

REGULATORY OPTIONS & CHALLENGES IN HYDRAULIC FRACTURING



By Phi Nguyen
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About the Program

Founded in 1980 through the collaborative efforts of several professional engineering societies, the WISE Program allows for engineering students from around the nation to interact with prominent governmental and non-governmental leaders and are mentored by representatives of their sponsoring societies as well as societies that support the WISE Program. During the internship, these students learn how future leaders of engineering can contribute to legislative and regulatory public policy decisions where complex technological issues are involved.

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Executive Summary

Increasing concerns for the reduction of foreign fuel dependency as well as greenhouse gas emissions has led to shale reserves quickly gaining attention as a cleaner and more cost-effective source of natural gas production. The use of shale as a natural gas resource has been known for decades, however, the means of extracting the gas efficiently was not available until recently. In the United States alone, these shale deposits are dispersed throughout 33 states, totaling to approximately 2,119 trillion cubic feet of recoverable natural gas, which would meet the country's needs for over 100 years.

In the late 1940s, the use of hydraulic fracturing allowed for increase in natural gas flow by creating fractures in these underground formations, though the majority of the deposits occupied the area below residential communities. Through the advancements in horizontal drilling, industries would be able to extract more natural gas using less well pads without dramatically impacting these cities' infrastructure. The combination of hydraulic fracturing and horizontal drilling provided an economic boost in the oil and gas industry, and often times, would directly enhance the economic statuses of the residents as well by providing compensation for leased lands. However, with new technology come new concerns.

Hydraulic fracturing uses millions of gallons of water as well as a blend of sand and proppant chemicals that is rapidly pumped underground to create fractures of adequate width for extraction. Several environmental and human health problems have emerged, primarily with the contents of the chemicals. Because these wells are drilled beyond aquifers, the public has attributed water contamination to hydraulic fracturing. The lack of disclosure of the chemicals by several gas industries prevents surrounding residents from knowing what could be leaking into their drinking water supply and possibly be emitted into the air. Sudden well blowouts, unexpected earthquakes and the method of waste disposal of produced waters have also added to the concerns of the adverse effects of hydraulic fracturing. Currently, under the Safe Drinking Water Act, the Environmental Protection Agency (EPA) has the authority to regulate underground injection that would impact public water systems. However, through the Energy Policy Act of 2005, hydraulic fracturing was specifically exempt from national regulation. Both states and industries have argued that hydraulic fracturing has been effectively regulated by state agencies and that disclosure of the chemicals would impede upon proprietary rights. Though, due to the increasing number of public concerns, a national regulation has been proposed by Congress under the Fracturing Responsibility and Awareness of Chemicals (FRAC) Act (H.R. 2766, S. 1215).

The alternatives that surround the regulation of hydraulic fracturing include a permanent moratorium on all hydraulic fracturing activities, maintaining regulation through the states, delegating the authority of regulation to the federal government, or advancing on new technologies to mitigate these negative impacts. With hydraulic fracturing implemented in over 90% of natural gas activities, a permanent moratorium would be very unlikely, and the development of new technology for present use would prolong natural gas extraction, which would lead to a decline in the economy. Therefore, a blend of both national and state regulations is recommended.

The exemption of hydraulic fracturing from the Safe Drinking Water Act would be removed, allowing the EPA to gain oversight to regulation of this natural gas activity. However, due to compositional and regional differences, further regulation would be delegated to both state and local officials in order to ensure safety standards on a well-by-well basis. Chemicals would be made available to the public, though proprietary formulas would only be disclosed to both national and state officials in order to warrant that these chemicals would not supersede the maximum contaminant levels. An initial test of water quality would be performed by state officials to maintain a reference of water conditions throughout the hydraulic fracturing process. Further studies would be completed by the EPA to develop better technology that would minimize the water and chemical use and improve waste disposal and

recovery methods.

Until zero-carbon techniques are achieved, the role of fossil fuels will continue to increase through the development of shale gas. Hydraulic fracturing has played a prominent role in the oil and gas industry and will continue to advance as more shale deposits come into play. These slight changes in the current regulation of hydraulic fracturing will allow for a more efficient and effective production of our domestic fuel.

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1.0 Overview of Purpose

With the growing desire to mitigate dependence on foreign resources by the United States as well as the stress to unlocking clean energy, the importance of domestic natural gas production has also increased. Of the sources of oil consumed in 2008, the United States led with the amount exhausted at approximately 34%, followed by Canada. This means that the United States consumes the most amount of oil of all the nations, hence greater dependence on foreign resources. The revival of the extraction of natural gas from shale formations has provided additional means for onshore gas production. This natural gas is trapped inside these shale rock formations which are widely deposited throughout the United States. Advancements in the combination of hydraulic fracturing and horizontal drilling have made the extraction of this unconventional gas possible to execute more efficiently.

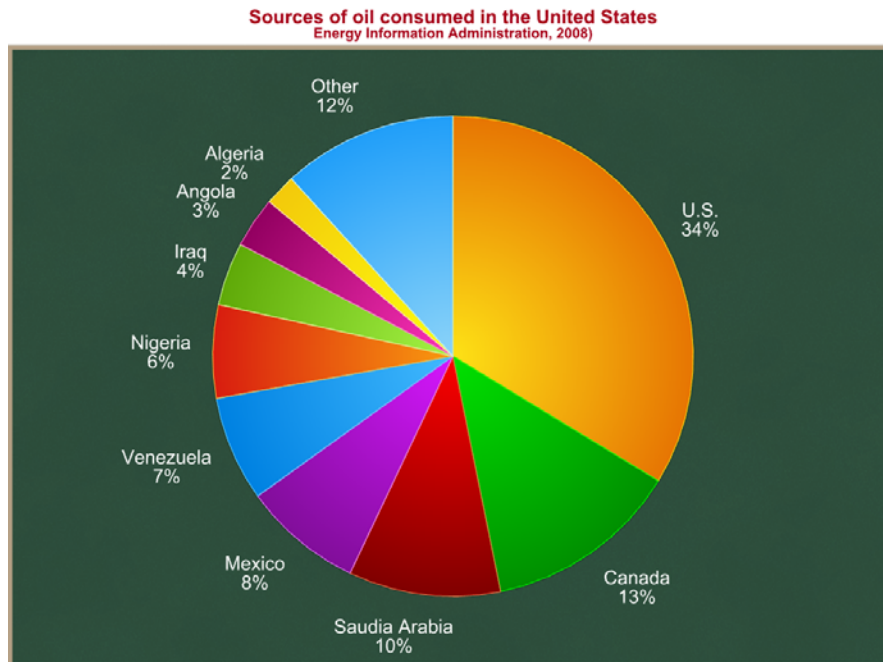


Figure 1 Sources of Oil Consumed in 2008 (Source: Energy Information Administration, 2008)

Hydraulic fracturing uses water, sand and a mixture of chemicals under high pressure to create cracks in rock that would release the oil and natural gas contained within the rock. However, the method that each energy company uses, specifically the chemicals applied during hydraulic fracturing, are currently not regulated by the U. S. Environmental Protection Agency (EPA). Although the EPA has recently begun to hold hearings in order to discuss the development of regulation for this technology, some interests have countered that nationwide regulation would intrude upon corporate trade secrets and would hinder the economic benefits of shale production.

There are also some environmental concerns and arguments that the different methods of hydraulic fracturing are causing the possible contamination of aquifers with such carcinogenic substances as benzene as well as air pollution due to emissions of the various chemical mixes such as arsenic and lead from the natural gas wells. State agencies such as the Colorado Department of Natural Resources, Oil and Gas Conservation Commission have developed new rules to oversee the oil and gas companies to publicize what chemicals are being pumped underground. However, even with state regulations to test both water and air qualities around gas wells, there is no federal mandate to report levels of emissions caused by hydraulic fracturing to the EPA. Based upon the Energy Policy Act (P.L. 109-58) of 2005, Alabama is required to report methane levels produced from coal beds, though no other state is held to

this requirement.¹ In Texas, primarily with the production of the Barnett Shale, the incidents of several well blowouts, the chemical levels of the benzene leaks as well as the air emissions of arsenic, barium, chromium, lead and selenium that were unreported by the Texas Commission on Environmental Quality to the EPA raise concerns that a nationwide regulation may be necessary.

This project will explore why hydraulic fracturing is causing environmental alarms and why these different methods are currently not regulated by the EPA. These questions have become significant due to the fact that onshore natural gas drilling sites are currently located in suburban neighborhoods. Any environmental impacts of the drilling could possibly incur adverse health effects and the obvious degradation to the area surrounding the gas well. Possible policy alternatives involving various regulatory techniques as well as the development of a new technology will also be assessed.

2.0 Background



Figure 2 Marcellus Shale Outcrop
(Source: Lvklock, 2008)

2.1 What is Shale?

Shale is any group of fine-grained sedimentary rock consisting of silt-and clay-sized particles. Deposition of such organic matter from algae, plants and animal debris can become compacted in addition to the clay particles. Rocks with approximately 1-2% of organic material are rich enough to be source rocks, though some rocks contain much more.² Hence, shale is known as a petroleum source rock in which the petroleum fluids are formed within the rock. Synthetic crude oil is extracted from this oil shale by means of pyrolysis, or destructive distillation, in which intense heat during burial breaks down a complex organic matter known as kerogen; this releases oil, gas, water and residual solids. Oil comes out first between the temperatures of 60 – 120°C (known as the oil window); the gas window is between 120-225°C. Rocks that haven't been heated up to at least 60°C are called potential source rocks.³ Shale oil deposits are known for their very low permeability, which limits the ability of easy fluid flow within a rock. This low permeability classifies shale as an unconventional reservoir, in

which it is typically necessary to stimulate the reservoir to create additional permeability.⁴ Though due to its good porosity, shale is able to store these fluids.

Typically buried 6000 feet or more underground, the composite of shale varies widely depending upon such factors as high silica content, high calcium content and a large percentage of alumina. Shale containing a large percentage of carbon matter can grade into bituminous coal, which would become a

¹ This ruling was the result of the 11th Circuit Court of Appeals (LEAF v. EPA) that ruled that underground injection did cover hydraulic fracturing. Although possibilities of water contamination were denied by the EPA, the court established a time frame for the EPA to withdraw UIC primacy in Alabama. Drilling Contractor. "Alabama lawsuit poses threat to hydraulic fracturing across US." Jan-Feb 2000. <http://www.iadc.org/dcp/dc-janfeb00/j-coalbed.pdf> (accessed July 19, 2010).

² The Barnett Shale, currently the United States' most active natural gas play, averages about 6% of organic material and is believed to contain as much as 15% more. "Contacts." Message to Phi Nguyen from Dr. John Breyer, Professor of Geology, TCU. 25 June 2010. E-mail.

³ Ibid.

⁴ Conventional reservoirs contain the gas in interconnected pore spaces that allow for free flow of oil or gas to the wellbore, much like a kitchen sponge. Shale that falls under unconventional gas have typical permeabilities on the order of 0.01 to 0.00001 millidarcies. Fanchi, Christopher J. Fanchi and John R. "The Barnett Shale -- Frequently Asked Questions." Fort Worth, 2010.

future source of petroleum.⁵ Typically shale gas, which is created and stored within the shale bed, is comprised of approximately 90% or more methane that is generated from the organic material.⁶ Two important properties of shale that must be considered during the extraction of natural gas are the clay mineral content, which would determine how it reacts to drilling and completion fluids, and the strength, which would determine how it would respond to fracture stimulation techniques.⁷ The factors have played a crucial role in developing domestic natural gas because they provide the needed information on various drilling procedures for each specific site.

2.1.1 The Emergence of Shale Production

Shale has been used as a source of liquid fuel all over the world including Scotland, Sweden, France, South Africa, Australia, China and Brazil.⁸ The United States oil shale contains about 14 times the chemical content of all the known hydrocarbon reserves in the world—with most of the shale deposited in huge lakes in the western U.S. between 30 and 60 million years ago—but it hasn't been buried deep enough to generate hydrocarbons. Hence, industries must provide the energy and money to heat it, which is both uneconomical and environmentally unfriendly. In regards to shale oil, normal oil can be generated in source rocks that have not migrated into typical, or conventional, reservoirs thus, shale oil is known as an unconventional source. Nature has aided this process by heating these rocks, making it more economical; though, due to its deficiency in hydrogen and its excessive amounts of nitrogen and sulfur compounds, shale oil must be hydrogenated and chemically treated.⁹ If extracted, this natural gas would provide for a relatively clean burning energy source, with gas-burning electricity generators releasing only half of the greenhouse gases of conventional coal-burning plants.¹⁰

In 1821, the first producing gas well in the United States was completed in the Devonian-aged shale near the town of Fredonia, New York in order to provide for city illumination.¹¹ Other shale gas wells gradually developed following the Fredonia well, but the lack of technology made production of petroleum from unconventional sources seem less economical than that of oil and coal.¹² The Barnett Shale in Fort Worth, Texas, which has long acted as an important source and sealing cap rock for conventional oil and gas reservoirs, launched the nation's attention on natural gas plays in the 1980s. However, significant drilling activity did not begin until gas prices began to increase in the 1990s.

