Hydraulic Fracturing

Guidebook on the Current and Future Environmental, Regulatory, and Legal Challenges

Prepared by The Horinko Group

Fall 2012

The Horinko Group
2300 N ST NW, Suite 2130
Washington, DC 20037

Tel: 202.955.6202
Fax: 202.955.6207

info@thehorinkogroup.org
www.thehorinkogroup.org

Table of Contents

Introduction

Over the past decade, natural gas has emerged as a key component of the United States' energy supply. The availability and increase in supply has been attributed to non-traditional reserves unlocked by the technologies of hydraulic fracturing and horizontal drilling. The Energy Information Administration's (EIA) Annual Energy Outlook of 2012 projects an increase in domestic natural gas production by about 30%, from 21.6 trillion cubic feet in 2010 to 27.9 trillion cubic feet in 2035. Given this increase, the U.S. is expected to be a net exporter of natural gas by 2035.[1] The rapid escalation in unconventional gas development has been hailed as beneficial for economic growth, job creation, reduced reliance on foreign fossil fuels, and reducing U.S. greenhouse gas emissions. The natural gas industry, however, has faced much criticism for perceived environmental and social impacts. This perception has been exacerbated by the fact that regulation, permitting, and enforcement mechanisms have not been able to keep pace with the growth of this industry. There is a pressing need for a regulatory framework that both mitigates the impacts of extraction and enables the continued growth of the industry and the benefits associated with that growth.

Key Terms

Conventional gas is found in a pocket beneath a rock layer and is relatively easy and inexpensive to extract. **Unconventional gas**, on the other hand, is gas trapped in rock with low permeability, making it more difficult and costly to remove. The extraction of the three varieties of unconventional gas reserves—**coalbed methane**, **tight gas** and **shale gas**—only became economically feasible once hydraulic fracturing and directional drilling, together referred to as **unconventional drilling**, were introduced. These methods have unlocked vast amounts of natural gas reserves, of which shale gas makes up the largest percentage. **Directional** or **horizontal drilling** enables wells to be extended vertically for a distance below the surface, then horizontally through the gas-containing rock formation, thereby increasing exposure to the target formation.[2] Horizontal drilling increases efficiency and reduces surface disturbance. Six to eight horizontal wells can be drilled from one well pad, whereas with vertical drilling, eight separate well pads would be needed to reach the same amount of gas.[3]

---

[1] U.S. Energy Information Administration, *Annual Energy Outlook 2012,* Jun 2012, p. 112, http://www.eia.gov/forecasts/aeo/pdf/0383(2012).pdf.
[2] Heather Cooley and Kristina Donnelly, *Hydraulic Fracturing and Water Resources: Separating the Frack from the Fiction*, Pacific Institute, Jun 2012, p. 9,
[2] Heather Cooley and Kristina Donnelly, *Hydraulic Fracturing and Water Resources: Separating the Frack from the Fiction*, Pacific Institute, Jun 2012, p. 9, http://www.pacinst.org/reports/fracking/index.htm.
[3] Mary Tiemann and Adam Vann, *Hydraulic Fracturing and Safe Drinking Water Act Issues*, Congressional Research Service, 12 Jul 2012, p. 2 http://www.fas.org/sgp/crs/misc/R41760.pdf.

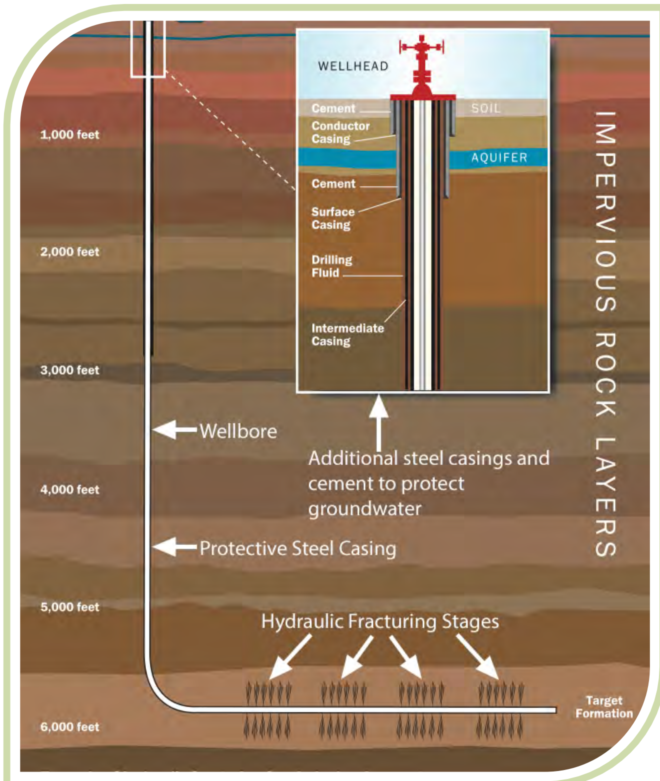

Figure 1. Cross-section of a typical horizontal well that has been drilled into shale and hydraulically fractured. Source: Suchy and Newell, Kansas Geological Survey.

Once wells have been drilled, cased[4] and cemented, **hydraulic fracturing,** or "fracking"—the injection of large volumes of fluids under high-pressure into wells to create cracks and fissures in rock formations—is utilized to improve production of the well. **Fracturing fluid**, containing water, chemical additives, and a propping agent or **proppant**, is pumped into the well in stages. Proppants are typically an incompressible material like sand or ceramic beads. Once basic fluids are used to fracture the formation, the proppant is then pumped in so its particles can hold open the created fractures and enhance the flow of gas out to the surface. Wells may be fractured multiple times, as is typical for deep shale formations.[5]

After the pressure on the well is released, there is a **flowback period** of days to weeks during which some of the injected fluid (estimates range from 30% - 70% of the original fluid volume)[6] along with fluid naturally occurring in the formation, returns to the surface before gas begins to flow. Collectively this wastewater, often termed **flowback** or **produced water**, contains chemicals present in the original fracturing fluid as well as brines, heavy metals, radionuclides, and organics from the formation that can make wastewater treatment difficult and expensive.[7]

---

4 The Schlumberger Oilfield Glossary defines a well casing as: "Steel pipe cemented in place during the construction process to stabilize the wellbore. The casing forms a major structural component of the wellbore and serves several important functions: preventing the formation wall from caving into the wellbore, isolating the different formations to prevent the flow or crossflow of formation fluid, and providing a means of maintaining control of formation fluids and pressure as the well is drilled". Source: Schlumberger Oilfield Glossary, 2012, http://www.glossary.oilfield.slb.com/default.cfm.

5 Tiemann, 4.

6 ibid, 1.

7 Daniel Soeder and William Kappel, *Water Resources and Natural Gas Production from the Marcellus Shale,* U.S. Geological Survey (USGS), May 2009, p. 5, http://md.water.usgs.gov/publications/fs-2009-3032/fs-2009-3032.pdf.

As with many engineering processes, variation in terminology often impedes comparative discussions and skews statistics. Hydraulic fracturing is technically defined as the phase of well development during which fluids are injected into the reservoir under high pressure to open fractures in the formation.[8] However, the phases of well construction, fracturing of the formation, flowback, well production, and waste removal are all associated with environmental, seismic and health impacts. *For the purposes of this paper, the term "hydraulic fracturing" will refer to all processes surrounding gas extraction, from the initial to final stages.* Unless otherwise specified, hydraulic fracturing as used here refers to high-volume "**slickwater**" fracturing, meaning the fracturing fluids used include chemical additives to increase the efficacy of the injection.[9]

History of Hydraulic Fracturing and Unconventional Drilling

Hydraulic fracturing was first commercially used in the mid-to-late 1940's primarily for drilling conventional oil and gas wells.[10] It wasn't until the late 1990's, however, that the modern methods of hydraulic fracturing and horizontal drilling were introduced. The process of hydraulic fracturing is used today in more than 90% of new oil and natural gas wells in the U.S.[11] Industry estimates show that hydraulic fracturing has been applied to more than one million wells nationwide in thirty three states where oil and gas production occur.[12]

Of the three unconventional reserves, tight gas has had the longest history of development in the U.S., steadily expanding for several decades. Coalbed methane was commercially produced as early as 1980, but production expanded dramatically in the 1990's. Shale gas has also been in production for many decades, but unconventional drilling and hydraulic fracturing triggered a resurgence of development in the mid-2000s. Shale gas production grew at more than 45% per year between 2005 and 2010.[13] Overall, the contribution of unconventional resources to the U.S. natural gas supply has increased from approximately 15% of total gas production in 1990 to 60% of the total supply in 2010 (shale gas comprises 23% of the total) and is projected to reach 77% by 2035.[14,15] Shale gas is expected to

[8] Schlumberger Oilfield Glossary, 2012.

[9] Tiemann, 4.

[10] Hydraulic fracturing has also been applied for other uses including developing drinking water wells, disposing of waste, and enhancing geothermal production wells. Source: Cooley, 12.

[11] Tiemann, 2.

[12] American Petroleum Institute (API), *Freeing Up Energy,* 19 Jul 2010 http://www.api.org/policy/exploration/hydraulicfracturing/upload/HYDRAULIC_FRACTURING_PRIMER.pdf.

[13] International Energy Agency (IEA), *Golden Rules for a Golden Age of Gas: World Energy Outlook Special Report on Unconventional Gas*, 2012, p. 102, http://www.worldenergyoutlook.org/media/weowebsite/2012/goldenrules/WEO2012_GoldenRulesReport.pdf.

[14] EIA 2012, 3.

be the main source of growth in the overall gas supply in the coming decades, comprising 49% of the domestic gas supply by 2035.[16] This guidebook will focus on the use of hydraulic fracturing and horizontal drilling for unconventional resource development, particularly shale gas reserves, which have had the largest impact on the U.S. energy supply.

Purpose Statement

This guidebook aims to provide a reader-friendly overview of the current and near-term environmental, regulatory, and legal issues tied to unconventional natural gas development. First, it provides an explanation of the environmental concerns, supplying evidence from the disparate viewpoints in the ongoing debate. It then investigates the regulatory framework underlying the industry's practices, looking at existing federal regulations and exemptions as well as differences in state regulations. Finally, the legal implications of such a diverse regulatory framework are examined.

Our objective is to provide the context around which a coalition of stakeholders could potentially be formed to ensure the industry's continued growth while proactively addressing issues of concern. Such a coalition would bring together perspectives from oil and gas companies, law firms, government agencies, NGOs, universities and others to exchange knowledge and expertise on these issues and work to pinpoint actionable solutions so that this critical resource may be developed efficiently, but in a manner that is protective of our shared environment.

Overview of The Horinko Group

The Horinko Group is an environmental and business development consulting firm operating at the intersection of practice, policy, and communications. Our firm has established itself as an innovator, as well as a trusted, third-party convener addressing complex natural resource challenges. We have expertise in site remediation and revitalization of urban and rural communities, regulatory intervention, and the water-energy-land use nexus.

The Horinko Group advocates for efficiency, sustainability, and holistic solutions based on cutting-edge science and sound business practice. We work alongside federal, state, and local governments, NGOs, and the private sector to achieve measurable results for our clients, partners, and the communities and markets in which they operate.

We emphasize transparency, partnerships, and systemic problem-solving in order to inform the national mainstream on sustainable and innovative practices.

---

[15] Cooley, 8.
[16] EIA 2012, 3.

We understand the value of relationships and the importance of effective collaboration in making real progress toward tackling tough challenges and seizing unique opportunities.

These guiding values and our expertise are well suited to address the complex and cross-cutting issues that unconventional gas development presents.

Unconventional Gas Resources and Economic Potential

Domestic Resources

In the U.S., vast unconventional gas reserves and the potential they hold for the economy, job creation, energy cost reduction, and national energy security has brought hydraulic fracturing debates to a new level. The EIA's Annual Energy Outlook estimates that the U.S. has 2,203 trillion cubic feet (Tcf) of technically recoverable natural gas, enough to supply over 90 years of use at 2011 consumption rates.[17]

These significant shale gas resources are widely distributed across the country in "plays," shale formations containing accumulations of natural gas that share geologic and geographic properties. In the 2000's, the initial scale up in gas production came from the Barnett Shale in Texas. The Marcellus Shale, stretching from New York to Tennessee, and thought to be the largest shale gas reservoir in the country, is now under rapid development as well. Operations in this geographic area are being scrutinized, primarily due to the proximity to population centers and public perception regarding oil and gas drilling. Other active shale plays include the Bakken, Haynesville/Bossier, Antrim, Fayetteville, New Albany, Woodford, and Eagle Ford (see Fig. 2 below).[18] Coalbed methane and tight gas, though less widely distributed, are often found in the same regions as shale gas formations.

---

[17] U.S. Energy Information Administration, "Market Trends—Natural Gas", *Annual Energy Outlook 2012,* Jun 25, 2012, http://www.eia.gov/forecasts/aeo/MT_naturalgas.cfm#growth.

[18] Ground Water Protection Council (GWPC) and ALL Consulting, *Modern Shale Gas Development in the United States,* Apr 2009, p. ES-2, http://www.marcellus.psu.edu/resources/PDFs/NETLprimer.pdf.

