra* note 171, at 35.

340 *Fluid Flow in the Subsurface (Darcy's Law)*, FRACFOCUS.ORG, http://fracfocus.org/groundwater-protection/fluid-flow-subsurface-darcys-law (last visited Nov. 20, 2012), defines Darcy's law as:

> Darcy's law is the equation that defines the ability of a fluid to flow through a porous media such as rock. It relies on the principle that the amount of flow between two points is directly proportional to the difference in pressure between the points and the ability of the media through which it is flowing to impede the flow. . . . This factor of flow impedance is referred to as permeability. Put another way, Darcy's law is a simple proportional relationship between the instantaneous discharge rate through a porous medium and the pressure drop over a given distance.

341 *Id.*

342 *See* King, *supra* note 171, at 4.

343 SEC'Y OF ENERGY ADVISORY BD., *supra* note 16, at 19.

numerous pathways underground. Migration can occur: between the casing and well bore; from an injection zone through the confining strata; vertically through abandoned and inchoate wells; through faulty injection well casing; laterally from an injection zone into a protected area of the same stratum; directly into a drinking water source; and migration through faulty well casing.[344] Industry must acknowledge these risks exist, rather than remaining adamant that public fears about fracking are baseless.[345] These risks must also be addressed proactively by industry to earn the public's trust and support to operate in local communities. A progressive path for industry is put forth in the following section.

Thus, what most people perceive to be the environmental problems caused by fracking are more likely caused by the well drilling and completion processes. To reiterate, risks still exist, especially when the producing formation is shallow or in close proximity to an aquifer. Nonetheless, interested parties should commit themselves to understanding the anatomy and taxonomy of the complicated set of processes that comprise unconventional gas development. Until this happens, the disconnect between public perception and reality will persist, and a functional social discourse on the risks and benefits of unconventional gas development will be significantly impeded. As the Pacific Institute concluded, "[a]dditional work is needed to clarify terms and definitions associated with hydraulic fracturing to support more fruitful and informed dialog and develop appropriate energy, water, and environmental policy."[346]

But, surmounting the semantic and technocratic hurdles is only a first step. The second step falls to industry—to move beyond mere assurances that fracking is safe, and to confront head-on the growing unease about fracking and unconventional oil and gas development. Unless industry engages the public in a discussion of the risks associated with unconventional oil and gas development and commits itself to addressing those risks responsibly, the public will continue to be suspicious of fracking and will prove a willing audience for those who oppose all forms of oil and gas development. To avoid such an outcome, industry must proactively commit itself to use socially—and environmentally—protective best practices, and must communicate honestly with the public to gain a social license to operate.

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[344] U.S. EPA, *supra* note 225, at 14.

[345] *See* Kate Galbraith, *Seeking Disclosure on Fracking*, N.Y. TIMES, May 30, 2012, *available at* http://www.nytimes.com/2012/05/31/business/energy-environment/seeking-disclosure-on-fracking.html?_r=0.

[346] Cooley et al., *supra* note 318, at 5.

VI. Earning a Social License to Operate: Best Practices for Modern Unconventional Oil and Gas Development

As the International Energy Agency (IEA) has found, "[t]he environmental and social hazards related to [fracking] and other features of unconventional gas development have generated keen public anxiety in many places."[347] And, as outlined above, the public's apprehension is more than justified. While reports of fracking-related illnesses and environmental harms continue, industry appears, to the public, content to operate in a business-as-usual fashion.[348] Thus, current practices are not likely to inspire confidence in the industry's willingness to adopt socially and environmentally sustainable operating practices.[349] The following section examines how industry might proceed to earn the public's trust and gain a social license to operate in order to sustain unconventional oil and gas development in the long-term.

A. Addressing Impacts and Earning a Social License to Operate

1. Defining the Social License to Operate

A social license to operate in the United States is not a legal or physical license. Rather, it is an implied grant of ongoing approval by the public and other stakeholders.[350] Such a license allows a company to engage in a certain activity in relative harmony with the local community and other stakeholders.[351] The activities in this case are those involved in unconventional oil and gas development. A company earns the license by conforming to "jointly construct[ed] norms of legal compliance and standards for appropriate business conduct"[352] that are trusted and accepted by the public. A company that fails to acquire such a license may have the legal right to operate, but will likely face ongoing conflict and controversy due to practical, economic, or moral obstacles. A social license is also dynamic: its grant by the public is impermanent and can be lost when public opinion and perception change.

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[347] INT'L ENERGY AGENCY, *supra* note 118, at 17.

[348] *See, e.g.*, Edward Humes, *Fractured Lives: Detritus of Pennsylvania's Shale Gas Boom*, SIERRA MAGAZINE, July/Aug. 2012, *available at* http://www.sierraclub.org/sierra/201207/pennsylvania-fracking-shale-gas-199.aspx.

[349] *See, e.g.*, INT'L ENERGY AGENCY, *supra* note 118, at 9 ("Natural gas is poised to enter a golden age, but will do so only if a significant proportion of the world's vast resources of unconventional gas . . . can be developed profitably and in an environmentally acceptable manner.").

[350] *See What is the Social License?*, SOCIALLICENSE.COM, http://socialicense.com/definition.html (last visited Nov. 20, 2012).

[351] *See* Jennifer Howard-Grenville et al., *supra* note 4, at 73, 77 (A "license to operate" is a "label [that] has been widely used by companies, analysts, journalists, and scholars to refer to the idea that industrial [operations] must comply with tacit expectations of regulators, local communities, and the public in order to continue operations.").

[352] *See id.*

Currently, the public remains skeptical about and sometimes even hostile towards fracking. Indeed, the word "fracking" alone carries sufficient baggage to taint the perception of the public and affected communities regarding unconventional oil and gas operations. For the reasons discussed below, industry must overcome this problem.

