Hydraulic Fracturing for Natural Gas Extraction: Research and Regulatory Impacts

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Overview

Even though the practice of hydraulic fracturing, or fracking, has been around since 1947, it has not been until the rise of natural gas extractions in shale formations within the last ten years or so that the topic has become highly controversial. Fracking, quite simply, has become known as a technique used to extract natural gas trapped deep inside of shale rock. A mixture of water, sand, and chemicals are pumped into a natural gas well at high pressure to create fissures in the rock to allow the natural gas to flow towards a perforated wellbore so that it can then be extracted. Within the last decade new horizontal drilling techniques have been introduced in the industry allowing companies to tap into shale formations where it traditionally had not been physically possible or economically feasible before. By 2035, the United States Energy Information Administration ("EIA") is projecting that shale gas production will reach more than 340 billion cubic meters per year, or in other words about 47% of the projected gas production in this country will be extracted from shale (Jackson, Pearson, Osborn, Warner, & Vengosh, 2011).

Proponents of fracking believe that natural gas provides the United States with a stable source of domestic energy in an industry that employs more than 9.3 million people, with the oil and gas industry contributing more than $1.2 trillion to the Gross Domestic Product ("GDP") in 2011 (American Petroleum Institute, 2013). While opponents believe fracking has created a number of hazards to water and air quality, there is also belief of negative impacts to the health of the general public as well as the environment due to the millions of gallons of fluid being pumped into the ground causing concern for contamination in drinking water wells.

There are a variety of regulatory bodies that are involved in the regulation of gas production and fracking at the federal, state, and local level. However, at the federal level there is surprisingly little authority the United States Environmental Protection Agency ("EPA") can provide in regards to the injection of the fracking fluid underground unless the fluid contains diesel fuel. The EPA has presently begun to take steps for a proposed rulemaking docket to address regulations that would require disclosure of the composition of chemicals

being used for fracking, however many companies are claiming this rulemaking could jeopardize trade secrets in the industry (Trager, 2014).

At the state level, many have been revisiting oil and gas rules to address the use of hydraulic fracturing. Wyoming became the first state, in 2010, to require the disclosure of the chemicals being utilized during the hydraulic fracturing process but allowed exemptions for confidential information, or trade secrets (American Petroleum Institute, 2012). Several other states have followed similar paths as Wyoming in regards to a requirement of the disclosure of chemicals used; however some states including New York, Pennsylvania, Texas, and Colorado have varied their rules regarding exemptions for confidential information.

Local governments in states such as Pennsylvania or New York have been successful in banning hydraulic fracturing operations using zoning provisions or through noise regulations (Frackwire, 2013). These bans have managed to be upheld as ligation made its way through the court system; particularly within the New York courts on several occasions, although more recently New York has actually banned the practice of fracking in shale formations. Pennsylvania currently has several cases pending even though precedence indicates that the courts will continue to side with local governments (Frackwire, 2013).

History

The concept of fracking can be dated back as early as the 1860s with the use of dynamite or other explosives to increase the extraction of oil and natural gas from petroleum bearing formations underground. By April 1865, Colonel Edward A. L. Roberts patented a torpedo, or a canister filled with explosives (Argonne National Laboratory, 2013). The torpedo was intended to fracture the rock at the bottom of an oil well, stimulate the flow of oil, and remove things that typically tended to restrict the flow, such as paraffin wax. These methods became popular in states like West Virginia, Pennsylvania, Kentucky, and New York.

By the 1930s, it was determined that acids could be used to stimulate wells more efficiently versus torpedoes (Argonne National Laboratory, 2013). By using a method known as acid etching, the fractures that were created deep beneath the surface would not close

completely as with the use of torpedoes. This eventually led to more oil and gas being extracted an increases to well productivity. With the arrival of this new method for the stimulation of wells to extract oil and gas came the realization that there was a relationship between the treatment pressures being applied and the performance of the well. In 1947, Floyd Farris of the Stanolind Oil and Gas Corporation conducted the first experiment using a hydraulic fracturing treatment to extract natural gas (Argonne National Laboratory, 2013). At the time, a mixture of gelled gasoline, or napalm, and sand was used to inject into an underground gas formation. Unfortunately for Mr. Farris, his experiment was not that successful.