Shale deposits can be found throughout the United States—each in its own basin, which is why operational criteria vary with each location. With over 20 known shale gas deposits, the most active sites include the Barnett Shale, the Haynesville-Bossier Shale, the Antrim Shale, the Fayetteville Shale, the Marcellus Shale and the New Albany Shale. Natural gas from these shale formations soon became one of the most rapidly growing petroleum productions, with advancements in drilling technologies—directional drilling and hydraulic fracturing.¹³ In 2000, shale gas accounted for approximately 1% of the United States' gas supply; it now contributes to 20% of the gas supply, making unconventional gas rise to 50% of

⁵ "Shale." The Columbia Encyclopedia, Sixth Edition. 2008. Encyclopedia.com. (July 6, 2010).
<http://www.encyclopedia.com/doc/1E1-shale.html>

⁶ The potential of shale can be evaluated by examining the total organic carbon, thermal maturity and kerogen analysis. U. S. Department of Energy, Office of Fossil Energy. "Modern Shale Gas Development in the United States: A Primer." Primer, Oklahoma, April 2009

⁷ "Contacts." Message to Phi Nguyen from Dr. John Breyer, Professor of Geology, TCU. 24 June 2010. E-mail.

⁸ Lee, Sunggyu. *Oil Shale Technology*. Boca Raton, FL: CRC Press, 1991.

⁹ "Contacts." Message to Phi Nguyen from Dr. John Breyer, Professor of Geology, TCU. 25 June 2010. E-mail.

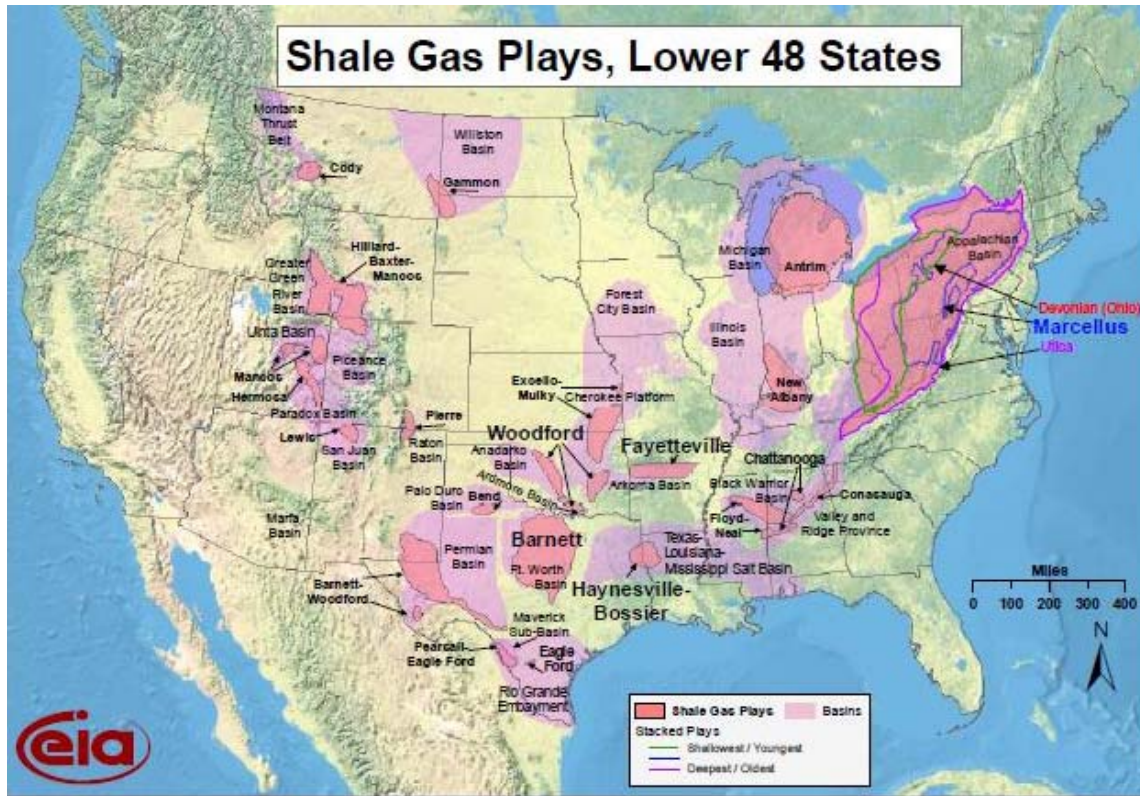
¹⁰ Kirkland, Joel. Climate Wire. 7 July 2010. <http://www.eenews.net/climatewire/print/2010/07/07/1> (accessed July 7, 2010).

¹¹ U. S. Department of Energy, Office of Fossil Energy. "Modern Shale Gas Development in the United States: A Primer." Primer, Oklahoma, April 2009.

¹² The Ohio Shale in the Big Sandy Field of Kentucky was developed during the 1920s and later grew to 3000-square-mile play that covered five counties, while the Antrim Shale in Michigan began to rapidly expand in the 1980s, eventually reaching 9000 wells. U. S. Department of Energy, Office of Fossil Energy. "Modern Shale Gas Development in the United States: A Primer." Primer, Oklahoma, April 2009

¹³ Production from the Barnett Shale increased 3000% from 1998 to 2007. Kerr, Richard A. "SCIENCE." *Resource for the Future*. 25 June 2010. <http://www.rff.org/Documents/kerr-science.pdf> (accessed July 8, 2010).

the nation's total domestic energy production. As an alternative resource, this addition to unconventional gas has allowed for alleviation in the declining conventional gas plays.¹⁴



Source: Energy Information Administration based on data from various published studies. Updated: March 10, 2010

Figure 3 Shale Gas Plays (Source: Energy Information Administration, 2010)

2.1.2 Impact of Shale Gas Plays

The use of natural gas as a reliable fuel source compels people to continue to develop advancements in technology in order to efficiently obtain such resources. Unconventional gas resources include tight sands, coalbed methane as well as gas shales. These are characterized by low-permeability reservoirs that primarily produce dry natural gas and must be stimulated in order to recover a larger percentage of the gas in place.¹⁵ Over the last decade, production from unconventional sources has increased around 65% and it is expected that shale gas will make up 20% of the total U. S. gas supply by 2020.¹⁶

The development of the Barnett Shale has made it the most productive shale gas play in the United States with such companies as Devon, Chesapeake, XTO and several others aiding with the production of roughly 4.3% of the total output of natural gas in the U.S.¹⁷ Techniques established at this site have allowed for further expansion to other major shale gas plays in the U.S. as well as nations such as Canada by providing a foundation for the improved technology of onshore drilling.¹⁸ The Marcellus

¹⁴ Kerr, Richard A. "SCIENCE." *Resource for the Future*. 25 June 2010. <http://www.rff.org/Documents/kerr-science.pdf> (accessed July 8, 2010).

¹⁵ National Petroleum Council. "Unconventional Gas." *NPC Study Topic Papers*. 18 July 2007. http://www.npc.org/Study_Topic_Papers/29-TTG-Unconventional-Gas.pdf (accessed July 19, 2010).

¹⁶ Navigant Consulting. "North American Natural Gas Supply Assessment." Report for American Clean Skies Foundation, 2008.

¹⁷ Ibid.

¹⁸ Chinese companies signed a deal to take a stake in the Eagle Ford shale in Texas in order to understand how to expand China's own domestic deposits of unconventional gas reserves. United Press International. "Chinese Investors eyeing U.S."

Shale, currently the largest gas play in North America, is estimated to have an average of 34.2 trillion cubic feet (tcf) of technically recoverable gas, which is about 31% higher than that estimated for the Barnett Shale.¹⁹

2.2 Use of Hydraulic Fracturing

First commercially operated in the late 1940s, hydraulic fracturing, or fracing (pronounced “frack-ing”), was used to increase natural gas flow by creating fractures in the underground formations; however, until recently, it was primarily used for conventional oil and gas wells. The method of hydraulic fracturing uses a mixture composed of approximately 99% water and sand with the remaining 1% being chemicals that vary between each energy corporation.²⁰ The fracturing fluids must be viscous enough to create a fracture of adequate width, maximize fluid travel distance to extend the fracture length, be able to transport large amounts of proppant into the fracture and require minimum gelling agent to allow for easier breakdown.²¹ The amount of water, typically obtained from surface water or groundwater near the site location, can range from two to five million gallons of water for each drilling well. The mixture is rapidly pumped into the well to increase the pressure at certain locations which then creates the fractures in the rock, allowing for the petroleum fluids to flow to the well pipes. The fracturing fluids return back to the surface, though there are various methods to dispose of the wastewaters during hydraulic fracturing.

Slickwater fracturing has become one of the most common hydraulic fracturing techniques used on shale. It is a combination of base fluids, such as water, with a friction reducer and proppant. The friction reducer increases the speed of the process, thus saving time and energy in the fracturing process.²² Also, because the length of the wells tends to extend thousands of feet, multi-stage fracturing has been used to hydraulically fracturing one section at a time.

Initially, hydraulic fracturing was paired with vertical drilling, where the rig on the surface drills straight down to the resources underground in order to access conventional sources. However, this drilling technique was not compatible with unconventional shale reservoirs because many of the shale concentrations resided directly below residential or urban locations. Multiple wells would need to be drilled to cover the area of the shale deposits in these locations. Therefore vertical drilling would not only be uneconomical but also become a local disturbance.

The introduction to horizontal, or directional, drilling opened up a new technology to advancing natural gas production. Although the first documented use of horizontal drilling was in 1929, its true potential did not expand until the late 1980s.²³ Horizontal drilling begins as a vertical bore that extends from the surface to the subsurface location just above the reservoir, and then gradually curves horizontally approximately a mile deep into the reservoir where it will remain for the hydraulic process. Since many of the shale reservoirs extend further in area rather than thickness, horizontal drilling, when paired with

shale?" *UPI.com*. 9 July 2010. http://www.upi.com/Science_News/Resource-Wars/2010/07/09/Chinese-investors-eyeing-US-shale/UPI-37331278687743/ (accessed July 13, 2010).

¹⁹ Natural gas is usually priced and sold in units of thousand cubic feet (Mcf). A trillion cubic feet (tcf) is used to measure large quantities of reserves; one tcf is enough natural gas to generate a billion kilowatt-hours of electricity. U. S. Department of Energy, Office of Fossil Energy. "Modern Shale Gas Development in the United States: A Primer." Primer, Oklahoma, April 2009.

²⁰ According to Chesapeake Energy, the typical mixture makeup reveals that around 99.5% is comprised of freshwater and sand, while the remaining 0.5% includes chemicals such as acid, friction reducer, surfactant, gelling agent, scale inhibitor, pH adjusting agent, breaker, crosslinker, iron control, corrosion inhibitor, antibacterial agent and clay stabilizer. "Hydraulic Fracturing." *Chesapeake Energy*. March 2010. http://www.chk.com/Media/CorpMediaKits/Hydraulic_Fracturing_Fact_Sheet.pdf (accessed July 8, 2010).

²¹ U.S. Environmental Protection Agency. "Hydraulic Fracturing Fluids." *EPA 816-R-04-003*. June 2004. http://www.epa.gov/ogwdw000/uic/pdfs/cbmstudy_attach_uic_ch04_hyd_frac_fluids.pdf (accessed July 20, 2010).

²² Fanchi, Christopher J. and John R. "The Barnett Shale -- Frequently Asked Questions." Fort Worth, 2010.