2. Why Industry Should Want a Social License to Operate

Because a social license to operate is both implied and theoretical, it does not by itself dictate a company's course of action. Rather, numerous external and internal factors affect how a company conducts itself.[353] Whether unconventional gas development at a particular time and place is a "good thing," oil and gas developers nonetheless have an interest in ensuring that affected communities and other stakeholders are engaged in meaningful ways regarding how development will proceed. Otherwise, the future of unconventional gas development is in jeopardy.

The IEA recently addressed the question of whether public opinion about fracking could impede the future domestic and worldwide development of unconventional reservoirs. It acknowledged that unconventional oil and gas development can have major implications for local communities, including impacts to land use and water resources; and when "*[i]mproperly addressed, these concerns threaten to curb, if not halt, the development of unconventional resources*."[354] The IEA also noted that a critical link exists between the way governments and industry respond to social and environmental challenges associated with unconventional gas development and the continuation of unconventional oil and gas production.[355] The bottom line is this: unless industry effectively addresses the social and environmental concerns surrounding fracking and horizontal drilling, it will not have the social acceptance necessary to operate effectively—and profitably.

Increased public opposition does not necessarily mean that *all* development will cease, especially in the near-term. It does, however, raise questions about how it might affect oil and gas companies financially in the long run. Some investors, for example, are already concerned about local opposition and how consequential new regulations might pose operational risks.[356] One corporate

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[353] *See, e.g.*, *id.* at 77–85.

[354] *See* INT'L ENERGY AGENCY, *supra* note 118, at 9 (emphasis added).

[355] *Id.*

[356] *See, e.g.*, *Investors to Challenge ExxonMobil and Chevron to Disclose and Minimize Environmental & Community Impacts of Fracking,* GREEN CENTURY FUNDS, (May 23, 2012), http://www.greencentury.com/news/news/investors_challange_exxon_chevron_on_fracking.

> "Companies that engage in fracking are meeting significant opposition from affected communities," said Michael Passoff, Senior Strategist at As You Sow, a shareholder

responsibility advocacy group, As You Sow, has brought shareholder proposals to ExxonMobil, Chevron, Anadarko, Range Resources, and Ultra Petroleum to report on, *inter alia*, the short- and long-term risks to the company's operations, finances, and gas exploration associated with community concerns and public opposition to hydraulic fracturing and related natural gas development.[357] The recent 2012 shareholder request was voted on at annual shareholder meetings for ExxonMobil, Chevron, and Ultra Petroleum, where the resolution received thirty, twenty-seven, and thirty-five percent voting support, respectively.[358]

Other investment groups are also keen to see industry proactively seek a social license to operate, realizing it makes business sense to proactively operate in ways that are more environmentally sound and socially aware. Investors "are uniquely positioned to ensure that companies earn their social license to operate by requiring them to prove that they are taking rigorous measures to identify and reduce risks, and to systematically minimize negative impacts from their extraction procedures."[359] Investors led by Boston Common Asset Management, a group totaling fifty-five investment organizations with almost one trillion dollars in assets under their management, recently applauded IEA's "Golden Rules" as being substantially in line with their own core message "that companies need to fully engage communities to secure their social license to operate."[360] Another group, the Interfaith Center on Corporate Responsibility (ICCR), which released its own report, found that the IEA proposals championed its own ideal "that a critical element of such [community] engagement is responding to community concerns and reporting fully on operational practices."[361]

In addition to appeasing potential investors, companies can also build good will by engaging communities and committing themselves to be as socially and

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> advocacy group that filed the ExxonMobil resolution on behalf of the Park Foundation. "Bans, moratoriums, and increased regulatory scrutiny all impose a wide range of costs and risks which need to be disclosed to investors." * * * "In order to maintain their social license to operate, all companies—ExxonMobil and Chevron in particular—must fully disclose the steps they are taking to minimize risks, to acknowledge their challenges and failures, and clearly adopt best management practices throughout the life cycle of gas development," added Sister Nora Nash of the Sisters of St. Francis of Philadelphia, the co-lead filer of the proposal at Chevron.

Id.

[357] *See Hydraulic Fracturing (Fracking)*, AS YOU SOW, http://www.asyousow.org/health_safety/Frack.shtml (last visited Nov. 20, 2012).

[358] *See id.*

[359] *Building Accountability in the Energy Sector: Natural Gas and Hydraulic Fracturing*, BOS. COMMON ASSET MGMT., http://www.bostoncommonasset.com/news/natural-gas-and-hyrdrolic-fracturing.php (last visited Nov. 20, 2012).

[360] *Groups: IEA "Golden Rules" for Fracking Track Closely With Steps Already Called for by Investors*, INTERFAITH CENTER ON CORP. RESP., (May 29, 2012), http://www.iccr.org/news/press_releases/2012/pr_frack053012.php.

[361] *Id.*

environmentally responsible as possible. The hopeful consequence of engaging communities and employing the best practices possible is reaching a mutually beneficial result: social and environmental impacts will be mitigated, and operating companies will be able to thrive on the good will and social acceptance they have earned through their actions.