By 1949, Halliburton Oil Well Cementing Company refined the technique using the process described by Stanolind Oil and Gas Corporation and successfully performed hydraulic fracturing to stimulate two wells, one in Oklahoma and the other in Texas (Argonne National Laboratory, 2013). The success of this operation led to greater advances in the technology used and soon discussion turned towards whether or not hydraulic fracturing could be used on a larger scale and not just for the stimulation of wells. In 1968, the Pan American Petroleum and Transport Company was the first to use hydraulic fracturing on a larger scale. This method became known as massive hydraulic fracturing and involved injecting more than 300,000 pounds of sand like material known as proppant into a well (American Petroleum Institute, 2012). By the early 1970s, thousands of gas wells across various basins in the western United States were using massive hydraulic fracturing to extract gas from many of the hard rock formations. Within ten years, the technique of massive hydraulic fracturing had made its way into parts of western Canada as well as over in some European nations including Germany, the Netherlands, and the United Kingdom.

During the 1970s, American geologists had become increasingly aware of huge volumes of various gas-saturated geological formations with low permeability come to be known as shales. This resulted in the United States Department of Energy ("DOE") initiating the Eastern Gas Shales Project ("EGSP") in 1976 (Tiemann & Vann, 2012). The EGSP was intended to determine the potential of gas production and enhancement of said production in the Devonian

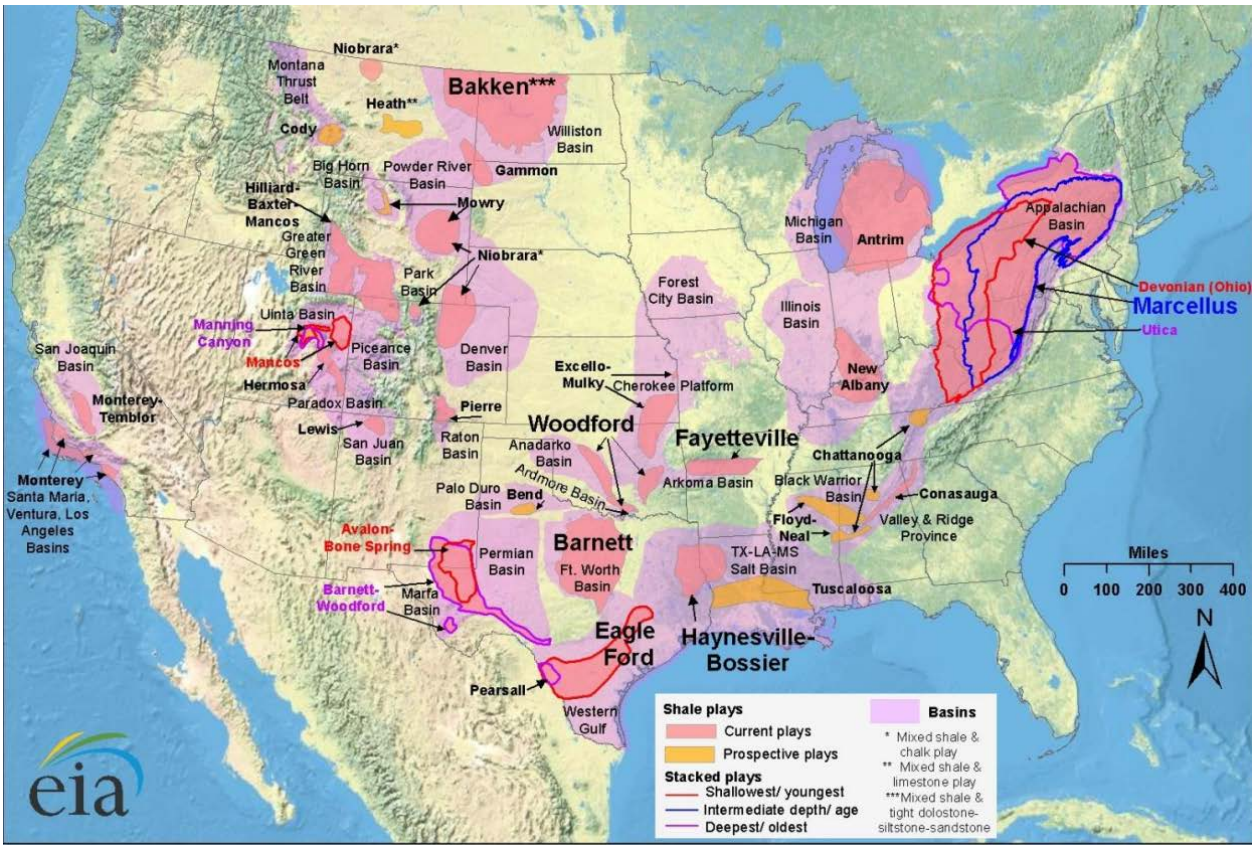

Figure 1 – Illustrates known shales containing natural gas in the United States.
Retrieved from: U.S. Energy Information Administration

