Spring 4-15-2014

An Ethical Look at Hydraulic Fracturing

Daniel Brock

An Ethical Look at Hydraulic Fracturing

SMU Engaged Learning

By Daniel Brock

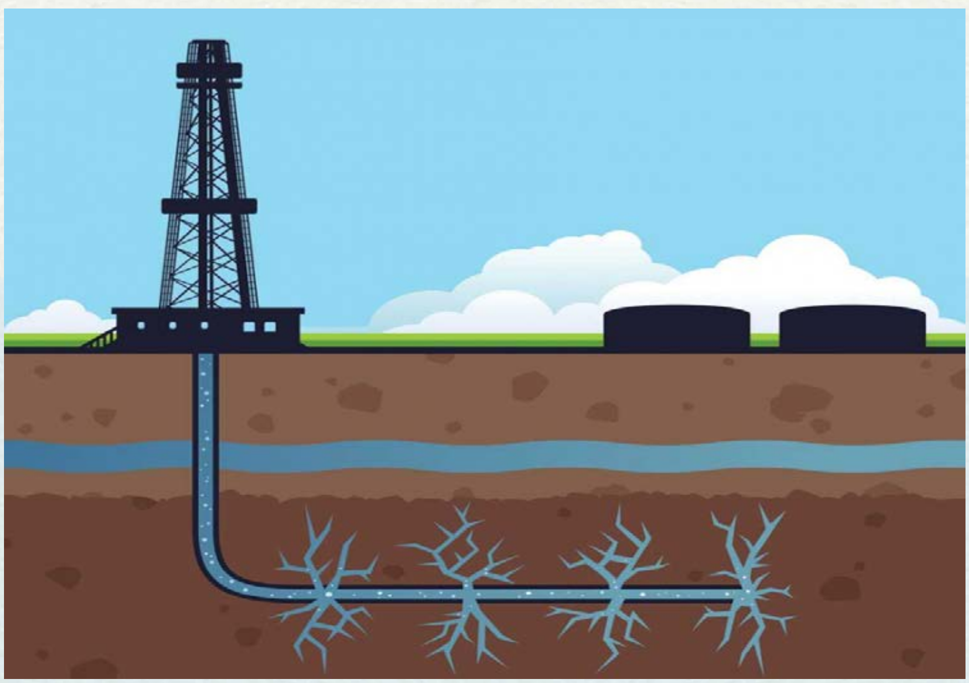


Table of Contents

I. Introduction

Following the wake of the global economic recession in 2009, a speedy economic recovery seemed to be nowhere insight. Until the oil and gas industry pioneered a technique, known as hydraulic fracturing, that could tap into the unconventional reserves of oil and gas that was once deemed impossible. The oil and gas industry combined the process of hydraulic fracturing and horizontal drilling to unleash the oceans of natural gas, crude oil and natural gas liquids embedded in the shale formations deep below our feet. The boom of hydraulic fracturing, referred to as the "shale revolution," created an unforeseen economic opportunity for the United States that carries the future of the country's economic stability on its back.

However, not everyone feels positively about hydraulic fracturing and many environmental groups vow to ban fracing in order to prevent water contamination. Shale's development in the United States is now a subject of controversy for the last 5 years. The potential economic benefits from both the drilling activities and the lease and royalty payments compete with the public's concern for environmentally safe drilling practices and protection of groundwater and surface water.

Just like all forms of energy production, externalities will exist and hydraulic fracturing is no exemption. Fear of groundwater contamination, earthquakes, and methane leaks beg the question if hydraulic fracturing is worth the risks. Regardless of the economic growth and job creation fracing has brought to the United States, we must evaluate both the pros and cons of hydraulic fracturing before deciding the fate of the best bridge fuel to the future we have.

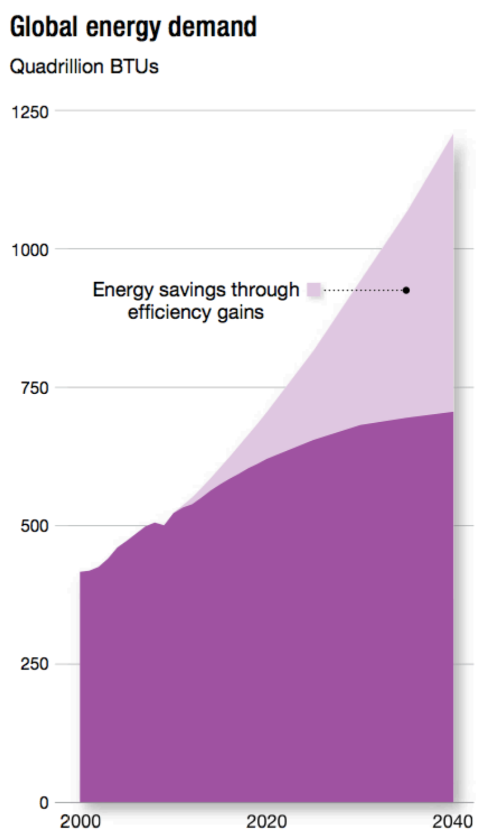
Only by means of energy use can we supply the world innovators of tomorrow with the education and resources they need to create a sustainable future. That is why we will need clean natural gas from hydraulic fracturing to provide a better quality life for our children. However, hydraulic fracturing faces some ethical issues that we must address (like sustainability and negative externalities). Nevertheless, we will need natural gas to access a better future, but it is our ethical duty to ensure we conduct hydraulic fracturing as safely and sustainably as possible.

II. Why Hydraulic Fracturing

The United States economy has such a gigantic appetite for energy, that there is no way we can simultaneously give up coal, oil, nuclear and natural gas, as much as the environment would like the economy to, without bringing things to a screeching halt. Therefore, pragmatically the world needs to pick its poison. As coal becomes too expensive, nuclear power seems uncertain and green energy technology slowly becomes more efficient, some would argue that natural gas is the bridge fuel for the future. "Conventional wisdom has been that natural gas is the lesser of the four evils, especially after Fukushima, where nuclear lost most of whatever remaining luster it had" (Siegel 2014) Currently, natural gas offers the only hydrocarbon alternative that can reasonably fulfill the world's energy demand with the least amount of impact to climate change.

Economically, the shale boom has revitalized the U.S.'s domestic oil and gas production in ways never imagined. In 2013, the Wall Street Journal confirmed that the U.S. is now the largest natural gas producer in the world and is on track to surpass Saudi Arabia as the world's largest oil producer by 2017. More natural gas means more U.S. jobs, energy security and lower carbon emissions.

And the world will need that natural gas, as well. In ExxonMobil's 2014 Energy Outlook, they predict by 2040 the world will expect to see:



- 2 billion more people
- A 130% larger global economy
- About **35% greater demand for energy** (doubled without efficiency gains)
- About **60% of demand supplied by oil and natural gas**
- **Natural gas will surpass coal** as the second-largest source of energy
- 90% growth in demand for electricity

Ethically we need this energy. "Energy is a critical part of boosting prosperity and eradicating poverty," says the World Bank President Jim Yong Kim. Technology and energy advances have helped bring about an unprecedented improvement of human-well being, including higher incomes, literacy rates and average life expectancy in many parts of the world. Columbia's University Center of Global

Energy Policy says, “Energy is a necessary input to improving quality of life and economic growth. Access to reliable and affordable energy sources can reduce poverty, improve public health, and improve living standards in myriad ways.” As populations and economies grow, and as living standards improve for billions, the energy the world consumes will continue to rise. Even with significant efficiency gains, global energy demand is projected to rise by about 35% from 2010 to 2040. (ExxonMobil 2014 Outlook)

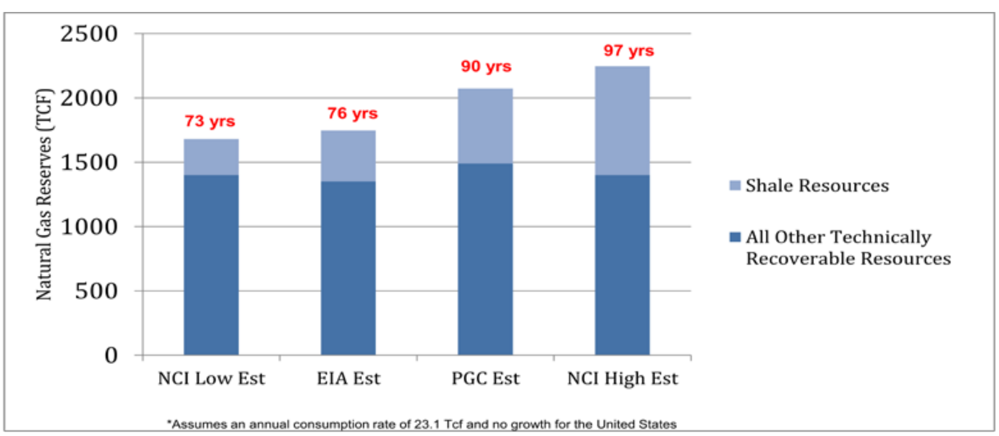
Few people realize how much energy has changed and shaped the world. Without energy to get people to the next era of carbonless, green energy, the world will need carbon energy to get people there. The reality is the expanding use of advanced technologies has also been correlated with increasing demand for coal, oil and natural gas. For that reason, people should exclusively use natural gas, which is the cleanest hydrocarbon fuel the world has. And as of right now, the natural gas the world demands can only be extracted by hydraulic fracturing. Therefore, the world will rely upon hydraulic fracturing to bridge civilization to the next era of green energy.

III. Natural Gas

Despite the hope of a world powered by alternative energy sources, the world remains without a reliable renewable energy resource that could replace the use of all hydrocarbons in the immediate future. Natural gas will be a vital long run energy source as the bridge fuel to the future. After the Obama administration’s crack down on greenhouse gases, his climate change policy will virtually eliminate coal-fired power plants across the U.S. Therefore, natural gas power plants will dominate the U.S. for power generation for the next upcoming decades. Consequently, natural gas appears to be the only link to a sustainable renewable energy future while fulfilling our energy needs for 7 key reasons natural gas is:

1. **ABUNDANT**: A 70-100 year supply and growing
2. **CLEAN**: Lower combustion emissions than coal and oil
3. **DOMESTIC**: Produced in 32 states, used nationwide
4. **VERSATILE**: Electricity generation, home, business and transportation
5. **SECURE**: Does not require importation, distribution systems in place
6. **VALUABLE**: Oil & Natural Gas industry supports 9.2 million U.S. jobs
7. **GEOPOLITICAL:** Maybe used for internal bargaining power and trade

(1) Natural gas is abundant: In the United States, current industry and government estimates of natural gas reserves range from 70-100 years of supply at current consumption and estimates continue to grow.