²³ The first horizontal well was drilled in Texon, TX, however did not become cost-effective and technically feasible until 2003. Senvold, Mark. *CNN Money*. 13 October 2008. http://money.cnn.com/2008/10/07/smallbusiness/horizontal_well.fsb/index.htm (accessed July 12, 2010).

hydraulic fracturing, becomes a very valuable technology to extract the natural gas. Thus, it allows for the reduction of surface impact from multiple vertical wells emerging from multiple well pads to fewer horizontal wells from a single well pad. This will then parallel with less impact on nearby urban settings and even on wildlife habitats.²⁴ Natural gas can, therefore, be recovered from thin reservoirs, reservoirs with natural vertical fractures, isolated and bypass reservoirs as well as environmentally sensitive reservoirs. With horizontal wells, drillers can now make a 90° turn in less than 100 feet as compared to the previous 2000 feet, which increases productivity to at least 2 to 3 times that of vertical wells.²⁵

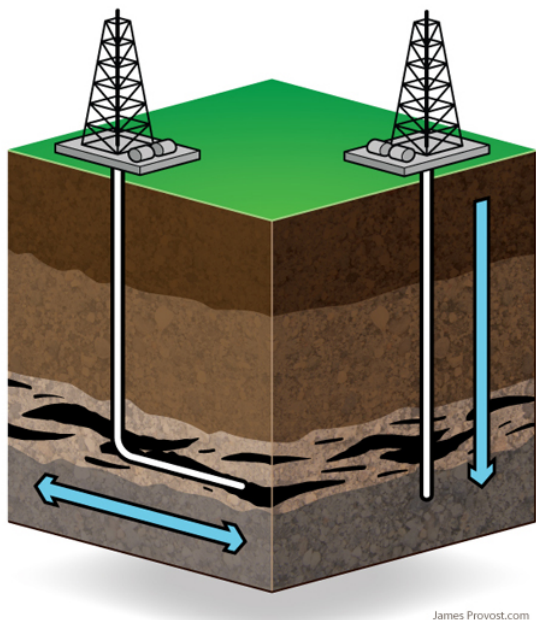


Figure 4 Illustration of Horizontal Drilling (Left) versus Vertical Drilling (Right) (Source: James Provost, 2010)

Hydraulic fracturing has become a key element of the natural gas development throughout the world, and when paired with horizontal drilling, it has become one of the most widely used techniques for natural gas wells in the U.S. today.

2.2.1 Economic Impact

The United States has approximately 2, 119 tcf of recoverable natural gas and another 347 tcf for unproved technically recoverable natural gas²⁶ with unconventional gas accounting for 60% of the onshore resource. According to the U. S. Energy Information Administration, a marketed production of natural gas averages about 21.9 tcf over the year in 2009.²⁷ With continuing growth of domestic reserves, the U.S. would be able to minimize its dependence on foreign resources with domestic gas reserves meeting the country's needs for more than 100 years.²⁸ It has become an international advancement by providing nations like China the information needed to understand how to develop their own shale gas reserves.²⁹ Expansion of natural gas has spurred economic activity in some of the poorest and most rural parts in the United States.

Improvements on such techniques as the steering systems and the instrumentation monitoring equipment in both horizontal drilling and hydraulic fracturing has made shale gas the largest source of growth in the U.S. natural gas production by “contribut[ing] to higher success and recovery rates, reduced cycle times, lower costs and shorter times required to bring new shale gas production to the market.”³⁰ In a report to the American Petroleum Institute, it is estimated that the development in the Marcellus Shale could

²⁴ Fewer well pads can result in fewer roads, reduced traffic, fewer pipelines, and fewer surface facilities. U. S. Department of Energy, Office of Fossil Energy. "Modern Shale Gas Development in the United States: A Primer." Primer, Oklahoma, April 2009.

²⁵ EnerMax. *Directional Drilling*. 2007. <http://www.enermaxinc.com/directional-drilling/> (accessed July 20, 2010).

²⁶ U. S. Energy Information Administration. *Natural Gas Year-In-Review 2009*. July 2010. http://www.eia.gov/pub/oil_gas/natural_gas/feature_articles/2010/ngyr2009/ngyr2009.html (accessed July 13, 2010).

²⁷ U. S. Energy Information Administration. *Natural Gas Year-In-Review 2009*. July 2010. http://www.eia.gov/pub/oil_gas/natural_gas/feature_articles/2010/ngyr2009/ngyr2009.html (accessed July 13, 2010).

²⁸ IHS Cambridge Energy Research Associates estimated that recoverable shale gas outside of North America could turn out to be equivalent to 211 years' worth of natural gas consumption in the U.S. Krauss, Clifford. "New Way to Tap Gas May Expand Global Supplies." *New York Times*. 9 October 2009. http://www.nytimes.com/2009/10/10/business/energy-environment/10gas.html?_r=3&ref=energy-environment (accessed July 20, 2010).

²⁹ International Energy Agency estimates China's shale gas has approximately 26 tcf of untapped reserves. Winning, David. "China invests in North American shale to unlock reserves at home." *E&E News*. 25 June 2010. <http://www.eenews.net/Greenwire/2010/06/25/17/> (accessed July 20, 2010).

³⁰ "Annual Energy Outlook 2010." *Environmental Information Administration*. 2010. http://www.eia.doe.gov/oiaf/aeo/pdf/trend_4.pdf (accessed 8 2010, July).

generate nearly \$25 billion as well as create 230,000 new jobs by 2020.³¹ With several of the drilling activities occurring in low-income and rural areas, hydraulic fracturing for the production of natural gas has become a significant economic boost.

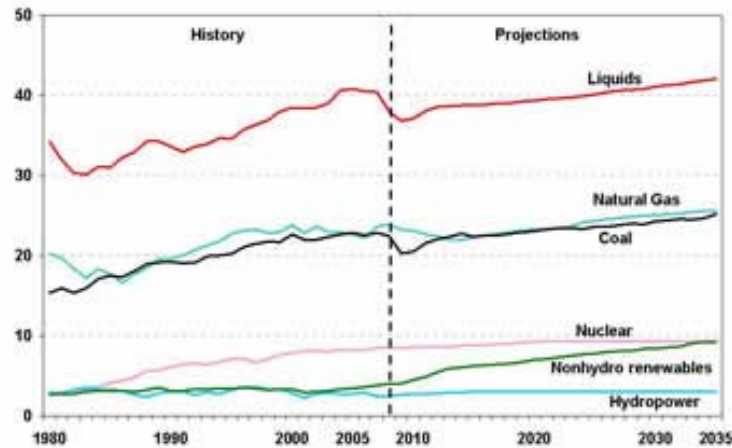


Figure 5 U. S. Energy Fuel Consumption Outlook (Source: Energy Information Administration, 2010)

2.2.2 Environmental Impact

Shale gas companies take much precaution to mitigate any urban disturbances; therefore certain procedures are used in specific situations. Sound walls and blankets are used to reduce noise; directional lighting is used to reduce nighttime disturbance to nearby residences and businesses; pipelines to transport water is used to reduce truck traffic; and solar-powered telemetry to monitor gas production is used to reduce personnel visits to well sites.³² Although, these precautionary measures have been taken for each drilling well, there have been major incidents due to faulty well designs and uninformed oversight personnel. This combination has caused several well blowouts, which will be discussed further in this report.

Natural gas is the cleanest-burning fossil fuel, so the production of natural gas from shale reservoirs also has the potential to reduce that nation's carbon dioxide (CO₂) emissions, which is a primary cause of greenhouse gas emissions in the United States. With the extraction of natural gas, the carbon dioxide levels would be reduced by half in comparison to coal and approximately 30% in comparison to fuel oil.³³ Although natural gas only accounts for 28.5% of the U.S. fossil energy use as of 2008, it only contributes to 21.4% of the total energy-related CO₂ emissions.³⁴ Even with progression in renewable energy sources such as wind and solar power, another energy source is required to be available for demands during inclement weather conditions and when there is a lack of electrical storage capacity.³⁵ Thus, by converting to the use of natural gas it could also introduce further benefits to the environment. Nonetheless, the reduction of carbon dioxide comes at the cost of possible benzene emissions from hydraulic fracturing equipment leaks.

³¹ Considine, Timothy J. "The Economic Impacts of the Marcellus Shale: Implications for NY, PA and WV." *E&E News*. 14 July 2010. http://www.eenews.net/assets/2010/07/21/document_pm_01.pdf (accessed July 22, 2010).

³² U. S. Department of Energy, Office of Fossil Energy. "Modern Shale Gas Development in the United States: A Primer." Primer, Oklahoma, April 2009.

³³ Ibid.

³⁴ U. S. Energy Information Administration. *Emissions of Greenhouse Gases Report*. December 8 2009. <http://www.eia.doe.gov/oiaf/1605/ggrpt/> (accessed June 16, 2010).

³⁵ Epstein, Dr. Alan. *Natural Gas Briefing*. Briefing Presented in Coordination with ASME, NSF, IEEE and Discover, Washington D. C. : Gas Turbine Association, July 14, 2010.

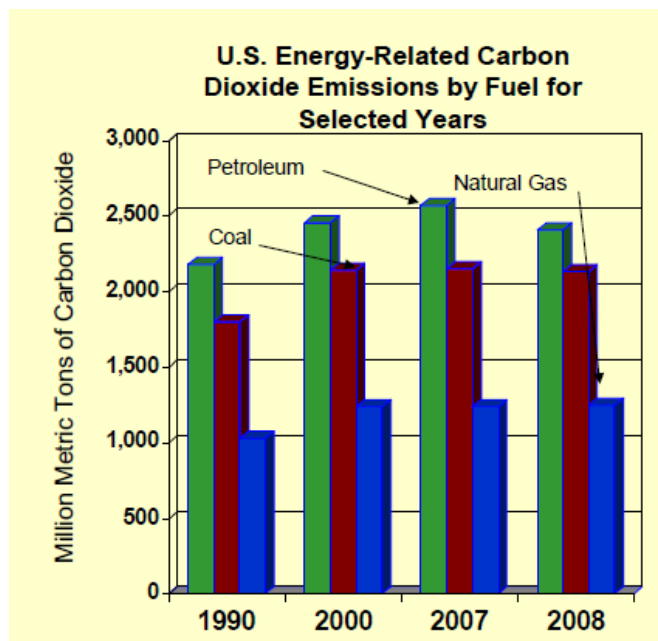


Figure 6 U. S. Carbon Dioxide Emissions by Fuel (Source: Energy Information Administration, 2009)

Earlier it was mentioned that wastewaters from hydraulic fracturing could be disposed using various methods. These include returning the fracturing fluids by using a permitted injection well to pump the water underground, treating the fluids to remove contaminants then discharging the fluids back to the surface waters, or applying the fluids to land surfaces. Some companies may reuse the fluids as a means of recycling by applying the flowback fluids to hydraulically fracture more than one well, though it is estimated that between 15-80% of these fluids are recovered.³⁶ The unrecovered fracturing fluids as well as possible leakage from disposal methods of these fluids have raised concerns over the possibilities of drinking water contamination, which would therefore be challenging such federal legislation as the Safe Drinking Water Act. Some of the chemicals that comprises these fracturing fluids include formaldehyde, boric acid, methanol, and isopropanol and have been known to cause harm to the eyes, skin, sensory organs, respiratory system as well as the brain and nervous systems.³⁷

Other environmental degradation that has been attributed to gas drilling occurred at the Barnett Shale during the time when North Texas was experiencing several unexpected earthquakes. Natural earthquakes are rarely localized, though the ones pinpointed seem to originate from the same location.³⁸ In the past, earthquakes have been induced by the pumping of fluids at oil and gas fields or by the injection of fluids due to the disposal of chemical wastes, thus a causal relationship has developed between the sudden bursts of earthquakes and the vast amounts of producing wells, though geologists have not accredited these quakes to hydraulic fracturing.³⁹

³⁶ The amount of fluids recovered depends on the volume injected on the site. U.S. Environmental Protection Agency. "Hydraulic Fracturing Research Study." *EPA Office of Research and Development*. 29 June 2010. <http://www.epa.gov/safewater/uic/pdfs/hfresearchstudyfs.pdf> (accessed July 12, 2010).

³⁷ Tronche, John-Laurent. "States or Feds: Who gets to regulate hydraulic fracturing?" *Fort Worth Business Press*. 8 June 2009. <http://www.fwbusinesspress.com/display.php?id=10369> (accessed July 28, 2010).

³⁸ North Texas does not have a history of tectonic quakes. Tronche, John-Laurent. "Earthquakes in Cleburne? Some North Texans suspect drilling behind recent quakes." *Fort Worth Business Press*. 10 June 2009. <http://www.fwbusinesspress.com/display.php?id=10402> (accessed July 16, 2010).

³⁹ Ibid.