and Mississippian shales located within the Appalachian, Illinois, and Michigan basins in the eastern United States. Figure 1 identifies the various shales and basins known in the United States. Another aspect intended to result from the EGSP was the development and implementation of new drilling, well stimulation, and other related well technologies to maximize well production (Tiemann & Vann, 2012). Interestingly enough, around the same time of the commencement of the EGSP by the DOE, the Gas Research Institute, received approval for research and funding with similar guidelines from the Federal Energy Regulatory Commission ("FERC") (Tiemann & Vann, 2012).

Up until the late 1980s horizontal drilling in oil or gas wells was not commonplace. It would not be until 1991 when the first horizontal well in the Barnett Shale of Texas would be drilled (IHS CERA, 2013). It had not been until the well in the Barnett Shale was drilled that it was demonstrated that gas could be economically extracted. Over the years drill technology became even more effective. This has led to quite an increase in the number of active wells in

the United States, presently; there are over 1.1 million wells in all but 15 states (FracTracker Alliance, 2014).

The Process of Hydraulic Fracturing and Shale Gas Production

As discussed earlier, hydraulic fracturing, or fracking, is a process used to stimulate a natural gas, oil, or a geothermal energy well to maximize the extraction. The EPA views the process of hydraulic fracturing to include the procurement of source water, construction of the well and subsequent stimulation, and disposal of waste. While typical mineral formations that contain natural gas deposits can have high permeability, shale formations have low permeability. This low permeability can naturally limit the flow of gas or water. In shale formations, natural gas can be found in largely unconnected pores and natural fractures in the formation. This is where hydraulic fracturing comes into play; this process is what is being used to connect these pores together so that the gas is able to flow. Many believe that fracking is an all-encompassing term that includes all steps of extracting gas from shale. This is not the case; fracking refers simply to the process utilized in order to extract the gas from the well. There are many other steps that must be completed prior to the extraction such as road and well pad construction, actually drilling the well, installation of the well casing and perforating. Once those steps have been accomplished then the well can be considered a production well. After a well has been exhausted or if it is determined it is no longer economically feasible to drill, then the well is prepared for abandonment, and a reclamation process can begin.

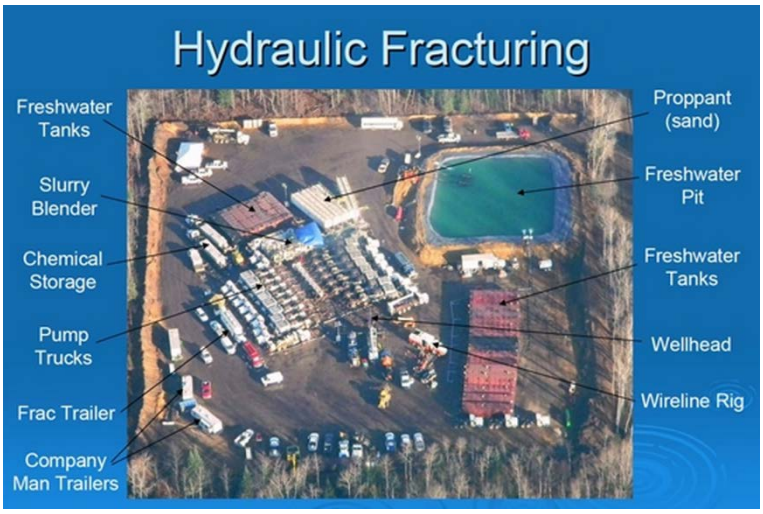

Figure 2 – An overview of a typical natural gas extraction well pad using hydraulic fracturing. Retrieved from: Tip of the Mitt Watershed Council

There is quite a process involved in the installation of the well, even outside from the permitting and approval processes. First and foremost, all wells will require what is known as a well pad. This pad will contain the

wellhead and serve as the base for drilling equipment, water storage tanks, loading areas for water trucks and other associated equipment. An example of a well pad is shown in Figure 2. A pad can typically span over the area of several acres depending on the depth and number of wells to be drilled.