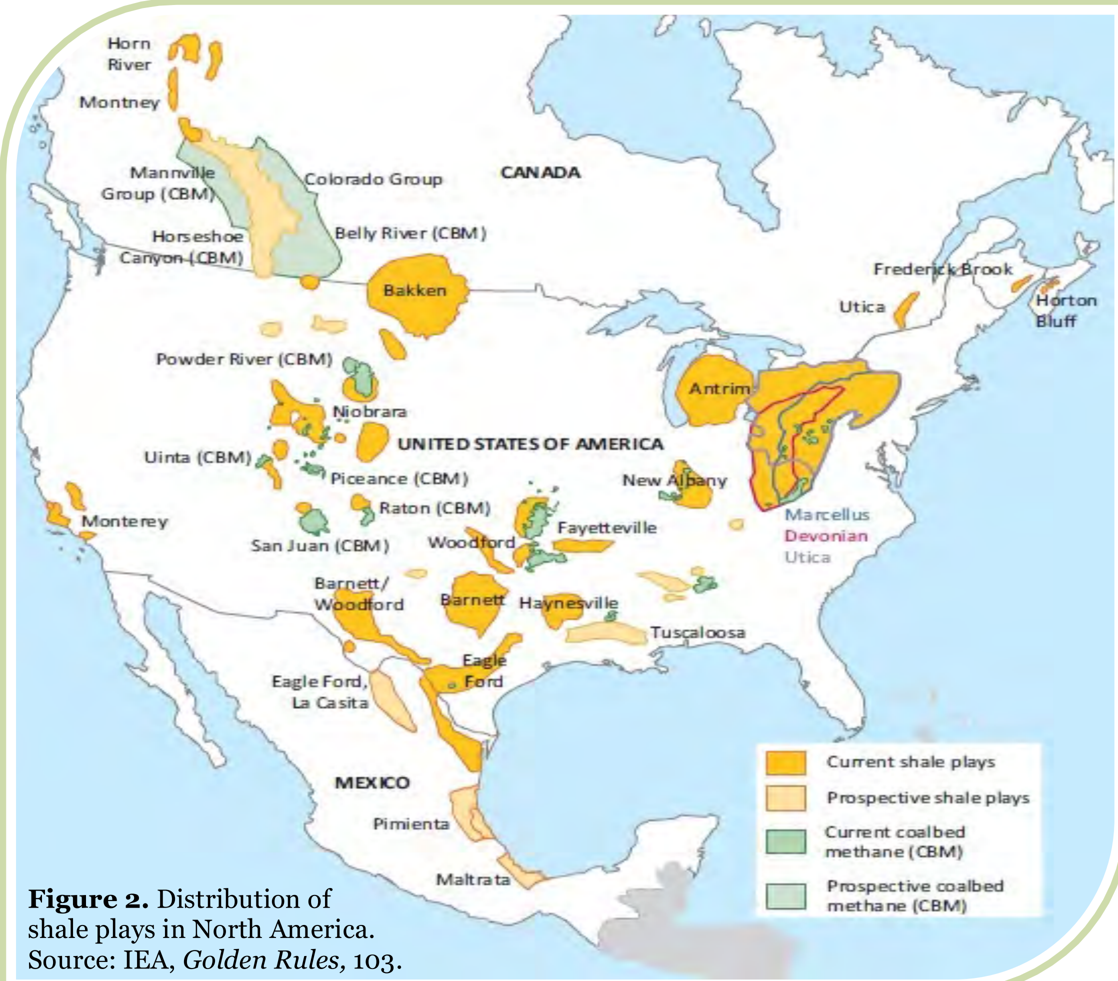

Figure 2. Distribution of shale plays in North America. Source: IEA, *Golden Rules,* 103.

Shale gas development has in a few short years impacted the economy in significant ways, contributing jobs, government revenue, and GDP gains in addition to lower prices for consumers. In the past four years alone, development of U.S. resources has pushed natural gas prices down more than 70%. This has facilitated the replacement of coal with natural gas as the chief fuel used to generate power.[19] In 2010, the shale gas industry supported more than 600,000 jobs, contributed more than $76 billion to GDP, and $18.6 billion in federal, state, and local government tax and federal royalty revenues.[20] The most significant levels of job creation are in states with large reserves such as Colorado, Pennsylvania, and Texas.

Future Outlook

---

[19] U.S. Energy Information Administration, "Monthly coal- and natural gas-fired generation equal for first time in April 2012", Jul 6 2012, http://www.eia.gov/todayinenergy/detail.cfm?id=6990.

[20] IHS Global Insight, *The Economic and Employment Contributions of Shale Gas in the United States,* prepared for America's Natural Gas Alliance, Dec 2011, p. v, http://anga.us/media/235626/shale-gas-economic-impact-dec-2011.pdf.

Given the country's resources and its technical capabilities for developing them, by 2035 the U.S. shale gas industry is expected to support 1.6 million jobs, contribute more than $231 billion to GDP, and $57 billion in government revenues.[21] Though less than ten years ago the U.S. was projected to rely on imports of liquefied natural gas (LNG) indefinitely, the EIA now estimates that the U.S. will become a net exporter of natural gas by 2035.[22] In April 2012, the Henry Hub spot price[23] for 1,000 cubic feet of natural gas in the U.S. fell below $2 while prices in Europe and Asia were over $11 and $15, respectively.[24] As of April 2012, only the Sabine Pass LNG exporting facility on the Gulf Coast had cleared the necessary regulatory hurdles. Exports could begin there as early as 2015. Seven other exporting terminal projects await approval from the U.S. DOE.[25] The implications of exporting LNG are immense for the U.S. economy, balance of trade, energy security, and climate change mitigation efforts.

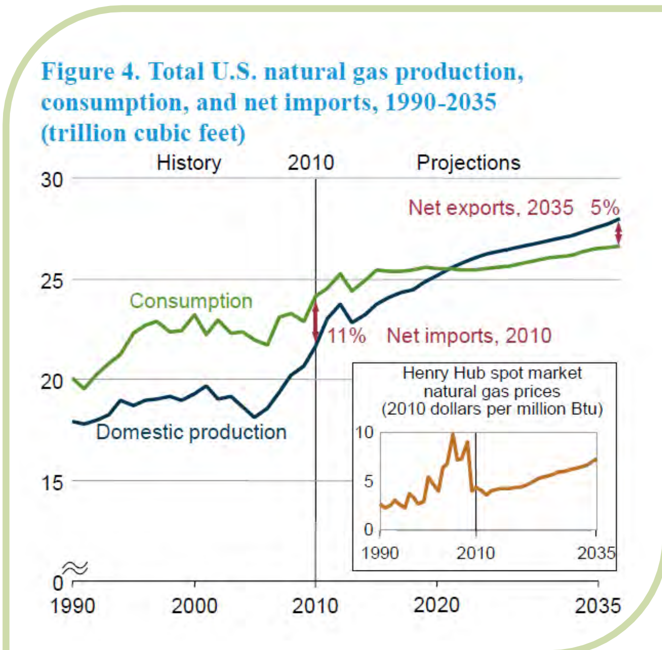

Figure 3. U.S. natural gas production, consumption, and net imports 1990-2035. Source: EIA 2012.

---

[21] IHS Global Insight, 2.
[22] EIA 2012, 62.
[23] The Henry Hub is a distribution hub on the natural gas pipeline in Louisiana that connects nine interstate and four intrastate pipelines. Unlike the wellhead price, the Henry Hub spot price refers to next-day transactions at the Henry Hub processing plant after natural gas liquids have been removed and transportation cost has been taken into account, thus it more closely reflects the market price for natural gas. Source: Philip Budzik, *U.S. Natural Gas Markets: Relationship Between Henry Hub Spot Prices and U.S. Wellhead Prices,* U.S. Energy Information Administration, http://www.eia.gov/oiaf/analysispaper/henryhub/.
[24] Brookings Institute, *A Strategy for U.S. Natural Gas Exports,* The Hamilton Project, Jun 2012, p. 3, http://www.brookings.edu/~/media/research/files/papers/2012/6/13%20exports%20levi/06_exports_levi_brief.pdf.
[25] IEA, 108.

When considering hydraulic fracturing on an international scale, it is important to note that many countries have significant unconventional reserves. Development projects have begun in China, Australia, the United Kingdom, Poland, and Canada. In some countries, projects have been met with resistance, and a small but significant number of jurisdictions. France, Bulgaria, Quebec, and South Africa are among the countries that have banned or placed moratoria on unconventional drilling.[26] The United States has an opportunity to capitalize on such foreign resistance to drilling if domestic practices are undertaken in a safe and environmentally conscious manner. The need for such an approach is urgent since domestic bans or moratoria have already been put in place in a number of U.S. towns, cities, and states. Public information and education campaigns are required to avoid the type of resistance that spurred opposition elsewhere.

Exports could, according to a 2012 Brookings Institute report, create up to 8,000 near term jobs in export facility construction, displace dirtier coal-fired plants abroad, provide the U.S. leverage in trade negotiations, and bring in up to $4 billion annually from overseas sales.[27]

There are many concerns related to exporting, however, which are likely responsible for the delay in widespread approval for export applications. Environmental concerns like water and air pollution, for which the domestic industry is currently facing heavy criticism, become more pressing on a larger scale. The domestic price of natural gas would rise slightly, and lowered energy costs abroad could lead to increased energy consumption and thus an increase in greenhouse gas emissions. There is also concern of a “gold rush” phenomenon occurring, whereby inexperienced developers, or states unfamiliar with oil and gas development, drawn by the prospect of profit from exports, would begin development using unsafe practices. An expansion of development within an already overburdened regulatory system could lead to missteps that would dramatically shift public perceptions against the industry.

The Brookings report thus underscores the need for prudent environmental protection to be strengthened in gas development areas, even if costs of safe operation undermine some of the economic gain from exports. Without these protections, the industry risks a negative backlash. If regulations and exporting go forward in tandem, there is much to be gained for the U.S. economy, trade negotiations and efforts to combat climate change.[28]

---

[26] Molly Wurzer, *Taking Unconventional Gas to the International Arena,* Texas Journal of Oil, Gas, and Energy Law, 14 Jun 2012, p. 366, http://tjogel.org/wp-content/uploads/2012/07/Wurzer-Formatted_Final_June13.pdf.
[27] Brookings, 4.
[28] ibid, 6.

Environmental Concerns

Figure 4. Shale gas drilling rig. Source: Marcellus Shale Coalition.

Unconventional drilling is associated with an array of potential environmental impacts occurring at varying phases of the process. From well site construction through drilling and casing of the well, through fracturing and flowback stages, to production and waste disposal phases, there are concerns about air pollution, greenhouse gas emissions, water withdrawals, groundwater contamination, wastewater disposal, surface water contamination, and ecosystem degradation from spills and leaks, seismic activity, and road traffic. Though most public attention has focused on the chemicals used in the fracturing fluid and their impacts on groundwater, this may not be the most pressing of the environmental concerns. The Pacific Institute conducted interviews of major stakeholders and found that wastewater volumes and quality, as well as the water volumes required for hydraulic fracturing, were more often cited as key issues.[29] Each area of concern is at a different stage of review, depending on the amount of data available, the extent of the research that has been conducted, and the development of associated regulations.

Air Quality and Atmospheric Impacts

The most significant air emissions associated with hydraulic fracturing occur during well completion.[30] After a well is drilled, fluid and debris from the

---

[29] Cooley, 30.

[30] The Schlumberger Oilfield Glossary defines well completion as: "A generic term used to describe the events and equipment necessary to bring a wellbore into production once drilling operations have been concluded, including but not limited to the assembly of

wellbore and rock formation flow to the surface during the flowback stage. This fluid is accompanied by natural gas from the formation. As a result, before the well actually goes into production, significant quantities of methane, volatile organic compounds (VOCs), and air toxics are emitted. Methane, the primary component of natural gas, is a greenhouse gas twenty times as potent as carbon dioxide according to EPA. Byproducts like VOCs and air toxics pose health risks. Some are known carcinogens and others are precursors to the formation of ground-level ozone, or smog.[31] These emissions can be greatly reduced using a process known as "green completion," whereby special equipment separates gas and liquid hydrocarbons in the flowback. The separated hydrocarbons can then be treated or sold, avoiding the currently more common practices of flaring or venting[32] of excess gas.

Similar types of air pollution escape from engines used to move equipment and materials, drill wells, power pumps and compressors to pressurize the well, pump fluids in, and bring produced gas to the surface. Leaks from pipe connections and related equipment may result in further emissions as well.[33]

i. Greenhouse Gas Emissions

It is uncertain exactly how much natural gas escapes to the atmosphere during drilling completion and due to leakages during storage and transportation. As a result of this uncertainty, debates have unfolded over how "clean" natural gas is as an energy source. Since methane is such a potent greenhouse gas, estimates of natural gas emissions and leakage are critical to determining the overall climate impact of this fuel source.

Though it is clear that substitution of natural gas for coal and other fossil fuels will not bring adequate greenhouse gas reductions to stop global climate change,[34] many support the idea that natural gas has an important role to play as a bridge fuel to lower emissions while renewable energy sources continue to be

---

downhole tubulars and equipment required to enable safe and efficient production from an oil or gas well. Completion quality can significantly affect production from shale reservoirs." Source: Schlumberger Oilfield Glossary, 2012.