3. The Need for the Complete and Accurate Disclosure of Relevant Information

A major area of public concern is the lack of adequate information. Without it, the public lacks a sufficient basis for evaluating fracking and horizontal drilling operations,[362] and is left with only its intuition and the information put forth by third parties. Not surprisingly, this has resulted in a wide range of public perceptions about fracking. The SEAB subcommittee even commented that it was "struck by the enormous difference in perception about the consequences of shale gas activities."[363] Unsurprisingly, the first recommendation in SEAB's first 90-Day Report was to improve public information about shale gas operations.[364] SEAB neatly summed up its assessment of why information was so important for continued shale gas development:

> Opponents point to failures and accidents and other environmental impacts, but these incidents are typically unrelated to hydraulic fracturing *per se* and sometimes lack supporting data about the relationship of shale gas development to incidence and consequences. An industry response that hydraulic fracturing has been performed safely for decades rather than engaging the range of issues concerning the public will not succeed.[365]

The IEA took an all-important step in furtherance of SEAB's recommendation by acknowledging that unconventional gas development is not socially and environmentally benign. As SEAB highlighted, industry must move past blanket claims that fracking is safe, and discuss the actual, inherent risks of unconventional development.[366] And while this article does not assert that any particular fracking and horizontal drilling operations can be done "safely," it emphasizes a need for the frank discussion of the risks associated with those processes and that the best practices for managing those risks are mutually beneficial exercises.

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[362] *See* Hannah Wiseman, *Trade Secrets, Disclosure, and Dissent in a Fracturing Energy Revolution*, 111 COLUM. L. REV. SIDEBAR 1, 5–8, 13 (2011) ("As thousands of new gas wells are drilled and fractured each year, citizens need effective means of participating in the policy dialogue and contributing to new regulations of fracing, where needed. Without better information, this effort will be futile.").

[363] SEC'Y OF ENERGY ADVISORY BD., *supra* note 16, at 13.

[364] *See id.* at 1.

[365] *Id.* at 13 (footnote omitted).

[366] *See id.* at 13.

The grant of a social license requires public awareness of *what* it is granting. Although this might sound simplistic, it is essential that regulators, the public, and industry share a common understanding of the true risks associated with large-scale unconventional gas development. If, as many industry experts believe, the risks associated with fracking and horizontal drilling have been misunderstood and contorted,[367] it would behoove all parties to have an honest conversation about what we know, and what we do not know. "[C]redible, science-based background information . . . can underpin an informed debate and provide the necessary stimulus for joint endeavor between the stakeholders."[368] What is essential here, though, is that all sides engage in a discussion based on the facts.

Ideally the stakeholders would start anew, agreeing on the scope of the issues to be addressed and on the meaning of key terms like fracking. Arriving at such consensuses would help to avoid communication problems resulting in different perceptions[369] before key facts are known. Ultimately, society must be "adequately convinced that the environmental and social risks will be well enough managed to warrant consent to unconventional gas production, in the interests of the broader economic, social and environmental benefits that the development of unconventional resources can bring."[370] Such convincing requires the discussion to be based on the collection and analysis of the best information available. Even though parties now lack certain data,[371] it is essential for all stakeholders, including the media and industry, to avoid vitriol and wholesale denials. The converse would serve to perpetuate the current standoff between the opponents and supporters of unconventional gas development who too often present only their side of the story.

Though the measurement and disclosure of impacts are indeed indispensable first steps in a proper social discourse, industry proactively engaging in a stakeholder-based approach is also necessary for the retention of a social license to operate. It makes good business sense, as well. The IEA has recently established a set of "Golden Rules" for gas development that, if applied, could likely "bring a level of environmental performance and public acceptance that [could] maintain or earn the industry a 'social license to operate' within a given jurisdiction."[372] As the IEA and API argue, "full transparency, measuring and monitoring of environmental impacts and engagement with local communities are critical

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[367] *See supra* note 209 and accompanying text.

[368] INT'L ENERGY AGENCY, *supra* note 118, at 43.

[369] *See* SEC'Y OF ENERGY ADVISORY BD., *supra* note 16, at 13.

[370] INT'L ENERGY AGENCY, *supra* note 118, at 42.

[371] *Cf.* Wiseman, *supra* note 57, at 140 ("The rapid expansion of fracing has not allowed researchers to keep up, and the effects of fracing vary widely by region, making a comprehensive and thorough study difficult.").

[372] INT'L ENERGY AGENCY, *supra* note 118, at 10.

to addressing public concerns,"[373] and needed to demonstrate that industry is "committed to protecting [its] employees, the environment, and the communities where [it] operate[s]."[374]

When these public concerns are addressed, everyone benefits. If industry were to continue to neglect community concerns and refuse to engage stakeholders in a proper discourse through informed-consent-type procedures, an even more widespread backlash to oil and gas development could ensue.

B. Best Management Practices

Company actions often reveal where their priorities lie. In the case of unconventional oil and gas development, many operators and service providers have failed to show communities they are committed to protecting the public health and welfare, as well as the environment. While industry certainly espouses a "commitment to environmentally safe practices," they must *show* how they are committed to those practices. As IEA remarked, "[c]ompanies have to convince society that they have both the interest and the incentive to constantly seek ways of improving their performance."[375] One way to do this is by utilizing current best management practices, but also by continuing to reassess options and proactively employ new, more environmentally sound methods. "[O]perators need to go beyond minimally satisfying legal requirements in demonstrating their commitment to local development and environmental protection."[376] After all, "the ultimate responsibility for sustaining public confidence rests with the industry."[377]

1. Air Impacts

Although water quality received the lion's share of attention when the media first latched onto the story of fracking and its environmental impacts, it has become clear that air impacts from unconventional gas operations are quite problematic. The processes of greatest concern are well completions,[378] emissions from operational equipment, and leaks from processing equipment.[379] Most

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[373] *Id.*

[374] Reid Porter, *API Welcomes IEA's Natural Gas Report*, AM. PETROLEUM INST. (June 1, 2012), http://www.api.org/news-and-media/news/newsitems/2012/jun-2012/api-welcomes-iea-natural-gas-report.aspx.

[375] INT'L ENERGY AGENCY, *supra* note 118, at 53.

[376] *Id.* at 43.

