JUST THE FRACKING FACTS

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Abstract- *Many people today are looking for more eco-friendly energy; for many, natural gas is the energy source of choice, as it emits forty percent less carbon dioxide than coal, when burned. The Marcellus shale formation stretches from Tennessee to New York, and it is estimated that there may be enough natural gas housed in these structures to supply the United States for approximately 100 years at current consumption rates. Being able to extract this gas may ultimately drive down consumers' energy costs, create approximately 280,000 jobs, and raise millions of dollars in local revenue. Hydraulic fracturing, or fracking, is a process used in the drilling and extracting of natural gas from layers of shale located thousands of feet below the surface. This method involves cracking open the shale by injecting water, sand, and chemicals at an extremely high pressure. The content of this essay will explain the fracking process in detail and examine the risks, benefits, sustainability, and common misconceptions in an effort to better educate others on this topic.*

Key Words- Hydraulic fracturing, hydrofracking, Marcellus Shale, gas drilling, natural gas, frack water chemicals, groundwater contamination, sustainability

OVERVIEW OF HYDRAULIC FRACTURING

What Is It?

Hydraulic fracturing is a process used in the extraction of oil and gas from layers of rock formations located thousands of feet beneath the earth's surface. Originally, the practice was developed to jump start production in old oil and gas wells and was used commercially for the first time in 1949; however, after years of improvements and the development of new technologies, it is used more frequently now as a means to stimulate production in irregular earth formations, such as shale [1].

After vertically drilling more than a mile deep (roughly 6,500 feet) into the earth, large steel casings are placed and cemented into the new well, with the casings' size decreasing in thickness as depth increases, as seen in Figure 1. Once the shale is reached, the well turns ninety degrees and continues horizontally through the formation for up to 3,000 feet in any direction. This is when the fracking process begins. A high-powered perforation gun is fed into the well bore, and at specific locations, punctures the casing, cement, and rock. Next, water, proppants, and chemicals are pumped into the well at pressures high enough to fracture the shale. Proppants are extremely small particles usually made up of fine quartz sand or ceramic material and are what hold these fissures open after the fracturing process is complete. Without proppants, the holes would soon close due to geostatic pressure and the well would completely cease production. Through the resulting fractures, natural gas can seep out of the shale's pores, be effectively captured, and stored [2].

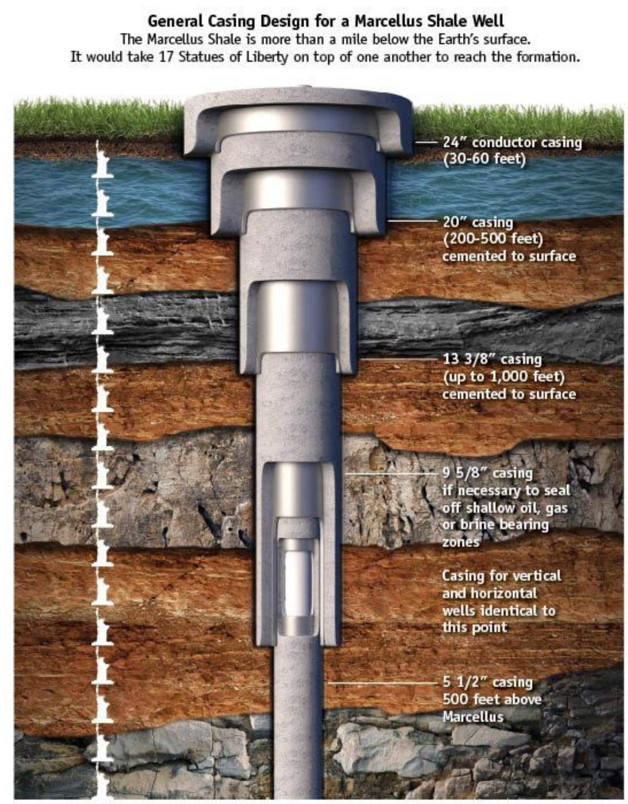

FIGURE 1
GENERAL CASING DESIGN FOR A MARCELLUS SHALE WELL.
COURTESY RANGERESOURCES.COM [1]

There is a wide range of chemicals added to the carrier fluid, all having a very specific purpose. This mixture, however, is considered proprietary to each company, so it is difficult to name the exact compounds. Furthermore, each well differs in structure and makeup, so in most cases, concentrations of certain chemicals in the mix are decided upon by the engineers to fit the needs of that particular site. What is most available to the public is the purpose and composition by volume of the chemicals added. Water is the main component, making up around 94% of the mixture, and acts as the carrier fluid for the proppant, which is about 5-