[31] U.S. Environmental Protection Agency (EPA), *Overview of Final Amendments to Air Regulations for the Oil and Natural Gas Industry Fact Sheet,* 2012, http://epa.gov/airquality/oilandgas/pdfs/20120417fs.pdf.

[32] Flaring is the process by which excess gas is burned off in stacks or flares. Venting occurs when gas escapes from the wellbore into the atmosphere. Source: Resources for the Future, *A Review of Shale Gas Regulations by State,* Jul 2012, http://www.rff.org/centers/energy_economics_and_policy/Pages/Shale_Maps.aspx.

[33] GWPC and ALL Consulting, 72.

[34] David Victor, fossil fuel expert at the University of California, San Diego, proposes that a 50-80% reduction in greenhouse gas emissions would be required to stop global climate change. Source: "From Coal to Gas: The Potential Risks and Rewards", National Public Radio, 15 Jul 2012, http://www.npr.org/2012/07/15/156814490/from-coal-to-gas-the-potential-risks-and-rewards.

developed. There is a good deal of evidence to support the claim that natural gas is a cleaner burning fuel than coal. Cornell University professor Lawrence Cathles concluded in a recent study that replacing coal with natural gas would decrease greenhouse gas emissions by up to 40 percent.[35] Levels of CO_2 emissions in 2012 are thought to be the lowest in 20 years. A major contributor to this decline is likely the rapid replacement of coal with natural gas for electricity generation. It is estimated that a gas-fired plant emits about half the CO_2 as a coal-fired one. Coal's share of electricity generation has decreased in the last five years from around 50% to 32% in April 2012, nearly equal to that of natural gas.[36]

Though most agree that as fuel for electricity generation natural gas is cleaner than coal (both in GHG and pollutant emissions), its overall climate impact is still in question. The root of uncertainty lies in quantifying the amount of natural gas, or methane, that escapes to the atmosphere during production and transport.

The disagreement over these estimates is largely due to a lack of concrete data. The official EPA numbers, published in 2009, which have been relied upon by follow-up studies arguing that coal is cleaner than gas, are outdated and constrained by uncertainties, as EPA itself admits.[37] Industry officials refute EPAs numbers, arguing that, if correct, these estimates translate to millions of dollars worth of natural gas escaping to the atmosphere; losses which are certainly not taking place.[38] A 2012 study prepared for the American Petroleum Institute and American Natural Gas Alliance pegs emissions at half of what the EPA has estimated.[39] Another group of Cornell scientists, however, have published two studies claiming that the GHG footprint of shale gas is greater than

[35] Lawrence M. Cathles, *Assessing the greenhouse impact of natural gas,* Geochemistry Geophysics Geosystems, 19 Jun 2012, http://www.energyindepth.org/wp-content/uploads/2012/07/Cathles-Assessing-greenhouse-impact-natgas-June2012.pdf
[36] Bjorn Lomborg, "A Fracking Good Story", *Project Syndicate*, 15 Sep 2012, http://www.slate.com/articles/health_and_science/project_syndicate/2012/09/thanks_to_fracking_u_s_carbon_emissions_are_at_the_lowest_levels_in_20_years_.html.
[37] U.S. Environmental Protection Agency, *Technical Note on the 1990-2009 Inventory Estimates for Natural Gas Systems*, 15 Apr 2011, http://epa.gov/methane/downloads/TechNote_Natural%20gas_4-15-11.pdf
[38] *Review of Recent Environmental Protection Agency Air Standards for Hydraulically Fractured Gas Wells and Oil and Natural Gas Storage: hearing before Subcommittee on Clean Air and Nuclear Safety of the Committee on Environment and Public Works,* U.S. Senate, 112th Congress, 19 Jun 2012.
[39] Terri Shires and Miriam Lev-On, *Characterizing Pivotal Sources of Methane Emissions from Unconventional Natural Gas Production*, URS Corporation and The LEVON Group, Prepared for API and ANGA, 1 Jun 2012, http://www.api.org/news-and-media/news/newsitems/2012/jun-2012/~/media/Files/News/2012/12-July/Task2-API-ANGA-Survey-Report-19-July.ashx.

any other fossil fuel on time scales up to 100 years.[40,41] (While methane has a stronger warming effect than CO_2, CO_2 lingers for much longer in the atmosphere.) NOAA also conducted a recent study in Colorado that corroborates these claims, reporting that methane emissions are at least twice what industry has estimated.[42]

Where actual data is sparse, differing assumptions have led to varying estimates. Plaguing this debate is a lack of adequate measurements. Direct emission measurement is extremely expensive and complex for companies given the thousands of wells, storage tanks, and other equipment that potentially leak methane. The American Petroleum Institute says that companies are attempting to improve their estimates. Meanwhile, the Environmental Defense Fund, in partnership with four universities and eight gas companies, is working on a study to answer these questions.[43] Industry, academia, government agencies, and NGOs all have a role to play in the continued effort to collect better information and draw empirically sound conclusions.

Water Impacts

While there are many unanswered questions regarding air and climate impacts from unconventional gas development, there are dozens more pertaining to water. Large volume withdrawals, contamination of drinking water and surface water, and wastewater disposal, comprise the key water issues. As with impacts on climate, many water-related debates largely stem from insufficient data.

i. Water Withdrawals

Estimates of water use for unconventional gas operations vary. For shale gas, estimates range from 2-10 million gallons per well, while for coalbed methane 50,000 to 350,000 gallons are reportedly used.[44,45] The amount of water used

---

[40] Robert Howarth et al., *Methane and the Greenhouse-gas Footprint of Natural Gas from Shale Formations*, 13 Mar 2011, http://www.sustainablefuture.cornell.edu/news/attachments/Howarth-EtAl-2011.pdf.
[41] Robert Howarth et al., *Venting and Leaking of Methane from Shale Gas Development: Response to Cathles et al.,* 1 Feb 2012, http://www.springerlink.com/content/c338g7j559580172/fulltext.pdf?MUD=MP.
[42] Gabrielle Petron et al., *Hydrocarbon emissions characterization in the Colorado Front Range – A pilot study,* Journal of Geophysical Research, 2012, http://www.agu.org/pubs/crossref/pip/2011JD016360.shtml.
[43] "Getting Natural Gas Right", *Environmental Defense Fund,* 2012, http://www.edf.org/energy/getting-natural-gas-right.
[44] David Kargbo et al., *Natural Gas Plays in the Marcellus Shale: Challenges and Potential Opportunities*, Environmental Science and Technology, Vol. 44, No. 15, 2010, http://pubs.acs.org/doi/pdf/10.1021/es903811p.
[45] U.S. Environmental Protection Agency, *Hydraulic Fracturing Research Study,* Jun 2010, http://www.epa.gov/safewater/uic/pdfs/hfresearchstudyfs.pdf.

depends on the specific geology, the depth of the well, and the number of times the well is fractured. Evidence shows that in a given state or water basin, water requirements for hydraulic fracturing are small relative to other uses. For example, in 2010 the water required by hydraulic fracturing in Colorado was 0.08% of the state total, whereas the agricultural sector used 85.5%.[46] MIT's 2011 Future of Natural Gas study looks at four different major shale plays comparing shale gas water requirements to those of the public supply, industry and mining, irrigation, and livestock.[47] The authors conclude that in all cases, shale gas development represents less than 1% of total water usage. Furthermore, shale gas requires only one gallon of water for every MMBtu of energy produced.[48] Compared to other energy sources, this "water intensity" is fairly low.

The impacts on local water sources, however, can still be serious. Much of the water injected into the wells is not recovered or is unfit for further use after recovery, and must be stored in underground injection wells or disposed of in another manner. Therefore, hydraulic fracturing represents a consumptive water use and over a long period of time, the water requirements may have cumulative impacts on watersheds or aquifers. Recycling does occur, and has been on the rise in recent years as water scarcity and limitations on injection well availability have placed pressure on companies to reuse their water. These practices, however, are not yet widespread enough to change the consumptive nature of unconventional gas drilling (see more on recycling in Box 1).

There have been cases where water needs for fracturing have come in conflict with other uses. This has occurred in drought-prone areas like Texas, where natural gas companies have tried to purchase water from local farmers or outbid them in water auctions for unallocated resources. More notably, it has also occurred in water-rich areas. For instance, in Pennsylvania in 2011 and 2012, permits for water withdrawals for gas companies had to be temporarily suspended due to low stream levels.[49,50]

Large Volume Withdrawals Impact on Water Quality

---

[46] *Water Sources and Demand for the Hydraulic Fracturing of Oil and Gas Wells in Colorado from 2010 through 2015,* prepared by the Colorado Division of Water Resources, the Colorado Water Conservation Board, and the Colorado Oil and Gas Conservation Commission, http://cogcc.state.co.us/Library/Oil_and_Gas_Water_Sources_Fact_Sheet.pdf.
[47] *The Future of Natural* Gas, Massachusetts Institute of Technology, 2011, p. 52, http://web.mit.edu/mitei/research/studies/natural-gas-2011.shtml.
[48] ibid.
[49] Cooley, 16.
[50] Kasia Klimasinska and Jim Efstathiou Jr., "Drought Helps Fracking Foes Build Momentum For Recycling", *Bloomberg News*, 23 Jul 2012, http://www.bloomberg.com/news/2012-07-23/drought-helps-fracking-foes-build-momentum-for-recycling.html.

Aside from water volume and availability concerns, the withdrawal requirements of hydraulic fracturing can also affect water quality. When large volumes of groundwater are removed, naturally occurring contaminants may be mobilized, bacterial growth is promoted, land subsidence may occur, and lower quality water from surrounding areas moves in. Removals from surface water sources may reduce the ability of the water source to dilute municipal or industrial wastewater discharges.[51]

To address the water use concerns of hydraulic fracturing, as is the case with many of the associated environmental concerns, the first place to start is more sound data. Accurate figures for volumes extracted and analysis of the impact on local sources and water availability are necessary. To reduce the impact from this consumptive use activity, methods of recycling wastewater from hydraulic fracturing must be further investigated and scaled up to be more cost effective.

ii. Wastewater Management

Figure 5. Drilling Rig in Upshur County, West Virginia.
Source: GWPC and ALL Consulting, 48.

Managing the large volumes of wastewater generated during the drilling process is a valid concern. The fracturing fluid and produced fluid that return to the surface during the flowback period comprise fracturing wastewater. Wastewater traditionally contains remnant chemicals initially present in the fracturing fluid, and natural substances such as radioactive materials, metals, and salts.[52] The

---

[51] Cooley, 17.
[52] ibid, 23.

properties and volume of hydraulic fracturing wastewater vary depending on the local geology, the type of hydrocarbon being extracted, and the specific method of production.[53]

Disposal of wastewater typically consists of its temporary storage in pits, embankments, or tanks at the well site and subsequent transportation via pipeline or truck to a disposal site. Storage pits pose a threat to groundwater especially when unlined or when the lining is compromised. Once transported to a disposal site, the required method of disposal is injection into a Class II well. Under EPA framework, Class II wells have less stringent requirements than Class I and thus present greater risk to groundwater and triggering earthquakes than Class I wells (see more on injection regulations in *Regulatory Framework* section).[54] Conducted properly, this type of disposal may somewhat reduce the likelihood of releasing wastewater contaminants into the environment. However, seismic risks (explained in depth in *Seismic Activity* section below) and transportation requirements make injection wells a risky solution. Many states do not have sufficient disposal well capacity thus wastewater must be transported over long distances, increasing the chance of leaks and spills.

Fracturing wastewater has also been processed through municipal water treatment plants. This is fairly uncommon and controversial because traditional wastewater treatment plants are not designed to handle fluid with the characteristics of fracturing flowback and produced water. This treatment method can therefore result in downstream water quality problems.[55] Reuse of wastewater is becoming more common as its disposal becomes more challenging. When used for fracturing new wells or refracturing existing wells, wastewater reuse reduces the total withdrawal volume required. Investigating reuse and recycling possibilities may minimize impacts both with respect to wastewater management as well as withdrawal requirements of unconventional gas and oil operations.

---

[53] U.S. Government Accountability Office, *Information on the Quantity, Quality, and Management of Water Produced during Oil and Gas Production*, Jan 2012, http://www.gao.gov/assets/590/587522.pdf.

[54] Rebecca Hammer and Jeanne VanBriesen, *In Fracking's Wake: New Rules are Needed to Protect Our Health and Environment from Contaminated Wastewater*, National Resources Defense Council, May 2012, http://www.nrdc.org/energy/files/Fracking-Wastewater-FullReport.pdf.

[55] ibid, 6.

Box 1: Recycling

In reducing the water and contaminant footprint of hydraulic fracturing, reusing wastewater for fracturing or other purposes holds great potential. Serious drought conditions in the U.S. in 2012 have pressured natural gas drillers to increase efforts on wastewater recycling. Devon Energy Corporations has estimated, however, that recycling is as much as 75% more costly than wastewater injection into deep wells (Klimasinska, 2012). In Texas, however, as prices to haul in freshwater have increased due to drought, more companies are recycling water and using brackish water in place of freshwater. According to the director of technology at the Energy Research Institute at Texas A&M, the use of fresh groundwater for hydraulic fracturing has decreased by 50% in the last 12 months (Klimasinska, 2012). No rules for water conservation or recycling have been implemented thus far, but rules to require reuse of water and limit the amount of freshwater that can be used have been proposed in Texas. There is a growing interest—by natural-gas drillers and environmentalists alike—to make recycling more cost effective as water resources become threatened.