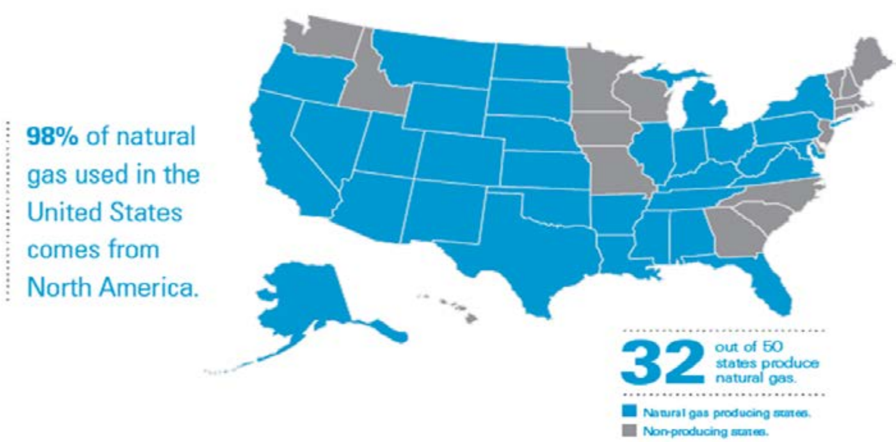
Source: EIA, Potential Gas Committee, Navigant Consulting, American Clean Skies Foundation

(2) Natural gas is clean: Unlike coal and oil, natural gas has the lowest amount of carbon emissions and is basically sulfur free, as seen in the graph on the below. The natural gas combustion process produces 29% less CO2 than oil and 44% less coal with out solid wastes. The California Energy Commission stated, "emissions from natural gas is 23% lower than diesel, and 30% lower than gasoline." (Weinstein 2013)

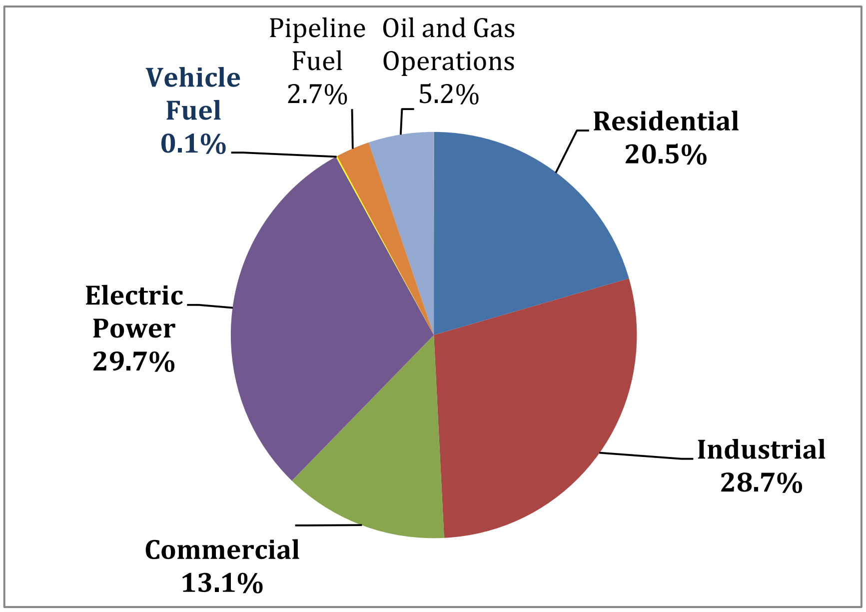
	Combustion Emissions (Pounds/Billion BTU of Energy Input)		
	Natural Gas	Oil	Coal
Carbon Dioxide	117,000	164,000	208,000
Carbon Monoxide	40	33	208
Nitrogen Oxides	92	448	457
Sulfur Dioxides	.6	1,122	2,591
Particulates	7	84	2,744

Source: *U.S. Energy Information Administration (EIA)*

(3) Natural gas is domestic: In the United States, natural gas can be found in 32 states and is used nationwide. North America supplies the United States with 98% of its natural gas needs. (Weinstein 2013)



(4) Natural gas is versatile: Citizens could use natural gas for transportation and to generate electricity for homes and businesses. Natural gas heats and cools over 50% of US homes, which is over 65 million residential customers. Currently, a small but growing number of vehicles can run on natural gas. Natural gas can provide clean fuel to power industry, manufacture fertilizer for food, and many other specialty uses and products. (Weinstein 2013)

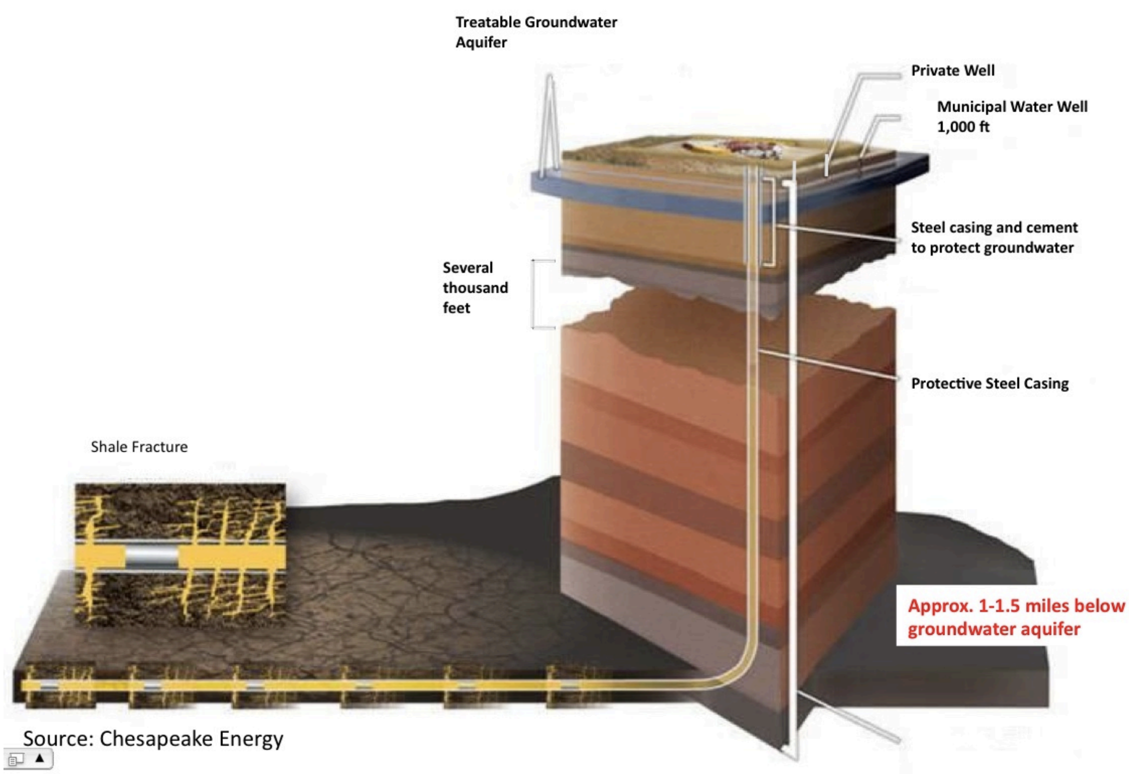


(5) Natural gas is secure: Distribution systems for natural gas are already in place and the United States is not dependent on foreign countries to use it. (Weinstein 2013)

(6) Natural gas is valuable: The oil and gas industry supports 9.2 million U.S. jobs and 7.5% of the U.S.'s GDP. Also, the hydrocarbon industry employs 4% or more of total employment in 15 states. (Weinstein 2013)

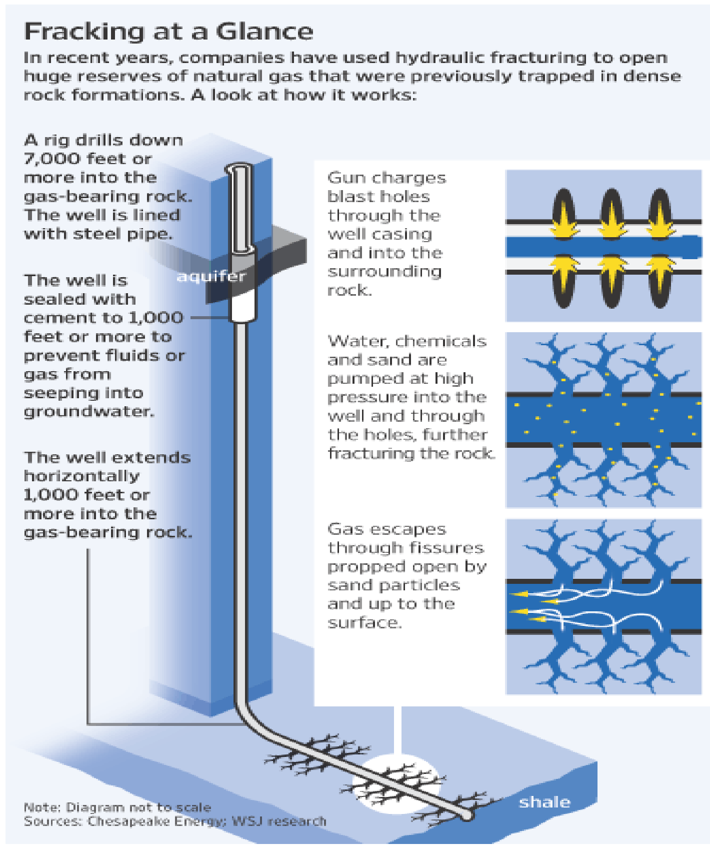
(7) Natural gas is a geopolitical tool: Russia's 2014 invasion and annexation of Crimea was a reminder to the world that keeping Russia in check would rely on ending the European powers' dependence on Russian natural gas. The United States could replace Russia as Europe's largest supplier of natural gas to eliminate Russian's chokehold on the European powers. Russia has been known to shut off natural gas pipelines to Europe from time to time in order to assert dominance over them. Also, natural gas can be exported as a major source of revenue for the United States.