6% of the makeup by volume. As with all heavy equipment working under pressure, a lubricant is necessary to reduce friction and heat; in this case, the friction between the fluid and pipe must be controlled, and this component is approximately 0.05% of the solution. In previous years, diesel fuel was used to slick the fluid, but because of its obvious dangers, this constituent has widely been replaced by non-toxic ingredients such as plant-based oils or other privately owned solutions. Corrosion and scale buildup are both concerns when dealing with thousands of pounds of steel, so to combat this problem, antimicrobial agents and scale inhibitors are introduced to the slurry, making up 0.06% and 0.01% of the mixture, respectively. One of the most important additions to the fluid is diluted acid, which participates in dissolving minerals to create more productive fractures (percentage makeup 0.03%) [3]. Once the well has been successfully drilled and made productive, the gas is processed in a treatment facility and stored until it is purchased. The practice of hydraulic fracturing, seemingly straightforward though it may be, is actually one of the most discussed current events and hotly debated topics on a local, state and national level.

Why Is It Important?

The recent developments in hydraulic fracturing have allowed drilling companies to extract valuable natural gas with much less of an environmental 'footprint' left behind, as seen in Image 1. Instead of having to constantly drill new vertical wells, drillers can now branch out far in many directions from one well head, making much more of the gas accessible to one pad. Under ideal conditions, one well head can access natural gas from an area spanning more than one mile wide. This efficiency has also made the process, as a whole, much less of a financial burden, as each well already costs anywhere from 3 to 5 million dollars [2]. Often, these savings can eventually be passed on to the customers.

IMAGE 1

WHAT WAS ONCE A MAJOR PRODUCTION IS NOW A SMALL, UNOBTRUSIVE PIPE. PICTURE TAKEN NEAR CROSS CREEK PARK, PA. [19]

On a national level, the United States will benefit, as this could cut down the amount of energy we need to import, saving us billions of dollars and releasing us from our dependence on other nations for our basic energy needs. There are productive gas play developments all across the nation, including the Barnett Shale, Haynesville/Bossier Shale, Antrim Shale, Fayetteville Shale, and New Albany Shale [4]. Locally, the Marcellus shale formation, spanning from Tennessee to New York, is being extensively developed all across Pennsylvania, as well as in the suburbs of the city of Pittsburgh.

THE GOOD, THE BAD, AND THE UGLY DEBATE

It's Not All Fun and Games

Unfortunately, there are some risks to the process. A variety of chemicals, such as hydrochloric acid, methanol, formaldehyde amine, and benzene, are added to the fracturing liquid, although the chemicals and concentrations vary depending on the drilling company and individual well [3]. While each of the chemicals has a specific purpose (as previously discussed) many are hazardous and if care is not taken, this liquid could find its way to and pollute local water supplies. Tanker trucks must transport the chemical prior to addition to the frack liquid, and there is always some risk of spilling during transportation. Not only is there risk involved with the fluid going into the well, there is also danger in the drill cuttings and fluid that return to the surface after fracturing, known as flowback. Normally occurring radioactive material (NORMs), such as uranium and thorium, is naturally present in shale, but is considered to be in elevated amounts in the Marcellus Shale. Because of pressure and/or temperature changes during drilling, the radioactivity in these materials can become concentrated. These technologically enhanced NORMs are called TENORMs and are considered to be more hazardous than their non-enhanced counterparts due to the elevated concentration of radioactivity. While the radioactive levels are relatively low, there is still a real safety issue in containing, transporting and disposing of the material [2].

Air pollution is another factor that must be taken into consideration. Near the end of the well development, there is a practice called flaring that is used to get rid of the waste gas that is not able to be used. The excess gas is essentially set ablaze, leaving flames spewing far into the sky, burning for days on end, and emitting a significant amount of noxious gases. Where there is natural gas, there must also be plants, as seen in Image 2, to process it and trucks to transport it. VOCs, or volatile organic compounds such as carbon dioxide and methane, are a major contributor to air quality problems and these levels may be elevated to an unsafe extent due to plant and vehicle emissions during this industrial development [2]. Another side effect of the development is the state of disrepair local roads and

IMAGE 2
GAS TREATMENT FACILITY IN WESTLAND, PA [19]

highways can fall into because of the heavy machinery and trucks constantly traveling in and out. Although companies are responsible for repairing the roads their equipment damages, they often do not do so until the project is complete, which can take months or even years, depending on the extent of gas play development in the area. Between the condition of the roads and the physical appearance of industrial sites, the natural gas wells may also have a negative impact on the marketability of property in the area. Many people are still wary of the process, and prefer not to live so close to these sites.