Omni Water Solutions in Austin, TX and Rettew Flowback Inc. in Lancaster, PA are among a few technology startups that have developed onsite wastewater treatment systems. These use filtration and chemical treatment to remove undesirable contaminants from the water. Usually the treated product is a clean form of brine, containing salts that would have been required for hydraulic fracturing in the base case. With this treatment, water can be reused over and over for fracturing wells. This decreases the need for companies to purchase additional salts, decreases the amount of freshwater needed, the number of trucks needed to haul water to and from the site, and prevents potential pollution and seismic problems related to deep well injections (Henricks, 2012).

In contrast to Devon's estimates, these water-recycling companies claim that their technologies are more cost effective than purchasing and transporting freshwater plus transporting and disposing of wastewater by traditional methods. In fact, according to Chesapeake Energy, by using water-recycling technologies like Rettew Flowback Inc.'s, the company is reusing more than 10 million gallons per month in its Marcellus Shale fracturing operations and saving an estimated $12 million per year (Chesapeake Energy, *Aqua Renew*).

These types of treatment systems, while improving water needs, do not eliminate all disposal problems. Ultimately, the contaminants remaining after treatment like barium, strontium, and radioactive elements form a highly concentrated sludge that must still be disposed. Most of the time, it is sent to landfills or injection disposal wells.

In some cases, wastewater has been repurposed for de-icing roads and dust suppression. Though, still contaminated with radioactive chemicals when used for these purposes, the wastewater remains exempt from EPA hazardous waste regulations once it is generated, regardless of how it is treated or used (Urbina, 2011). This type of repurposing and the final disposal stages of contaminants from hydraulic fracturing wastewater, recycled or not, may still pose environmental threats, unless they are characterized and treated as hazardous wastes.

iii. Groundwater Contamination

The potential risks to groundwater posed by hydraulic fracturing activities have received the most public attention of the various water-related concerns. Contamination risks include methane build up, elevated salinity levels, and chemicals from fracturing and naturally occurring fluids entering drinking water sources. Contamination may occur in a variety of ways. Since the gas being extracted is generally located below drinking water sources, wells must be drilled through these aquifers to access the gas. Short-term impacts from drilling include changes in color, turbidity, and odor of water due to the vibrations and pressure changes.[56] Moreover, if wells are not drilled, sealed, and cased properly, chemicals and natural gas can escape the well bore and enter the groundwater. When accidents or failures occur in the process, contamination becomes a possibility.

Another means of groundwater contamination is that of methane and contaminant migration through fractures in the rock formation. Fractures occur naturally and are also created during the fracturing process.[57] Old abandoned wells, of which there are an estimated 150,000 in the U.S., might also serve as pathways for contamination.[58] Coalbed methane is often found at shallower depths closer to underground sources of drinking water and therefore may pose greater risk of contamination.

Methane Contamination

Much public attention and speculation has focused on methane contamination in drinking water. In 2009, a well exploded in Dimock, Pennsylvania due to excessive methane concentrations. A subsequent Pennsylvania Department of Environmental Protection (PDEP) investigation confirmed Cabot Oil & Gas was responsible for polluting 18 drinking water wells in the area due to the improper casing and cementing of these wells. A Consent Order and Settlement Agreement was filed by PDEP and Cabot was fined and banned from continuing gas drilling operations until it met all provisions of the decree such as restoring water supplies and fixing improperly cased wells.[59] A 2011 Duke University study also

---

[56] Charles G. Groat and Thomas W. Grimshaw, *Fact-Based Regulation for Environmental Protection in Shale Gas Development,* University of Texas at Austin, Feb 2012, p. 19, http://energy.utexas.edu/images/ei_shale_gas_regulation120215.pdf.
[57] Tom Myers, *Potential Contaminant Pathways from Hydraulically Fractured Shale to Aquifers,* National Ground Water Association, 17 Apr 2012, http://onlinelibrary.wiley.com/doi/10.1111/j.1745-6584.2012.00933.x/full.
[58] Interstate Oil and Gas Compact Commission, *Protecting Our Country's Resources: The States' Case,* Orphaned Well Plugging Initiative, Department of Energy National Energy Technology Laboratory, 2008, http://iogcc.publishpath.com/Websites/iogcc/pdfs/2008-Protecting-Our-Country's-Resources-The-States'-Case.pdf.
[59] Pennsylvania Department of Environmental Protection, "Consent Order and Settlement Agreement", 2010, http://www.cabotog.com/pdfs/FinalA_12-15-10.pdf.

provides evidence of methane contamination from hydraulic fracturing operations, finding concentrations of methane to be 17 times higher in areas within 1 km of gas wells compared to those outside of the active production areas.[60]

Chemical and Brine Contamination

The issue of chemical contamination and elevated salinity resulting from fracturing fluids is also under scrutiny. In 2011, after Cabot had complied with the consent order and been authorized to recommence its operations, EPA was presented with more data from Dimock residents of elevated contaminant levels. As a safety measure, EPA conducted further testing of private water wells serving 64 homes in Dimock and found arsenic, barium, or manganese in well water at 5 homes at levels that could present health concerns. EPA decided not to conduct further testing in this area, since water supplies were deemed primarily safe and residents with dangerous contaminant levels have their own treatment systems. The Agency drew no conclusions about the relationship of these chemical contaminants to gas drilling operations nearby.[61] Researchers speculate that, by creating fractures and pathways in the rock formation, drilling activities enable the migration of these naturally occurring chemicals into groundwater supplies.

The same 2011 Duke study that correlated methane concentration with proximity to gas wells found no evidence of contamination from fracturing fluid chemicals. Furthermore, a 2012 Duke University study confirmed that elevated salinity levels in groundwater are not directly linked to shale gas development, but instead, are due to brine migration through naturally occurring pathways in underground formations.[62] There is some speculation that these pathways will increase the chances of contamination related to hydraulic fracturing, especially methane leakages.

Another controversial case of contamination occurred in 2008 in Pavillion, Wyoming. Following reports of water taste and odor problems from well owners, EPA's initial study concluded that nearby drilling likely enhanced methane migration to wells and found chemicals associated with hydraulic fracturing to be present in the wells. The findings were disputed and EPA's testing methods

[60] Stephen G. Osborn et al., *Methane contamination of drinking water accompanying gas-well drilling and hydraulic fracturing,* Proceedings of the National Academy of Sciences, 17 May 2011, http://www.pnas.org/content/108/20/8172.
[61] U.S. Environmental Protection Agency, "EPA Completes Drinking Water Sampling in Dimock, PA.", 25 Jul 2012, http://yosemite.epa.gov/opa/admpress.nsf/0/1A6E49D193E1007585257A46005B61AD.
[62] Nathaniel R. Warner et al., *Geochemical evidence for possible natural migration of Marcellus Formation brine to shallow aquifers in Pennsylvania*, Proceedings of the National Academy of Science, 9 Jul 2012, http://www.pnas.org/content/early/2012/07/03/1121181109.full.pdf+html

questioned by Encana Oil & Gas, the alleged offender, but a lack of baseline data meant that no final conclusions could be drawn. The wells are currently being retested.[63]

By keeping to the narrowest version of the definition of hydraulic fracturing, solely the injection of fluids, industry officials have been able to claim that there have been no confirmed cases of contamination related to fracturing itself. When considering issues of well casing integrity and wastewater disposal, however, there is evidence to suggest that fracking related activities have been responsible for groundwater contamination. As of yet, there have not been confirmed instances of contamination due to chemicals from the injection fluid. A lack of baseline data has hindered firm conclusions from being drawn in many cases. The need for water to be tested before drilling begins has been called for by many. This would represent an important step towards better determining the safety of the practice.

Many drilling companies point to the fact that chemicals in fracturing fluids often represent less than 1% of the total volume, with sand and water comprising the other 99%.[64] It is worth noting, however, that this small fraction translates into large volumes when considering the total amount of fluid used for fracturing a well. Furthermore, the confidential business information status of fracturing fluid composition has been problematic for determining the extent to which the fluids are associated with well contamination. In the past few years, more companies have begun voluntarily reporting the composition of their fluids primarily via the online portal, FracFocus, created by the Ground Water Protection Council (GWPC) and the Interstate Oil & Gas Compact Commission (IOGCC).

There have been many calls for further research in this area. To this end, EPA is conducting a study to research impacts of hydraulic fracturing on drinking water resources, looking at all stages of water use from acquisition through wastewater management treatment and disposal. The results are due out in 2014 with an interim report expected in late 2012.[65] Aside from further research, baseline data collection is necessary for all new drilling operations. Public misconceptions could be mitigated if gas-drilling companies were transparent about definitional differences and disclosed chemical information to the public. Finally, better transparency from researchers and institutions over funding sources and industry ties is essential.[66] A commitment is needed from all sides to conduct honest, pure science and answer these time sensitive questions as soon as possible.

---

[63] U.S. Environmental Protection Agency, *Groundwater Investigation Pavillion,* updated Jun 2012, http://www.epa.gov/region8/superfund/wy/pavillion/#1.
[64] GWPC and ALL Consulting, 61.
[65] U.S. Environmental Protection Agency, *EPA's Study of Hydraulic Fracturing and Its Potential Impact on Drinking Water Resources,* http://www.epa.gov/hfstudy/.
[66] There have been multiple cases where studies presenting evidence for the safety of hydraulic fracturing have been funded by gas companies, including the commonly cited

Ecosystem Impacts

i. Truck Traffic

Figure 6. Trucks for the transport of hydraulic fracturing materials near a Marcellus Shale gas well, West Virginia.
Source: GWPC and ALL Consulting, 60

Truck traffic associated with early stage well development to transport materials and equipment including water and chemicals both to and from the drilling site, poses additional concerns. It has been estimated that in the Marcellus region, a typical drilling rig can require 20,000 to 30,000 truckload movements per year. Considering that there were 138 rigs operating in the Marcellus Shale alone at the time that estimate was made (Apr. 2012), the implications of these figures become even more evident.[67] Truck traffic increases noise and air pollution, erosion on local roads, and risk of groundwater and surface water contamination

---

Groat and Grimshaw University of Texas study that concluded that fracking did not contaminate groundwater. The researcher, a board member of a gas producer, received over $400,000 from in compensation from the company. Source: Jim Efstathiou Jr., "Frackers Fund University Research that Proves their Case", *Bloomberg News*, 23 Jul 2012, http://www.bloomberg.com/news/2012-07-23/frackers-fund-university-research-that-proves-their-case.html.

[67] Deloitte Consulting LLP, *On the road again: Managing transportation logistics for unconventional drilling*, 2012, http://www.deloitte.com/assets/Dcom-UnitedStates/Local%20Assets/Documents/Consulting%20MOs/CSMLs/us_consulting_Managingtransportationlogisticsforunconventional_06212012.pdf.

from spills. The construction of additional roads in areas with new gas developments raises further issues of ecological disturbances.[68] Recycling wastewater has again been pointed to as one way to reduce the number of truckloads needed for each well.

ii. Surface Spills, Leaks, and Runoff

There is concern not only of surface spills during transportation phases but at all stages of the drilling lifecycle involving fracturing fluids and additives, as well as flowback and produced water. The contaminants in these fluids are problematic for surface water quality and can seep into and contaminate groundwater. Accidents and equipment failures can occur during mixing and storing of fracturing fluids on site. There have also been incidents of surface water contamination from improper wastewater disposal. For example, in March 2012 in southwestern Pennsylvania, a waste hauling company dumped millions of gallons of produced water into streams and mine shafts.[69] The frequency of these events and the extent of their impact are not yet well understood. While many violations have been documented, proponents argue that the number of spills and leaks is small relative to the size of the industry.

Stormwater runoff from well sites and related infrastructure impacts the water quality and ecosystem health of local waterways. A one-acre construction site without runoff controls can contribute as much as 16 times the runoff of a natural vegetated area.[70] Natural gas drilling requires about seven-to-eight acres of land clearing per well pad. Runoff concerns are exacerbated by the fact that stormwater coming in contact with these cleared sites may contain pollutants from the fracturing fluid and produced water being stored on site. However, the horizontal drilling used in unconventional development actually increases the surface area of the target formation that can be reached from one well pad. The amount of land that needs to be cleared for natural gas extraction from unconventional sources is therefore less than that needed for comparable resource extraction with conventional drilling.

---

[68] Cooley, 36.

[69] Pennsylvania Attorney General, "Greene County Business Owner Charged with Illegally Dumping Millions of Gallons of Gas Drilling Waste Water and Sewage Sludge", 17 Mar 2011, http://www.attorneygeneral.gov/press.aspx?id=6030.