Once the installation of the well pad has been completed, then the drilling can begin. Typically, shale gas is found at depths of 6,000 feet or more below ground through a thin yet low permeable layer of rock (Jackson, Pearson, Osborn, Warner, & Vengosh, 2011). For the most efficient manner of extracting natural gas the shale must be drilled through horizontally. As made evident in Figure 3, the initial drill is done vertically until the drill bit begins to reach the shale formation. Once the shale gets closer, a directional drill creates a 90-degree curve, thus making the wellbore horizontal. Multiple horizontal wells can be drilled from a single well pad and can continue for up to two miles from the well pad. It can be argued that because a larger area of shale is accessed from a single pad that there is a reduction in the footprint of these operations.

As in all wells, the well casing is perforated. However, in this case, natural gas will not really flow freely into the well that has been drilled into the shale. This is where hydraulic fracturing comes into play. Fractures must be created in the shale so that the gas can escape various pores and natural fractures contained in the rock. This is done by taking millions of gallons of water, sand, and a blend of chemicals made up of acids, biocides, corrosion and scale inhibitors, a type of either gel or gum, and a friction reducer to ensure that the fluids carrying the sand can get into small fractures within the shale (IHS CERA, 2013). This fluid is pumped into the well casing which exits through the perforations. Once the fluid has left the well casing it forces fractures to open in the shale and connects various natural pores and existing fractures allowing for the natural gas to flow back to the perforated well casing. The sand gets stuck in the small fractures so that once the fluid pressure is reduced, the fluid flows back out of the well. This is a very tedious process that must be done in stages starting at the furthest point of the wellbore as typically only 1,000 feet of wellbore can be fractured at a time (Argonne National Laboratory, 2013). Cement plugs are also used during the process so that each

fracture stage is being isolated and using the pressure to provide the natural gas with the opportunity to go up the well after each hydraulic fracturing section is completed.

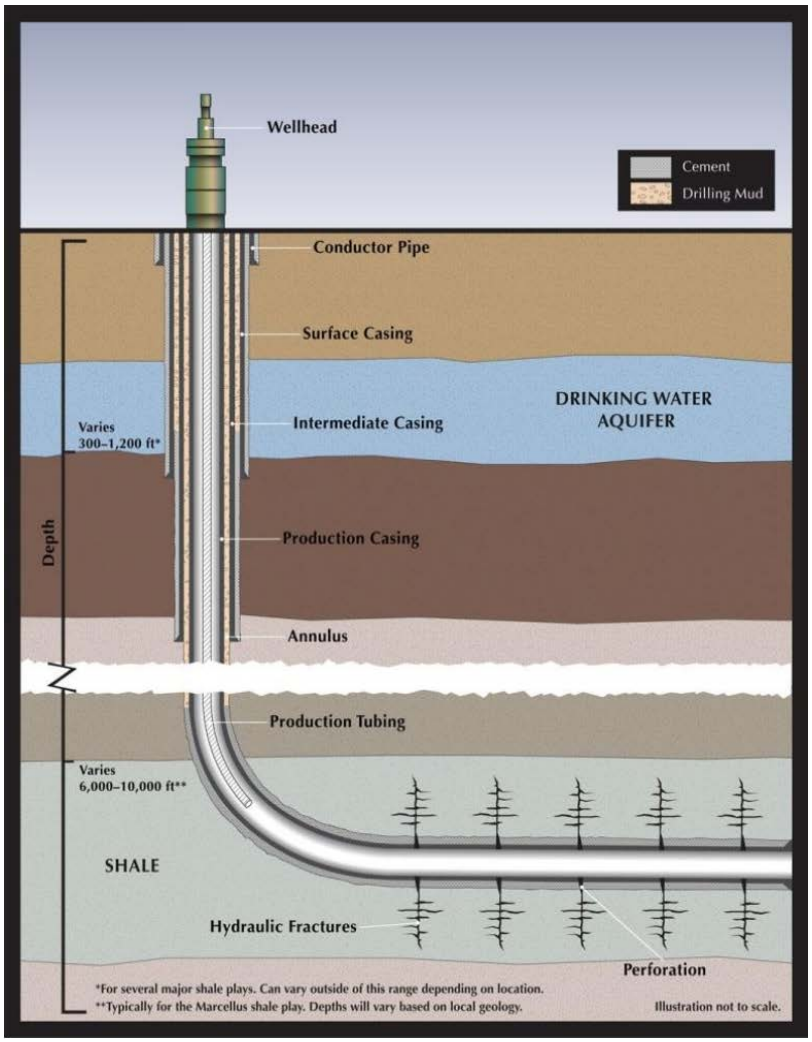

Figure 3 – Example of a Horizontally Drilled and Fractured Shale Gas Well. Retrieved from: Argonne National Laboratory