[377] *Id.* at 49.

[378] *See supra* notes 202–09 and accompanying text.

[379] *See, e.g.*, Proposed NSPS, 76 Fed. Reg. at 52756.

of these areas now fall under the newly promulgated New Source Performance Standards (NSPS) for the oil and gas sector.[380] Some of the best practices EPA has recognized in its NSPS regulations include RECs[381] and replacing seals on processing equipment to reduce leaks.[382] The implementation of RECs alone has the potential to capture billions of cubic feet of methane every year.[383] If industry needs another reason to employ RECs, data and estimates show that RECs may actually yield net economic benefits for operators, even when natural gas is priced at $3/Mcf.[384] If nothing else, capturing substantial amounts of GHGs at the wellhead-level can earn operating companies increased good will with regulators, the public, especially in places like Pinedale and the Uintah Basin, as well as with environmental advocates.

Another step to further reduce the air impacts of operations includes switching vehicles and turbines to alternative fuels, such as natural gas. Some companies have already committed to the use of their own product in well site and fleet engines.[385] In addition to reduced air emissions, the use of compressed natural gas (CNG) and hybrid vehicles could also reduce the noise caused by running traditional combustion engines,[386] which can be a true nuisance to nearby residents.

Further, companies can address fugitive emissions by monitoring and identifying leaks within a system, and subsequently sealing them.[387] EPA estimates that leaks result in VOC emissions of 2.6 tpy, 9.8 tpy, and 2.7 tpy from wellhead production sites, gather/boosting facilities, and transmission/storage facilities, respectively.[388] Other emission-reducing practices include

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[380] *See* National Emission Standards for Hazardous Air Pollutants for Source Categories, 40 C.F.R. pt. 63 (2012).

[381] As discussed above, RECs involve "separating the flowback water, sand, hydrocarbon condensate and natural gas to reduce the portion of natural gas and VOC vented to the atmosphere, while maximizing recovery of salable natural gas and VOC condensate." Proposed NSPS, 76 Fed. Reg. at 52757

[382] *See, e.g.*, *id.* at 52761–52762.

[383] *See* U.S. EPA, *supra* note 208, at 2 (noting that twenty-seven billion cubic feet of methane is emitted in the United States, even when venting and flaring are employed for completions and workovers).

[384] *See* U.S. EPA, LESSONS LEARNED FROM NATURAL GAS STAR PARTNERS: REDUCED EMISSIONS COMPLETIONS FOR HYDRAULICALLY FRACTURED NATURAL GAS WELLS 1 (2011), *available at* http://www.epa.gov/gasstar/documents/reduced_emissions_completions.pdf.

[385] *See, e.g.*, *Climate Change*, NOBLE ENERGY, http://www.nobleenergyinc.com/stewardship/eh-and-s/environmental/climate-change-186.html (last visited Nov. 21, 2012).

[386] *See* INT'L ENERGY AGENCY, *supra* note 118, at 46 ("Operators and service providers should consider the advantages of deploying the cleanest vehicles and equipment available, for example, electric vehicles and gas-powered rig engines, to reduce both local air and noise pollution.").

[387] *See Minimizing Air Pollution*, EARTHWORKS, http://www.earthworksaction.org/issues/detail/air_pollution (last visited Nov. 21, 2012).

[388] *See* Proposed NSPS, 76 Fed. Reg. at.52765.

installing no-bleed pneumatic devices, vapor recovery units, replacing control valves, and using combustion units to destroy noxious vapors from condensate tanks and glycol dehydrators.[389] For example, replacing wet seals with dry seal systems in centrifugal compressors could reduce VOC emissions by 21.1 tpy from production through storage.[390] Storage vessel emissions[391] can also be reduced by installing vapor recovery units (VRUs) or flare control devices, both of which can achieve 95% reductions of VOCs from such vessels.[392] At the production stage, using non-gas-driver controller systems could eliminate virtually all VOC emissions from that stage.[393]

The topographic placement of processing equipment is also a factor to consider. The noxious odors from some operations can be extreme nuisances for nearby residents even if non-toxic.[394] Being told public health is not in jeopardy despite the foul odors by an official of the oil and gas company does not detract from the nuisance, nor would it eliminate the basis for a civil nuisance claim. Placing stations and equipment where they will not impact residents is one important way to remove this rather large irritation. For example, if the gases released by tanks and dehydrators will settle in low-lying areas, they should not be placed directly above a community. Even if there will be some unpleasant and impossible-to-eliminate odors, efforts should still be made to reduce their effects on local residents.

2. Water Impacts

Although the air impacts of unconventional gas development are of great concern, contaminated drinking water from fracking and drilling operations remains a potent public fear. This is also a fear industry must address in pursuit of a social license. Several steps can be taken to reduce the impacts to water resources from oil and gas development. First, developers must be smart about where and how drilling takes place.[395] For example, in Pavillion, Wyoming, where a draft EPA report found evidence of groundwater contamination linked to fracking activities, the underlying producing formation was very shallow. There,

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389 *See* EARTHWORKS, *supra* note 387.

390 *See* Proposed NSPS, 76 Fed. Reg. at.52761–52763.

391 Storage vessel emissions result from working, breathing, and flash losses. *See id.* at 52763. Condensate tanks emit, on average, 33.3 lb VOC per barrel of condensate throughput. *Id.* at 52764.

392 *See id.* at 52763.

393 *See id.* at 52760. According to EPA, when considering the savings of salable natural gas that would have otherwise be emitted, installing new low-bleed controllers at processing plants would result in a net savings of $1,519 per ton of VOC reduced. *Id.* The VOC reduction from these systems is only sixty-six percent. *Id.* EPA concluded that the non-gas-driven controller systems would cost more, but be reasonable at $1,824 per ton of VOC reduced. *Id.*

394 *See* Kaden, *supra* note 313.