[70] T.R. Schueler,"The Importance of Imperviousness", *Watershed Protection Techniques,* 1994, http://yosemite.epa.gov/R10/WATER.NSF/840a5de5d0a8d1418825650f00715a27/159859e0c556f1c988256b7f007525b9/$FILE/The%20Importance%20of%20Imperviousness.pdf.

iii. Seismic Activity

The underground injection of wastewater from unconventional drilling has been linked to an increase in induced seismic activity.[71] Both a recent British Department of Energy and Climate Change study and a U.S. Geologic Survey study have found an increase in seismic frequency that parallels increases in wastewater injections into deep wells in certain areas.[72,73] The National Research Council recently concluded its *Induced Seismicity Potential in Energy Technologies* study, which found that while hydraulic fracturing a well does not pose high risk for inducing detectable seismic events, the injection of fluids for waste disposal does pose some risk.[74] The study notes that these earthquakes are small and at times go unnoticed, but they have been measured and felt locally in a number of places.

Since the earthquakes are not associated with the actual fracturing stage of gas development, definitional discrepancy has once again fueled conflicting interpretation of studies and opposing claims by representatives on either side of the debate. In addition, as with the lack of baseline data for water contamination, poor pre-drilling seismic records have prevented firm conclusions from being drawn in some cases. The majority of evidence, however, suggests a correlation exists between increased injection well use and increased seismic activity. Though the seismic events to this point have been fairly benign, concern lies in the question of how an increasing number of injection wells receiving increasingly large volumes of disposal fluids will impact the frequency and strength of induced seismic events.

Across all areas of environmental concern there are recurring sources of contention that can be addressed by industry, researchers, and regulators so that progress can be made to clarify these debates. Issues include lack of baseline data, lack of transparency over definitional differences, protection of trade secrets for fracturing fluid composition, lack of transparency over funding sources, and reliance on assumptions and estimations. Where better regulations could ensure disclosure of fracturing fluid composition and require baseline testing; industry and academia must commit to transparency and honest research and reporting, relying on sound science. All stakeholders have a role in furthering the efforts to increase wastewater recycling and undertake other technological innovations to reduce the impact of unconventional drilling.

---

[71] "Induced seismic events" or "induced earthquakes" are those attributable to human activities.

[72] Christopher Green et al., *Review & Recommendations for Induced Seismic Mitigation*, British Department of Energy and Climate Change, Apr 2012, http://og.decc.gov.uk/assets/og/ep/onshore/5075-preese-hall-shale-gas-fracturing-review.pdf.

[73] W.L. Ellsworth et al., *Are Seismicity Rate Changes in the Midcontinent Natural or Manmade?* , U.S. Geological Survey, 18 April 2012, http://www.seismosoc.org/.

[74] National Research Council, *Induced Seismicity Potential in Energy Technologies*, The National Academies Press, 2012, http://books.nap.edu/catalog.php?record_id=13355.

Regulatory Framework

Oil and gas development in the U.S., including unconventional resource development using hydraulic fracturing, is regulated by a host of federal, state, and local laws. The majority of these exist at the state level. Debate is growing over the need for increased federal regulation. Many are skeptical that the current patchwork of state regulations cannot ensure that the safest and best practices will be upheld across the country, or provide uniformity and predictability for industry. Opponents to federal regulation argue, however, that states are better equipped to deal with both the physical environment and the standards of local communities within their borders. In this view, more regulation would only inhibit the development of what has proven to be a crucial energy source. There has been an increasing amount of federal involvement as public outcry over the impacts of drilling has intensified.

Federal Authority

EPA is the federal agency primarily responsible for the administration of federal environmental protection laws. Certain portions of the Clean Air Act (CAA), Clean Water Act (CWA), Safe Drinking Water Act (SDWA), Resource Conservation and Recovery Act (RCRA), Toxic Substances Control Act (TSCA), Emergency Planning and Community Right-To-Know Act (EPCRTKA) and Oil Pollution Act (OPA) apply to natural gas development. Many of these federal regulations grant primacy to the states to adopt their own standards. Where a state has acquired delegated authority under federal law, state regulations must be as protective as the proscribed federal standard, but may be more stringent than the federal standards they replace.

In addition, unconventional gas resource development on federally owned land is administered by multiple federal agencies, including the Bureau of Land Management (BLM) within the U.S. Department of the Interior (DOI) and the U.S. Forest Service within the U.S. Department of Agriculture (USDA).
In May 2012, U.S. DOI released a draft of its new rules for regulating hydraulic fracturing on federal and tribal lands. The proposed rule would implement three major policies: 1) public disclosure of all chemicals used in drilling following the completion of the well fracturing; 2) new guidelines for how drillers case wells, which must be approved prior to drilling; and, 3) submission of water management plans including wastewater disposal prior to drilling.[75] The extended public comment period closed in early September 2012.

[75] Bureau of Land Management, *Oil and Gas; Well Stimulation, Including Hydraulic Fracturing, on Federal and Indian* Lands, 43 CFR Part 3160, 11 May 2012, http://www.doi.gov/news/pressreleases/loader.cfm?csModule=security/getfile&pageid=293916.

State Authority

At the state level, standards are specific to varying conditions such as geology, hydrology, climate, topography, industry characteristics, development history, state legal structures, population density, and local economics.[76] Within each state there are often a variety of agencies responsible for regulation, permitting, and enforcement of activities related to all components of natural gas development—drilling and fracturing of the well, production, management and disposal of wastes, and abandonment and plugging of the well. Approaches to each component and enforcement mechanism vary across different states. Proponents of state regulation remark that states have a vested interest in protecting their natural resources and there is no "one-size-fits-all" approach given the many conditions that vary between states.

All oil and gas producing states require well operators to obtain a permit before they are authorized to begin drilling. Permit applications include information about well location, construction, operation, and reclamation that agency staff reviews for compliance with regulations in order to ensure adequate environmental safeguards. Due to the large number of permit requests, states have faced permitting and regulatory personnel shortages to grant and enforce these permits. Given the sheer increase in permit request volume, it is difficult to discern if adequate review is being conducted.

Given the complexity and diversity of the regulatory framework, many states have partnered with the Ground Water Protection Council (GWPC) and the State Review of Oil and Natural Gas Environmental Regulation, Inc. (STRONGER) to conduct voluntary reviews of state programs. GWPC specifically reviews Underground Injection Control programs while STRONGER reviews and documents improvements and effectiveness of other programs. The Secretary of Energy Advisory Board's (SEAB) Natural Gas Subcommittee, formed in 2011, recommends more support for these voluntary review programs.[77]

Existing & Proposed Federal Regulations

i. Regulations Applying to Air

Requirements for air emissions from unconventional gas production are largely consistent with the Clean Air Act, which sets national standards to limit levels of certain pollutants. When geographic areas do not meet required levels they are deemed "nonattainment areas." Gas developers located in nonattainment areas often must comply with more stringent requirements, imposed at the local or state level, until the area has achieved compliance levels.

---

[76] GWPC and ALL Consulting, ES-3.
[77] Secretary of Energy Advisory Board, *Shale Gas Production Subcommittee Second Ninety Day Report*, U.S. Department of Energy, 18 Nov 2011, http://www.shalegas.energy.gov/resources/111811_final_report.pdf.

Permits are required for air emissions, specifying what emission levels must be met and how the sources must be operated and monitored to ensure ongoing compliance. These permits must be amended following developments in regulations or changes to processes or equipment that impacts the existing permit.[78]

Industry specific regulations for certain air pollutants have become more prevalent in recent years. In April 2012, EPA finalized New Source Performance Standards (NSPS) and National Emission Standards for Hazardous Air Pollutants (NESHAPs) for oil and gas industries, for the first time expanding these air regulations to wells that are hydraulically fractured. The rules, said to be based on cost-effective and tested technologies currently in use by leaders in the hydraulic fracturing industry, aim to reduce emissions of VOCs, air toxics, and methane.

The central feature of the new rule is the requirement of a "reduced emission completion," or "green completion," to be use on all newly hydraulically fractured wells. The "green completion" process captures gas currently escaping during the flowback period, thereby reducing dangerous air pollutants including methane emissions. According to EPA estimates, this change would annually bring about a 95% reduction in VOCs emitted, prevent 12,000 to 20,000 tons of air toxics from entering the atmosphere, and prevent the equivalent of 19 to 33 million tons of CO_2 equivalent (in the form of methane) from escaping. When the rules are fully implemented in 2015, this would bring an estimated $11 to $19 million in cost savings to the industry from the resale of captured natural gas.[79] Though EPA's estimates of methane emission and cost savings are challenged by some in the industry, the willingness of other companies to implement this technology voluntarily, and the success of similar regulations where they already exist in states like Colorado and Wyoming, suggest that the rules will protect air quality, prevent greenhouse gas emissions, and allow for continued expansion of the industry.

The process by which this rule was created, revised, and finalized, provides a benchmark for addressing other issues of concern presented by fracking. EPA worked with states where similar rules were already in place and with industry leaders using the technology. The agency also incorporated many changes to the first draft of the regulations in response to public feedback. In doing so, regulations were made to be more flexible so that companies had time to obtain the needed equipment and have a more streamlined, less burdensome reporting framework. Such an adaptive, collaborative, and flexible approach is likely to be necessary moving forward on all issues surrounding hydraulic fracturing.

[78] GWPC and ALL Consulting, 37.
[79] U.S. EPA, *Overview of Final Amendments,* 2012.

ii. Regulations Applying to Water

Withdrawals

While state permitting requirements exist for water withdrawals, there are no federal limits on water use or requirements that recycled water make up a certain percentage of the total water volume used for fracturing a well.

Groundwater Contamination

The SDWA is EPA's central regulatory framework for protecting drinking water. Within this Act, the Underground Injection Control (UIC) program regulates subsurface injection of fluids. In passing the Energy Policy Act of 2005, however, Congress provided for an exclusion of hydraulic fracturing fluids from this regulation except when diesel fuels are used in the fracturing fluid.[80]

In May 2012, EPA published draft UIC Program permitting guidance for hydraulic fracturing activities using diesel fuels where EPA is the permitting authority. This guiding document attempts to provide "regulatory certainty" to existing standards. The public comment period for the draft ended in late August 2012.[81]

The Emergency Planning and Community Right-To-Know Act (EPCRTKA), enacted in 1986, was designed to protect public health and the environment from chemical hazards by requiring EPA and the states to collect data on releases and transfers of listed toxic chemicals manufactured, processed, or used above certain levels by industries. Industrial facilities subject to such reporting requirements must be included in the listing as a Standard Industrial Classification (SIC). The oil and gas industry has yet to be included as an SIC and is thus exempt from reporting requirements for chemicals such as those in fracturing fluids.[82]

In 2009, legislation known as the Fracturing Responsibility and Awareness of Chemicals, (FRAC Act) was proposed in both the House and Senate. The bill calls for the repeal of the SDWA exemption and mandatory disclosure of chemicals used in operations. The bill has not been acted upon, ostensibly in anticipation of

[80] U.S. Environmental Protection Agency, *Regulation of Hydraulic Fracturing Under the Safe Drinking Water Act,* http://water.epa.gov/type/groundwater/uic/class2/hydraulicfracturing/wells_hydroreg.cfm.

[81] U.S. Environmental Protection Agency, *Permitting Guidance for Oil and Gas Hydraulic Fracturing Activities Using Diesel Fuels – Draft: Underground Injection Control Program Guidance #84,* May 2012, http://water.epa.gov/type/groundwater/uic/class2/hydraulicfracturing/upload/hfdieselfuelsguidance508.pdf.

[82] William J. Brady, *Hydraulic Fracturing Regulation in the United States: The Laissez-Faire Approach of the Federal Government and Varying State Regulations*, University of Denver Sturm College of Law, 2012, p. 7, http://law.du.edu/documents/faculty-highlights/Intersol-2012-HydroFracking.pdf.

results from EPA's planned study.[83] Voluntary disclosure of chemicals used in fracturing operations has been ongoing via FracFocus and at least ten states have implemented or are developing public disclosure rules related to fracturing.[84]

Wastewater

The disposal of wastewater into injection wells, the most commonly used disposal method, is also regulated under the SDWA's UIC program, which intends to prevent the injection of wastes into underground sources of drinking water (USDW). Although wastewater from unconventional gas development is known to contain toxins such as dissolved solids, metals, and radionuclides, wastes associated with oil and gas production were determined in 1989 by EPA to be exempt from hazardous waste regulations under the Resource Conservation and Recovery Act (RCRA).[85] Thus, injection wells for unconventional drilling wastewater are categorized as Class II wells.[86] Where Class I wells are defined as those for the injection of fluids containing hazardous wastes and are thus regulated under RCRA, Class II well requirements are much less stringent, as this category is intended for nonhazardous wastes. This categorization was made following an EPA report that noted that while some oil and gas wastes were hazardous, federal regulation under RCRA was unwarranted because of the economic importance of the industry and the regulations in place in the states. Since fluids associated with oil and gas production only require Class II wells, states may obtain primacy over regulation and—due to mandated considerations of local conditions and practices—do not have to adopt all of the federal UIC regulations.[87] The state must, however, demonstrate that its existing program protects USDWs as effectively as the federal controls.