IV. How Hydraulic Fracturing Works with Horizontal Wells

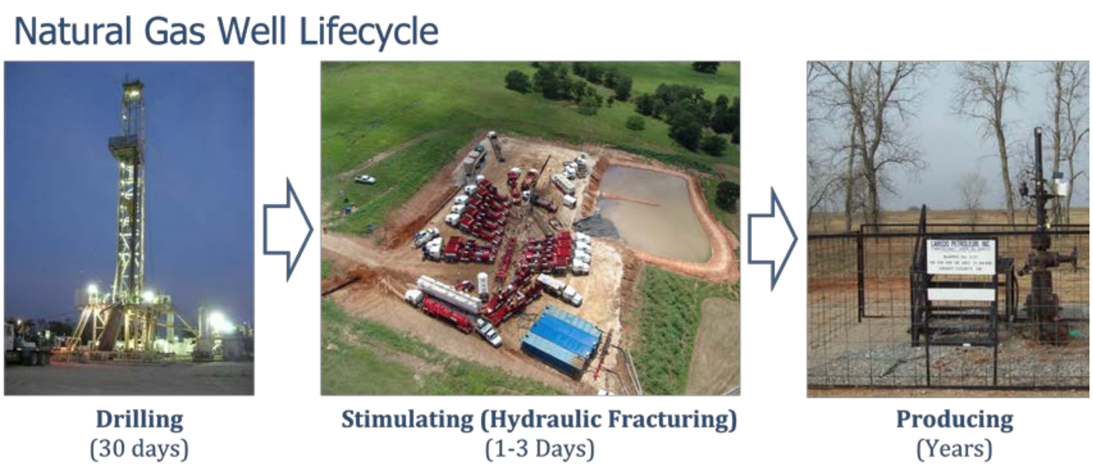


Source: Chesapeake Energy

Hydraulic fracturing works by first drilling a shaft several hundred meters into the earth's crust to reach a hydrocarbon-bearing shale formation. From there, horizontal drilling allows the drill to bend horizontally into shale rock. Next fracing fluid is forced into the ground using high performance pumps. On average the fluid consists of 8 million liters of water, plus several thousand tons of sand and 200,000 liters of chemicals. The mixture penetrates into the rock layer and produces a numerous amount of tiny cracks. The sand prevents the cracks from closing again and the chemicals perform various tasks. Among other things, the chemicals compress the water, kill off bacteria, dissolve minerals and increase the viscosity of the hydrocarbons. Next a majority of the fracing fluid is pumped out again and stored on site. Now the natural gas can be recovered for many years. As soon as the gas source is exhausted the drill hole is sealed. In order to dispose of the waste, the fracing fluid is then pumped back into the ground and sealed for safety. (Samjovic and Dettmer 2013)



Before the fracing process begins, exploration companies conduct geographical surveys and identify regions with potential oil and gas reserves. Then a “landman” contacts the mineral owners of the land and establishes a lease with the owner. The oil and gas company is entitled to a reasonable amount of land to conduct the drilling process. Typical drilling pad sites require about 4 acres. The entire drilling process may take up to 30 days before the operator moves on to the hydraulic fracturing process. Now with horizontal drilling, one drilling pad can drill horizontally in multiple directions or stem out to any number of hydrocarbon producing shales. Hydraulic fracturing the oil bearing rock may last anywhere from 1 to 3 days. Finally, the wellhead is constructed and the well may produce for any number of years. Production pad sites require about 1 acre of land.



V. Problems Identified with Hydraulic Fracturing

Since the birth of the shale revolution, hydraulic fracturing has continued to be the alleged culprit in a new wave of environmental concerns. Drilling for oil and gas has never been known as an environmentally friendly process, but never before has hydraulic fracturing been under so much scrutiny. For 60 years, hydraulic fracturing has been used to extract hydrocarbons from "conventional" or traditional oil and gas plays, but now the world has entered into the era of unconventional shale development. The Oil & Gas Industry: A Nontechnical Guide describes conventional drilling and nonconventional drilling as

> conventional is generally used to describe natural gas produced from well-understood geologic formations known through experience to hold natural gas. Examples include limestones and sandstones at depths of a few thousand feet. Conventional gas that is produced during the extraction of crude oil is commonly referred to as associated gas. (Hilyard 31)
>
> Unconventional natural gas is gas that cannot be economically produced unless one or more technologies are used to stimulate the gas-bearing formation and to expose more of the formation to the wellbore. Shale gas can also exist in deposits of shale, a fine-grained and soft sedimentary rock that breaks easily into thin, parallel layers. (Hilyard 32)

Even though hydraulic fracturing has been used for 60 years, drilling for unconventional natural gas requires a whole set of new environmental issues. Unconventional drilling requires more chemicals, more water and more wastewater injection wells. Since the technology is so new, critics argue more hydraulic fracturing can wait until oil and gas companies understand how it will impact the environment better. However, the oil and gas companies argue that hydraulic fracturing cannot wait. The 2014 polar vortex was a sobering reminder how much the United States relies on natural gas after hitting terrifying low reserves across the country.

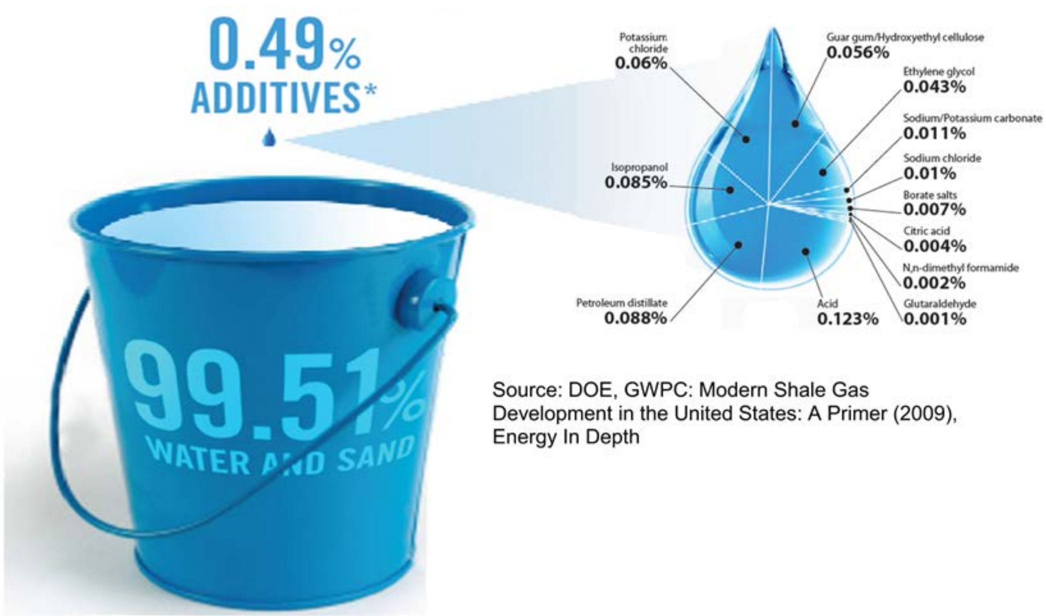
Hydraulic fracturing is a highly controversial topic, but one must remember how political the issue has become. Understanding both sides of the argument will allow people to understand the pros and cons of fracing, so that it can be done in an ethical and sustainable way. Many major alleged negative environmental impacts are associated with hydraulic fracturing, but the most notable ones can be broken down into 4 broad categories:

- Water Contamination

- Methane Leaks
- Water Use
- Seismic Activity and Injection Wells

Water Contamination

Issue: Fracing fluid, which contains over 700 chemicals, is believed to cause cancer, kill animals and taint clean drinking water sources. On average, 99.51% of hydraulic fracturing fluids are comprised of freshwater and sand. Reports continue to pile up in Pennsylvania of landowners who claim their drinking water has been contaminated due to improper well casing or waste disposal negligence. Another concern among residents is that oil and gas companies refuse to disclose what chemicals are in the fracing fluid, because of a loophole put into the Safe Drinking Water Act in 2005. Critics argue that nobody knows how the enclosed fluid will behave and long-term risks are unforeseeable and require more in depth research before conducting more hydraulic fracturing.



Source: DOE, GWPC: Modern Shale Gas Development in the United States: A Primer (2009), Energy In Depth

Groundwater contamination from hydraulic fracturing became a popular topic after the movie *Gasland* aired on HBO. Josh Fox the director of the movie filmed the famous scene of a family going to their sink and lighting their tap water on fire. Many families that have leased out their land for drilling purposes claim that their once clean tap water is undrinkable and now filled with toxic chemicals. What actually lights water on fire is the hydrocarbon known as methane, one of the byproducts when drilling for oil and gas. What the major debate among fracing opponents is whether the water lighting on fire is from natural gas or the chemicals in the fluid. The chemicals can get into the groundwater two ways: surface spills and poorly constructed wells.

(1) **Above surface spills:** After a multistep frac job, the well operator recovers a large proportion of these fluids by pumping them out of the well, and disposes of them through wastewater treatment plants or injection wells. However, any drilling fluids or frac fluids spilled on the surface could infiltrate downwards to shallow groundwater and could pose a risk to freshwater aquifers.

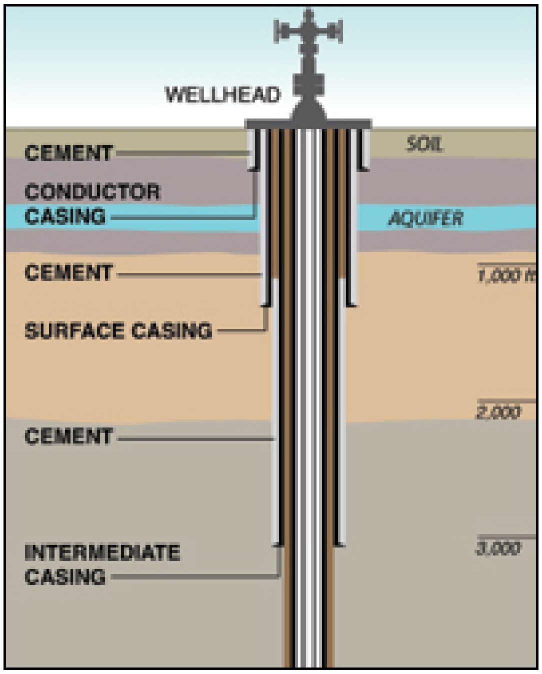
(2) **Poorly constructed wells:** Generally, drinking water wells are shallower than natural gas wells, and their casing may not extend their entire depth. A water well that is not cased from the surface, or is not constructed and cased properly, might allow contaminated water to flow from the ground surface and enter the water well, possibly compromising the integrity of drinking water.