395 *See* INT'L ENERGY AGENCY, *supra* note 118, at 44.

"[h]ydraulic fracturing . . . occurred as shallow as 372 meters below ground surface with associated surface casing as shallow as 110 meters below ground surface. Domestic and stock wells in the area [were] screened as deep as 244 meters below ground surface."[396] Thus, the proximity of the fractures to the water table suggested Pavillion was a risky place to conduct hydraulic fracturing. Pavillion may, however, be a unique example of hydrology and geology.[397] But, like Pavillion, other older CBM plays[398] have revealed a common trend of, at worst, aquifer contamination, and at best, numerous complaints from justifiably concerned citizens.[399]

Second, additional precautions should be taken when drilling in previously developed areas. The increased risks for contamination from orphan wells and existing fissures are significantly higher in previously drilled areas. For instance, in places like the Denver-Julesburg Basin where there has previously been vertical oil and gas development,[400] new horizontal operations could allow for new communication between the deeper horizontal producing formations and pre-existing well bores. In turn, this could lead to the contamination of overlying aquifers via existing holes and fractures. Additional logging and testing (e.g., pressure, acoustic, temperature, and hydraulic testing) can help guard against such unintended contaminations.

A third step is ensuring well integrity by following the industry's best practices for well construction. These practices include running casing and cementing the borehole to ensure there can be no communication between the well and any freshwater aquifer.[401] The best way to do this is by installing surface casing below the deepest freshwater aquifer,[402] as well as by entirely cementing the surface casing to further isolate aquifers from production hydrocarbons and fracking fluids.[403] Part of ensuring well integrity extends beyond mere design and construction to

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[396] U.S. EPA, *supra* note 222, at xi.

[397] *See Why EnCana Refutes U.S. EPA Pavillion Groundwater Report*, ENCANA, http://www.encana.com/news-stories/news-releases/details.html?release=632327 (last visited Nov. 21, 2012).

[398] EnCana drilled its Pavillion, Wyoming wells from 2004 to 2007. *See id.*

[399] *See* Wiseman, *supra* note 57, at 127–33, (citing a 2004 EPA report finding that: "'In many coalbed methane-producing regions, the target coalbeds occur within [underground sources of drinking water], and the fracturing process injects stimulation fluids directly into' the underground drinking water source.").

[400] For a list of Colorado's orphan wells, see COLO. OIL AND GAS CONSERVATION COMM., 2012 COLORADO CURRENT ORPHAN WELL LIST, (2012), *available at* http://cogcc.state.co.us/Library/OrphanWells2012.pdf.

[401] *See supra* notes 130–40 and accompanying text.

[402] *See* AM. PETROLEUM INST., *supra* note 120, at 11; Kurth et al., *supra* note 5, at 3A-4 to 3A-5.

[403] Kurth et al., *supra* note 5, 3A-6.

conducting tests (similar to those mentioned above) to determine if there are any voids in the cement, any communication with overlying aquifers, and whether the well can withstand the pressures of the fracking process.[404]

A fourth step involves avoiding surface contaminations by properly storing, recycling, and treating flowback and produced water. While some surface incidents leading to contamination are unavoidable "accidents," best practices reduce the risks of such aboveground contamination. One available practice is called "pitless" or closed-loop drilling.[405] "Pitless drilling systems are equipped with a 'chemically-enhanced' centrifuge that separates drilling mud liquids from solids," resulting in the reduction of drilling costs and can even reduce the amount of water used and waste created by upwards of seventy percent.[406] "The separated drilling mud solids are stored in a steel tank and then transferred to a synthetically-lined clay pad for drying . . . . The pads are designed to prevent the runoff of any liquids."[407] The result is a lessened chance that drilling wastes will seep out and contaminate the soil, aquifers, or threaten wildlife.[408] Everything from birds to big game animals are susceptible to being harmed or killed by pits, which they often mistake for bodies of water.[409] Pitless operations have other added benefits, as well. They can reduce airborne odors that can be noxious and even harmful; they require less upkeep than pits; and unlike most pits, they can be reused and transferred to new well sites.[410]

The amount of fresh water needed in fracturing operations is also a primary concern,[411] especially for operations in western states. While technological

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[404] *See supra* notes 147–52 and accompanying text.

[405] Many companies already use closed-loop systems for certain drilling operations, such as Shell, El Paso, Chevron-Texaco, and Exxon. *See Alternatives to Pits*, EARTHWORKS, http://www.earthworksaction.org/issues/detail/alternatives_to_pits#CLOSEDLOOP (last visited Nov. 21, 2012).

[406] U.S. FISH & WILDLIFE SERVICE, RESERVE PIT MANAGEMENT: RISKS TO MIGRATORY BIRDS 6 (2009), *available at* http://www.fws.gov/mountain-prairie/contaminants/documents/ReservePits.pdf.

[407] *Id.*

[408] Even if pits are used, best practices can reduce their environmental impacts. Pits should be lined with multiple layers to prevent groundwater contamination; there should be a leak detection system employed; fences should be constructed to prevent game from entering the pit; and nets should be erected to stop birds. Importantly, though, effects to wildlife from unconventional oil and gas development still exist. For example, even with the use of pits, stream health can be affected by the withdrawal of water for fracking; and equipment used to withdraw such water can introduce invasive species and disease spores to surface sources, as well. *See* Wiseman, *supra* note 242, at 366; *Nuts and Bolts of Marcellus Shale Drilling and Hydraulic Fracturing*, *supra* note 45, at 10591 (discussing the "great degree of earth disturbance activities" required for well site preparation and sedimentation being "one of the leading causes of stream impairment in Pennsylvania").