Shale and other unconventional gas operators must comply with traditional National Pollutant Discharge Elimination System (NPDES) permitting requirements under the Clean Water Act (CWA). Thus, if producers or commercial facilities that handle disposal intend to discharge directly to surface waters, permits must be obtained. The permitting authority must consider the impact to the receiving water and ensure that the water body remains in compliance with the CWA and NPDES, so more stringent limits may be included in the permit. [88]

---

[83] Carolyn Bergner, *Regulating Hydraulic Fractuing in Natural Gas Development*: *A Policy Analysis*, U.S. EPA Office of Research and Development, 22 Jul 2011, http://www.sts.virginia.edu/pip/research_papers/2011/Bergner.pdf.
[84] FracFocus, *Chemicals & Public Disclosure,* 2012, http://fracfocus.org/chemical-use/chemicals-public-disclosure.
[85] GWPC and ALL Consulting, 37.
[86] ibid, 32.
[87] ibid, 33.
[88] Ibid, 30.

EPA has relied on the development of the voluntary STRONGER program to improve state regulations that have deficiencies in waste control. STRONGER has reviewed 22 states (representing over 94% of domestic oil and gas development) and conducted hydraulic fracturing specific reviews in six states.[89] While this is an important component to ensuring regulations are robust, it lacks the all-encompassing nature and enforcement capability of federal regulations. Some states, like Pennsylvania, have special handling and disposal requirements for oil and gas wastes, despite the RCRA exemption.[90] While some states are adding further measures of protection, this type of regulatory action is not universal. Nationwide inconsistency is concerning, especially given the known hazardous characteristics of much of the wastewater from unconventional oil and gas development.

In October 2011, EPA initiated a rulemaking process to address wastewater concerns from shale gas development when water is disposed of via treatment facilities. The rule would likely be a pretreatment standard for wastewater that must be met before the water can be transported to a treatment facility, since facilities are currently unequipped to deal with the characteristic contaminants of waste fluids from unconventional gas extraction. The new standards are expected to be published for public comment in 2014.[91]

None of the current or proposed regulation related to groundwater contamination or wastewater management addresses the issue of wastewater reuse. Wastewater may be repurposed for deicing roads, dust suppression, irrigation, livestock watering, or other industrial uses. In these capacities its exemption status from hazardous waste classification under RCRA is unchanged. The risk of groundwater contamination from these uses is therefore significant.

iii. Regulations Applying to Ecosystem Degradation

Spills, Leaks, and Runoff

Concerning surface spills, operators must report releases of hazardous chemicals at threshold quantities (other than oil and gas) under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and may then be liable for cleaning up the spills. This would include spills of fracturing

---

[89] State Review of Oil & Natural Gas Environmental Regulations, *Past Reviews*, http://www.strongerinc.org/past-reviews.

[90] Hannah J. Wiseman and Francis Gradijan, *Regulation of Shale Gas Development, Including Hydraulic Fracturing,* Energy Institute, University of Texas Austin, 31 Oct 2011, p. 24, http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1953547&download=yes.

[91] U.S. Environmental Protection Agency, *Fact Sheet: EPA Initiates Rulemaking to Set Discharge Standards for Wastewater from Shale Gas Extraction*, Oct 2011, http://water.epa.gov/scitech/wastetech/guide/upload/shalereporterfactsheet.pdf

chemicals and flowback fluid, but operators would not be liable for oil or natural gas, including liquefied natural gas.[92]

The CWA Section 402(1)(2) regulates stormwater runoff from municipal, industrial, and construction sites under an NPDES permitting structure as well. This framework, however, was modified to exclude all oil and gas field activities and operations as a result of the Energy Policy Act of 2005. The modification was revised following a 2008 U.S. Court of Appeals ruling.[93] Now, contaminated stormwater discharges (including those contaminated with sediment) causing or resulting in a water quality violation require permit coverage under the NPDES stormwater permitting program. EPA has made clear that states and tribes are free to regulate other stormwater discharges under their own non-NPDES permit programs. The industry has a voluntary program of Reasonable and Prudent Practices for Stabilization (RAPPS) of oil and gas construction sites to control erosion and sedimentation due to stormwater runoff from areas that have been cleared, graded, or excavated for site preparation.[94]

Seismic Activity

Due to the categorization of waste from shale and other unconventional gas extraction as a non-hazardous waste, the disposal injection wells are only subject to Class II well requirements. Unlike Class I requirements, Class II requirements do not specify consideration of earthquake risk in well siting.[95]

Differences in State Regulations

Given the frequent exemptions of the oil and gas industry from federal regulations, the focus turns to state regulations and whether or not they adequately protect the environment and human health. States can regulate hydraulic fracturing and related processes as they see fit but must meet the minimum requirements of federal regulations where they apply. In many cases, state laws are even more protective, but in others there are still gaps and varying levels of complexity and specificity, leaving room for continued concern in light of environmental threats.

Some states, like Vermont, New York, New Jersey, and Maryland have banned or set moratoria on unconventional development using hydraulic fracturing. New York's governor, Andrew Cuomo, is expected to allow shale gas drilling in several New York counties along the border with Pennsylvania, but only in communities

---

[92]Wiseman and Gradijan, 25.
[93] *National Resource Defense Council v. U.S. Environmental Protection Agency*, U.S. Court of Appeals, 9th Circuit Court, 23 May 2008, http://www.epa.gov/npdes/regulations/oilandgas_nrdc_v_epa.pdf.
[94] GWPC and ALL Consulting, 32.
[95] Hammer and van Briesen, 2012, Chp 4.

that support it.[96] North Carolina's Senate and House of Representatives voted in July 2012 to legalize hydraulic fracturing and horizontal drilling in the state where it was previously banned.[97]

Certain states have often stood out as leaders in regulation of natural gas development. Wyoming and Colorado, for example, implemented statewide requirements for green completions before they were included in the latest NSPS updates from EPA. Wyoming also introduced chemical disclosure regulations in 2010 that require disclosure both before and after well fracturing.[98]

Implementation of standards in some cases has been a reaction to environmentally harmful practices. For example, in North Dakota, more than 1,000 accidental releases of oil, drilling wastewater, and other fluids from truckloads dumped along the road or illegally drained waste pits occurred in 2011. Only 50 disciplinary actions for those types of violations were filed in the past three years. In response, North Dakota's legislature passed new regulations in 2012 including banning storage of wastewater in open pits.[99] California is the only other state that has banned storage in open pits.[100] Examples like this challenge the notion that the regulatory framework set up by the states is adequate; for there is no doubt that similar violations are occurring in other states.

Best Practices

The widespread adoption of best management practices (BMPs) has been touted as one way to standardize and ensure safety across operations where regulations are inconsistent. Entities including federal and state agencies, communities, industry, and academic groups have compiled BMPs or encourage their use so as to avoid unnecessary harm to the environment and inefficiencies in the extraction process. The University of Colorado's Natural Resource Law Center includes a searchable database of BMPs as part of their Intermountain Oil and Gas BMP Project. The Marcellus Shale Coalition, based in Pennsylvania, has been working

---

[96] Danny Hakim, "Cuomo Proposal Would Restrict Gas Drilling to a Struggling Area", *New York Times,* 13 Jun 2012, http://www.nytimes.com/2012/06/14/nyregion/hydrofracking-under-cuomo-plan-would-be-restricted-to-a-few-counties.html?hp.
[97] Spilman Thomas & Battle, PLLC, *The State of Hydraulic Fracturing in North Carolina,* 27 Jul 2012, http://www.jdsupra.com/legalnews/the-state-of-hydraulic-fracturing-in-nor-94206/.
[98] "Fracking Chemical Disclosure Rules", *ProPublica,* 16 Feb 2012, http://www.propublica.org/special/fracking-chemical-disclosure-rules.
[99] Nicholas Kusnetz, "North Dakota Turns Blind Eye to Dumping of Fracking Waste in Waterwars and Farmland", *Inside Climate News*, 8 Jun 2012, http://insideclimatenews.org/news/20120608/oil-campanies-north-dakota-boom-gas-drilling-fracking-wastewater-waterways-pollution-dumping-grounds.
[100] Resources for the Future, *A Review of Shale Gas Regulations by State,* Jul 2012, http://www.rff.org/centers/energy_economics_and_policy/Pages/Shale_Maps.aspx.

with its industry members and other stakeholders to compile an online library of recommended practices.

The American Petroleum Institute is one group that has set out a comprehensive set of guidelines for the industry[101]. The extent to which state laws reflect these standards varies greatly. Table 1 (below) shows selected results from a recent review of state regulations for oil and gas drilling, specifically for hydraulic fracturing, as they relate to the environmental concerns outlined previously. Researchers from Resource for the Future's Center for Energy Economics and Policy examined more than 20 types of regulations and surveyed regulators in 31 states, using API guidelines to put regulatory differences in perspective.[102] This is not a comprehensive list of their findings, but rather details some differences in regulations most pertinent to the environmental concerns discussed in this paper and regarding enforcement. The study's authors note that instances where states regulate parts of the extraction process on a case-by-case basis through permitting requirements are not included in the study.

As Table 1 demonstrates, state regulations have a fair number of inconsistencies. Though BMPs are useful and their implementation should be encouraged, they lack any means of ensuring implementation or compliance.

Table 1.

Environmental Concern Area		Patterns and Variances in State Regulations	API Best Practices Guidelines
Air	Natural Gas Emissions	Most states surveyed have some form of **venting** (22 states) or **flaring** (23 states) regulations. Some regulations restrict the amount of gas, length of time, or specific phase of development during which flaring or venting can occur. Some states have "aspirational standards" which require operators to minimize gas waste or protect public health with no effective requirement or standard.	All gas resources of value that cannot be captured and sold should be flared. Both venting and flaring should be restricted to safe locations and oriented downwind.

[101] American Petroleum Institute, *Overview of Industry Guidance/Best Practices on Hydraulic Fracturing*, 2011, http://www.api.org/~/media/Files/Policy/Exploration/Hydraulic_Fracturing_InfoSheet.ashx.
[102] Resources for the Future, *A Review of Shale Gas Regulations by State,* Jul 2012, http://www.rff.org/centers/energy_economics_and_policy/Pages/Shale_Maps.aspx.

Water	**Withdrawal Limits**	21 of the States require general **permits**, but several states do not require permits for volumes below a threshold level. Louisiana and Kentucky exempt oil and gas industry from water withdrawal requirements.	Consultation with appropriate water management agencies is a must and operators should consider using non-potable water for drilling and hydraulic fracturing.
	Potential Groundwater Contamination	Regulations in 22 states do not mention **pre-drilling testing** of well water at drilling sites to establish baseline water quality prior to development. These include 4 of the 5 biggest shale gas producing states as of 2009.	Water samples from any source located near the well (based on anticipated fracture length) should be tested before drilling or fracturing begins.
		Fewer than half of the States studied (14) require mandatory **disclosure of chemicals** and many of these allow drillers to claim trade secret protection for chemicals considered proprietary.	Operators should be prepared to disclose information on chemical additives. The best practice is to use additives that pose minimal risk to human health while maintaining effectiveness for fracturing.
		10 states specify **cement type for well casing** that API guidelines specify should be used as a critical barrier to prevent gas or wastewater leaks from contaminating water aquifers.	API established standards for cement type should be consulted and selected cements, additives, and mixing fluid should be laboratory tested in advance of use.
		13 states specify the **casing depth** based on the water table (ranging from 30-120 ft. below it). 10 states set depths for individual wells and have a general performance standard requiring drillers to protect freshwater aquifers. VA has no regulations for casing or cementing.	Casing and cementing depth should be 100 feet below the deepest underground source of drinking water encountered while drilling the well.
	Wastewater	Wastewater and pre-drilling fluids may be stored on-site in storage pits. 18 of the 27 states that allow pit storage require **liners**. Some states have conditional liner requirements while 6 states have none. **Freeboard requirements** prevent overflows in these pits.[103] Only 16 states have freeboard regulations ranging from 1-3 ft.	Depending on the fluids being place in the pits, a lining may be necessary to prevent infiltration of fluids into the subsurface. Pits should be constructed with sufficient freeboard to prevent overflow under maximum anticipated operating requirements and precipitation.

---

103 The freeboard is the distance between the maximum water level and the top of the pit. Source: Resources for the Future, 2012.

Ecosystem Degradation	**Seismic Concerns**	Areas of Texas, Ohio and Arkansas have moratoria on **injection well** drilling due to recent seismic activity. 30 states allow deep well injection. North Carolina prohibits it.	Where an injection well is available, fluids should be disposed of by underground injection as the practice "is widely recognized as being environmentally sound, is well regulated, and has been proven effective."
	Spills and Leaks	26 states require **reporting of accidents** (spills, leaks, and fires). The time range reporting requirement varies from immediate reporting to 48 hours	A spill or leak should be promptly reported.
Enforcement	**Inspectors per Well**	State regulations range from having one inspector for 30 to 140 wells (IN) to having 1 inspector for 501-1,630 wells (in KS, WY, CO, TX, four of the largest shale gas development states as of 2009).	Appropriate equipment should be used for all operations, and inspections/maintenance performed according to design and manufacturer's requirements. Pipelines should be tested for integrity after installation and inspected as appropriate to ensure they are not leaking.