The Political Debate

Hydraulic fracturing has been specifically excluded from the Safe Drinking Water Act since 2005; companies are not required to disclose the chemicals they are using to the public or even the government. This modification to the original act has been labeled as a ‘loophole’ by many and has been the target of much scrutiny, as it was supported by then Vice President Dick Cheney, the former CEO of Halliburton, a major energy company [5]. In reality, the Safe Drinking Water Act never included coverage of hydraulic fracturing and was only set in place to cover the underground injection of waste. The following is an excerpt from the Safe Drinking Water Act of 2005:

> “SEC. 322. HYDRAULIC FRACTURING.
> Paragraph (1) of section 1421(d) of the Safe Drinking Water Act (42 U.S.C. 300h(d)) is amended to read as follows:
> (1) UNDERGROUND INJECTION.—The term ‘underground injection’—
> (A) means the subsurface emplacement of fluids by well injection; and
> (B) excludes—
> (i) the underground injection of natural gas for purposes of storage; and
> (ii) the underground injection of fluids or propping agents (other than diesel fuels) pursuant to hydraulic fracturing operations related to oil, gas, or geothermal production activities” [6].

This amendment was simply set forth to clarify the wording from the original act, not change its regulations. In the initial legislation, an injection well was one that was used for placement of fluids beneath the surface for reason of waste management [7]. Now, there are many classifications of injection wells to help lawmakers decide which are to be regulated and for what reason. A Class II injection well is one that is associated with drilling for oil or gas, though it is not considered as a hazard by the EPA. The reason for this is that the fracking liquid is completely contained in casings of steel and cement and is to be disposed of either in the formation from which it came, or a formation of similar depth and makeup. Furthermore, the Safe Drinking Water Act places the vast majority of gas drilling guidelines in the state’s hands, provided their regulations are at least as rigorous as those set forth by the federal government [8]. Even though the Environmental Protection Agency has classified the process of hydraulic fracturing as a nonhazardous act, there have been measures to get the 2005 Amendment overturned. In 2009, the FRAC (Fracturing Responsibility and Awareness of Chemicals) Act was proposed to repeal the previous exemption and require drilling companies to reveal the chemicals used. The bill was never passed, though it was passed off to the Committee on Environment and Public Works [9].

Drilling companies are not required to reveal the chemicals they use, and they often don’t simply because they each have their own formulas that they have developed over years of research. The general components, though, are no secret and can be obtained online with minimal searching. The desire to keep their proprietary mixtures a secret is often misconstrued as the desire to hide the use of toxic chemicals from the unsuspecting public. As a result, there has been widespread fear and concern among local residents, farmers, and lawmakers who fear for the safety of their families and livelihood, should the water supply and air be contaminated. The lack of disclosure does, however, cause a problem for the recycling facilities, as they are unaware of the impurities in the water that they are trying to filter out [2]. Often, the only time this information is revealed to anyone outside the industry would be whenever there is an emergency- every job site must have a complete material safety data sheet listing all chemicals used so hazmat and medical crews are able to treat the situation as quickly and effectively as possible.

Another aspect of the debate is whether or not to join a group of thirty other states and pass a severance tax on the extraction of this non-renewable resource. Currently, Pennsylvania has a debt of about $4 billion and has no plans to tax the gas companies, even though this would raise hundreds of millions of dollars over the next several years. Regardless of whether a tax is levied or not, this industry has already raised an exorbitant amount of money for the state- about $43 million per year. This includes $13 million a year from fees on drilling permits and $30 million a year from gas royalties; furthermore, $525 million has been raised over the last three years from the leasing of state lands to drilling companies [10]. Even if the state chooses not to tax, this industry will still undoubtedly create thousands of jobs and raise millions of dollars in indirect local and state tax revenue.

Is It Really Eco-Friendly?