As the cement plugs are drilled out to release the pressure, the water will flow back out the top of the well, otherwise known as flowback water. This flowback water will contain the various proprietary blends of chemicals from the hydraulic fracturing fluid as well as other chemicals that were existing in the shale. Things already present would include things like salts, minerals, hydrocarbons and salty water. Depending on the condition of the flowback water it can be recycled for several different hydraulic fracturing cycles. Disposal of flowback water is regulated by the EPA's Underground Injection Control Program (Argonne National Laboratory, 2013). This program prevents past disposal of this flowback water into surface waters or treatment plants that cannot treat flowback water. These injection wells receive the flowback water in underground formations away from drinking water sources.

During the useful life of the well, otherwise known as production, gas is retrieved from the well through a small pipe connecting to larger pipes that are collecting the gas from all of the production wells at the respective well pads. Since the extraction of shale gas is relatively

new, the production lifetime of these production wells is not quite defined. It is a general assumption that shale gas wells tend to decline quicker than conventional natural gas production wells (Argonne National Laboratory, 2013). Once the output of the well ceases to be productive, the wellhead is removed and the wellbore is filled with cement to prevent leakage of gas into the air. Typically then the site is then returned back to its original state to the land owner and the site is abandoned.

Economic Effects

The increase in the extraction of shale gas over the past several years has led to a general decrease in the price for natural gas mainly due to the large domestic supply of the gas. As like other free markets, prices for natural gas are significantly driven by supply and demand. Since there is now considered to be an abundant supply of natural gas coupled with lower prices, the result has sparked interest in the use of natural gas for electricity production and even as a transportation fuel.

It is important to recognize that in reality, natural gas has an effect over virtually every aspect in the life of the average American. Natural gas tends to be the fuel of choice of many American manufacturing businesses primarily due to the relative stability of natural gas fuel prices. Natural gas can be used to make things like steel, glass, various chemicals and textiles, automobiles, food and so much more. In the end the cost savings from the energy choices of manufacturers are reflected in the costs consumers pay for the respective products. A study released from IHS CERA, a leading energy consulting firm, shows that in part due to low natural gas prices, the average household experiences a $2,000 increase to disposable income (2013).

There is no denying that natural gas extraction plays a significant role in contributing to the economy of the United States particularly with the advent of shale gas extraction. Even while the nation experienced an economic downturn, the oil and natural gas industry continued to add jobs in part to rise of extraction of natural gas from shale. The Perryman Group, an economic and financial analysis firm, has estimated that the total economic benefits of oil and gas exploration, development, and production represent almost 7% of the United States economy within an industry that supports more than 9.3 million permanent jobs (2014).

The Current Economic Benefits of Oil and Gas Exploration and Production: Gains in Selected Major Energy-Producing States		
	Gross Product (Billions of 2014 Dollars)	Employment (Permanent Jobs)
Texas	$472.535	3,794,527
Oklahoma	$111.569	874,456
California	$57.010	446,800
Louisiana	$47.925	401,191
Colorado	$47.686	373,349
Ohio	$30.343	234,807
Pennsylvania	$25.716	205,478
New Mexico	$20.543	164,626
Wyoming	$11.389	88,548
North Dakota	$11.322	102,087
Alaska	$7.405	58,201
Utah	$6.221	49,054
US TOTAL	**$1,171.304**	**9,312,478**

Figure 4 – Top 10 energy-producing states based on gross product. Retrieved from: The Perryman Group

Additionally, the United States receives more than $138 billion in revenues from oil and gas activity (Argonne National Laboratory, 2013). While Delaware is not known to have any shale formations to extract oil and natural gas, Delaware still does experience indirect economic benefits from the oil and natural gas industry that can be felt by the contribution of more than 34,000 jobs, or approximately 6.5% of the state's work force (Argonne National Laboratory, 2013). The economic impacts of natural gas can be better measured at the state level. As evident in Figure 4, our neighboring state of Pennsylvania benefits more directly from the extraction of natural gas from its shales in terms of GDP and the number of permanent jobs created by natural gas.