2.3 Site Demonstrations and Case Studies

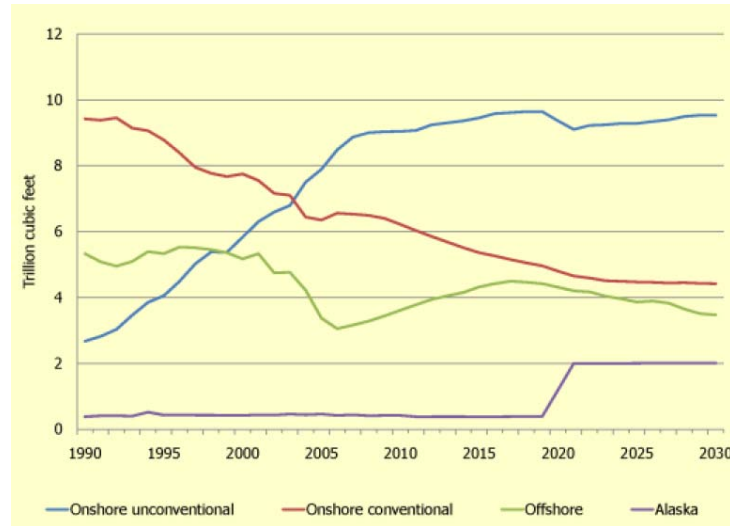


Figure 7 Natural Gas Production shows growth in unconventional onshore gas (Source: Energy Information Administration, 2008)

Although the emergence of shale gas has expanded both the technology of directional drilling and hydraulic fracturing as well as aided the economy by lessening our dependence on foreign resources, slight errors in oversight have produced immediate and possibly long-term consequences including well explosions and both air and water pollution. The following sections present cases in which these consequences greatly impacted the site at which they occurred, altering society's views on the need for fossil fuel energy.

2.3.1 Well Explosion Incidents

Well blowouts have not been uncommon throughout the development of shale gas. A well blowout is the uncontrolled release of crude oil or natural gas from a well after pressure control systems have failed. These can occur during the drilling phase, well testing, well completion, production or workover activities.⁴⁰ Gas blowouts can be very dangerous to control since a spark can set off an explosion. Well blowout preventers, which sit atop the well, allows for wellheads to control the pressure inside. However, these blowout preventers are not failsafe.⁴¹ With the Barnett Shale, from 1997 to 2006, there had been 14 blowouts at Wise County wells and 4 at Denton County; a blowout in 2002 forced the evacuation of 30 homes in Haslet, TX. Due to gas from a new well seeping to an old, uncapped well nearby, an explosion at a drilling site in Palo Pinto County blew a huge crater in the ground. On April 22, 2006, a worker from XTO Energy well site in the Barnett Shale “removed a safety plug within a valve port in error, while there was pressure on the wellhead” causing an explosion at the well surface.⁴²

On June 3, 2010, the Marcellus well in Clearfield County, Pennsylvania suffered a leak and expelled approximately 35,000 gallons of gas as well as wastewater into the air over a 16-hour period until it was capped around noon the following day. The well, owned by EOG Resources and presently

⁴⁰ Westergaard, R. *All About Blowout*. Norwegian Oil Review, 1987.

⁴¹ Madrak, Susie. *Natural Gas Well Blowout in Marcellus Shale Brought Under Control After 14 Hours. What Happened to the Blowout Preventer?* 5 June 2010. <http://crooksandliars.com/susie-madrak/natural-gas-well-blowout-marcellus-sh> (accessed July 19, 2010).

⁴² Smith, Jack Z. "More than 20 blowouts have occurred at Barnett Shale wells." *Star-Telegram*. 5 June 2010. <http://www.star-telegram.com/2010/06/04/2240728/more-than-20-blowouts-have-occurred.html> (accessed July 14, 2010).

being drilled by C.C. Forbes, suffered a faulty blowout preventer—the same equipment blamed for the Deepwater Horizon explosion.⁴³ EOG failed to notify the Pennsylvania Emergency Management Agency immediately. Instead of calling the state's 24-hour emergency response line, EOG left a message with the Department of Environmental Protection. However, the known contaminations from the fracturing fluid were limited to a small stream approximately 1500 feet northwest of the well and no injuries were reported.⁴⁴



Figure 8 Image of Well Blowout in WV on June 3 (Source: Taylor, 2010)

Another blowout occurred four days later in West Virginia on June 7, 2010 when drillers struck a methane gas opening, blasting flames approximately 50 feet into the air and injuring seven workers. AB Resources was cited for failing to set casing (which consists of steel pipe that supports the well bore and seals off water and gas) at the permitted depth and inaccurately reporting coal seam depth in the permit application.⁴⁵

2.3.2 Air Emissions

With the concern of increased greenhouse gas emissions, the impact of air emissions has become a strong subject in the environmental movement. Some of these emissions have been acknowledged as being harmless to human health due to the low amount of emissions recorded. Naturally occurring radioactive material, or NORM, is one of these identified emissions. NORM is brought to the surface during shale gas production but remains in such places as rock pieces of the drill cutting or mixed in with the produced water.⁴⁶ The radiation from this NORM is weak, so it cannot penetrate dense materials or cause extreme risks from exposure. However, radiation hazards must be evaluated so that it does not exceed regulatory standards; regulations vary by state depending upon the NORM concentrations.⁴⁷

However, there are some chemicals that have been detected in drilling locations that are highly detrimental. For benzene, a carcinogen that typically causes leukemia, health concerns will arise once the level reaches 1.4 parts per billion. In 2009, scientists gathered air samples from a Targa Resources compressor station outside Decatur, Texas and revealed that the level of benzene reached 1,100 parts per billion; a sample taken at a nearby Devon Energy well revealed 15,000 parts per billion.⁴⁸ Of the 300 air samples taken from 30 facilities in north central Texas, 50 samples exceeded the Texas Commission of

⁴³ The Deepwater Horizon explosion that occurred on April 21, 2010 is currently estimated to be the largest oil spill in U. S. History. The damaged blowout preventer is one attribution to the explosion. Mufson, Steven. "Oil Spill investigators find critical problems in blowout preventer." *The Washington Post*. 13 May 2010. Tronche, John-Laurent. "Earthquakes in Cleburne? Some North Texans suspect drilling behind recent quakes." Fort Worth Business Press. 10 June 2009. <http://www.fwbusinesspress.com/display.php?id=10402> (accessed July 16, 2010). (accessed July 16, 2010).

⁴⁴ Department of Environmental Protection, Pennsylvania. "Independent Report Faults Clearfield County Gas Well Operators for June 3 Blowout DEP Outlines Proper Procedures for all Marcellus Drilling Firms." *Pennsylvania Department of Environmental Protection*. 13 July 2010. <http://www.portal.state.pa.us/portal/server.pt/community/newsroom/14287?id=12818&typeid=1> (accessed July 14, 2010).

⁴⁵ West Virginia Department of Environmental Protection. "DEP temporarily halts AB Resources operations in state." *West Virginia Department of Environmental Protection*. 10 June 2010. <http://www.dep.wv.gov/news/Pages/WestVirginiaDepartmentofEnvironmentalProtectionTemporarilyHaltsABResourcesOperationsandIssuesNoticesofViolationforMarshallC.aspx> (accessed July 14, 2010).

⁴⁶ Drilling stirs up the radioactive material with the flowback process bringing it above ground. U. S. Department of Energy, Office of Fossil Energy. "Modern Shale Gas Development in the United States: A Primer." Primer, Oklahoma, April 2009

⁴⁷ High levels of NORM must be disposed of at a licensed facility. Ibid.

⁴⁸ Hawes, Chris. "Barnett Shale air study reveals alarming results." *WFAA Dallas-Fort Worth*. 25 November 2009. <http://www.wfaa.com/home/related/More-Known-about-Barnett-Shale-Air-Quality-Study-73645207.html> (accessed July 15, 2010).

Environmental Quality's standard for long-term health risk.⁴⁹ In Fort Worth, Texas, emissions for natural gas production now match the emissions from cars and trucks.⁵⁰

Air emissions can also be attributed to the equipment needed to extract this natural gas. The millions of gallons of water are commonly transported by several tanker trucks, which could require up to over 1000 truck trips for one fracture. Each truck trip could stir up dust and release such particulate matter such as nitrous oxides and carbon dioxide into the air. Diesel engines needed to run the drilling equipment use lots of fuel as well as compressors and compressor stations used to store and transport gas also produce a significant amount of emissions.⁵¹



Figure 9 Buckeye Creek, in Doddridge County, WV contaminated with drilling fluid dumped into stream from nearby site (Source: Louanne McConnell Fatora, 2009)

2.3.3 Water Contamination

More recently, cases of water contamination have revealed short-term impacts of pollutions possibly caused by hydraulic fracturing and the mix of chemicals involved. With at least 30 percent of the fluids never recovered, these chemicals could possibly seep into the groundwater. With the rise in production at the Barnett Shale, surrounding North Texas counties have reaped the consequences. In 2002, the Texas Railroad Commission confirmed that a well in Panola County was contaminated with barium, toluene, benzene and other dangerous chemicals. A well accident in 2005 allowed salt water to bubble out of the ground near Chico in Wise County. In another test by the Texas Railroad Commission done on June 7, 2010 showed that the residential water in DISH was contaminated with arsenic, barium, chromium, lead and selenium.⁵²

Now known as the place where people's water has started to turn brown and in some instances able to be ignited, Dimock, Pennsylvania also has become a city filled with controversies over hydraulic fracturing. In 2009, leaks of over 8,000 gallons of fracturing fluid contaminated a nearby stream, killing the various fish population and polluted the drinking water of more than a

dozen families. The fluid, which was manufactured by Halliburton, continued to flow into Stevens Creek and an adjoining wetland. From the Material Safety Data Sheet of the chemicals that were disclosed, warnings for such substances have led to skin cancer during laboratory tests and "may cause headaches, dizziness and other central nervous system effects" to anyone who inhales these fluids.⁵³ In some areas of the city, more than 60 gas wells are drilled in a nine-square-mile area and images of the water in a local creek that turned "Kool-aid red with diesel fuel" continue to bring concerns to the residents.⁵⁴

2.4 Governmental Involvement

⁴⁹ Ibid.

⁵⁰ Bateman, Christopher. "A Colossal Fracking Mess." *Vanity Fair*. 21 June 2010.

<http://www.vanityfair.com/business/features/2010/06/fracking-in-pennsylvania-201006> (accessed July 14, 2010).

⁵¹ Abelbeck, Hannah. *Marcellus drilling transforms the state*. 31 March 2010. <http://voicesweb.org/node/3905> (accessed July 28, 2010).

⁵² Hawes, Chris. "Barnett Shale air study reveals alarming results." *WFAA Dallas-Fort Worth*. 25 November 2009.

<http://www.wfaa.com/home/related/More-Known-about-Barnett-Shale-Air-Quality-Study-73645207.html> (accessed July 15, 2010).

⁵³ Water Contamination Center. "Dimock, A Town Fractured." *Water Contamination Center*. n.d.

<http://watercontaminationfromfracking.com/index.php> (accessed July 16, 2010).

⁵⁴ Bateman, Christopher. "A Colossal Fracking Mess." *Vanity Fair*. 21 June 2010.

<http://www.vanityfair.com/business/features/2010/06/fracking-in-pennsylvania-201006> (accessed July 14, 2010).