Proponents: In 2011, President Obama's leading environmental regulator, former EPA administrator Lisa Jackson, testified under oath to a House committee that she was "not aware of any proven cases where the fracing process itself has affected water." And the EPA still stands by that fact today.

The biggest misconception among all the hydraulic fracturing debates is the public's general lack of knowledge between the different phases of fracing. The *actual* process of hydraulic fracturing is when air, sand and water is pumped into the ground with high pressure to shatter the shale to release the hydrocarbons. Depending on the shale, average fracing depth can range anywhere from 5000ft to 10,000ft below the surface. The Marcellus shale averages about 5,000ft below the surface (Explore Shale 2011). These depths are well below the average depth of water aquifers in the United States. Water aquifers tend to be no lower than 1,000ft below the surface. The Marcellus shale's water aquifer lies about 933ft below the surface (Explore Shale 2011). Therefore, the EPA confidently can confirm there have been no cases of water contamination from the *actual* hydraulic fracturing process.

However, what the general public fails to realize is that hydraulic fracturing does not pose a risk to groundwater contamination, but improper well casing and surface spills can. Well casing issues have been around since the dawn of the oil and gas industry, but often tend to be extremely rare events. In 2014, the *Associated Press* completed an investigation on confirmed cases of water contamination from drilling in several states. Based on Pennsylvania's Department of Environmental Protection data, the AP estimated that "the well failure rate is about one third of one-percent (0.33 percent) of all the oil and gas wells drilled in Pennsylvania since

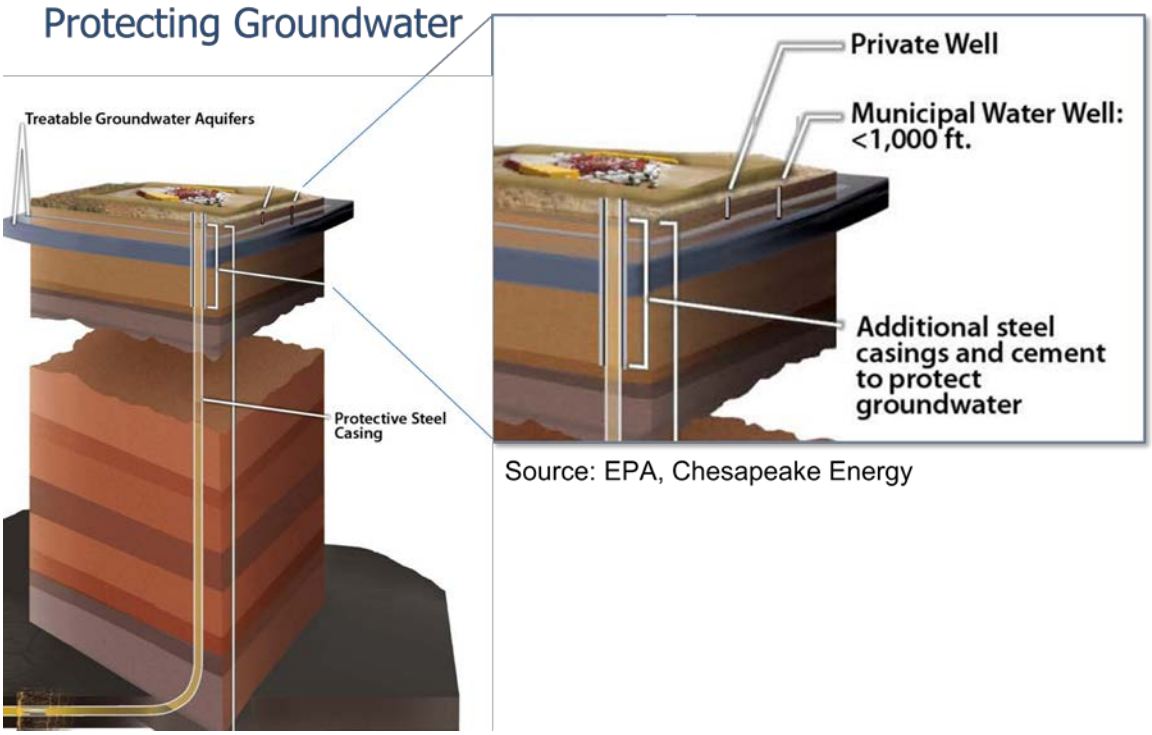
2005"(Brown 2014). The AP's findings are right in line with a 2011 report by the Ground Water Protection Council, which found a well failure rate of less than one percent in Ohio and Texas. While a well failure rate of above zero still as room for improvement, numerous states continue to enhance their existing regulations, including those governing well integrity. Rates below 1% show that failures are far from common occurrences despite what the critics believe (Brown 2014).



Pennsylvania regulations indicate that casing must be cemented with approved cement to minimum of 50ft deeper than the groundwater (Explore Shale 2011). Groundwater aquifers, which occur at shallow depths, are protected by multiple strings of cemented metal casing and are regulated by local states and municipalities, but there is always room for improvement. Frackwire writer, Hannah Wittmeyer, describes well design as a

> very complex and attention to detail must span the construction, testing phase, and decommissioning of the well post-production. Moreover, drilling wells are often constructed uniquely with regard to the geology and geography of the specific location. For instance, because much of the shale formation in Pennsylvania lies beneath a shallower gas formation, it is easier for the shallower gas to escape during the initial drilling process. This in turn has made it difficult for drillers to design failproof wells that can be sealed off from the younger deposits completely. The well itself is made of several layers of steel – or multiple concentric pipes – surrounded by cement; these sections of steel pipe are screwed together end to end and encased with cement to make a chain. Isolating and cushioning the wellbore

> with this chain of steel as well as cement – if correctly designed – should prevent leaks. (Wittermeyer 2013)



Source: EPA, Chesapeake Energy

Chemical spills on the surface are more likely the culprits for water contamination, but fracing sites are not always the obvious perpetrators. According to a 2009 Congressional Research Service report:

> leaky septic system, or improper disposal of domestic refuse such as car batteries or used oil, could leak from the surface into the water well. If this is the case, a dispute could ensue as to who is responsible for contaminating the water well. Resolving the dispute could involve a hydrogeological investigation to prove or disprove any linkage between natural gas development activities and water well contamination, often at considerable expense and with an uncertain outcome, given the complexity of groundwater flow at most sites. (Congressional Research Service 2009)

This remains the ongoing dilemma of environmental law and the oil and gas industry. Pinpointing a culprit of groundwater contamination is not an easy task due to the high volume of variables.

Many opponents of fracing fluid often site that companies fail to disclose all the chemicals in the fracing process. That simply isn't true anymore. Of the hundreds of chemicals in fracing fluid, a limited number of them are routinely used. The FracFocus Chemical Disclosure Registry discloses a list of the chemicals used most without disclosing all the substantial information that could put oil and gas company's trade secrets at risk (Prewitt and Cisneros 2013). Even though, FracFocus falls short of disclosing all the chemicals, the website at least establishes a middle ground between energy companies' rights to competitive advantage through trade secrets and a general respect of transparency to the public.

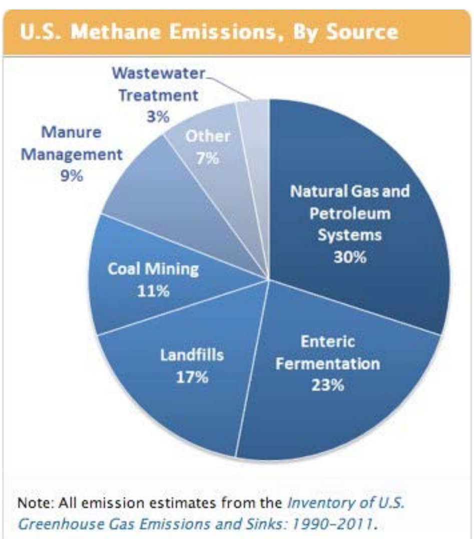
Lastly, in response to the *Gasland* documentary, many people felt that Josh Fox failed to tell the complete truth about fracing. Therefore, counter documentaries like *Truthland* and *FrackNation* offered the other side of the fracing story. Most notably, what these documentaries pointed out was the integrity of the people that claimed they could light their water on fire after they leased out their land for fracing. *FrackNation* pointed out the other side of the story of the residents in towns who claim that their water has not been affected at all by fracing.

Brain Swistock, a Water Resources Specialist at Penn State, released a report stating that they had not seen any changes in water quality or increases in methane in regards to fracing. Swistock commented that the flaming faucets are not a new concept and may appear from biogenic methane (naturally occurring methane) in specific geographic regions. Louisiana was once known for the its "Flaming Fountain" in front of a local courthouse. When digging a well they struck natural gas 600 feet below the surface, which caused the fountain to have a continually lit flame for several years. The Locey family in Dimock, Pennsylvania, claimed that even when her father drilled a water well in 1955, there was methane in the water and that there has always been some naturally occurring methane in the water in Dimock.

Determining who is telling the truth about water contamination with regards pre and post fracing is a subject of debate, but the documentaries like *FrackNation* at least call into question the integrity of the people reporting the contamination. Frivolous lawsuits that attempt to reach into the pockets of oil and gas companies are not an uncommon practice in the United States.

Methane Leaks

Issue: Methane leaks from drilling and fracing may potentially impact global warming more than burning natural gas. While carbon dioxide emissions are discussed in the media quite regularly, methane often stays comfortably under the radar unless something happens. Meanwhile, according to the EPA, methane (CH4) is the second most prevalent greenhouse gas emitted in the United States. The vast majority of this gas comes from oil and gas activities. Analysts estimate that the energy sector is responsible for about 30% of global methane emissions, with North America leading the charge. During the exploration phase, it is often cheaper to flare gas than capture it for use as fuel onsite and it’s less dangerous than allowing it to leak freely because methane is highly combustible (Kilisek 2014).