Public Opinion

Hydraulic fracturing has become a hot button policy discussion issue more recently over the years due to the rise in anti-fracking movements that have arisen both here in the United States as well as internationally. Most recently public opinion has been swayed through the release of a variety of movies and documentaries that have typically drew unwanted negative attention to the practice of hydraulic fracturing of shale.

In 2010, the film Gasland became the focal point of opposition to hydraulic fracturing of natural gas from shale. The film specifically highlights problems with ground water contamination in drinking water wells in Pennsylvania, Wyoming, and Colorado. The documentary insinuates the contaminations are the result of the flowback water getting into local aquifers. The film contains scenes of individual homeowners who are able to light their drinking water on fire as it flows from kitchen faucets. Not surprisingly, various oil and gas

industry lobbying groups called many of the film's portrayals to be grossly inaccurate and misleading saying that Gasland's director showcased homeowners that have long had a history of being able to ignite methane in their water long before the fracking commenced. In response to the film, large oil and gas companies including Exxon Mobil, Chevron, and ConocoPhillips all aired advertisements in attempts to describe the economic and environmental benefits of natural gas and declared that hydraulic fracturing was safe (IHS CERA, 2013). Other films, such as Promised Land, released in 2012 and starring Matt Damon, highlights hydraulic fracturing and provides many criticisms in regards to the practice. In 2013, a follow up documentary to Gasland, entitled Gasland 2, was released arguing that the natural gas industries portrayal of natural gas as a clean and safe alternative to oil is a myth and alleges that hydraulically fractured wells are doomed to leak over time, contaminating both the water and air, cause medical issues, and can endangering the earth's climate with the release of methane from wells.

Also in 2013, the documentary film FrackNation was released. The film's director claims that he was inspired to release the documentary after seeing Gasland and realizing that many of the claims made in that documentary were unsupported. This left more questions than answers and the director believed that Gasland was a one sided approach to the public policy debate that fracking deserves. FrackNation received praise from critics for how well researched the film was and highlighted its success at the documentary's portrayal of just exactly how complex the issue of fracking really is.

Health Factors

Over the years, many of those opposed to the use of hydraulic fracturing in shale have argued that there is cause for concern in that these specialized chemicals could contaminate drinking water aquifers since the flowback water is not always able to be completely removed from the well after completion of natural gas extraction. Depending on the geographic location, the flowback water that remains in the well could vary from less than 30% to as much as 70% (Argonne National Laboratory, 2013). As a result, questions still remain regarding the impacts of this flowback water remaining in the ground and its effects on the groundwater

quality of public and private wells. Opponents of fracking argue that since production of these wells have been increasing and expanding in more populated areas that the fracturing process could potentially introduce chemicals, methane, and other contaminants into aquifers. The thought process is that these contaminants could potentially flow through the creation or extension of new fractures created in the producing zone. It is assumed that the introduction of flowback water in our aquifers can negatively affect the health of those who consume this water (Tiemann & Vann, 2012).

However, the general consensus among geologists and regulators is that there is little possibility of creating a fracture that could reach a potable aquifer during the hydraulic fracturing process as usually there is great vertical distance between shale and water aquifers (Argonne National Laboratory, 2013). It is generally believed, that in reality, the largest risk for groundwater contamination from hydraulic fracturing results from improperly cased or cement wells and not from fractures underground created during the hydraulic fracturing process (Argonne National Laboratory, 2013).

The rapidly increasing and geographically expanding use of fracturing, along with a number of complaints of well water contamination and other water quality problems attributed to this practice, have led to calls for greater state and/or federal oversight of this activity. However, as of now, there are no published studies or available agency investigation reports that have identified a direct connection between hydraulic fracturing of shale formations and drinking water aquifer contamination (Tiemann & Vann, 2012).

Other believed health risks include the increase of exposure to potential accidents at wells and continuing exposure to harmful substances being used at fractured wells. Many have recommended full disclosure of the chemicals being used for hydraulic fracturing to determine if there are any immediate or long-term adverse health effects. While there have not been any published studies or available investigation reports in the United States regarding potential health impacts, in June of 2014, Public Health England published a report highlighting potential public health impacts due to exposure to chemicals and other pollutants from shale gas extraction in the United Kingdom (Jackson, Pearson, Osborn, Warner, & Vengosh, 2011). Public

Health England concluded that the risk is low if operations are properly run and regulated and similarly concluded that the largest risk of groundwater contamination results from the risk associated by a faulty or improperly cased well.