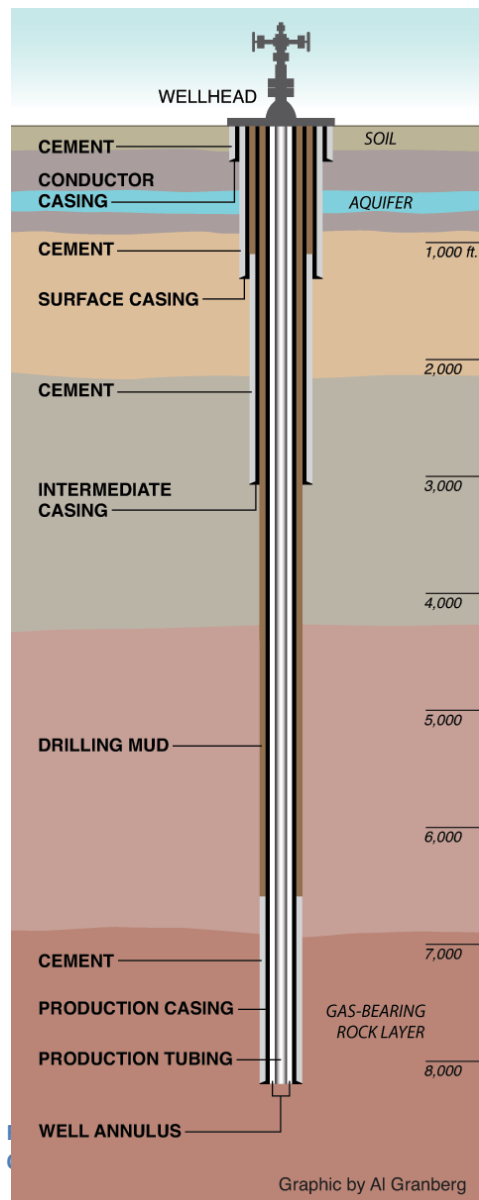


Figure 10 Diagram of Proper Well Casing and Cementing (Source: Granberg, 2010)

In 1997, the 11th Circuit Court of Appeals required that hydraulic fracturing be regulated in Alabama due to the fact that the hydraulic fracturing of coalbed methane wells was not regulated under Alabama's Underground Injection Control (UIC) program. Still concerns for water contamination near drilling sites continued to increase, thus the EPA began to weigh in on this technology and its environmental impacts. In 2000, the EPA initiated a three-phase study to determine whether hydraulic fracturing could cause the contamination of drinking water. Phase I would examine the "existing literature to identify and assess potential threat to underground safe drinking waters (USDWs) posed by hydraulic fracturing fluid injections;" Phase II was to conduct field investigations by performing water quality tests near wells; Phase III was to analyze various regulatory mechanisms to reduce the risks posed to drinking water.⁵⁵ The EPA concluded that there was "little or no threat" to drinking water supplies and that a shale gas well was "not an injection well because [the well] is used primarily for gas extraction," hence there was no regulation for hydraulic fracturing of shale gas plays and the study was discontinued.⁵⁶ However, there were certain inconsistencies between the data gathered and the results published; a major exclusion was that of the chemicals evaluated, nine had point-of-injection concentrations that exceeded regulatory standards with some being 13000 times higher than the safety standards.⁵⁷ With the limited amount of resources, federal agencies are unable to effectively regulate all the environmental programs for the thousands of oil and gas locations in the nation.

At this time, regulations on protecting groundwater and the safety of hydraulic fracturing are authorized by the state government. To attain authorization to fracture, a company must ensure proper well construction with the cementing of the steel casing in order to isolate everything except the target formation and ensure proper surface monitoring by a trained personnel. Proper casing techniques are intended to not only be a foundation for the well construction but also prevent the caving of surface soils as well as seal off potential freshwater bearing zones.⁵⁸ Although companies are required to report emissions to the state, there is little information for

comparisons since many of these industries do not have to report the water quality data before and after hydraulic fracturing takes place, thus eliminating a baseline for testing.⁵⁹

⁵⁵ Western Organization of Resource Councils. "History and Analysis of EPA Hydraulic Fracturing Study." July 2009. <http://www.worc.org/userfiles/file/EPA-FracStudyFactSheet.pdf> (accessed July 13, 2010).

⁵⁶ Ibid.

⁵⁷ Ibid.

⁵⁸ U. S. Department of Energy, Office of Fossil Energy. "Modern Shale Gas Development in the United States: A Primer." Primer, Oklahoma, April 2009.

⁵⁹ Western Organization of Resource Councils. "History and Analysis of EPA Hydraulic Fracturing Study." July 2009. <http://www.worc.org/userfiles/file/EPA-FracStudyFactSheet.pdf> (accessed July 13, 2010).

2.4.1 Federal Regulation

In the FY 2010 budget report, the U. S. House of Representatives Appropriation Conference Committee acknowledged the need for the Office of Research and Development in the EPA to conduct a more focused study on the possible impacts of hydraulic fracturing on drinking water, which is predicted to be completed by September 2010.⁶⁰ The following are current legislations that are being disputed through the discussions of hydraulic fracturing.⁶¹



Figure 12 Timeline of Governmental Impacts on Hydraulic Fracturing (Source: Energy in Depth, 2010)

Clean Air Act

The Clean Air Act, which was amended in 1990 to implement a plan for attaining significant reductions in emissions of air pollutants, is the law that defines the EPA's responsibilities for protecting and improving the nation's air quality and the stratospheric ozone layer.⁶² An estimate 2.7 billion pounds of toxic air pollutants were emitted into the atmosphere, contributing to approximately 300-1500 cancer fatalities each year.⁶³ Under the Clean Air Act, the "Best Available Control Technology (BACT) means emission limitation based on maximum degree of reduction of each pollutant subject to regulation under this act, emitted from...any major emitting facility, which the permitting authority on a case-by-case basis, taking into account energy, environmental, and economic impacts and other costs, determines is achievable for such facility."⁶⁴ Hence, the EPA is required to set national standards to limit the levels of certain pollutants that may cause harm to human health or damage to the environment. These standards are not constrained by the type of operation, thus they can be applicable to air emissions for a shale play, although they may vary due to differences in location and equipment needs.

⁶⁰ U. S. Environmental Protection Agency. *Hydraulic Fracturing*. 30 June 2010.

http://www.epa.gov/ogwdw000/uic/wells_hydrofrac.html (accessed July 13, 2010).

⁶¹ The U.S. Energy Information Administration provides a list for further legislative actions that have shaped the natural gas market. U.S. Energy Information Administration. *Major Legislative and Regulatory Actions*. 30 January 2009.

http://www.eia.gov/oil_gas/natural_gas/analysis_publications/ngmajorleg/ngmajorleg.html (accessed July 19, 2010).

⁶² U. S. Environmental Protection Agency. *Clean Air Act*. 24 June 2010. <http://www.epa.gov/air/caa/> (accessed July 19, 2010).

⁶³ *Ibid.*

⁶⁴ Colorado School of Mines. *Oil Shale: the Environmental Challenges III*. Golden, Colorado: Colorado School of Mines Press, 1983.

Clean Water Act

The Clean Water Act is the primary federal law that governs the pollution of surface water, including limits on the discharge of waters produced from hydraulic fracturing operations.⁶⁵ The National Pollutant Discharge Elimination System controls the water pollution by regulating point sources that discharge pollutants into the nation's waters and ensure compliance with state water quality standards.⁶⁶ Therefore, industrial facilities must obtain permits if their discharges go directly to surface waters. Since these general permits are not tailored to each specific discharge, states that meet the federal primacy requirements are allowed to set more state-specific standards. However, this would be slightly difficult for some shale reserves in which the drainage basin may be located within two or more states, such as the Marcellus Shale that occupies parts of Pennsylvania, New York, Maryland and West Virginia. Prior to the granting of the permit, the agency must consider the potential impact of every proposed surface water discharge on the quality of the receiving water. If the technology-based effluent limits are not sufficient enough to ensure that water quality standards will be attained in the receiving water, the states will need to develop more stringent standards.⁶⁷

Safe Drinking Water Act

Enacted in 1974, the Safe Drinking Water Act (SDWA) gives the EPA the central authority to protect drinking water using the Underground Injection Control (UIC) that regulates the fluids injected into an underground well—essentially applied to all industrial activity in the United States. The SDWA allows for the EPA to set national health standards for drinking water to protect against naturally occurring and man-made contaminants. The EPA then works with both state and local agencies to ensure that the standards are met for all water systems.⁶⁸ Although it limits what levels of pollution are permitted and sets minimum standards for well design, states are allowed to create more detailed regulations if they choose.⁶⁹ Also under the SDWA, the Underground Injection Control groups these underground injection wells into five classes for regulatory control; most injection wells associated with gas production are Class II wells, in which these wells are allowed to inject water and other fluids to enhance recovery.⁷⁰ However, these injected fluids must not contaminate any underground sources of drinking water but rather remain in the designated injection zone. Currently, the SDWA excludes hydraulic fracturing from UIC regulation unless the use of diesel fuel is involved in the process.⁷¹

Energy Policy Act 2005

In the Energy Policy Act of 2005 (EPACT), the “oil and gas exploration, production, processing, or treatment operations or transmission facilities” are defined to include all activities related to these facilities “whether or not such field activities may be considered to be construction activities” in order to

⁶⁵ The disposal of the flowback fluid into surface waters of the United States is regulated by the National Pollutant Discharge Elimination System permit program. U.S. Environmental Protection Agency. *Regulation of Hydraulic Fracturing by the Office of Water*. 28 June 2010. http://www.epa.gov/ogwdw000/uic/wells_hydroreg.html (accessed July 13, 2010).

⁶⁶ Dougherty, Cynthia. "Hydraulic Fracturing: Applicability of the Safe Drinking Water Act and Clean Water Act." *U.S. Environmental Protection Agency*. 7 April 2010. [http://yosemite.epa.gov/sab/sabproduct.nsf/5DEE6115FCA43661852576FD006B8460/\\$File/EPA%2BPresentation%2BMaterials%2B4-6-10%2Bfor%2BEEC%2BApr%2B7-8%2B2010%2BMeeting.pdf](http://yosemite.epa.gov/sab/sabproduct.nsf/5DEE6115FCA43661852576FD006B8460/$File/EPA%2BPresentation%2BMaterials%2B4-6-10%2Bfor%2BEEC%2BApr%2B7-8%2B2010%2BMeeting.pdf) (accessed July 14, 2010).

⁶⁷ U.S. Environmental Protection Agency. *Water Quality and Technology-Based Permitting*. 9 April 2007. <http://cfpub.epa.gov/npdes/generalissues/watertechnology.cfm> (accessed July 20, 2010).

⁶⁸ U. S. Department of Energy, Office of Fossil Energy. "Modern Shale Gas Development in the United States: A Primer." Primer, Oklahoma, April 2009.

⁶⁹ Lustgarten, Abraham. "DeGette, Salazar spilt on proposed natural gas drilling regs." *The Colorado Independent*. 27 May 2009. <http://coloradoindependent.com/29710/degette-salazar-split-on-proposed-natural-gas-drilling-regs> (accessed July 16, 2010).

⁷⁰ U. S. Department of Energy, Office of Fossil Energy. "Modern Shale Gas Development in the United States: A Primer." Primer, Oklahoma, April 2009

⁷¹ Hydraulic fracturing excluded under SDWA Sec. 1421(d)(1). U. S. Environmental Protection Agency. *Regulation of Hydraulic Fracturing by the Office of Water*. 28 June 2010. http://www.epa.gov/ogwdw000/uic/wells_hydroreg.html (accessed July 13, 2010).

exempt well site activities that disturb one or more acres for stormwater permits for sediment runoff based upon the Clean Water Act.⁷² Also, the EPACT notes that the underground injection of natural gas for purposes of storage and of fluids or propping agents for hydraulic fracturing operations was excluded in the Safe Drinking Water Act from Underground Injection Control. The protection of the groundwater resources during oil and gas extraction activities is the responsibility of the state government. Hence, the state department retains full authority to regulate these activities to prevent pollution and protect both the environment and public health.⁷³

FRAC Act

In the “Fracturing Responsibility and Awareness of Chemicals Act of 2009,” or FRAC Act (111th Congress: H.R. 2766; S. 1215), introduced by Representative Diana DeGette of Colorado, amendments to the Safe Water Drinking Act were proposed to include “the underground injection of fluids or propping agents pursuant to hydraulic fracturing operations related to oil and gas production activities” as well as the disclosure of the “chemical constituents (but not the proprietary chemical formulas) used in the fracturing process...[and make it] available to the public, including a posting of the information on an appropriate Internet website.”⁷⁴ The bill also notes that in case of a medical emergency the chemicals and formulas must be immediately disclosed to the state oversight agency or the treating physician regardless of confidentiality agreement. Although this Act, which is pending in Congress, is suggesting more stringent regulations on hydraulic fracturing, several controversies surrounding this Act include deterrence on state regulations, violations on corporate trade secrets and possible decline in the economy.

2.4.2 State Regulation

As the law currently stands, the EPA is not allowed to set conditions for hydraulic fracturing or even require states to have regulations of their own if it does not infringe upon the aforementioned federal legislation. In 2009, the Interstate Oil and Gas Compact Commission hosted two briefings on Capitol Hill to explain how existing state regulations have been successful in preventing contamination of drinking water resources during hydraulic fracturing.⁷⁵

Hydraulic fracturing in the Barnett Shale is overseen by two primary entities in the Texas government. The Texas Railroad Commission (RRC), the oldest regulatory agency in the state, considers the protection of the environment and preservation of individual property rights. It regulates the exploration and production of oil and natural gas, prevents waste of oil and gas resources, protects the surface and subsurface water and ensures all mineral interest owners have the opportunity to develop their fair share of the minerals underlying their property.⁷⁶ The Texas Commission of Environmental Quality (TCEQ) began solely as the agency that regulated the access to natural resources and later emerged as the agency that protects both the public health as well as conserves the natural resources for future generations of Texans. The TCEQ holds jurisdiction over both air and water contaminants.⁷⁷

However, on January of 2010, the deputy director of the TCEQ announced that eight air samples analyzed in Fort Worth found no traces of benzene. However, the agency failed to mention to the Fort Worth City Council that the equipment being used was not sensitive enough to detect the lower levels of benzene that have been known to lead to cancer if sustained over a period of years. Therefore, when

⁷² New York State Department of Environmental Conservation. *Effect of Federal Safe Drinking Water Act, Clean Water Act and Emergency Planning and Community Right-to-Know Act*. 2010. <http://www.dec.ny.gov/energy/46445.html> (accessed July 21, 2010).