Critics of hydraulic fracturing argue that the process is not only dangerous, but wasteful. Each well requires up to eight million gallons of fracturing fluid to complete, and many wells need to be fractured more than once during their lifetime to continue producing at profitable levels [11]-[12]. This is a huge amount of water and chemicals without even taking into account that there are already two hundred and fifty thousand wells currently planned for Pennsylvania alone. Of the total water used for each well, only about 10-20% is recovered [12]. The liquid that stays behind is of no danger to water supplies, as it is located thousands of feet deeper than any watershed and the chemicals within do break down over time [2]. Much of the back-flow liquid is contained and stored onsite in steel tanks or earthen pits (whether they are lined or not is up to state regulation) and will ultimately need to be either recycled or disposed of in an EPA-approved underground well [13]. The main problem that fuels the fracking debate is the lack of evidentiary support available to the public that will prove its safety, or lack thereof. The Environmental Protection Agency issued a report in June of 2004 that basically described the chemical slurry as 'soap', which is chemically defined as a substance that breaks down both polar (water-soluble) and non-polar (greasy) substances. Surfactants may also be included in this definition, as they are substances which are used primarily to lubricate and lower the surface tension of a liquid. Some environmentalists, however, claim the EPA's statement was scientifically inaccurate and motivated by political agenda [14]. There are accounts circulating of residents' claims that their water was contaminated by methane released during drilling, some even to the point of being flammable. It is important to note that not one case of pollution due to hydraulic fracturing has ever been recorded, though there have been occurrences due to other stages of the drilling process [15]. Many operators now are choosing to be proactive and work with the state to analyze the private and public water supplies prior to drilling, so any future claims can either be legitimately proved or disproved [13].

FRACTURING FLUID

Water, Water, Everywhere…Right?

Although the use of toxic chemicals in the fracturing water is of great concern to many, another concern is where to find the millions of gallons of water necessary to put these chemicals in. Pennsylvania is lucky enough to have sustainable water resources- much more so than many other western states that are also in the middle of their own natural gas industrial booms. Between surface and ground water, there is roughly 82 trillion gallons of water available, with only 10 billion of those gallons used each day. Much of this water comes from the Delaware, Susquehanna, and Ohio River basins and also from the Great Lakes watershed. Although water is plentiful in these regions, many of the gas wells are drilled in wilderness areas, where water is not nearly as available. Of all the water used for hydraulic fracturing, only about thirty percent comes from the public water supply. This means that the vast majority of water used will have to either be brought in by truck, a costly and time consuming endeavor, or be pumped from nearby creeks and lakes after proper permits and contracts have been obtained. Image 3 shows a typical pumping site at a creek local to drilling activities. Creeks' water levels are often higher in the winter and spring months, so removing this

IMAGE 3
RANGE RESOURCES' PUMP SITE CR4 (CHARTIERS CREEK). THE AVERAGE DAILY WITHDRAWAL FOR THIS SITE WAS POSTED AS .2 MILL GAL/DAY. [19]

volume of water may have little effect on the surrounding community. If care is not taken in the summer months, however, there is a potential for disrupting the ecological balance of the creek and surrounding flora and fauna [12]. In order to combat this problem before it happens, high-flow diversion ponds are created to collect water during periods of heavy precipitation. These ponds are built to work with the natural environment and have two major benefits. During times of heavy rain, many waterways are susceptible to flooding. While flooding is a natural and normal occurrence, it still may disrupt the wildlife in and around the waterway.

These diversion ponds are built so that any waters above the flood stage are, instead, rerouted to fill these temporary holding ponds. The drilling companies can then use these sources as an extra supply of water, if necessary [13].

Compared to other energy sources, the use of water for natural gas production is minimal- only 10% of what it would require to produce a comparable amount of energy from coal. According to the Susquehanna River Basin Commission, the maximum approved daily consumptive use by power generation in Pennsylvania is 150 million gallons per day, while gas drilling is around 35 million gallons per day [13]. All things considered, water usage for the Marcellus Shale gas drilling appears to be sustainable; though special attention must still be given to where the water is being taken from and at what quantities.

What Is That, and Why Is It In My Fracturing Fluid?

Because the chemicals added to the hydrofracturing liquid are not regulated and companies are not required to reveal that information, it is hard to say exactly what is included in the mixture. More and more companies, however, are choosing to make this information unrestricted in order to quell the public's anxieties. The following information has been taken from numerous Range Resources Well Record and Completion Reports submitted to the Pennsylvania DEP. While these particular additives are not representative of all fracking fluid, it is some of the most detailed information available to the public at this time.