Legal Implications

The rapidity of unconventional resource development has led to a parallel escalation in litigation regarding aquifer contamination, property rights, injury torts, disposal of wastewater, and the apparent link between hydraulic fracturing and earthquakes. Since 2008, there have been at least 80 lawsuits related to hydraulic fracturing including civil tort actions, citizen suits, government enforcement actions, Freedom of Information Act (FOIA) lawsuits, challenges to municipal actions, challenges to agency actions, challenges to state and federal laws and regulations, contract disputes, oil & gas lease disputes, other land use disputes, defamation and strategic lawsuit against public participation (SLAPP) suits, and constitutional claims.[104] Plaintiffs have filed under a broad range of claims including: negligence, nuisance, strict liability, trespass, medical monitoring, breach of contract, fraud, assault, and intentional infliction of emotional distress.[105]

Many cases have alleged a causal connection between hydraulic fracturing activities and nearby water contamination. Plaintiffs have claimed that toxic

---

[104] Hydraulic Fracturing Case Chart, *Arnold & Porter LLP*, 10 Sep 2012, http://www.arnoldporter.com/resources/documents/Hydraulic%20Fracturing%20Case%20Chart.pdf.

[105] Beverlee Silva and Joshua Becker, "Lawsuits Related to Shale Gas Drilling", *58thAannual Meeting – San Francisco*, 13 Jun 2012.

chemicals used during the fracturing process polluted freshwater aquifers, that defective casing allowed diesel fuel, barium, manganese, methane, ethane, and strontium to migrate to water wells, and that natural gas migration resulted in elevated levels of dissolved methane in well water. Cases of this nature are ongoing in Pennsylvania, Texas, Arkansas, Colorado, Louisiana, New York, and West Virginia. In addition to civil suits, state government agencies have filed actions against oil and gas companies on behalf of plaintiffs. In the well contamination cases in Dimock, Pennsylvania (detailed in *Groundwater Contamination* section), a 2010 lawsuit was filed by the Pennsylvania Department of Environmental Protection on behalf of families in Dimock against Cabot Oil and Gas. The government action ended in a settlement under which Cabot paid $4.1 million in compensation to families and a $500,000 penalty to PDEP.[106] Cabot resumed drilling and the families continued their civil suit against the company. This was finally settled in August 2012 after EPA released testing on over 60 wells that found the drinking water to be safe.[107] The terms of the settlement are confidential. In many similar cases, settlements agreements have been reached or the plaintiffs have dismissed the cases.

Class action cases have also been brought against gas companies for property damages caused by earthquakes associated with hydraulic fracturing operations. A number of recent studies, including those mentioned previously (see *Seismicity* section), are drawing connections between wastewater injections and earthquake frequency. Expert testimony regarding these studies is likely to influence the outcome of cases filed in that regard, and ultimately inform the decision-making process where specific regulations are absent. The pending environmental studies and regulations under consideration, ongoing debate over federal versus state regulations, and continued development of industry standards and voluntary best practices not yet under regulation, will continue to shape the evolution of litigation around these issues.

---

[106] Barclay Nicholson et al., *Fracking's Alleged Links to Water Contamination and Earthquakes,* American Bar Association, 9 May 2012, http://apps.americanbar.org/litigation/committees/energy/articles/spring2012-0512-frackings-alleged-links-water-contamination-earthquakes.html. .

[107] U.S. EPA, "EPA Completes Drinking Water Sampling in Dimock".

Conclusion

While there are many unknowns surrounding the ever-heightened hydraulic fracturing debate, there is clarity on a few aspects. First, the economic potential that the development of U.S. natural gas supply holds is undeniable. The vast unconventional reserves—now accessible with the technologies of hydraulic fracturing and horizontal drilling—have led to job creation, decreased energy costs, reduced dependence on foreign oil, and if exported, could come to bear on the balance of trade and improve the U.S.'s international negotiating position. It is also generally agreed that natural gas for electricity generation is a cleaner burning fuel—with fewer air pollutants and greenhouse gas emissions—than coal power. Given their promise and proven contributions to the U.S. energy supply, the technologies of hydraulic fracturing and horizontal drilling should be explored with a goal toward safe, environmentally sound development.

The risks of these practices, however, are yet to be fully known. The lack of concrete information has led to public distrust, restrictive regulation, litigation, and, in some cases, outright bans. For these results to be avoided, industry must be proactive in self-regulation and sensitive to concerns. This must go beyond simple compliance with regulations now in place. For the industry to gain the public's trust, it must follow best practices and standards that are available, and in general, proceed with care and attentiveness to the influence of operations on the environment and communities. In particular, focus must be placed on finding and implementing innovative methods or technologies for minimizing impact on water resources and reusing waste generated. Where reuse is not possible, proper disposal is absolutely essential. Transparency, provision of data, and collaboration, especially as academics and regulators seek stronger empirical evidence, will determine the fate of the industry.

Non-governmental organizations, universities, and scientific institutions researching the vital questions surrounding hydraulic fracturing must also uphold standards of transparency, especially when it comes to presenting empirical evidence and diagnosing uncertainties fairly. Matters of definitional discrepancy must not be exploited, and a more concerted effort must be made by reporting bodies to present the information clearly and concisely. The goal should be public understanding, not simply public pronouncements.

Regulatory bodies, both state and federal, must take a careful look at the evidence presented and the tools available, using the best science to inform decisions. States should utilize review programs like STRONGER to ensure their regulations are adequate and be ready and willing to implement new rules as new evidence dictates. They must also work closely with the federal government. EPA and other federal agencies must likewise be ready and willing to integrate feedback from states, industry, and researchers into their decisions. As with the new NSPS standards, both state and industry must participate in reshaping and informing federal regulation.

The federal government has already taken some strides toward a collaborative approach to this issue with the formation of the *Interagency Working Group to Support Safe and Responsible Development of Unconventional Domestic Natural Gas Resources*. This body was established following an Executive Order from the President on Aril 13, 2012 and consists of thirteen federal agencies tasked with coordinating policy activities, sharing of scientific environmental, technical and economic information, long-term planning for natural resource assessment and infrastructure development, and promoting interagency communication.[108]

Where further federal regulations are under consideration, decision-makers must uphold a flexible, adaptable, and collaborative approach, and other stakeholders, including states, industry, academia, and NGOs, must participate fully. It is possible that many aspects of this issue are best regulated at the state level where regulators have the necessary familiarity with local conditions, geology, industry characteristics, legal structures, and economics. In areas where pollutants know no legal boundaries, as with air and water, and in cases where inconsistencies in state regulations jeopardize natural resources and human health, there may be a real need for the establishment of consistent standards and protections nationwide. Any new federal regulations must be based on sound science, retain flexibility for states or operational differences, be adaptable as the surrounding science becomes stronger, and strive to keep the processes of permitting and compliance as streamlined as possible to increase accountability and enforceability while maintaining cost efficiency. In this way, the continued development of this industry with minimal impacts on the environment and natural resources, negligible impacts to human health, and maximum benefits to communities and citizens across the nation and across the globe, remains within reach.

[108] Office of the Press Secretary, "Executive Order—Supporting Safe and Responsible Development of Unconventional Domestic Natural Gas Resources", 13 Apr 2012, http://www.whitehouse.gov/the-press-office/2012/04/13/executive-order-supporting-safe-and-responsible-development-unconvention.

Key Take-Aways

The following summarizes the key take-aways from The Horinko Group's Guidebook on Hydraulic Fracturing:

Adaptability & Flexibility

- Flexibility of regulations as scientific certainty evolves
- Regulation tailored to diversity across industry
- Willingness of industry practitioners to adopt changes as best practices and new technologies emerge

Transparency & Reliance on Sound Science

- Industry must remain open and honest about its practices
- Research and regulation based on unbiased data and sound science
- Present information clearly to the public to prevent an uninformed and unproductive dialogue

Innovative Research

- Continued pursuit of creative solutions to environmental issues, especially as related to mitigating the burden on water resources and managing wastewater
- Continued investment in renewable resources by government and industry

Collaboration

- Build on the experience and expertise of others
- Dissemination of best practices that mitigate environmental detriment while enabling industrial growth
- Identification of the most critical research needs and the steps needed to address them
- Sharing of scientific, technical, economic, legal, and long-term planning information

Path Forward

The Horinko Group, in its tradition of fostering productive collaboration around complex issues, aims to canvass stakeholders in the coming months to determine whether enough interest exists for a new form of coalition to be created around unconventional gas development. Given our experience and expertise in water quality and supply, waste remediation, and environmental regulation, we are uniquely equipped to facilitate effective conversation and strategic alignment between public and private organizations with a stake in the success of unconventional gas development.

This guidebook explores the crosscutting and interdisciplinary nature of the environmental, regulatory, and legal issues associated with hydraulic fracturing. An exchange of ideas and expertise across all disciplines would provide the springboard to proactively address the issues outlined within this document. This is the role that The Horinko Group envisions such a coalition fulfilling, while providing members with the opportunity to remain involved in the process and keep track of its many moving pieces.

In a time of economic and regulatory uncertainty as well as environmental vulnerability, the need for efficient and effective progress to be made is clear. We propose that a coalition would go a long way towards protecting our natural resources, protecting human health, and ensuring the intelligent and environmentally sound growth of an industry that will play an undeniable role in the nation's energy future.

Contact Us

For additional information on any aspect of this guidebook and interest in joining a coalition around the issues presented, please contact:

Brendan P. McGinnis
Managing Partner
The Horinko Group
bmcginnis@thehorinkogroup.org

2300 N ST NW
Suite 2130
Washington, DC 20037

References

American Petroleum Institute. *Freeing Up Energy*. 19 Jul 2010. http://www.api.org/policy/exploration/hydraulicfracturing/upload/HYDRAULIC_FRACTURING_PRIMER.pdf.

American Petroleum Institute. *Overview of Industry Guidance/Best Practices on Hydraulic Fracturing*. 2011. http://www.api.org/~/media/Files/Policy/Exploration/Hydraulic_Fracturing_InfoSheet.ashx.

Bergner, Carolyn. *Regulating Hydraulic Fractuing in Natural Gas Development*: *A Policy Analysis*. U.S. EPA Office of Research and Development. 22 Jul 2011. http://www.sts.virginia.edu/pip/research_papers/2011/Bergner.pdf.

Budzik, Philip. *U.S. Natural Gas Markets: Relationship Between Henry Hub Spot Prices and U.S. Wellhead Prices*. U.S. Energy Information Administration. http://www.eia.gov/oiaf/analysispaper/henryhub/.

Bureau of Land Management. *Oil and Gas; Well Stimulation, Including Hydraulic Fracturing, on Federal and Indian* Lands. 43 CFR Part 3160. 11 May 2012. http://www.doi.gov/news/pressreleases/loader.cfm?csModule=security/getfile&pageid=293916.

Brady, William J. *Hydraulic Fracturing Regulation in the United States: The Laissez-Faire Approach of the Federal Government and Varying State Regulations*. University of Denver Sturm College of Law. 2012. http://law.du.edu/documents/faculty-highlights/Intersol-2012-HydroFracking.pdf.

Brookings Institute. *A Strategy for U.S. Natural Gas Exports*. The Hamilton Project. Jun 2012. http://www.brookings.edu/~/media/research/files/papers/2012/6/13%20exports%20levi/06_exports_levi_brief.pdf.

Cathles, Lawrence. *Assessing the greenhouse impact of natural gas*. Geochemistry Geophysics Geosystems. 19 Jun 2012. http://www.energyindepth.org/wp-content/uploads/2012/07/Cathles-Assessing-greenhouse-impact-natgas-June2012.pdf.

Chesapeake Energy. *Aqua Renew*. http://www.chk.com/environment/water/pages/aqua-renew.aspx

Cooley, Heather and Kristina Donnelly. *Hydraulic Fracturing and Water Resources: Separating the Frack from the Fiction*. Pacific Institute. Jun 2012. http://www.pacinst.org/reports/fracking/index.htm.

Deloitte Consulting LLP. *On the road again: Managing transportation logistics for unconventional drilling*. 2012. http://www.deloitte.com/assets/Dcom-UnitedStates/Local%20Assets/Documents/Consulting%20MOs/CSMLs/us_consulting_Managingtransportationlogisticsforunconventional_06212012.pdf.

Efstathiou, Jim Jr. "Frackers Fund University Research that Proves their Case". *Bloomberg News*. 23 Jul 2012. http://www.bloomberg.com/news/2012-07-23/frackers-fund-university-research-that-proves-their-case.html.

Ellsworth, W.L. et al. *Are Seismicity Rate Changes in the Midcontinent Natural or Manmade?* U.S. Geological Survey. 18 April 2012. http://www.seismosoc.org/.

FracFocus. *Chemicals & Public Disclosure*. 2012. http://fracfocus.org/chemical-use/chemicals-public-disclosure.

"Fracking Chemical Disclosure Rules". *ProPublica*. 16 Feb 2012. http://www.propublica.org/special/fracking-chemical-disclosure-rules.

"From Coal to Gas: The Potential Risks and Rewards". *National Public Radio*. 15 Jul 2012. http://www.npr.org/2012/07/15/156814490/from-coal-to-gas-the-potential-risks-and-rewards.

The Future of Natural Gas. Massachusetts Institute of Technology. 2011. http://web.mit.edu/mitei/research/studies/natural-gas-2011.shtml.