⁷³ Ibid.

⁷⁴ DeGette, Diana. "FRAC Act." *DeGette*. n.d. http://degette.house.gov/images/pdf/frack_house.pdf (accessed July 16, 2010).

⁷⁵ Arthur, J. Daniel, Brian Bohm, and Mark Layne. "Hydraulic Fracturing Considerations for Natural Gas Wells of the Marcellus Shale." Presented at The Ground Water Protection Council, Cincinnati, Ohio, 2008.

⁷⁶ The Railroad Commission was established in 1891 to regulate rail industry but was later given oversight of various activities when pipelines began to emerge along the rail lines. Railroad Commission of Texas. *Barnett Shale*. 1 March 2010. <http://www.rrc.state.tx.us/barnettshale/index.php> (accessed July 19, 2010).

⁷⁷ Texas Commission on Environmental Quality. *Texas Commission on Environmental Quality*. 2 November 2009. <http://www.tceq.state.tx.us/about/tceqhistory.html#1900s> (accessed July 20, 2010).

tested again, four of the eight samples indicated levels above what the commission considered safe when investigating the long-term effects.⁷⁸ This sparked Representative Michael Burgess to address the Texas Sunset Advisory Commission to review the performance of the TCEQ due to this information that was withheld from both Representative Burgess as well as other local officials.⁷⁹

State regulation on the Marcellus Shale proves more difficult than that of the Barnett Shale because the formation occupies approximately 5 states—Maryland, New York, Ohio, Pennsylvania, and

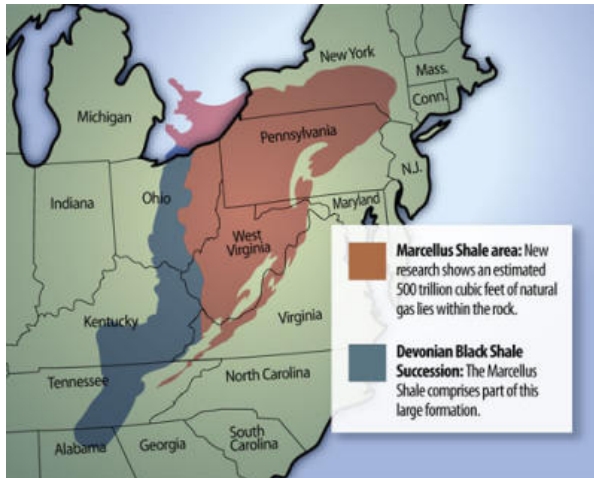


Figure 13 Marcellus and Devonian Shale Areas (Source: Becker & Green, 2010)

West Virginia. Currently, the majority of the shale gas drilling has occurred in both Pennsylvania and West Virginia. During the well explosion on June 3, the Pennsylvania Department of Environmental Protection suspended the drilling of EOG for 40 days until further evaluations were compiled and emergency notification procedures were developed. Currently, the Department of Environmental Protection has issued 565 violations at 207 of the 1,458 wells drilled into the Marcellus Shale in Pennsylvania since 2005.⁸⁰

In West Virginia, however, regulations prove just as difficult to manage. Union Drilling, which was responsible for the June 7th explosion, has been

known for more than 12 dozen violations of Occupational Safety Health Administration

(OSHA) workplace safety rules; West Virginia officials only temporarily halted the activities of Union Drilling. The number of natural gas wells being permitted is growing faster than the number of inspectors in the state Department of Environmental Protection. The number of permits issued for unconventional drilling operations more than tripled between 2007 and 2009, though the number of inspectors only increased by one, making it difficult for eighteen people to handle over a thousand new Marcellus wells as well as the shallow gas wells previously drilled.⁸¹ Figure 14 depicts the number of permits to the Marcellus wells as issued by the West Virginia Department of Environmental Protection from 2007 to 2010.

⁷⁸ Hawes, Chris. "State regulators fail to disclose benzene in Fort Worth air." *WFAA*. May 26 2010. <http://www.wfaa.com/news/local/Report-State-regulators-failed-to-disclose-benzene-in-Fort-Worth-air-94985339.html> (accessed July 20, 2010).

⁷⁹ Burgess, Michael C. Letter to Texas Sunset Advisory Commission Members. 9 June 2010. *Typepad*. Star-Telegram, June 2010. Web. <http://startelegram.typepad.com/files/6-9-2010---burgess-letter-to-texas-sunset-advisory-commission-on-tceq.pdf> (accessed July 21, 2010).

⁸⁰ Hopey, Don. "1200 hear Marcellus Shale debate." *Pittsburgh Post-Gazette*. 23 July 2010. <http://www.post-gazette.com/pg/10204/1074773-113.stm> (accessed July 26, 2010).

⁸¹ Smith, Vicki. "WV regulators scramble to keep up with drilling." *Bloomberg Businessweek*. 21 June 2010. <http://www.businessweek.com/ap/financialnews/D9GFROA06.htm> (accessed July 20, 2010).

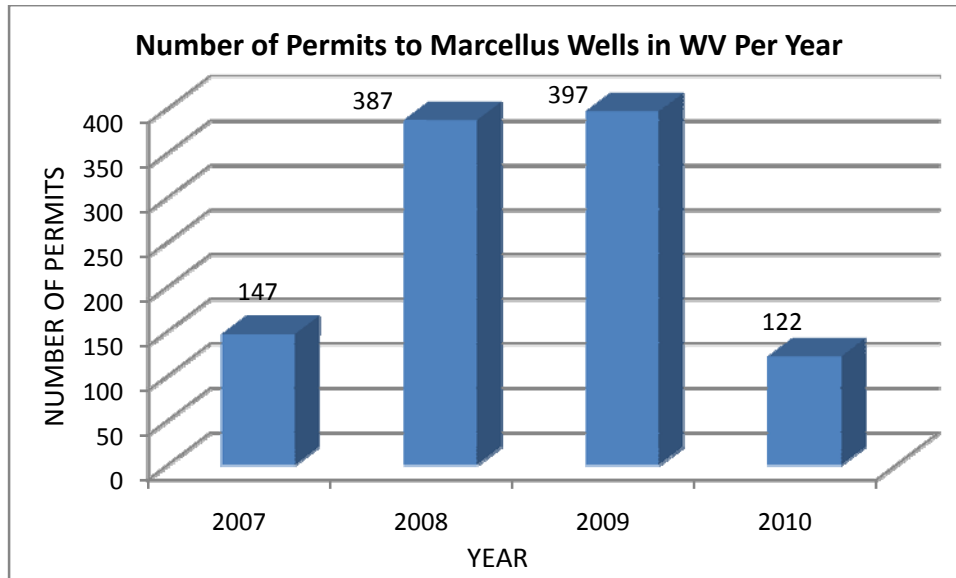


Figure 14 Number of issued permits in West Virginia to the Marcellus wells from 2007 to 2010 (Source: Bloomberg Businessweek, June 2010)

3.0 Policy Alternatives

With much of the conventional resources already discovered, new technologies are needed to develop the resources located in more remote and complex locations that may be environmentally sensitive. However, according to the information listed on the MSDS provided by the EPA, several of the fracturing fluids used can have toxic effects when people are exposed to significantly high concentrations through susceptible routes of exposure such as inhalation, ingestion or skin contact.⁸² Therefore, many individuals believe that some form of regulation must be applied to hydraulic fracturing activities. Below are the analyses of the various alternatives that surround the regulation of hydraulic fracturing.

3.1 No Hydraulic Fracturing Activities

Hydraulic fracturing has been around for over 60 years with its use in both the oil and gas industries. Until recently, this method was primarily used on conventional resources. However, as mentioned earlier, the emergence of hydraulic fracturing with unconventional resources has opened doors to a new technology that has reduced the amount of carbon dioxide emissions while reducing the dependence on foreign resources.

With shale gas being one of the fastest growing fuel sources, hydraulic fracturing has become a critical, and many times the only, method of production. The use of hydraulic fracturing currently occupies more than 90% of natural gas wells and produces over 600 tcf of natural gas, thus a halt to this technology would cause a decline in the economy.⁸³ We would be producing much less oil and gas in America and widening the gap between fuel production and consumption. The technology has allowed for the increase in jobs as well as such positive economic boosts such as royalties and taxes paid to the counties and the property owners.⁸⁴

⁸² U.S. Environmental Protection Agency. "Hydraulic Fracturing Fluids." *EPA 816-R-04-003*. June 2004.

http://www.epa.gov/ogwdw000/uic/pdfs/cbmstudy_attach_uic_ch04_hyd_frac_fluids.pdf (accessed July 20, 2010).

⁸³ Bateman, Christopher. "A Colossal Fracking Mess." *Vanity Fair*. 21 June 2010.

<http://www.vanityfair.com/business/features/2010/06/fracking-in-pennsylvania-201006> (accessed July 14, 2010).

⁸⁴ Independent Petroleum Association of America. "Hydraulic Fracturing: Effects on Energy Supply, the Economy and the Environment." *IPAA*. April 2008. <http://data.memberclicks.com/site/coga/IPAA.pdf> (accessed July 26, 2010).

Unless the United States is able to develop an efficient, zero-carbon resource, a permanent moratorium on hydraulic fracturing would not only be economically unfavorable but also impact society due to our dependence of such natural resources as shale. Therefore, the only feasible option at the present time is maintaining the use of hydraulic fracturing under effective regulation.

3.2 Current State Regulation of Hydraulic Fracturing

Many proponents of state regulation argue that hydraulic fracturing has “been regulated assiduously by the states for more than 50 years” without federal oversight.⁸⁵ Of the 33 states that currently have some form of oil or natural gas production, 27 have permitting requirements governing the locating, drilling completion and operation of wells; 18 require a list of materials used in the hydraulic fracturing process to be submitted to state agencies, 19 specify some of the volumes used, 22 require the reporting on treatment depths; 25 require surface casing to be set through the deepest ground water zone, 26 require cementing of the casing from bottom to top; and 26 states regulate waste management procedures, though none require a listing of the volume of fluid that flows back to the surface or remains in the formation.⁸⁶ Although the majority of these states do have standards for gas drilling and production, the numbers illustrate that these regulations are not necessarily uniform. Therefore, one state may have permitting requirements yet they lack regulations on disclosure of chemical volumes or even regulations on waste management. This absence of a baseline standard makes it difficult for officials to regulate shale plays, such as the Marcellus Shale, that occupy multiple states.

The option of state regulation on a shale play that lies solely within a state may be possible. However, as noted with the Barnett Shale, certain dismissals of emission levels could cause turmoil within these drilling communities, immediately shedding limelight on possible environmental damages. Although the Barnett Shale is the most productive gas shale play in the United States and both the drilling construction requirements involving the casing and cementing as well as the fluid injections into productive reservoirs are mentioned Texas Administrative Code, the state still faces several violations of well construction, which adds to the uncertainty in the safety of hydraulic fracturing.⁸⁷ Texas also faces the problem of multiple agencies overseeing environmental quality with the Railroad Commission managing water quality while the TCEQ is managing air quality.

Until Wyoming’s recent requirement for gas industries to disclose the chemicals used in hydraulic fracturing, Colorado was the only state to set such standards on hydraulic fracturing.⁸⁸ In Colorado, the oil and gas industry works to prevent surface spills as well as ensure casing protection. The operators must report to the Colorado Oil and Gas Conservation Commission (COGCC) surface and downhole activities to gain a permit to drill; oversee drilling operations to prevent fluid migration and surface spills; and disclose the information related to the contents of hydraulic fracturing to the COGCC.⁸⁹ These individual state actions depict that states have the capabilities to enact regulation on their own gas industries. However, not all states would agree to this form of regulation due to the interests

⁸⁵ Lustgarten, Abrahm. "FRAC Act--Congress Introduces Twin Bills to Control Drilling and Protect Drinking Water." *ProPublica*. 10 June 2009. <http://www.propublica.org/article/frac-act-congress-introduces-bills-to-control-drilling-609> (accessed July 27, 2010).