Two of the main additives in the solution normally include friction reducers and antibacterial agents to eliminate corrosive byproducts. Friction reducers contain no hazardous ingredients, although antibacterial agents contain chemicals like ethanol, glutaraldehyde, and formaldehyde amine. Both of these additives are diluted at approximately one-half gallon per one thousand gallons of water with an overall percentage of about 0.03. The next most prevalent chemical added is an acid mixture used to dissolve minerals to help instigate fractures, clean and protect the casing, and prevent precipitations. This component contains hydrochloric acid, methanol, and propargyl alcohol- all hazardous ingredients. This additive tends to be, however, no more than 0.01% of the total fluid used. Overall, the total concentration of hazardous components tends to be no more than 0.058%; the rest is pure water and sand [3]. What is hazardous about some of these ingredients is the concentration of the hydronium ion. When added to water, any strong electrolyte (acidic or basic) dissociates into its respective ions, so none of the original compound is present. For example, when hydrochloric acid (HCl) is added to water, the products are a positively charged hydronium ion and a negatively charged chlorine ion. The concentration of the hydronium ion is what determines the pH of an aqueous solution; the greater the concentration of the hydronium ion, the lower the pH will be, and vice versa. While the pH of pure water is around 7.0, humans can safely ingest solutions with a pH over 2.2 (roughly the pH of lemon juice) and up to 10.0 (the pH of milk of magnesia), provided they are in limited quantities. It is the particular concentration of this ion that partially determines how this solution will affect the environment, not the volume of chemical added to the fluid [16]. These chemicals, while they contain hazardous components, are no more dangerous at these concentrations than many common household products, although this is not to say the fluid is safe to ingest. Still, one must take into consideration the depth at which these chemicals are used (thousands of feet below watersheds), the safety precautions which are taken (layers of thick steel casing), and the earth's natural filtering effect on small amounts of chemicals, if spilled [13].

THERE IS ALWAYS ROOM FOR IMPROVEMENT

What's New?

Beyond looking to improve the overall safety of the procedure, a major focus is to develop ways to reduce water

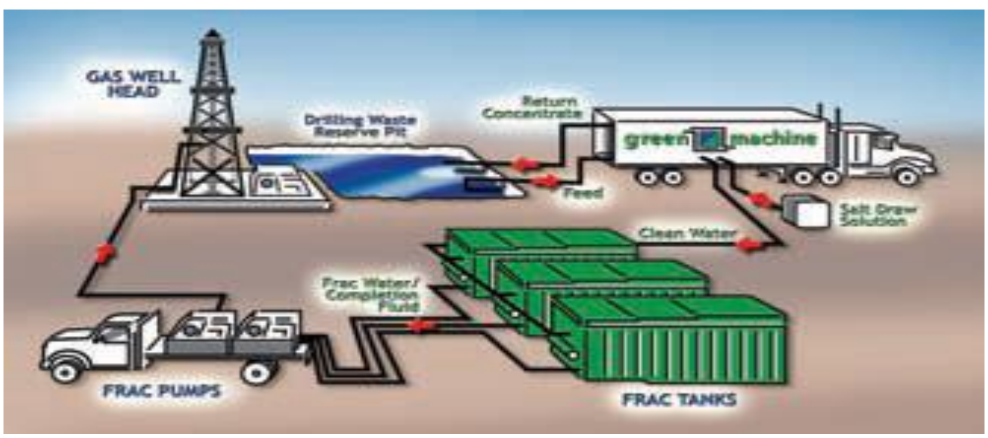

FIGURE 2

ILLUSTRATION OF FORWARD OSMOSIS SYSTEM, HOUSED AND TRANSPORTED IN LARGE TRUCKS LIKE THE ONE SHOWN ABOVE. IMAGE FOUND IN SOURCE [17].