[409] *See* U.S. FISH & WILDLIFE SERVICE, *supra* note 406, at 9.

[410] *See* EARTHWORKS, *supra* note 405.

[411] *See* Sakmar, *supra* note 6, at 402 ("Concerns have also been raised pertaining to the large volumes of water needed during the hydraulic fracturing process, and the disposal of the flowback or wastewater from fracturing operations.").

advances now allow returned water to be recycled up to ninety-five percent,[412] massive quantities of water still remain underground after fracking operations. Finding new ways to conserve and reduce the overall amount of water needed for fracking is critical if large-scale unconventional gas development is to continue in western states.

While entertaining suspicions about the causal link between fracking and groundwater contamination is certainly the public's prerogative, and is likely to continue even after best practices are adopted, these practices remain necessary steps in acquiring a social license to operate. Not only does attempting to address both water quantity and quality concerns aid in the public's acceptance of oil and gas operations, but it also works to reduce the health and environmental risks inherent in such operations.

3. Land Use Impacts

While there are land use benefits that fracking and horizontal drilling have compared to conventional development methods, there are ways to further reduce the extent to which unconventional oil and gas development impacts the land. Some of these methods have been discussed above, such as using pitless drilling, which reduces the impacts of drilling to wildlife and eliminates the need to construct a pit covering more than a half-acre.[413] Other means to reduce land use impacts include consolidating operations, for example, by centralizing staging, storage, and production operations.[414] By creating centralized locations for production materials and products, the amount of truck traffic can be reduced, as can the number of storage tanks at individual well sites and the construction of new roads.[415] Since most new drilling occurs in relatively rural areas, new roads must often be built to accommodate the truck traffic.[416] Reducing traffic is advantageous on multiple fronts: it will benefit not only the communities through which trucks would run less often, but will also benefit nearby wildlife by reducing habitat fragmentation that causes indirect animal deaths, road-kill, and air emissions.[417]

Comprehensive planning to minimize surface infrastructure needs can further reduce surface impacts. Examples of this planning are shared surface lines to move both water and completion fluids and the use of pipelines to transport

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[412] *See Intermountain Oil and Gas BMP Project: Hydraulic Fracturing*, NAT. RES. LAW CENTER, http://www.oilandgasbmps.org/resources/fracing.php (last visited Nov. 21, 2012).

[413] *See* U.S. FISH & WILDLIFE SERVICE, *supra* note 406, at 2.

[414] *See* NAT. RES. LAW CENTER, *supra* note 117.

[415] *See id.*

[416] *See* Cooley et al., *supra* note 318, at 26.

[417] NAT. RES. LAW CENTER, *supra* note 117.

water to centralized impoundments instead of trucks.[418] While pipelines can create other risks, such as leaks, their use could nevertheless reduce truck traffic by thirty percent.[419] Anadarko has undertaken such a program, the Anadarko Completion Transport System (ACTS). ACTS is designed to reduce surface impacts and improve the efficiency of their operations[420] by refurbishing existing pads and pits, as well as using temporary surface lines to transport completion and flowback fluids from one staging site to another.[421] Through increased planning and the use of lines instead of trucks, programs similar to ACTS can reduce the number of trucks needed and require less construction of new roads or right-of-ways.[422] While schemes like ACTS are beneficial practices by themselves, inter-company cooperation would amplify the benefits of these programs. If different operators and service providers worked together to utilize a similar infrastructure, it could further reduce the need to build new roads, utilize more vehicles, and build completion tanks on-site. It could even result in lower operational costs to participating companies.

4. Nuisances

There can be no doubt that those living in close proximity to unconventional gas development experience the impacts of such development[423] in a unique and personal way. While we may all be affected by the release of methane from well completion activities, we do not all experience day-to-day operational impacts from development activities. A common complaint of many who live next to development is the truck traffic driving through towns *continuously* at all hours of the day. For high-pressure horizontal drilling operations, roughly 3,950 truck trips are required per well during early development stages.[424] If there are multiple wells in the area, as is often the case, the amount of truck traffic is further compounded. And even before drilling begins, quiet rural communities could be rudely greeted by several seismic "thumpers" striking the ground to determine the production potential of a certain area.[425]

Other nuisances of oil and gas development, acute to those in close proximity to operations, are the noxious smell of chemicals, gases or produced liquids,

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418 *See* N.Y. DEP'T OF ENVTL. CONSERVATION, *supra* note 173, at 6-139; JEFF DUFRESNE, ANADARKO PETROLEUM CORP., ACTS: ANADARKO COMPLETION TRANSPORT SYSTEM, *available at* http://www.oilandgasbmps.org/workshops/vernal2010/ppt/Jeff_Dufresne_Anadarko_ACTS.pdf.

419 *See* Cooley et al., *supra* note 318, at 25.

420 *See* DUFRESNE, *supra* note 418, at 17.

421 *See id.* at 12.

422 *See id.* at 15.

423 *See* Wiseman, *supra* note 57, at 127 ("Fracing near human populations, whether urban or rural, will inevitably generate conflicts.").

424 Cooley et al., *supra* note 318, at 25.

425 *See* Wiseman, *supra* note 57, at 127.

as well as the lights and noise of drill rigs operating twenty-four hours a day. Operators and service providers must be cognizant of these impacts, and must engage in efforts to reduce the amount of dust, traffic, noise, waste, odor, and road-constructing activities. In doing so, they will significantly reduce the strain that unconventional gas development places on nearby communities. Efforts should also be made to heed local concerns about the timing of truck traffic.[426] Even if truck traffic cannot be entirely abrogated, it might be possible to reduce it in late hours of the evening. Companies should also be cognizant that even when drilling and fracking operations end, the impacts on roads from thousands of high-tonnage trucks will linger. These impacts should be mitigated to the extent possible and, at a minimum, must be quickly repaired.