⁸⁶ U. S. Department of Energy, Office of Fossil Energy. "State Oil and Natural Gas Regulations Designed to Protect Water Resources." May 2009. <http://www.gwpc.org/e-library/documents/general/State%20Oil%20and%20Gas%20Regulations%20Designed%20to%20Protect%20Water%20Resources.pdf> (accessed July 30, 2010).

⁸⁷ Railroad Commission of Texas. "Texas Administrative Code." n.d. [http://info.sos.state.tx.us/pls/pub/readtac\\$ext.TacPage?sl=R&app=9&p_dir=&p_rloc=&p_tloc=&p_ploc=&pg=1&p_tac=&ti=16&pt=1&ch=3&rl=13](http://info.sos.state.tx.us/pls/pub/readtac$ext.TacPage?sl=R&app=9&p_dir=&p_rloc=&p_tloc=&p_ploc=&pg=1&p_tac=&ti=16&pt=1&ch=3&rl=13) (accessed July 27, 2010).

⁸⁸ Wyoming became the first state to require specifically the disclosure of chemicals used in hydraulic fracturing. Howell, Katie. "Wyo. becomes first state to require disclosure of fracking chemicals." *Greenwire*. 9 June 2010. <http://www.eenews.net/Greenwire/2010/06/09/archive/4?terms=wyoming+hydraulic+fracturing> (accessed July 27, 2010).

⁸⁹ COGA. "Hydraulic Fracturing." *Natural Gas Facts*. 2009. http://data.memberclicks.com/site/coga/Fact_Sheet_Hydraulic_Fracturing.pdf (accessed July 27, 2010).

of the economic boost provided by increasing natural gas production and the idea that disclosure of chemicals would be impeding upon corporate trade secrets.

Under the SDWA, oil and gas production activities, hydraulic fracturing (with the exception of the use of diesel), and natural gas storage are not regulated. Therefore, states have the option to choose to regulate these activities. If the decision is made to maintain state primacy of regulating hydraulic fracturing, more stringent control may need to be adopted in order to inform local citizens of the precautionary measures that are being taken to ensure their safety as well as the protection of the environment.

3.3 Proposed National Regulation of Hydraulic Fracturing

With the introduction of the FRAC Act, several controversies arise from the possible implications in this proposal. The FRAC Act expounds upon two primary ideas: (1) disclosure of chemicals used in the hydraulic fracturing process and (2) removal of the hydraulic fracturing exemption in the Safe Drinking Water Act (SDWA).

The first of the two goals, while gaining much attention, is the less controversial of the two. Due to both Colorado's more rigid supervision of hydraulic fracturing as well as Wyoming's recent agreement for statewide disclosure, the release of the types of chemicals used in hydraulic fracturing is gradually becoming more accepted in order to educate citizens about the supervision taken in this process. These chemicals would be disclosed to respective state officials as well as an appropriate medical physician in case of an emergency and also publicized on the Internet.

However, when information becomes available to the public through networks such as the Internet, the concern for national security comes into play. National security must ensure that the critical infrastructure would not be gravely impacted. Critical infrastructure involves any assets essential for the functioning of the society or the economy. With renewable energy presently being less cost-effective, the significance of production of natural gas has abruptly increased. Hence, overly burdensome regulation may create a sense of reassurance but will cause a decline in the economy. More restrictive regulation would cause an increase in compliance cost, delays in permits and gas marketing, increase in wellhead cost, increase in energy cost for consumers, increase costs due to industry challenges to regulation and increase in funding for research and development for advancements in technologies that would offset the potential increases in gas extraction costs.⁹⁰

Then there is the issue with disclosing the proprietary formulas, or the volume of these chemicals, that are being used in the hydraulic fracturing process; every chemical over a certain concentration could pose a threat to public health. Although the current proposed legislation does not require the disclosure of these formulas, information is knowledge. Therefore, the disclosure of chemicals would bring about a natural inclination for citizens to know how much of each chemical would be pumped into the ground. With a minimum of 2 million gallons of water and with the chemicals accounting for 0.5% of the mixture, approximately 10,000 gallons of chemicals are being used for each fracturing job. If the decision for national disclosure of these fracturing chemicals is enacted, gas industries would need to develop a means to inform the public of these chemical volumes as well as how they are taking precautionary measures to ensure public safety. However, this would come as a disadvantage to the gas industries because the volumes would be available to the competition as well.

The second goal of the FRAC Act would include hydraulic fracturing under regulation of the SDWA. Although the idea of including hydraulic fracturing in the SDWA may be of little regulatory burden, this may be more pertinent on a state level. As mentioned earlier, shale reserves vary between regions. Shale deposits in Colorado may be more shallow and closer to the aquifers than those found in Texas where the deposits are miles below the surface allowing overlying rock formations to act as a cap

⁹⁰ U. S. Department of Energy. "More Restrictive Regulation (Hydraulic Fracturing) Could Impact Natural Gas Supply." *National Energy Technology Laboratory*. June 2001.
<http://www.netl.doe.gov/publications/factsheets/policy/Policy001.pdf> (accessed July 28, 2010).

rock between the shale reservoir and the drinking water source. The growth of technology has led to natural gas production to be completed as quickly as 3 weeks for one well site. Hence, while new state rules could be phased in over a period of months, this could greatly impact the economy of states in which the aquifers are properly protected.

However, both oil and gas industries as well as the EPA have been operating under the standards of the SDWA in terms of fracturing fluids that are being injected for disposal. Industry has already been approved for more than 150,000 injection wells, including wells used to inject waste fluids from drilling such as fracturing fluids.⁹¹ These injection wells must be tested to ensure that there are no leaks and they must be monitored to examine whether a contamination has occurred.

3.4 National Oversight and State Management of Hydraulic Fracturing

Both options for regulation, whether solely state or national, lacks effective control of hydraulic fracturing. Current state regulation varies widely between multiple states even though gas industries may be drilling in more than one state. A gas industry that has begun drilling in the Marcellus Shale may also be a large player in the Barnett Shale, though the regulations in each shale play may be very distinct from one another. However, with proposed national regulation, both state primacy and industry proprietary rights are at risk. Many contrasts occur with shale deposits in each state, thus state officials know what is best for their constituents and industries must create their chemical mixtures according to the respective shale plays. Hence, a blend of both national and state regulations would be a more successful method of control.

Allowing the EPA to regulate hydraulic fracturing merely at a national level remains inefficient due to the limited amount of resources to oversee all drilling activities in each state as well as focus on other environmental regulations. Hence, general oversight of hydraulic fracturing will be assigned to the EPA, but detailed management will remain with the states and possibly further delegated to local officials of whom these activities occur.

The EPA can set a baseline standard for national regulation of hydraulic fracturing, which includes disclosing the chemicals to the EPA, maintaining the Material Safety Data Sheets for all chemicals that are being used in the drilling process, and certifying that the well constructions take necessary precautions to prevent adverse impacts to human health and the environment. Often times a minimum national regulation is established in order to push states towards a common goal, and states must adopt regulations that are no less stringent than the federal regulations. Several states currently preserve a record of these chemicals and their adverse effects, thus obtaining the information of the types of chemicals used as well as the impacts should not be too difficult. To address industries' concerns of publicizing the information through the use of the Internet, the proprietary formulas of these chemicals will only need to be monitored by both the EPA and state regulatory agencies to ensure that the volumes used do not exceed health safety standards, taking into account the concentration of the chemical contents within the millions of gallons of water being utilized.

Since shale deposits as well as water supply systems vary between states and even between adjoining cities, state officials can tailor their regulations to respective local conditions. They can regulate hydraulic fracturing on a well-by-well basis and delegate authority to the local officials to monitor the surrounding environmental quality. State regulatory agencies would need to monitor water withdrawals since much of the water used in the fracturing process originates from local streams or groundwater. Rules would need to be developed for industries to develop a detailed breakdown of the process and the components involved in the process such as the location of the storage of chemicals or the path of the flowback fluids. In this respect, states would be able to retain jurisdiction over the process of hydraulic fracturing. However, both local officials and industries would work to ensure that the method is safe and would not cause detrimental impacts to the public.

⁹¹ Pagel, Lauren, and Dusty Horwitt. "Safe Drinking Water Act Should Cover Hydraulic Fracturing." *Environmental Working Group*. June 2009. <http://www.ewg.org/Safe-Drinking-Water-Act-Should-Cover-Hydraulic-Fracturing> (accessed July 28, 2010).

3.5 Development of New Technology: Fishbone Drilling

The major problems associated with horizontal drilling are fracture closures causing a decrease in gas production and the uncertainty of fracture placement due to the lack of knowledge of formation stresses. Therefore, fishbone drilling could be viewed as an alternative to hydraulic fracturing. Fishbone drilling is a fairly new technology that has been examined in the production of tight gas fields. Branches, which are referred to as “rib holes,” are drilled off of the original well and perform the same role as fractures in horizontal drilling.

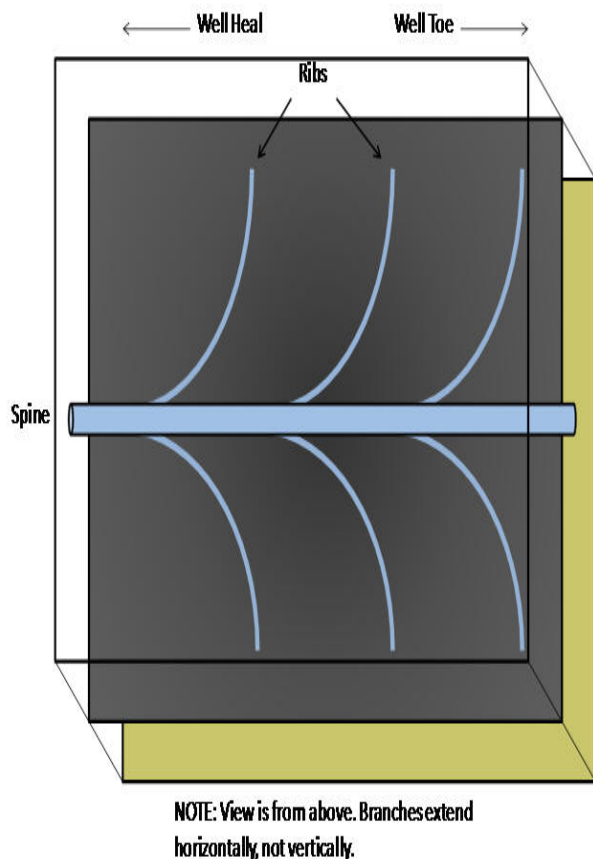


Figure 15 Example of Fishbone Drilling (Source: Fanchi Enterprise, 2010)

precise method of drilling, fishbone drilling would eliminate the need of the high-pressures associated with hydraulic fracturing as well as the large amounts of water pumped underground in order to house the mixture of proppant chemicals for the fractures.⁹⁴

In a study presented to the Society of Petroleum Engineers, a comparison was made between horizontal drilling and fishbone drilling to maximize the net-present value (NPV) of field development. Assuming that the number and location of fishbone wells are equal to that of horizontal wells, a change in the number of both the fractures and rib holes did not cause a proportional increase in the net-present value. The net-present value of the fishbone well was slightly higher than that of the horizontal well with the NPV of the fishbone well at \$35,750,000 and the NPV of the horizontal well at \$35,200,000.⁹² However, fishbone drilling is more beneficial when utilizing it in reservoirs with high-vertical permeabilities and when using a smaller number of fractures. Therefore, horizontal drilling should be used when the number of fractures is greater than 4, whereas fishbone drilling is better for the number of rib holes less than 6.⁹³

The use of fishbone drilling could possibly alleviate environmental ramifications. With a more

4.0 Recommendations

Although alternatives and advancements to hydraulic fracturing to mitigate the amount of water and chemicals used are desired, the lack of research and development makes such technology as fishbone

⁹² The NPV for both wells would increase with fracture or rib hole length but decrease with fracture or rib hole spacing. Yu, Xiance, Boyun Guo, Chi Ai, and Zhidan Bu. *A Comparison between Multi-Fractured Horizontal and Fishbone Wells for Development of Low-Permeability Fields*. SPE 120579, Society of Petroleum Engineers, 2009.

⁹³ For the number of rib holes between 6 and 8, the performances of the two types of wells are similar. Yu, Xiance, Boyun Guo, Chi Ai, and Zhidan Bu. *A Comparison between Multi-Fractured Horizontal and Fishbone Wells for Development of Low-Permeability Fields*. SPE 120579, Society of Petroleum Engineers, 2009.