The *New York Times* reported, "According to the Environmental Defense Fund, 'Methane is at least 28 times more powerful than CO2 as a greenhouse gas over the long-term and at least 84 times more potent in the near term'" (Begos 2013). However, methane gradually loses its potency as a greenhouse gas over time. According to an UNEP Finance Initiative article, the projected value of annual greenhouse emissions costs could reach $20.8 trillion by 20, equating to 12.93% of the projected global GDP.

Proponents: A new study from nine energy companies that drill for natural gas and several environmental groups, suggest that methane from drilling and fracing does not spew as much gas as expected. Kevin Begos from the *Associated Press* noted, "The study found that during the process of extracting natural gas from the ground, total leakage at the study sites was 0.42 percent of all produced gas." The results were published by the Proceedings of the National Academy of Sciences. (Begos 2013)

Katie Brown, a pro-fracing writer for Energy In Depth, reported in February 2014 that:

> "Last year [2013] the EPA downwardly revised its estimates of methane emissions from natural gas systems based on new technologies, a finding that was more or less confirmed by a study later published by the Proceedings of the National Academy of Sciences. Nonetheless, the new study is very clear that even if methane leaks are 50 percent higher than what EPA estimates, natural gas still retains its environmental advantage when used for power generation."

Brown says even with 50% higher leakage rates natural gas retains its environmental benefits. As the report puts it, "assessments using 100-year impact indicators show system-wide leakage is unlikely to be large enough to negate climate benefits" of natural gas. The researchers add that natural gas still delivers "robust climate benefits" when used for power generation MIT News published an interview with one of the co-authors, Francis O'Sullivan, who had the following to say about the paper: "the shift to natural gas is still a positive move for climate-change-mitigation efforts." (Brown 2014)

Water Usage

Sustainability Issue: The large amount of water used during fracing tends to strain fresh water resources in places that commonly experience drought. A single well requires more than 1 million gallons of water during a well's lifetime. Left over water is highly contaminated and so severe it cannot currently be retreated in a contamination plant. As water scarcity increases by 16% each decade, allocating our clean water supply to hydraulic fracturing creates a huge sustainability issue for our children (Lowry 2013).

Water scarcity is increasingly becoming a major issue in the United States, if not the number one such issue. However, water scarcity never hits home for many people, because of how easily citizens can access it here in the United States. Nevertheless, the allocation and demand for clean water will be a major debate amongst politicians in the next decade. Most recently, California's water crisis of 2013 could be a window into the future of what is in store for the United States.

Proponents: Industry supporters claim that the 1 million gallons of water used are less than what a typical golf course uses in 2 weeks (Lowry 2013). And that oil and gas companies are constantly seeking new ways to recycle fracing fluid or find other nontoxic fluids to utilize instead.

Seismic Activity and Injection Wells

Issue: While fear of groundwater contamination is more worrisome to the local towns impacted by drilling, the fear of earthquakes hits home for the general public. The most common root of fear lies in what people don't understand and a lack of knowledge on a specific issue. Now combining increased seismic activity near fracing regions with very little data explaining the seismic activity creates a perfect breeding ground for public hysteria and anti-fracing movements.

The public's suspicion is not without warrant, 20-plus minor earthquakes were reported in North Texas in November 2013 according to the *Dallas Observer*. North Texas is home to the Barnett Shale and the birthplace of the fracing movement, so it would be easy for one to draw the conclusion that there lies a connection between more seismic activity and frac jobs done in the surrounding area.

And it's not just the Barnett Shale. In 2010, the U.K. ordered a moratorium on fracing following two tremors believed to be the caused by the Preese Hall site in Blackpool, England. The country just reopened the site after Cuadrilla Resources and the British Geological Survey said they would be installing up to 80 geophone detectors at each site to keep a close eye on any earth tremors, which may be produced by the processes (The Gazette 2013). In the United States, along with other normally seismically calm states like Texas, Kansas and Arkansas, Oklahoma has been experiencing unusual amounts of seismic activity in areas near to both oil and gas drilling sites and injection wells.

> Between 1975 and 2008 the state of Oklahoma in the United States recorded less than six earthquakes. But since then the annual number of quakes in Oklahoma has increased dramatically - to the extent that in 2013 the state experienced 109 earthquakes measuring a magnitude of 3.0 and above, a level strong enough to shake objects inside a home. (Truthloader 2014).

According to Oklahoma seismic data, less than four months into 2014, the state has recorded 253 such tremors (matching all of Oklahoma's seismic activity in 2013), and the finger is being pointed at Oklahoma's fracing industry (Gilliam 2014). Earthquakes about 2.5 magnitudes or above are strong enough to rattle items on a shelf. Not only is Oklahoma now the 2nd most seismically active state, but also it is the center of the United States hydrocarbon industry. Noticeably, Oklahoma houses more than 10,000 wastewater wells (second to Texas in housing the most class II injection wells), triggering red flags to geologist (EPA 2011).

To understand the increased seismic activity's connection to fracing, one must differentiate between the processes of fracturing shale rock versus wastewater well injection. Following the extraction process of a well, the fracing fluid is then shipped to waste water injection wells where millions of gallons of water are pumped back into the porous shale rock layers. The process is then thought to open up cracks and faults in the layers triggering minor earthquakes. "Most earthquakes occur naturally. But scientists have long linked some small earthquakes to oil and gas work underground, which can alter pressure points and cause shifts in the earth" (Gillam2014). Numerous studies, including SMU's seismologist Heather DeShon's research on injection wells, point out that injection wells could be a possible culprit of increased seismic activity. A study of seismic activity near Dallas/Fort Worth International Airport by researchers from SMU and UT-Austin revealed that the operation of a saltwater injection disposal well in the area was a "plausible cause" for the series of small earthquakes that occurred in the area between October 30, 2008, and May 16, 2009.

Though the public commonly confuses the difference between the actual fracturing process and wastewater injection wells, one must distinguish between seismic activity caused by the extraction process and the wastewater injection process. Though the extraction process may be linked to minor seismic activity, the wastewater disposal process is linked to more noticeable seismic activity. SMU and UT-Austin's report on the 2009 DFW seismic activity noted that earthquakes do not appear to be directly connected to the drilling, hydraulic fracturing or gas production in the Barnett Shale. However, re-injection of waste fluids into a zone below the Barnett Shale near the disposal well began in September 2008, seven weeks before the first DFW earthquakes occurred, and none were recorded in the area after the injection well stopped operating in August 2009. (Frohlich, Potter, Hayward, Stump 2010)

Proponents: Yet, the scientific community has yet to provide a report definitively linking increased seismic activity to fracing or wastewater injection wells. Numerous reports suspect injection wells as the number one suspect for the seismic activity, but fail to produce actual data supporting a definite conclusion for the root cause. SMU seismologists, who are investigating possible causes of the seismic activity in North Texas, stated that the research could take 6 months to a year before they had any definitive data to publish. Much of the research investigating the injection wells is years away from concrete evidence. One researcher, Brain Stump, stated:

> "What we have is a correlation between seismicity, and the time and location of saltwater injection," Stump said. "What we don't have is complete information about the subsurface structure in the area – things like the porosity and permeability of the rock, the fluid path and how that might induce an earthquake." (SMU Research 2010)

Much of what the research says is plausible; the seismic activity is due to increased injection at all the wells across Texas, but it's also possible the activity is just the onset of stresses shifting in Texas, and same goes for Oklahoma. State seismologist, Austin Holland noted historically that high water levels in Oklahoma's Arcadia Lake could be playing a role in the seismic activity. Supporters of fracing do not deny the correlation between injection wells and seismic activity, but continue to wait for more accurate information to prove the hypothesis correct and that the seismic activity is not just a natural phenomenon.

Other proponents look to California as an example of where injection well events near fault lines have been occurring for many decades and that these wells have been operating with no evidence of induced earthquakes (Margolis 2014). The data does not demonstrate in California any history of seismic activity with regards to injection wells. These injection wells have been operated for decades, without causing any earthquakes. In 2013 EID, reported on the lack of seismic activity connected to oil and gas development stating:

> There has never been a felt seismic event related to hydraulic fracturing in our state — even though the process has been used thousands of times over more than five decades. In fact, California's state geologist, John Parrish, said last year "we have a lot of

> information about the seismicity that is caused by hydraulic fracing."(Quest 2013)
>
> Not only have there been no felt seismic events linked to hydraulic fracturing in California, there have also been no earthquakes linked to wastewater disposal in California. Not one! (Quest 2013)

Finally, many geologists say that until earthquakes reach a magnitude of 5.0 or above, only minor damage is likely to occur and is not much to worry about. Of all the seismic activity researchers associated with injection wells, most of them then to be microquakes, earthquakes with a 2.0 or less magnitude, or on the far end of the spectrum, magnitudes of 3.0 or less. Either way, fracing supporters believe that these low intensity mircoquakes are nothing to worry about.

VI. Alternatives

According to the *National Journal*, as more independent studies tend to prove that fracing has little evidence as a threat to groundwater contamination, the fight for fracing has shifted from local water issues onto broader environmental issues. The anti-fracing campaign is now another tactic of environmental groups to ban fossil fuels in order to stop climate change. Yet, fracing fluid is still toxic and companies need to find alternative methods to ensure drilling fluids cannot contaminate groundwater.

1. **Recycling Fracing Fluid:** Develop a method to reuse fracing fluid or a process that decontaminates the water
2. **Fracing Fluid Alternatives:** Find or develop a nontoxic fracing fluid

3. **Smart Regulation:** Introduce smart regulation that ensures fracing is conducted safely and encourages new innovation that makes the process safer and more affordable
4. **Ban Fracing All Together:** Ban the entire process to stop more greenhouse emissions and water contamination

VII. Evaluating Alternatives

Recycling Fracing Fluid:

As experts predict that clean water will become scarcer in the future, finding methods to reduce or recycle fracing fluid will be essential. The Associated Press reported that drillers are finding new methods "to get by with less water: They recycle it using systems that not long ago they may have eyed with suspicion." One example is Fasken Oil and Ranch, a company in West Texas, is now 90 percent toward its goal of not using any freshwater for fracing. The AP article goes on to explain "water recycling methods have rapidly become not only a more environmentally sound option, but also an economical one" (Carr 2013)

Fracing Fluid Alternatives:

Many environmentalists argue that storing leftover fracing fluid underground has unforeseen long-term consequences and should not be underestimated. Therefore, finding new fracing fluid alternatives would eliminate any threat to long-term groundwater contamination. Halliburton, for example, has already developed a toxic-free fracing fluid. However, the company says sales for the clean drilling fluid are low because the new fluid is less effective and too expensive compared to conventional fracing fluids. Some companies are experimenting with propane as a drilling fluid, which would be less toxic than regular fluids. Development of a clean fracing fluid would eliminate a negative externality from hydraulic fracturing and even give a company a competitive advantage when signing drilling leases.