"Getting Natural Gas Right", *Environmental Defense Fund,* 2012, http://www.edf.org/energy/getting-natural-gas-right.

Green, Christopher et al. *Review & Recommendations for Induced Seismic Mitigation*. British Department of Energy and Climate Change. http://og.decc.gov.uk/assets/og/ep/onshore/5075-preese-hall-shale-gas-fracturing-review.pdf.

Groat, Charles and Thomas Grimshaw. *Fact-Based Regulation for Environmental Protection in Shale Gas Development*. University of Texas at Austin. Feb 2012. http://energy.utexas.edu/images/ei_shale_gas_regulation120215.pdf.

Ground Water Protection Council (GWPC) and ALL Consulting. *Modern Shale Gas Development in the United States*. Apr 2009. http://www.marcellus.psu.edu/resources/PDFs/NETLprimer.pdf.

Hakim, Danny. "Cuomo Proposal Would Restrict Gas Drilling to a Struggling Area". *New York Times*. 13 Jun 2012. http://www.nytimes.com/2012/06/14/nyregion/hydrofracking-under-cuomo-plan-would-be-restricted-to-a-few-counties.html?hp.

Hammer, Rebecca and Jeanne VanBriesen. *In Fracking's Wake: New Rules are Needed to Protect Our Health and Environment from Contaminated Wastewater*. National Resources Defense Council. May 2012. http://www.nrdc.org/energy/files/Fracking-Wastewater-FullReport.pdf.

Henricks, Mark. "Energy industry works to recycle hydrofracking waste water." *American Recycler*. May 2012.

Howarth, Robert et al. *Methane and the Greenhouse-gas Footprint of Natural Gas from Shale Formations*. 13 Mar 2011. http://www.sustainablefuture.cornell.edu/news/attachments/Howarth-EtAl-2011.pdf.

Howarth, Robert et al. *Venting and Leaking of Methane from Shale Gas Development: Response to Cathles et al.* 1 Feb 2012. http://www.springerlink.com/content/c338g7j559580172/fulltext.pdf?MUD=MP.

IHS Global Insight. *The Economic and Employment Contributions of Shale Gas in the United States*. Prepared for America's Natural Gas Alliance. Dec 2011. http://anga.us/media/235626/shale-gas-economic-impact-dec-2011.pdf.

"In Wyoming, industry foots bill to hire more regulators". *Energy & Environment News*, *Greenwire*. 25 Jun 2012.

International Energy Agency. *Golden Rules for a Golden Age of Gas: World Energy Outlook Special Report on Unconventional Gas*. 2012. http://www.worldenergyoutlook.org/media/weowebsite/2012/goldenrules/WEO2012_GoldenRulesReport.pdf .

Interstate Oil and Gas Compact Commission. *Protecting Our Country's Resources: The States' Case*. Orphaned Well Plugging Initiative, Department of Energy National Energy Technology Laboratory. 2008. http://groundwork.iogcc.org/sites/default/files/2008-Protecting- Our-Country%27s-Resources-The-States%27-Case.pdf.

Kargbo, David et al. *Natural Gas Plays in the Marcellus Shale: Challenges and Potential Opportunities*. Environmental Science and Technology. Vol. 44, No. 15. 2010. http://pubs.acs.org/doi/pdf/10.1021/es903811p.

Klimasinska, Kasia and Jim Efstathiou Jr. "Drought Helps Fracking Foes Build Momentum For Recycling". *Bloomberg News*. 23 Jul 2012. http://www.bloomberg.com/news/2012-07-23/drought-helps-fracking-foes-build-momentum-for-recycling.html.

Kusnetz, Nicholas. "North Dakota Turns Blind Eye to Dumping of Fracking Waste in Waterwars and Farmland". *Inside Climate News*. 8 Jun 2012. http://insideclimatenews.org/news/20120608/oil-campanies-north-dakota-boom-gas-drilling-fracking-wastewater-waterways-pollution-dumping-grounds.

Lomborg, Bjorn. "A Fracking Good Story". *Project Syndicate*. 15 Sep 2012. http://www.slate.com/articles/health_and_science/project_syndicate/2012/09/thanks_to_fracking_u_s_carbon_emissions_are_at_the_lowest_levels_in_20_years_.html.

Myers, Tom. *Potential Contaminant Pathways from Hydraulically Fractured Shale to Aquifers*. National Ground Water Association. 17 Apr 2012. http://onlinelibrary.wiley.com/doi/10.1111/j.1745-6584.2012.00933.x/full.

National Research Council. *Induced Seismicity Potential in Energy Technologies*. The National Academies Press. 2012. http://books.nap.edu/catalog.php?record_id=13355.

National Resource Defense Council v. U.S. Environmental Protection Agency. U.S. Court of Appeals, 9th Circuit Court. 23 May 2008. http://www.epa.gov/npdes/regulations/oilandgas_nrdc_v_epa.pdf.

Nicholson, Barclay et al. *Fracking's Alleged Links to Water Contamination and Earthquakes*. American Bar Association. 9 May 2012. http://apps.americanbar.org/litigation/committees/energy/articles/spring2012-0512-frackings-alleged-links-water-contamination-earthquakes.html.

Office of the Press Secretary. "Executive Order—Supporting Safe and Responsible Development of Unconventional Domestic Natural Gas Resources". 13 Apr 2012. http://www.whitehouse.gov/the-press-office/2012/04/13/executive-order-supporting-safe-and-responsible-development-unconvention.

Osborn, Stephen et al. *Methane contamination of drinking water accompanying gas-well drilling and hydraulic fracturing*. Proceedings of the National Academy of Sciences. 17 May 2011. http://www.pnas.org/content/108/20/8172.

Pennsylvania Attorney General. "Greene County Business Owner Charged with Illegally Dumping Millions of Gallons of Gas Drilling Waste Water and Sewage Sludge". 17 Mar 2011. http://www.attorneygeneral.gov/press.aspx?id=6030.

Pennsylvania Department of Environmental Protection. "Consent Order and Settlement Agreement". 2010. http://www.cabotog.com/pdfs/FinalA_12-15-10.pdf.

Petron, Gabrielle et al. *Hydrocarbon emissions characterization in the Colorado Front Range – A pilot study*. Journal of Geophysical Research. 2012. http://www.agu.org/pubs/crossref/pip/2011JD016360.shtml.

Resources for the Future. *A Review of Shale Gas Regulations by State*. Jul 2012. http://www.rff.org/centers/energy_economics_and_policy/Pages/Shale_Maps.aspx.

Schueler, T.R. "The Importance of Imperviousness." *Watershed Protection Techniques*. 1994. http://yosemite.epa.gov/R10/WATER.NSF/840a5de5d0a8d1418825650f00715a27/159859e0c556f1c988256b7f007525b9/$FILE/The%20Importance%20of%20Imperviousness.pdf.

Secretary of Energy Advisory Board. *Shale Gas Production Subcommittee Second Ninety Day Report*. U.S. Department of Energy. 18 Nov 2011. http://www.shalegas.energy.gov/resources/111811_final_report.pdf.

Shires, Terri and Miriam Lev-On. *Characterizing Pivotal Sources of Methane Emissions from Unconventional Natural Gas Production*. URS Corporation and The LEVON Group. Prepared for American Petroleum Institute and America's National Gas Alliance. 1 Jun 2012. http://www.api.org/news-and-media/news/newsitems/2012/jun-2012/~/media/Files/News/2012/12-July/Task2-API-ANGA-Survey-Report-19-July.ashx.

Silva, Beverlee and Joshua Becker. "Lawsuits Related to Shale Gas Drilling". *58th Aannual Meeting – San Francisco*. 13 Jun 2012.

Soeder, Daniel and William Kappel. *Water Resources and Natural Gas Production from the Marcellus Shale*. U.S. Geological Survey (USGS). May 2009. http://md.water.usgs.gov/publications/fs-2009-3032/fs-2009-3032.pdf.

Spilman Thomas & Battle, PLLC. *The State of Hydraulic Fracturing in North Carolina*. 27 Jul 2012. http://www.jdsupra.com/legalnews/the-state-of-hydraulic-fracturing-in-nor-94206/.

State Review of Oil & Natural Gas Environmental Regulations. *Past Reviews*. http://www.strongerinc.org/past-reviews.

Tiemann, Mary and Adam Vann. *Hydraulic Fracturing and Safe Drinking Water Act Issues*. Congressional Research Service. 10 Apr 2012. http://www.fas.org/sgp/crs/misc/R41760.pdf.

Urbina, Ian. "Recycling No Cure-All in Gas Process". *New York Times*. 1 Mar 2011. http://www.nytimes.com/2011/03/02/us/02gas.html/?pagewanted=all.

U.S. Energy Information Administration. *Annual Energy Outlook 2012*. Jun 2012. http://www.eia.gov/forecasts/aeo/pdf/0383(2012).pdf.

U.S. Energy Information Administration. "Market Trends—Natural Gas". *Annual Energy Outlook 2012*. Jun 25, 2012. http://www.eia.gov/forecasts/aeo/MT_naturalgas.cfm#growth.

U.S. Energy Information Administration. "Monthly coal- and natural gas-fired generation equal for first time in April 2012". Jul 6 2012. http://www.eia.gov/todayinenergy/detail.cfm?id=6990.

U.S. Environmental Protection Agency, "EPA Completes Drinking Water Sampling in Dimock, PA.", 25 Jul 2012, http://yosemite.epa.gov/opa/admpress.nsf/0/1A6E49D193E1007585257A46005B61AD.

U.S. Environmental Protection Agency. *EPA's Study of Hydraulic Fracturing and Its Potential Impact on Drinking Water Resources*. http://www.epa.gov/hfstudy/.

U.S. Environmental Protection Agency. *Fact Sheet: EPA Initiates Rulemaking to Set Discharge Standards for Wastewater from Shale Gas Extraction*. Oct 2011. http://water.epa.gov/scitech/wastetech/guide/upload/shalereporterfactsheet.pdf.

U.S. Environmental Protection Agency. *Groundwater Investigation, Pavillion*. Updated Jun 2012. http://www.epa.gov/region8/superfund/wy/pavillion/#1.

U.S. Environmental Protection Agency. *Hydraulic Fracturing Research Study*. Jun 2010. http://www.epa.gov/safewater/uic/pdfs/hfresearchstudyfs.pdf.

U.S. Environmental Protection Agency. *Overview of Final Amendments to Air Regulations for the Oil and Natural Gas Industry Fact Sheet*. 2012. http://epa.gov/airquality/oilandgas/pdfs/20120417fs.pdf.

U.S. Environmental Protection Agency. *Permitting Guidance for Oil and Gas Hydraulic Fracturing Activities Using Diesel Fuels – Draft: Underground Injection Control Program Guidance #84*. May 2012. http://water.epa.gov/type/groundwater/uic/class2/hydraulicfracturing/upload/hfdieselfuelsguidance508.pdf.

U.S. Environmental Protection Agency. *Regulation of Hydraulic Fracturing Under the Safe Drinking Water Act*. http://water.epa.gov/type/groundwater/uic/class2/hydraulicfracturing/wells_hydroreg.cfm.

U.S. Environmental Protection Agency. *Technical Note on the 1990-2009 Inventory Estimates for Natural Gas Systems*. 15 Apr 2011. http://epa.gov/methane/downloads/TechNote_Natural%20gas_4-15-11.pdf.

U.S. Government Accountability Office. *Information on the Quantity, Quality, and Management of Water Produced during Oil and Gas Production*. Jan 2012. http://www.gao.gov/assets/590/587522.pdf.

Warner, Nathaniel R. et al. *Geochemical evidence for possible natural migration of Marcellus Formation brine to shallow aquifers in Pennsylvania*. Proceedings of the National Academy of Science. 9 Jul 2012. http://www.pnas.org/content/early/2012/07/03/1121181109.full.pdf+html.

Water Sources and Demand for the Hydraulic Fracturing of Oil and Gas Wells in Colorado from 2010 through 2015. Prepared by the Colorado Division of Water Resources, the Colorado Water Conservation Board, and the Colorado Oil and Gas Conservation Commission. http://cogcc.state.co.us/Library/Oil_and_Gas_Water_Sources_Fact_Sheet.pdf.

Wiseman, Hannah J. and Francis Gradijan. *Regulation of Shale Gas Development, Including Hydraulic Fracturing*. Energy Institute, University of Texas Austin. 31 Oct 2011. http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1953547&download=yes.

Wurzer, Molly. *Taking Unconventional Gas to the International Arena*. Texas Journal of Oil, Gas, and Energy Law. 14 Jun 2012. http://tjogel.org/wp-content/uploads/2012/07/Wurzer-Formatted_Final_June13.pdf.

Figures

Figure 1. Source: Suchy, Daniel and David Newell. "Hydraulic Fracturing of Oil and Gas Wells in Kansas". *Kansas Geological Survey*. 15 May, 2012. http://www.kgs.ku.edu/Publications/PIC/pic32.html.

Figure 2. Source: IEA, Golden Rules, 103.

Figure 3. Source: EIA 2012, 3.

Figure 4. Source: Marcellus Shale Coalition. http://marcelluscoalition.org/about/.

Figure 5. Source: GWPC and ALL Consulting, 48.

Figure 6. Source: GWPC and ALL Consulting, 60.