Environmental Impacts

A variety of environmental impacts to hydraulic fracturing have been raised by those against the practice. This includes increases to air emissions contributing to climate change, higher water consumption, potential for water contamination and reporting of earthquakes near well pad sites (Argonne National Laboratory, 2013). Primarily methane gas tends to escape into the atmosphere from the wells along with emissions associated to the industrial equipment being utilized in the extraction process. Utility representatives are quick to point out that even though it is possible for methane gas to be released into the atmosphere, technology on newer wells has improved to prevent this from happening.

Depending on the size and location of the well inside the geological formation, it is estimated that anywhere from 1 to 3 million gallons of water is required per well, or as much as 3 to 8 million gallons of water over the lifetime of the well (IHS CERA, 2013). As discussed earlier, not all of the flowback water is retrieved during the hydraulic fracturing process which is why additional water is required. Many argue that the fracking process requires the use of too much water. This raises the risk for potential surface water contamination if water is spilled at the drill site or if underground injection wells that presently hold flowback water contain fractures that are able to reach and containment drinking water aquifers.

Lastly, there have been reports of seismic activity, or earthquakes, near well sites. It is typically assumed that these earthquakes are attributed to hydraulic fracturing. Most geologists insist that fracturing cannot cause huge events that would be detected by those on the ground (Argonne National Laboratory, 2013). Instead, geologists believe that tremors felt by people can actually be attributed to the injection of flowback water into disposal wells. It is believed that by understanding the geology of the area being fracked or being used as an injection site is ideal to diminish the potential for earthquakes (Argonne National Laboratory, 2013).

Regulatory Impacts

A majority of the regulation of hydraulic fracturing resides at the state level. Hydraulic fracturing is specifically excluded from the EPA's Safe Drinking Water Act regulation that relates to control of underground injections, except for when diesel fuel is used. An advocacy group known as the Ground Water Protection Council has coordinated with the DOE as well as various oil and gas industry groups to increase awareness and answer calls from those who believe there should be increased transparency or disclosure of chemicals being utilized in hydraulic fracturing fluid (Jackson, Pearson, Osborn, Warner, & Vengosh, 2011). The result of this effort has been the launch of the website known as FracFocus.org. This website is a voluntary disclosure database for hydraulic fracturing fluids, however, there is still a lack of laws, rules, or regulations at the federal level that define what can and cannot be used in hydraulic fracturing fluids.

Regionally, Maryland is currently debating legislation that would either outright ban the practice of hydraulic fracturing or place an eight-year moratorium on the practice (WBOC, 2015). Pennsylvania currently allows hydraulic fracturing although it is believed that Pennsylvania has some of most comprehensive fracking regulations in the country with the permitting and regulation authority handled by Pennsylvania's Department of Environmental Protection ("DEP") (StateImpact, n.d.). There have also been a variety of legal outcomes which affirm many of the regulations already in place. Most interestingly though is that many municipalities have been able to successfully utilize local zoning laws to gain more control over oil and natural gas drilling and in some cases have denied permits to oil and gas companies seeking to drill (StateImpact, n.d.). Legal challenges to the denied permits have typically been upheld throughout Pennsylvania's courts (StateImpact, n.d.).

To date, only two states, Vermont and New York, have actually went as far as enacted an outright ban on hydraulic fracturing citing potential risks to human health and to the environment (Tiemann & Vann, 2012). While the ban in Vermont is not particularly noteworthy since there is no known shale gas in Vermont, the ban in New York is somewhat surprising since New York does have shale gas.