Smart Regulation:

Striking a balance between economic potential and smart regulation would allow the oil and gas industry and some environmental groups to coexist until a breakthrough in green technology. However, finding that balance seems to be challenging when often times poor regulations tend to stop economic growth. Mark Brownstein, a counselor from the Environmental Defense Fund, said in an interview "If you're going to make the argument that there are benefits to developing this resource you have to also be prepared to make the argument that you're going to do everything possible to minimize risks to public health and the environment" (Efstathiou 2013).

Oil and gas companies know that making a profit and protecting the environment is their corporate responsibility. Therefore, they know they need to be more proactive in working with the government to develop safer and cleaner fracing regulations. With so many stakeholders involved, a new regulation must guarantee that “a two-way flow of value exists between both parties, and the interest of both parties are aligned” (Firms of Endearment).

Corporations are already agreeing to a new set of environmental regulations in the northeast region. Collaborative efforts for new regulations would raise the bar for environmental practices while companies could still be profitable and communities would be more supportive knowing regulations are in place to protect them. (Belsie 2013)

Ban Fracing All Together:

Environmental groups like the Sierra Club have vowed to ban hydraulic fracturing at all cost, because even though natural gas may be cleaner it is still a fossil fuel. Banning fracing altogether is the only way to virtually eliminate methane leaks, reduce natural gas production, and prevent water contamination. However, banning fracing would strip the world of the cleanest fossil fuel we have and is also extremely unlikely. Hydraulic fracturing has many powerful supporters and even President Obama defends how important the technology is for our future.

VIII. Why Not Renewable Resources

There is a common, bipartisan consensus among American's that we need more renewable energy resources in our energy mix. Ethically speaking, finding a renewable resource that had virtually no major impacts on the environment would be the best moral option for our country. However, the world still lacks a variety of renewable resources that are both cost effective and efficient enough to me the world's growing energy demands.

Though the coalition of environmental groups and our socially conscious voters is admirable; replacing our entire energy mix to all current renewable energy sources over the next decade is financially unreasonable and logistically impossible to fulfill the United States' energy demand. As a nation, we should be committed to reducing our carbon footprint and will be phasing out some of our coal-fired power plants in response to the recent carbon emission standards set by the Obama administration. However, we cannot phase out all of our coal-fired plants in the next decade for 4 main reasons.

(1) Wind Does Not Supply Enough Power

ERCOT, which manages Texas's power grid, estimates that wind's capacity factor is less than 9 percent. And in a 2007 report, the grid operator determined that just "8.7% of the installed wind capability can be counted on as dependable capacity during the peak demand period." In mid-2009, Texas had 8,203 megawatts of installed wind-power capacity. But ERCOT, in its forecasts for that summer's demand periods, when electricity use is the highest, was estimating that just 708 megawatts of the state's wind-generation capacity could actually be counted on as reliable. With total summer generation needs of 72,648 megawatts, the vast majority of which comes from gas-fired generation, wind power was providing just 1 percent of Texas's total reliable generation portfolio. (Bryce 93) Therefore, even if we tripled our installation of more wind turbines, we could not possibly fulfill the 30% power generation we derive by coal.

(2) Non-Dispatchable Technologies and Combustion Natural Gas Plants:

While the sun only shines during the day and wind doesn't blow regularly enough during our summer demand, the country would have to back up our wind turbines and solar facilities with gas-fired generators or the country would face rolling blackouts. According the American Gas Association in the graph below, even as wind turbines become more economical and the average levelized cost

(2011$/megawatt hour) for wind turbines is cheaper than coal-fired plants, adding any new natural gas combustion turbines to offset the lack of wind blowing would add additional economic cost. For each new farm of wind turbines at a levelized cost of 86.6 we would have to add an additional natural gas combustion turbine at a levelized cost of 104.6 in case of emergencies. The grand total levelized cost for wind would be 191.1. Also, natural gas combustion facilities would not meet the below 1000 pounds of CO2 per megawatt hour standard set by the Obama administration. Only combined cycle natural gas plants can economically meet the Obama administration standard.

Levelized Cost of New Generating Technologies - 2016

Plant Type	Capacity Factor (%)	Total System Levelized Cost (¢ per KWH)
Natural Gas – Combined Cycle	87	6.31
Natural Gas – Conventional	87	6.61
Natural Gas – Combined Cycle with CCS	87	8.93
Coal – Conventional	85	9.48
Coal – Advanced	85	10.94
Coal – Advanced with CCS	85	13.62
Wind – Onshore	34	9.70
Wind – Offshore	34	24.32
Solar – PV	25	21.07
Solar – Thermal	18	31.18
Biomass	83	11.25
Nuclear	90	11.39

(3) Lack of Land

If we compare the power and land use of a typical U.S. nuclear power plant with that of wind and solar, the amount of land needed to produce the same amount of electricity is unreasonable. Of a 12,000 acre nuclear power plant with two-reactors (2700 megawatts), the plant would yield a power density of about 300 horsepower per acre (56 watts per square meter). Compare that with wind power, which produces about 6.4 horsepower per acre (1.2 watts per square meter) or solar photovoltaic, which produces about 36 horsepower per acre (6.7 watts per square meter). While an average U.S. natural gas well produces about 287.5 horsepower per acre (53 watts per square meter). Therefore, wind power requires about 45 times as much land to produce a comparable amount of power as nuclear, and solar photovoltaic power requires 8 times as much as nuclear. While we would only need 5% more land for natural gas to produce a comparable amount of power as nuclear. (Bryce 93)

(4) Lack of Alternative Renewable Resources

If a state like Texas were to replace 30% of its coal-fired power plants with renewable energy sources, we would need an alternative source of energy that was at least comparable in power density and as affordable as coal. The simple truth is that until renewable energy resources, become as affordable as natural gas or coal, switching to wind and solar would not only bankrupt us, but also leave us without a dispatchable power source. Texas lacks the water capacity for more hydropower. Geothermal technology is extremely capital intensive and very risky to see financial returns on any reasonable scale. Currently, geothermal and solar are less than 1% of the U.S. energy mix, which means the technology is not there yet enough to supply enough power for the country. Wind and solar farms are not only extremely land intensive but also very intermittent, and as a result, not reliable. Nuclear could be a CO2 emission free alternative, but extremely capital intensive and would take at least 10 years to build. And let's not forget that after the Fukushima disaster building a new nuclear power plant is nearly impossible to receive government approval. Therefore, that is why natural gas produced from hydraulic fracturing is the world's next best alternative until a renewable energy breakthrough. However, even if a renewable energy breakthrough were to happen tomorrow, it would take years and even decades to completely alter an infrastructure without fossil fuels.

IX. The Political Situation and Current Trends

Huge potential awaits natural gas as the bridge fuel to the future, but the process of hydraulic fracturing sparks debate in both state and federal congressional arenas. What role should the government play in ensuring that hydraulic fracturing is done effectively, safely and cleanly? How much natural gas should the United States export? Should the United States use fracing at all?

While attempts to ban fracing in Congress have failed, the EPA has passed several rules on air pollution in 2012 and has delayed any new rulings on water until late 2013. Some states like Vermont placed bans on fracing to ease public pressure and mostly due to the fact that they lack any natural gas resources. Other states like New York have imposed a moratorium on fracing until further studies have been conducted on the long-term effects. While other states like North Dakota and Texas continue to encourage fracing after undergoing the largest GDP growths in the United States in 2012 according the Bureau of Economic Analysis.

Primarily, the future of hydraulic fracturing relies on how the energy industry guarantees the public that they are doing everything possible to minimize the risks to public health and the environment. However, trends indicate that more and more people are beginning to oppose hydraulic fracturing. Energy-related issues tend to be a misunderstood topic among low informed voters. And documentaries like *Gasland* have had an enormous negative impact on public opinion, even though many claims Josh Fox made in the documentary have been proven false and even deceptive. Many environmental groups, like the Sierra Club, believe that fracing is still "under-studied" as a campaign tactic to prevent, and eventually stop, the oil and gas industry from operating. (Quast 2013)

Such negative opinions and anti-fracing movements could hurt future natural gas development in shale plays like the Monterey shale in California and the Utica shale in Ohio. However, states like Pennsylvania and West Virginia, states long familiar with carbon production through oil drilling and coal mining, continue to support fracing after an experienced boom in jobs and domestic income.

The best indicator of the future of hydraulic fracturing may be witnessed in Colorado. Even though, three communities in Colorado decided to prohibit hydraulic fracturing within their borders, the state government both supports and leads the country in governing hydraulic fracturing. Colorado has worked with other states like Texas and Wyoming to establish standards that disclose the chemicals in fracing fluid, require groundwater testing near wells and regulate well integrity regularly. (Gold 2013)

The new regulation Colorado proposed in 2013 will require companies to test monthly for methane leakage, avoid methane venting from wells and retrofit the valves on wells to minimize leakage (Nocera 2013). Russell Gold wrote in the *Wall Street Journal* that, "States [like Colorado] are increasingly tightening regulations on oilfield activities, in an effort to convince local residents that the activity is safe to live near."

Ultimately, fracing should be able withstand the assault of anti-fracing groups as the process becomes safer and more efficient. But fracing also has the support from some unlikely candidates. President Obama and the executive branch have even come out explaining the importance of hydraulic fracturing for America's energy future. Even "Secretary of State John Kerry – who, throughout his career, has made climate change one of his top issue priorities – officially disagrees with the Sierra Club's position on natural gas" (Brown 2013).

X. The Ethics of Smart Regulation and Sustainable Fracing

For unconventional resources and shale development, more regulations about the fracing process are not a matter if it will happen, but a matter of when. Smart regulation is the optimal solution to the ethical issues that arise from hydraulic fracturing. Regulation can cover all the major problems of fracing and if done right it can be an advantage for all the stakeholders. If oil and gas companies preemptively comply with their social obligations they will find becoming environmentally friendly can lower cost and increase revenues. That is why sustainable regulation should be a touchstone reason for all new innovation. (Nidumolu, Prahalad, and Rangaswami 2009)

Rather than waiting for lawmakers to impose more regulations self-regulations can offer a long-term competitive advantage and allow for more influence when drafting new standards with lawmakers. The Center for Sustainable Shale Development, or CSSD, is the perfect example of an organization helping to assemble an ethical and sustainable hydraulic fracturing process.