A necessary step in addressing these and other nuisances that development operations create is community engagement. For example, while there might not be a panacea for all nuisances, such as noise and light pollution that are inevitable byproducts of oil and gas development, coordinating the timing of operational activities with affected peoples can at least serve as a mitigating best practice. Not only can community involvement help prepare nearby residents for the impacts and risks that unconventional development entails, community collaboration can be a useful tool for companies to help reduce risks and impacts. The earlier in the planning process citizens are engaged, the more impact they might have on how oil and gas operations are conducted around them.[427] And community involvement is not only a best practice, it is simply good for business. As one company, EnCana, has recognized regarding stakeholder and community engagement: "It offers those representing [the company] (employees, contractors and service providers) a benchmark for courteous and respectful behaviour."[428]

5. Monitoring and Disclosure

While it does not guarantee it, information is critical in earning the public's trust of unconventional oil and gas development. A prominent example of how a want of information breeds fear and skepticism is the lack of transparency regarding fracking fluid chemicals. As federal regulators are generally sluggish to install new regulatory regimes,[429] companies can better earn the trust of the

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426 *See* INT'L ENERGY AGENCY, *supra* note 118, at 43.

427 *Cf.* W. MICHELE SIMMONS, PARTICIPATION AND POWER: CIVIC DISCOURSE IN ENVIRONMENTAL POLICY DECISIONS 99–100 (2007) ("In order for citizens to contribute significantly to environmental policy decisions, they must be brought into the decision-making process early enough to contribute to the *design* of the policy, and their input must be viewed as valuable knowledge capable of *constructing* risk through discourse with technical experts.").

428 *Courtesy Matters*, ENCANA, http://www.encana.com/communities/courtesy-matters/ (last visited Nov. 21, 2012) ("Courtesy Matters is an important part of our overall approach to stakeholder engagement.").

429 *See generally* Kurth et al., *supra* note 5.

public if they voluntarily disclose all of the chemicals and compounds being used in fracking fluids. As the IEA noted, the "[r]eluctance to disclose the chemicals used in the hydraulic fracturing process and the volumes involved, though understandable in terms of commercial competition, can quickly breed mistrust among local citizens."[430]

Given the volume of fluids injected into the ground to fracture producing formations, citizens have a right to know what chemicals, and in what concentrations, are being used. Moreover, if the claims that fracking is completely safe, with no aquifer contamination whatsoever, there is even less of a reason for operating and service companies to maintain the confidentiality of the chemicals being used.

Several states have taken the regulatory lead regarding chemical disclosure—some only in recent months—and have helped to alleviate some concerns about the composition of fracking fluids.[431] Many members of industry supported these state-led moves toward mandatory disclosure in lieu of EPA regulation.[432] States that now have some form of required disclosure law (excepting trade secrets, save for disclosure to regulators and medical emergencies in some cases) include: Arkansas,[433] Colorado,[434] Montana,[435] Wyoming,[436] Idaho, North Dakota,[437] New York,[438] Texas,[439] and West Virginia.[440] Some states, however, like North Dakota and Utah, only require a "post-treatment report detailing chemicals and pressures used,"[441] which is preferable to no reporting at all, but less desirable than a pre-treatment reporting scheme. Following on the heels of these states, the Bureau of Land Management (BLM) has also proposed regulations that would require public disclosure of fracking chemicals before and after fracking operations

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430 INT'L ENERGY AGENCY, *supra* note 118, at 43.

431 For a thorough overview of state regulatory responses to fracking, see generally Kurth et al., *supra* note 5.

432 *See* Galbraith, *supra* note 345.

433 *See* ARK. OIL AND GAS COMM., GENERAL RULES AND REGULATIONS B-19(l)(3) (2012), *available at* http://www.aogc.state.ar.us/onlinedata/forms/rules%20and%20regulations.pdf.

434 Colorado would be the first State to require disclosure of names and concentrations of individual chemicals pumped into wells. *See* Lisa Song, *Secrecy Loophole Could Still Weaken BLM's Tougher Fracking Regs*, INSIDECLIMATE NEWS (Feb. 15, 2012), http://insideclimatenews.org/news/20120215/blm-fracking-chemicals-disclosure-hydraulic-fracturing-proprietary-natural-gas-drilling.

435 *See* MONT. ADMIN. R. §§ 36.22.608, 1015, 1016, 1106 (2011), *available at* http://bogc.dnrc.mt.gov/PDF/FinalFracRules.pdf.

436 *See* WOGCC RULES AND REGULATIONS, Ch. 3 § 45(d) (2010).

437 *See* Cohen et al., *supra* note 152, at 3C-55 to 56.

438 *See* Kurth et al., *supra* note 5, at 3A-47.

439 *See* H.B. 3328, 2011 Leg., 82nd Reg.Sess. (Tex. 2011) *available at* http://www.capitol.state.tx.us/tlodocs/82R/billtext/pdf/HB03328F.pdf

440 *See* W. VA. CODE R. § 47-13-13.6b (2002).