Delaware is not directly affected by hydraulic fracturing since there are no known shale gas reserves in the state and as a result there is no language in Delaware law to address this issue. However, the drinking water for most of the state's residents tends to flow from the Delaware River Basin, where fracking for gas is being considered in Pennsylvania (StateImpact, n.d.). This basin provides drinking water for approximately 15 million people including Delaware (StateImpact, n.d.). About one-third of the Delaware River Basin lies above the Marcellus Shale, with the water quality of the river basin managed by the Delaware River Basin Commission ("DRBC"). The DRBC is a five member commission that consists of the Governors of New York, New Jersey, Pennsylvania, and Delaware, and lastly the Army Corps of Engineers representing the federal government. Concerns about the amount of water withdrawals needed for drilling and impacts on water quality led to the Executive Director of the DRBC to issue a proclamation in May 2009 that all natural gas production within the basin needed to be reviewed by the DRBC (StateImpact, n.d.). A year later, in May of 2010, by unanimous vote of the five Commissioners, the DRBC voted to hold off any decisions regarding drilling in the basin until new regulations could be adopted (StateImpact, n.d.). As a result of this vote, a de-facto moratorium has prevented drilling for natural gas in the basin until the DRBC can establish its own regulations for gas drilling (StateImpact, n.d.). Later that year, the DRBC released its proposed regulations only to be met with an unprecedented amount of responses from both viewpoints. By November 2011, the DRBC posted a revised draft of the proposed regulations after having the opportunity to review the more than 60,000 public comments received by the DRBC (StateImpact, n.d.). Many environmentalists were not happy with the proposed regulations and still believed that a more extensive environmental impact study was needed before any such regulations could be finalized.

The DRBC planned to vote on the proposed rules on November 21, 2011, however just days before the meeting, Governor Jack Markell of Delaware announced that he intended to reject the proposed rules citing the need to conduct an extensive environmental impact study (StateImpact, n.d.). It was assumed that Pennsylvania and New Jersey would like approve the new regulations and with Delaware and New York voting against the regulations it would have left the federal government with the position of casting the deciding vote. The Commission

instead canceled the meeting and still has yet to revisit the regulations in a public forum (StateImpact, n.d.).

Gas Supply in Delaware

In Delaware, the Delaware Public Service Commission regulates the distribution of natural gas to Delaware consumers. There are two regulated gas utilities in Delaware, Chesapeake Utilities Corporation ("Chesapeake") and Delmarva Power & Light Company ("Delmarva"). Chesapeake provides gas service in all three counties of Delaware with its service territory beginning a few miles south the C & D Canal and continuing southward towards the Delaware/Maryland border. Chesapeake services approximately 45,000 customers. Delmarva provides gas service in New Castle County, including the City of Wilmington, and serves approximately 126,000 customers. Both of these regulated utilities receive their natural gas from a variety of sources with the majority of their supply coming from the gulf region supplementing with supply from shale gas.

Conclusions

Since there are no known shale formations in Delaware there are no direct benefits or drawbacks to hydraulic fracturing at this time. There are still quite a few misconceptions about the process of hydraulic fracturing in the mind of the public. Many confuse the concept of shale extraction of natural gas with the hydraulic fracturing process that is required in order to start up and oil and/or gas well. As discussed earlier, the concept of hydraulic fracturing has been in existence for close to 70 years now. As drilling technology enhanced over the years, the capabilities of horizontal drilling became more evident which has contributed to the boon of natural gas extraction from shale over the past decade. There is need to improve public confidence in relation to hydraulic fracturing and the extraction of shale gas. In order to improve public confidence the effort must continue to conduct the research necessary to determine the feasibility of drinking water contamination from the injection of flowback water into underground storage formations along with the development of strategies to educate the general public of such research. At the federal level, it would appear that the EPA and the

United States Geological Survey would be the most appropriate agencies to spearhead such an effort.

There also is a need to understand the ingredients of the fracking fluid that is being injected into the shales. However, because hydraulic fracturing fluid is specifically excluded from regulation under the Safe Drinking Water Act the hands of the EPA are effectively tied. As a result there is a reliance on voluntary disclosure of the ingredients involved. While it appears some companies have voluntarily shared this information, many have chosen not to. This makes the study of the effects of hydraulic fracturing fluid on drinking water more difficult than it has to be. Increased transparency regarding the ingredients of these fluids would allow for a more reliable study to be conducted on the effects of these chemicals in drinking water. This really can only be fixed legislatively with Congress having to act in order to modify the Safe Drinking Water Act to include fracking fluid so that the EPA can effectively regulate it.

Natural gas has been used as a fuel source for over a century and current domestic supply should help it last for another century. There are many desirable qualities of natural gas, it contains more energy than coal and does not release near the amount of greenhouse gases when being burned as compared to coal. Despite all of this, there is still a lot more room to further develop our knowledge of the effects that this extraction is having on our health and our environment. With better scientific study and the consideration of stronger state or federal regulation a more productive and positive path forward for the future of natural gas extraction techniques could be in the near future.

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