CSSD aspires to promote continuous improvement and innovative practices in fracing operations by way of voluntary performance standards and third-party certification. This NGO, or non-governmental organization, has already partnered with Royal Dutch Shell, Consul Energy, Chevron, and EQT. These four companies have agreed to a set of 15 voluntary standards in their fracing operations in the Marcellus Shale. While Marcellus is just one among many shale plays in the United States, it is nevertheless the beginning of a movement and has to start somewhere. (Murphy 2014)

The 15 standards are heavily detailed and encompass many such factors as topography, geology, varying technologies, and more. Too sum up the main points, the standards initially address two broad categories: (1) air and climate, and (2) surface and groundwater.

To protect the air and climate, companies agree to:

- Limitations on flaring, the practice of burning off excess gas during oil extraction, which releases methane.
- Use of "green completions," which allow the capture of natural gas at the wellhead as an alternative to flaring.
- Reduced engine emissions.
- Emissions controls on storage tanks.

To protect the surface and ground water, companies agree to:

- Maximized water recycling.
- Development of groundwater protection plans.
- Closed-loop drilling, which eliminates the common practice of storing waste fluids in open pits, thus greatly reducing the risk of toxic leaks and emissions.
- Well-casing design, also aimed at preventing leaks.

- Groundwater monitoring.
- Wastewater disposal.
- Reduced-toxicity in fracing fluid

Many people often argue that for-profit companies cannot go hand and hand with ethical principles, but that just is not the case anymore. News of Nike’s outsourcing of shoe manufacturing to factories with brutal work conditions oversees caused many consumers to switch to competitors. The news of unethical working conditions continued to hurt the company’s profits enough until they reached the point where Nike was forced to find better solutions to its manufacturing processes. Nike is just one example of several cases of where unethical business practices hurt a company’s reputation to the point where they were unable to turnover a profit.

Oil and gas companies are a different spectrum of business and often negative public opinion is not as detrimental to them when bringing a commodity like natural gas to market. So why would a for-profit energy company sign up for any of CSSD’s standards, which surely would carry additional cost for energy companies? Some companies like Chesapeake think they shouldn’t. Chesapeake Energy deemed there is no valid reason to go beyond existing regulatory requirements. The Motley Fool reported, “Chesapeake has publicly stated it won't join or support the CSSD.” Given Chesapeake's status as the largest leaseholder in the Marcellus, that will remain a large percentage of the region that will not be on board with the CSSD initiative.

Companies like Chesapeake are being shortsighted and not looking at the big picture. Consider the statements from some of the pioneering companies. Nicholas J. DeIuliis, president of Consol Energy, said, "[T]he aim is for these standards to represent excellence in performance." Bruce Niemeyer, president of Chevron Appalachia, said, "Raising the bar on performance and committing to public, rigorous, and verifiable standards demonstrates our companies' determination to develop this resource safely and responsibly." Behind those polished statements is a legitimate fear on the part of industry majors that fracing has become a free-for-all. Smaller, less accountable operators engaging in questionable practices strike fear into industry majors that that they could lead to a catastrophic-like event that would condemn fracing in the court of public opinion forever. Given this, creating a competitive advantage by means of environmental protection would strengthen companies in case the likely event of increased regulation. (Murphay 2014)

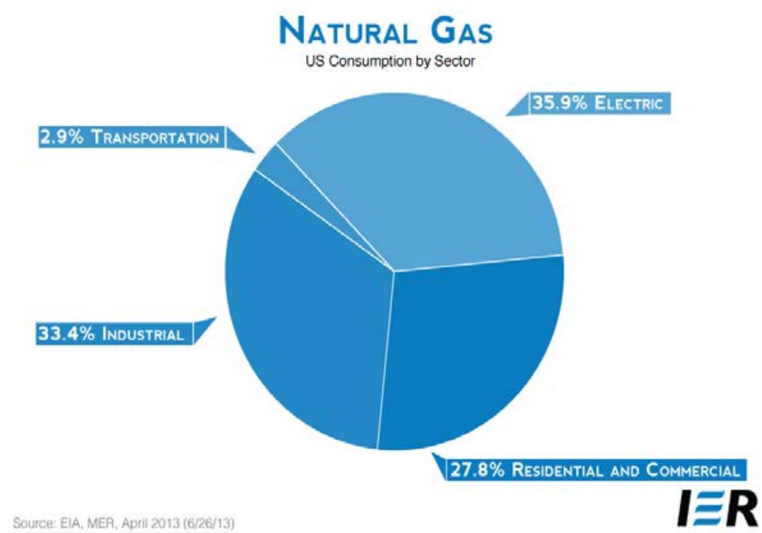
The environmental community has had mixed reviews about the CSSD. Richard Liroff, executive director of Investor Environmental Health Network, observed that there was very little industry disclosure on the CSSD practices. For example, the standard on less toxic fracing fluids has no provisions for the reporting process. While Liroff highlighted some of the weak spots, he still argues he doesn't see them as a deal breaker. However, the Sierra dismisses the initiative saying that voluntary standards are no substitute for tough regulations. (Murphy 2014)

The key to the success of CSSD's self-regulations will come down to the debate of how transparent the companies need to be. Ethically speaking, transparency is the cornerstone of ethical business practices. Without transparency, polished mission statements remain nothing but empty words until backed up by evidence. The ongoing dilemma companies struggle with is how much they can publicly disclose without losing their trade secrets. As discussed earlier, FracFocus is a great example of a reasonable balance between self-regulated transparencies while maintaining industry trade secrets.

CSSD's partner organization, the Environmental Defense Fund, acknowledges the transparency issues of the 15 regulations, but still sees CSSD as a crucial step forward. "CSSD isn't a substitute for effective regulation. Strong rules and robust oversight is a nonnegotiable bottom line," said EDF's Matt Watson in a press release. CSSD provides the potential to do for the natural gas industry what U.S. Green Building Council's LEED program did for the building industry. LEED's building-certification system continuous to drive the innovation need in the efficiency and sustainability of buildings in the U.S. (Murphy 2014)

XI. The Future of Hydraulic Fracturing and Conclusion

With support from many regulators, including the United States' president, and reasonable environmental groups like the EDF, natural gas is precisely the cleanest and most effective alternative as the bridge fuel to a renewable future. As new wells are being drilled every day to reach the abundant amount of natural gas and with the lack of alternative energy sources, there is simply no way the U.S. is turning its back on hydraulic fracturing. America will continue to become more dependent on natural gas to fuel its energy demands (depicted on the 2013 EIR graph on the page above) and will need hydraulic fracturing to do so. (Nocera 2013)



A study by McKinsey and IHS has contributed the natural gas is a reason for the "10% fall in the greenhouse-gas emissions from American power generation between 2010 and 2012. IHS reckons gas-fired stations will be providing 33% of America's electricity in 2020, compared with just 21% in 2008"(The Economist 2013). Cheap natural gas will raise disposal income for citizens by "adding $2,700 per household in 2020 and more than $3,500 by 2025" (Efstathiou 2013).

Despite all the benefits of hydraulic fracturing and the United States' growing dependence on natural gas, negative opinions could still prohibit the development of hydraulic fracturing. Groups like the Sierra Club continue to vow to ban hydraulic fracturing at all costs, because even though natural gas may be cleaner it is still a fossil fuel and water contamination is still a risk.

However, not all environmental groups believe banning fracing is the solution. The Environmental Defense Fund, who opposes greenhouse emissions, takes a different approach. EDF knows hydraulic fracturing is necessary for the future, so they want to work with companies to make it safer, cleaner and more transparent instead of banning frocking. More regulation of hydraulic fracturing is inevitable because it will give the public confidence that fracing can be done safely and responsibly. Therefore, companies should work with regulators to ensure regulations are created smartly instead of fighting an uphill battle. In order to conduct fracing both environmentally and profitably, companies will need to work on solving methane leaks, air quality problems, water scarcity and any other negatives environmental concerns first. Natural gas is already helping to improve the United States' energy independence, and it could play a role in constraining climate change, but only if it proves safe. With CSSD "companies like Chevron, Shell, EQT, and Consol Energy are demonstrating important leadership in securing natural gas' future, which will benefit them in the long run. Chesapeake may just get left behind" (Murphy 2014).

If fracing were ever banned, it would be unethical to deny our children the benefits that hydraulic fracturing has brought to our economy and quality of life.

Natural gas is the bridge fuel to a sustainable future and the only hydrocarbon alternative that can reasonably fulfill the world's energy demand with a minimal impact on climate change. Between all problems associated with hydraulic fracturing, smart regulation is the best solution to prevent them.

Companies realize that the future of the technology relies on whether the industry can be proactive and work with regulators to develop safer and cleaner standards. Even environmental groups like the Environmental Defense Fund, know that hydraulic fracturing is necessary for the future, so they want to work with companies to make it safer, cleaner and more transparent instead of banning fracing. In order to conduct fracing sustainably, profitably and responsibly, oil and gas companies will need to fulfill their social obligation by working with regulators to solve methane leaks, stop water contamination and reduce clean water consumption.

Works Cited

Albers, Mark. "Read 'On the Frontiers of Energy: The Future of Unconventional Natural Gas,' a Speech by Mark W. Albers." *ExxonMobil*. ExxonMobil, 8 Nov. 2011. Web. 15 Apr. 2014. <http://corporate.exxonmobil.com/en/company/news-and-updates/speeches/frontiers-of-energy-future-of-unconventional-natural-gas>.

Andrews, Anthony, Peter Folger, Marc Humphries, Claudia Copeland, Mary Tiemann, and Robert Meltz. *Unconventional Gas Shales: Development, Technology, and Policy Issues*. Issue brief. Washington D.C: Congressional Research Service, 2009. Print.

Avard, Karl. "How Well Do You Really Understand Fracking? - DailyFinance." *DailyFinance.com*. The Motley Fool, 22 Feb. 2014. Web. 15 Apr. 2014. <http://www.dailyfinance.com/2014/02/22/how-well-do-you-really-understand-fracking/>.