usage and waste. One of the systems currently being researched is the process of forward osmosis, which is driven by an osmotic pressure gradient to draw out the solution of higher concentration. These systems, pictured in Figure 2 above, are completely transportable, energy efficient, and safe. Only requiring less than twenty-five gallons of fuel per day to run, it can turn up to 80% of the drilling waste back into about 20% of the water used for hydraulic fracturing at each site. The reason the liquid needs to be recycled before its second use is that the backflow often has a high concentration of minerals that, if left unfiltered, would form scale on the well and possibly plug the existing fractures and hinder production. This new technology will not only provide a clean way to recycle the liquid, but will also cut down on the amount of trucks needed to transport large amounts of water and wastewater to and from the property [17]. The use of treated acid mine drainage is also a very real possibility as a solution to the water issue. Because this region was mined extensively for coal, there is a large supply of this wastewater that can be treated and put to use in fracking, thereby reducing the need for freshwater sources. In fact, 3 million gallons of this fluid has already been successfully used in a Marcellus Shale well. One suggestion for the final disposal of wastewater is to inject the fluid into rock formations located at depths lower than the shale formations that are being drilled. These formations are too low to ever be used as aquifers and may be the best place to store solutions that cannot be safely treated and reused [2]. Other ideas garnering the attention of environmentalists are the use of ultraviolet light in place of chemicals to eliminate bacteria around the wellbore and a defoamer to flush the wellbore and break down other chemicals used [1].

To better understand the weaknesses of the process and build new technologies for improving safety and sustainability, a number of agencies and companies are beginning more thorough examinations of exactly what goes into the process of natural gas drilling, from the first transportation of equipment to the final reclamation of the well site. Currently, the EPA is working on a new, $1.9 million comprehensive study on the safety of the procedure, though the results are not expected to be available until late 2012 [14].

Alternatives to Hydraulic Fracturing

Although the way the shale is fractured may change and improve over the years to come, the one thing that must remain constant is the process of fracturing. Shale is a sedimentary rock composed of fine grains and produced from years of pressure on clay and other minerals. This pressure forms the sheets of shale, and the natural gas is formed when the organic materials inside them break down. Unlike sandstone or some types of limestone, the pores in shale are extremely small, not well connected, and have a permeability not exceeding 10^{-2} millidarcies. This limited permeability is the reason that shale must be fractured: to open these pores and allow the gas to flow freely [18].

The only alternatives to the process then, are those that improve or completely change the fluid used to either cut back on the amount of chemicals needed or reduce the amount of water necessary. One option that solves both of these problems is the use of liquefied petroleum gas. This product is resultant of natural gas processing, though the main component is a gelled propane fluid. There is no water necessary for this process, and all of the backflow is able to be contained. Another option is called DryFrac, and it has already been successfully employed in natural gas well fracturing. The carrier fluid in this operation is liquid carbon dioxide, and the proppant is mixed in with the pressurized fluid. What is most remarkable about this development is that the amount of gas produced from this method is up to five times greater than that of hydraulic fracturing [2]. There are two significant drawbacks to this procedure, though. One is the difficulty in transporting the volume of liquid carbon dioxide necessary for this operation; there are no networks of underground pipes, so any liquid must be transported via tanker truck. The second is the fact that the formation of ice in the wells is a very real prospect with this technique. The benefits of this process, however, may be likely to outweigh the cost of the transportation and this is a technology that will likely be receiving much more attention in the near future.

WHAT HAPPENS NEXT

Twenty-five percent of energy used in the United States comes from natural gas, and it is estimated that our domestic supply will last for roughly 100 years at current consumption rates. In Pennsylvania and New York alone, there are 320,000 gas wells already planned [11]. Clearly, the natural gas boom is here to stay for quite some time, and the process of hydraulic fracturing is currently the most efficient, sustainable way of accessing this valuable resource. Every major procedure such as this must undergo constant evaluation and studies to ensure the drillers and engineers are running these operations safely, resourcefully, and with great regard to the environment and public as a whole. As long as time is taken to complete these studies and develop better ways to protect and recycle the waste produced, hydraulic fracturing will remain a viable practice in the extraction of natural gas for years to come. It is not a dangerous and toxic tool used by energy companies to line their own pockets, even though it is often made out to be by the media and those who have not taken the time to review the fracking facts. The government, engineers, and environmentalists often work together to build a standard of best practices to be followed by the energy and drilling companies. Safety for employees, co-workers, and the environment is one of the most important aspects in this line of work, and even if best practices are followed, accidents will always happen. The products of this industry will affect us all, and it would be wise for anyone to educate themselves on the past, present, and future of hydraulic fracturing. Even if the current methods of fracking are improved, though, engineers must always continue to search for safer and more efficient methods of natural gas extraction to ensure we can continue to produce and thrive in this industry with a minimum of waste produced. What we do now will affect all of the generations to come, and the engineer's job is more important to the future of this country now than ever before.

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