441 Cohen et al., *supra* note 152, at 3C-55 to 56.

on public lands.[442] If promulgated, BLM and Colorado would have the most stringent disclosure requirements.[443]

And even though there may be legitimate trade secret[444] rationales for not disclosing fracking fluid constituents, companies gain no public good will or trust by invoking "trade secrecy" as a pro forma excuse for keeping their affairs shielded from the view of the public. Databases like FracFocus.org already provide the venues for companies to inform the public, government regulators, legislators, and emergency personnel of what chemicals are injected and in what concentrations.[445] Public disclosure and transparency is not only a best practice, but is a critical step in obtaining a social license to operate and earning the public's trust.[446]

Disclosure extends beyond fracking fluid composition, as well. A key problem in identifying the true risks associated with fracking and horizontal drilling is that the public simply lacks enough *good* information. As the Pacific Institute concluded in a recent report, "we find that the lack of credible and comprehensive data and information is a major impediment to a robust analysis of the real concerns associated with hydraulic fracturing."[447] The more information companies gather and report to a public database, the more the public, regulators, decision makers, and the operators themselves will be able to ensure serious environmental degradation is not taking place and health standards are being met. For example, researchers from Duke University found aquifers overlying the Marcellus and Utica shales had higher concentrations of methane when located near fracking operations than aquifers in non-production areas.[448] The study further found the methane observed in examined active drilling areas was thermogenic, which is consistent with methane that is created naturally deep within the shale formation.[449] However, because no baseline data of the aquifers pre-drilling was available, an irrefutable connection between drilling and aquifer

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[442] *See* Mike Soraghan, *BLM Proposes More Fracking Disclosure than Most States*, ENVIRONMENT AND ENERGY DAILY (Feb. 9, 2012), http://rlch.org/news/blm-proposes-more-fracking-disclosure-most-states.

[443] *See* Song, *supra* note 434.

[444] *See* Wiseman, *supra* note 362, at 4–8.

[445] *See* Kurth et al., *supra* note 5, at 3A-92.

[446] *Cf.* Wiseman, *supra* note 362, at 8 ("Communities have often welcomed the fracing development as mineral leases . . . . But at the same time, growing concerns have led citizens to demand more information and expanded means to influence energy development. First and foremost, they are concerned about the quality of their water.").

[447] Cooley et al., *supra* note 318, at 6.

[448] *See* Stehpen G. Osborn et al., *Methane Contamination of Drinking Water Accompanying Gas-Well Drilling and Hydraulic Fracturing*, 108 PROCEEDINGS OF THE NAT'L ACAD. OF SCI. 20, 8172 (2011), *available at* http://www.nicholas.duke.edu/cgc/pnas2011.pdf.

[449] *See id.* at 8174.

contamination could not be made.[450] If better baseline information were available, it would allow the public to accurately assess whether the fear of methane releases into underground aquifers is justifiable, or is based on mere conjecture.

While industry has clear incentives to keep specifics of their operations secret for reasons of competition and to avoid litigation, until industry becomes more transparent, it "hinders a comprehensive analysis of the potential environmental and public health risks and strategies to minimize [those] risks."[451] Therefore, companies should engage in pre-drilling sampling of soil, water, and air around the intended well site, and publish their findings on a public database. Doing so would allow operators and service providers to continually monitor conditions and identify potential areas of concern by comparing new data to baseline samples. It would also provide points of reference for regulators and third party researchers. These third parties could then conduct their own monitoring and data analyses and compare their findings with operator-published results. Corroboration by non-industry actors would also help address the inherent risks associated with self-reporting, such as inaccuracy and misrepresentation.

If fracking is indeed as benign as it is claimed to be by industry and recent studies, the more publicly accessible data that is available to researchers, the more the public's skepticism will be assuaged. Increased monitoring and disclosure would also provide a heightened level of transparency to a traditionally furtive energy sector and would yield a new sense of accountability, as well as social and environmental responsibility. Furthermore, without increased monitoring and disclosure, less light would be shown on the implementation of best management practices. Placing best practices in full view of the public is the best avenue towards obtaining a social license to operate, as it would demonstrate industry's commitment to improving its practices and ensuring the health and welfare of the public and the environment.

But perhaps further still, increased transparency from all sides would help guarantee that regulations put in place by legislators and regulators are enforced.[452] What this means is that violations must be taken note of, not only by regulators, but also by the public, and that appropriate actions are taken to prevent future violations.[453] As Professor Wiseman points out, "[r]egulations that appear strong as written may have little effect as enforced while seemingly inconsequential regulations may meaningfully influence development if broadly interpreted

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[450] *See* NAT. RES. LAW CENTER, *supra* note 417.

[451] Cooley et al., *supra* note 318, at 6.

[452] *See* Wiseman, *supra* note 242, at 383.

[453] *See generally id.*

and frequently enforced by states."[454] And only through better information can the public monitor regulators to verify that they are regulating adequately and appropriately.[455]

VII. Conclusion

The term fracking is often used as convenient shorthand to describe a battery of complex oil and gas development activities carried out by a number of parties. When used in this broad sense it is most often intended to connote the harmful effects of oil and gas development. This use of the word fracking, when considered alongside the industry's historic penchant for secrecy and evidence of real-life adverse impacts from unconventional oil and gas development, has created a true disconnect between industry and affected communities, resulting in a failure to serve the interests or objectives of any stakeholder. Unless and until this disconnect is bridged, oil and gas developers will not be able to earn the social license necessary for accepted and economical operations. And regardless of whether one favors oil and gas development, the impacts from development will necessarily be minimized if industry proactively engages communities in a meaningful way prior to, during, and after drilling, and adopts best management practices. On the other hand, if industry adheres to its historic practices of failing to fully and meaningfully engage the public and proactively adopt best practices for all activities harmful to the environment and local communities, then, quite possibly, it will see its opportunities to develop oil and gas resources dwindle. This fairy tale can have a happy ending, but only if industry is willing to forge a compact with the interested public, ensuring protection of the environment and the health of affected communities.

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[454] *Id.* at 369.

[455] *See* Wiseman, *supra* note 362, at 10 ("In addition to improving the quality of citizen participation in fracing policy, better information . . . could allow the public to monitor agencies, ensuring that they are adequately regulating the practice.").