Begos, Kevin. "Methane Leaks from Gas Drilling Not Huge." *MSN News*. Associated Press, 16 Sept. 2013. Web. 01 Dec. 2013. <http://news.msn.com/science-technology/methane-leaks-from-gas-drilling-not-huge>.

"BEA News Release (GDP by State)." BEA News Release. U.S. Department of Commerce, 6 June 2013. Web. 02 Dec. 2013. <http://bea.gov/newsreleases/regional/gdp_state/gsp_newsrelease.htm>.

Begos, Kevin. "Some States Confirm Water Pollution from Drilling." *AP*. Associated Press, 5 Jan. 2014. Web. 15 Apr. 2014. <http://bigstory.ap.org/article/some-states-confirm-water-pollution-drilling>.

Belsie, Laurent. "Energy Firms, Environmentalists Agree on 'fracking' Standards." *The Christian Science Monitor*. The Christian Science Monitor, 21 Mar. 2013. Web. 02 Dec. 2013. <http://www.csmonitor.com/Environment/Energy-Voices/2013/0321/Energy-firms-environmentalists-agree-on-fracking-standards>.

Brown, Katie. "New Duke Paper a Rehash of Previous (Debunked) Studies." *Energy in Depth*. Energy in Depth, 25 Mar. 2014. Web. 15 Apr. 2014. <http://energyindepth.org/national/new-duke-paper-a-rehash-of-previous-

debunked-studies/>.

Brown, Katie. "New Methane Study Confirms Environmental Benefits of Natural Gas." *Energy in Depth*. Energy in Depth, 16 Feb. 2014. Web. 15 Apr. 2014. <http://energyindepth.org/national/new-methane-study-confirms-environmental-benefits-natural-gas/>.

Brown, Katie. "Sierra Snub: 'Climate Champion' John Kerry Touts Natural Gas." *Energy in Depth*. N.p., 22 Nov. 2013. Web. 02 Dec. 2013. <http://energyindepth.org/national/sierra-snub-climate-champion-john-kerry-touts-natural-gas/>.

Bryce, Robert. "Chapter *." *Power Hungry: The Myths of "Green" Energy and the Real Ruels of the Future*. New York, NY: PublicAffairs, 2010. 93-102. Print.

Carr, Julia. "CORRECTION: FRACKING-WATER RECYCLING STORY." *The Big Story*. The Associated Press, 12 Nov. 2013. Web. 02 Dec. 2013. <http://bigstory.ap.org/article/more-oil-and-gas-drillers-turn-water-recycling>.

"CNN Explains: Fracking." YouTube. CNN, 08 Mar. 2012. Web. 12 Apr. 2014. <https://www.youtube.com/watch?v=LAxsTJd7VCA>.

David, Javier E. "'Fracking' Debate Gets a Little More Complicated." *CNBC.com*. CNBC, 14 Apr. 2014. Web. 15 Apr. 2014. <http://www.cnbc.com/id/101581890>.

Efstathiou, Jim, Jr. "Fracking Boom Seen Raising Household Incomes by $1,200." *Bloomberg Businessweek*. Bloomberg News, 4 Sept. 2013. Web. 1 Dec. 2013. <http://www.businessweek.com/news/2013-09-04/fracking-boom-seen-raising-u-dot-s-dot-incomes-by-1-200-per-household>.

"EPA Administrator Lisa Jackson Tells Congress "No Proven Cases Where Fracking Has Affected Water"" YouTube. Fox News, 24 May 2011. Web. 01 Dec. 2013. <http://www.youtube.com/watch?v=L4RLzlcox5c>.

"Explore Shale. Marcellus Shale Development, Geology and Water." ExploreShale.org. PennState Public Broadcasting, 2011. Web. 14 Apr. 2014. <http://exploreshale.org/>.

"Fracking & Well Casing Failure." Frackwire. Hannah Wittmeyer, 27 June 2013. Web. 15 Apr. 2014. <http://frackwire.com/well-casing-failure/>.

Frohlich, Cliff, Eric Potter, Chris Hayward, Brian Stump, and Claude Albritton. *Dallas-Fort Worth Earthquakes Coincident with Activity Associated with Natural Gas*

Production. Publication. N.p.: Society of Exploration Geophysicists, 2010. Print.

"From Sunset to New Dawn." The Economist. The Economist, 16 Nov. 2013. Web. 2 Dec. 2013. <http://www.economist.com/news/business/21589870-capitalists-not-just-greens-are-now-questioning-how-significant-benefits-shale-gas-and>.

Gies, Erica. "Race Is On to Clean Up Hydraulic Fracturing." *The New York Times*. The New York Times, 04 Dec. 2012. Web. 15 Apr. 2014. <http://www.nytimes.com/2012/12/05/business/energy-environment/race-is-on-to-clean-up-hydraulic-fracturing.html?_r=2&>.

Gillum, Carey. "Seismologist: Record Earthquake Activity Continues to Rock Oklahoma | The Raw Story." *Raw Story*. Reuters, 5 Apr. 2014. Web. 11 Apr. 2014.

Gold, Russell. "Colorado to Tighten Drilling Rules." *Wall Street Journal*. N.p., 18 Nov. 2013. Web. 2 Dec. 2013. <http://online.wsj.com/news/articles/SB10001424052702303755504579206413230149896?KEYWORDS=Russell+Gold>.

Gordon, Scott. "North Texas Earthquakes." *NBC 5 Dallas-Fort Worth*. NBC 5, 21 Jan. 2014. Web. 11 Apr. 2014.

Harder, Amy. "The Fracking Fight Outgrows Itself." *The National Journal* (2013): n. pag. Web. 2 Dec. 2013.

Hilyard, Joseph. "Natural Gas Overview." *The Oil & Gas Industry: A Nontechnical Guide*. Tulsa, OK: PennWell, 2012. 31-33. Print.

Ingraffea, Anthony. *Fluid Migration Mechanisms Due to Faulty Well Design And/or Construction: An Overiew and Recent Experiences in The Pennsylvania Marcellus Play*. Tech. N.p.: Physicans Scientiest & Engineers for Health Energy, 2012. Print.

"Is Fracking to Blame for Oklahoma's Earthquake Surge? - Truthloader." YouTube. Trueloader, 10 Apr. 2014. Web. 11 Apr. 2014.

Kilisek, Roman. "Methane: The Odorless, Colorless and 'Annoying' US Shale Boom Companion." *Breaking Energy*. Breaking Energy, 21 Jan. 2014. Web. 15 Apr. 2014. <http://breakingenergy.com/2014/01/21/methane-the-odorless-colorless-and-annoying-us-shale-boom-companion/>.

Lowry, Bill. "Oil and Natural Gas." Enviromental and Energy Policy. St. Louis. 29 Oct. 2013. Lecture.

Margolis, Dan. "Earthworks Study Makes Shaky Assumptions on California Earthquakes." *Energy in Depth*. Energy in Depth, 18 Mar. 2014. Web. 12 Apr. 2014.

"Natural Gas." Institute for Energy Research. N.p., Apr. 2013. Web. 02 Dec. 2013. <http://www.instituteforenergyresearch.org/energy-overview/natural-gas/>.

"New Tremor Monitors for Fracking." The Gazette. The Gazette, 5 Dec. 2013. Web. 12 Apr. 2014. <http://www.blackpoolgazette.co.uk/news/business/local-business/new-tremor-monitors-for-fracking-1-6297339>.

Nocera, Joe. "Fracking's Achilles' Heel." *New York Times*. N.p., 18 Nov. 2013. Web. <http://www.nytimes.com/2013/11/19/opinion/nocera-frackings-achilles-heel.html?_r=1&>.

Prewitt, Matthew F., and Katherine G. Cisneros. *Protecting Fracking Fluid Trade Secrets*. Rep. N.p.: SchiffHardin LLP, 2013. *Google Scholar*. Web. 1 Dec. 2013.

"Obama White House Explains Importance of Hydraulic Fracturing." YouTube. Energy In Depth, 19 Nov. 2013. Web. 02 Dec. 2013. <http://www.youtube.com/watch?v=7uVGY3sIBsA>.

"Performance Standards." Center for Sustainable Shale Development. Center for Sustainable Shale Development, 2013. Web. 15 Apr. 2014. <https://www.sustainableshale.org/performance-standards/>.

Quast, David. "Hydraulic Fracturing: Tightly Regulated, Extensively Studied." *Energy in Depth*. N.p., 11 Nov. 2013. Web. 02 Dec. 2013. <http://energyindepth.org/california/hydraulic-fracturing-tightly-regulated-extensively-studied/>.

Quest, Dan. "Fear of "Fracking Earthquakes" Is Misplaced." *Energy in Depth*. Energy in Depth, 27 July 2013. Web. 12 Apr. 2014.

Samjovic, Alan, and Phillipp Dettmer. "Fracking Explained: Opportunity or Danger." *YouTube*. Kurzgesagt, 03 Sept. 2013. Web. 30 Nov. 2013. <http://www.youtube.com/watch?v=Uti2niW2BRA>.

Siegel, Freddie. "Fred Siegel: Fracking, Poverty and the New Liberal Gentry." *Wall Street Journal*. N.p., 7 Nov. 2013. Web. 2 Dec. 2013. <http://online.wsj.com/news/articles/SB10001424052702303936904579178201737694182?KEYWORDS=Fred+Siegel>.

Siegel, RP. "If We Can't Make Fracking Unnecessary, Can We At Least Make It Safer?" *JustMeans*. JustMeans, 10 Apr. 2014. Web. 15 Apr. 2014. <http://www.justmeans.com/blogs/if-we-cant-make-fracking-unnecessary-can-we-at-least-make-it-safer>.

"Sustainable Fracking? For Real?" The Motley Fool. The Motley Fool, 22 Jan. 2014. Web. 15 Apr. 2014. <http://www.fool.com/investing/general/2014/01/22/sustainable-fracking-for-real.aspx>.

United States. EPA. *UIC Inventory by State - 2011*. Washington D.C: EPA, 2011. Print.

Weinstein, Benard. "Class 9-23-13." Global Energy Policy. Southern Methodist University, Dallas. 23 Sept. 2013. Lecture.

"What Chemicals Are Used." Frac Focus: Chemical Disclosure Registry. Frac Focus, n.d. Web. 30 Nov. 2013. <http://fracfocus.org/chemical-use/what-chemicals-are-used>.