⁹⁴ Fanchi, Christopher J. and John R. "The Barnett Shale -- Frequently Asked Questions." Fort Worth, 2010.

drilling in shale gas applications less cost-effective. Hence, a blend of national and state regulations would be more preferable than a regulation of either form on its own.

In a study conducted by IHS Global Insight in 2009, the impact on the U.S. economic performance due to proposed policy changes on hydraulic fracturing was forecasted using three policy scenarios—elimination of hydraulic fracturing, fluid restrictions, and UIC compliance—with the existing regulations viewed as the baseline for comparison. If fracturing were eliminated, the country would experience a 45% reduction by 2014; this estimate would increase due to the nation's increasing dependence on hydraulic fracturing for unconventional resources. Fluid restrictions would reduce natural gas production by 22%, or 4.4 tcf, whereas UIC compliance would result in a slightly less reduction of natural gas production at 10%, or 2.1 tcf.⁹⁵

4.1 Regulation of Hydraulic Fracturing Under SDWA

Under the Safe Drinking Water Act, the EPA is granted the authority to regulate underground injection in order to protect the nation's public water systems. The SDWA Amendments signed by President Clinton in 1996 also includes changes to improve the regulatory program. Although the process of hydraulic fracturing is currently exempted from the SDWA, portions of the legislation that have been applicable to underground injection that would also be applicable to hydraulic fracturing. States that have adequate regulation should not be drastically hindered from the addition of hydraulic fracturing into the SDWA if appropriate underground injection regulations have been in place. The following passages provide brief overviews of these particular segments in the SDWA and justification for their applications to hydraulic fracturing.⁹⁶

[Section 1412 (b)] Sec. 102 (a) The EPA is granted general authority to set a Maximum Contaminant Level Goal (MCLG) and to regulate contaminants that may adversely affect human health; are known or likely to occur at a frequency and level of public health concern in public water systems; and for which regulation presents a meaningful opportunity for health risk reduction for persons served by public water systems.

Although several of the chemicals that are utilized in the hydraulic fracturing process may be found in everyday use, the concept of these chemicals being pumped underground draws attention to the possible negative impacts. Chemicals range from hydroxyethyl cellulose, which is commonly found in baked goods but may affect the blood or nerves,⁹⁷ to ammonium persulfate, which is commonly found in hair coloring but may produce asthma-like symptoms.⁹⁸ Industries take much precaution to ensure that the well construction, primarily the casing and cementing, would isolate the hydraulic fracturing activities from the public water supply. However, if the well construction has not been completed properly, these chemicals could seep into the water systems. With the thousands of wells already drilled and many which are fractured multiple times, faulty well designs cannot be ruled out. Therefore, the EPA should be able to regulate the disclosure of these chemicals to establish an MCLG.

[Section 1412 (b)] Sec. 103 Whenever the EPA proposes a national primary drinking water regulation, it must publish a cost-benefit analysis that would also include the consideration of effects on

⁹⁵ These statistics were prepared by IHS Global Insight using its own data, information and analysis with the economic assessment from the U.S. Macroeconomic and state economic models in order to assess national and state-level oil and gas production under different scenarios. IHS Global Insight. "Measuring the Economic and Energy Impacts of Proposals to Regulate Hydraulic Fracturing." June 2009. http://www.epa.gov/policy/exploration/hydraulicfracturing/upload/IHS_GI_Hydraulic_Fracturing_Exec_Summary.pdf (accessed July 13, 2010).

⁹⁶ All summaries of sections in the UDSW are taken from the EPA website. U. S. Environmental Protection Agency. "Safe Drinking Water Act Amendments of 1996." *U.S. Environmental Protection Agency*. August 1996. <http://www.epa.gov/safewater/sdwa/summ.html#3> (accessed July 28, 2010).

⁹⁷ Sigma Chemical Company. "MSDS Hydroxyethyl Cellulose." 1 July 1995. <http://siri.org/msds/f2/chz/chzvc.html> (accessed July 28, 2010).

⁹⁸ Mallinckrodt Chemicals. "Material Safety Data Sheet." *J. T. Baker*. 11 January 2008. <http://www.jtbaker.com/msds/englishhtml/a6096.htm> (accessed July 28, 2010).

sensitive subpopulations and taking into account the cost and benefit factors for a Maximum Contaminant Level (MCL) regulation. The EPA must also identify health benefit measurement and evaluation methods, including the consumer “willingness to pay” for reductions in health risks.

Both state officials and industry leaders believe that national regulation under the SDWA would cause a dramatic decline in the economic benefits provided by natural gas production from shale. However, the EPA is required to analyze the impacts of further regulations on public drinking water by weighing the costs and benefits. Therefore, they will be able to determine in which areas further regulations would be more appropriate and be able to consider the tradeoffs when establishing an MCL.

[Section 1412 (b)(8)] Sec. 107 The EPA shall issue regulations requiring disinfection “as necessary” for ground water systems and shall determine a criteria of whether disinfection shall be required as a treatment technique for groundwater systems.

In all industries, there should be a response plan in case of a well blowout and water or air pollution. Many industries have wastewater treatment procedures, though some of them may be weak. Thus, the EPA has the ability to ensure that a method for disinfection of the groundwater would be established as a treatment technique if in fact hydraulic fracturing chemicals do impact the public water systems.

[Section 1412 (b)(12)(B)] Sec. 109 (a) EPA must develop a study plan for both arsenic as well as sulfate. The arsenic study plan, in cooperation with the National Academy of Sciences, other federal agencies and interested stakeholders, must assess the health risks associated with exposure to low levels arsenic. The study conducted for sulfate must determine the dose response relationship for adverse human health effects from sulfate in drinking water.

In several instances, cases of benzene, arsenic and lead have been discovered in both water sources as well as air emissions and have been attributed to improper hydraulic fracturing activities. Under the SDWA, the EPA has already set MCLs for these contaminants; these MCLs are considered enforceable standards. There are national secondary standards for sulfate in drinking water standards. Airborne dust of ammonium persulfate can cause difficulty in breathing and exposure to this chemical could easily occur with storage of large volumes of such chemicals. Therefore, a study of such chemicals in the fracturing process as ammonium persulfate, previously mentioned, may need to be examined as well.

[Section 1445 (a)] Sec. 125 (c) The EPA must issue regulations establishing criteria for the monitoring of unregulated contaminants. The monitoring shall vary based on system size, source water, and contaminants likely to be found. Only a representative sample of systems serving 10,000 persons or fewer must monitor. Results of the monitoring are to be included in the national contaminant occurrence data base.

Many of these natural gas wells have been drilled in low-income, rural cities in which there is only one primary water supply for each household. Since these chemicals are currently unregulated, the EPA could set up a study to determine whether or not they are caused by leakage due to hydraulic fracturing and establish criteria to prevent further leakages.

4.2 Procedures to Establish More Effective Regulations

As mentioned earlier, the first step to alleviating public concerns about hydraulic fracturing is the disclosure of the chemicals used in the process. A breakdown of the chemicals for each well will need to be maintained on site and in local records; delegation to local officials would allow for an ease of oversight due to the thousands of wells drilled in these particular states. A few industries have agreed to disclosure of their chemicals, though the proprietary formula would only be revealed to national and state regulatory agencies rather than posted for public view. This way, the public would know which chemicals are being used in a nearby well; national regulatory agencies would be able to obtain oversight in case of emergencies and in order to enact any necessary studies to enhance the technology; state agencies would be able to tailor the regulations to their individual affairs in order to find a balance between health, environmental and economic impacts; and industries would be able to continue natural gas drilling

without ongoing concerns of adverse effects of hydraulic fracturing.

Further research and development programs could be established either with the EPA or the U. S. Department of Energy (primarily in the Office of Fossil Energy) to ensure that a systematic procedure is used to assure efficient and effective use of domestic resources. This can include a determination of appropriate recovery processes, mostly in the advancements of hydraulic fracturing or other extraction techniques that would require less water and chemical additives and also minimize the transportation of these components. With the inability to recover all of the fracturing fluids as well as the possible environmental hazards of produced water disposal, better technology could be applied to limit open waste pits. Incentives could be established to encourage reuse or recycling of hydraulic fracture water. Since much of the water used in hydraulic fracturing comes from local streams or water systems, better technology should also be mandated to ensure water efficiency by possibly requiring a 25% reduction in water use in 5 years and providing block grants to make such improvements. Certain technologies that have been underway involve the improvement of well design such as improved stimulation for real-time monitoring via electronic telemetry; improved cementing through zone isolation and use of lightweight cement and ceramic borehole sealants; development of various drilling techniques such as high-pressure coiled tubing drilling; and development of collecting downhole data through seismic signals or high-temperature MWD systems.⁹⁹

Due to the lack of a reference on initial water quality, industries as well as regulatory agencies are unable to conclude the sources of environmental concerns surrounding air and water pollution. Several states have provided air monitoring systems around the well sites to determine the level of air emissions from the process. Hence, either the state or local regulatory agencies should require the testing of public water systems surrounding the site as well as the source from which the water used in the fracturing process is being obtained. This would ensure the safety of the water source by defining the chemicals that have already existed in the water supply, providing a reference of whether or not hydraulic fracturing could be the culprit of water contamination. The water should be tested after the first fracture and after the well has been removed. If after the first fracture, tests reveal that there has been contamination, all well activity should be stopped and plugged, and the industry would be responsible for implementing appropriate clean-up and remediation methods. Then a test after the well has been removed should be performed to ensure proper treatment has been achieved. The industry would be given 24-hours to clarify the violations under public notification. The severity of the incident would determine whether the issue would fall under national or state regulation. Monetary fines would be imposed on the industry, though a liability cap could be reviewed on a case-by-case basis. If the well undergoes multiple fractures and tests prove that the first fracture caused no harmful implications, a test should be performed every 3 to 5 fractures as determined by the regulatory agencies since shale deposits vary.

To better examine potential health and safety risks to the public, process modifications should be employed. This would include a development and analysis of maps and overlays of how natural and community resources could be affected. The maps and overlays would include existing underground pipelines for water and natural gas systems, the city infrastructure and topography including groundwater resources, naturally occurring radioactive deposits and critical habitats, and the land use and paths that the hydraulic fracturing process would impact, which would include well sites, piping, gas storage and traffic routes or temporary roadways. Thus, high risk areas could be isolated for better evaluation; air emission streams could be traced to pinpoint the source in order to develop quantitative information on the adverse effects of air pollutants; and rates of pollutant dispersion could be analyzed to determine the best treatment methods.

More energy efficient and cost-effective means for natural gas extraction would allow for a development of competition in existing as well as advancing markets.

⁹⁹ Tomer, Brad. "Strategic Center for Natural Gas Integrates DOE's Natural Gas Program." 2002.
http://media.godashboard.com/gti/4ReportsPubs/4_7GasTips/Winter02/StrategicCenterForNaturalGasIntegrates.pdf
(accessed July 28, 2010).

5.0 Conclusion

According to MIT Energy Initiative Director Ernest J. Moniz, “very tight carbon constraints will likely phase out natural gas power generation in favor of zero-carbon or extremely low-carbon energy sources such as renewables, nuclear power or natural gas and coal with carbon capture and storage. For the next several decades, however, natural gas will play a crucial role in enabling very substantial reductions in carbon emissions.”¹⁰⁰

The main purpose of producing shale is to meet the shortage in crude reserves, and subsequently reducing the nation’s dependence on foreign petroleum. The main factor that governs the economics is the price of the fuel. With the reduction in carbon emissions in comparison to oil and coal as well as the abundant reserves of domestic gas, the production of shale plays has increasingly gained attention. Both advancements in hydraulic fracturing as well as horizontal drilling have made extraction of this natural gas possible while providing an economic boost to approximately thirty-three states.

However, environmental ramifications have brought to light the adverse effects of the hydraulic fracturing process. With the vast amounts of water used as well as the numerous chemicals pumped into the ground in each fracturing process, opponents to shale gas production believes that the initial step to making this process safer would be to apply more stringent regulations. Therefore, legislation has been proposed to address concerns about disclosure of the chemicals and the impacts of local water supplies.

The drastic increase in natural gas production will provide over 100 years’ worth of energy to the United States. Thus, while more advance technologies remain costly, discontinuing the use of hydraulic fracturing would cause a radical change in the economy as well as public lifestyles. To alleviate public concerns and ensure health and environmental safety, a combination of national and state regulation must be employed. With the cooperation at a federal and state level, society is one step closer to living green.

¹⁰⁰ Hirsch, Jen. "MIT releases major report: the Future of Natural Gas." *MIT media relations*. 25 June 2010. <http://web.mit.edu/press/2010/natural-gas> (accessed July 28, 2010).

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