Fracking: An Industry Under Pressure

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Three miles beneath the surface of the earth and at pressures exceeding one thousand atmospheres, a complex concoction of chemicals spurts, rupturing stone and cracking sheet rock through sheer force. As fractures creep out from the shattered bedrock, the fluid continues its destructive course, splitting millennia-old stone as if it were soft timber. As the pressure ebbs away further from the epicenter of the event and the initial pressure surge subsides, the wash of gushing liquid gives way to a tide of granular particles almost like a wave of quicksand. The particulate matter penetrates deep within the myriad ruptures, wedging them open so that the rocks themselves can release their precious bounty -- energy-rich shale gas trapped between layers of stratified rock.

The process that has just taken place is known as hydraulic fracturing, but is far more ubiquitous under a different name -- fracking. Fracking has had its fair share of the media spotlight recently, with innumerable reports and studies showing that it taints everything from our atmosphere to our water tables while similar amounts of reports and studies declare it not only perfectly safe, but vital for the stability of the energy economy. Both sides have convincing evidence and plenty of scientific clout; it is very likely that neither side is completely right. Whatever the case, it is vitally important that we acknowledge the benefits and consequences of hydraulic fracturing. Because of its vital importance to the extraction of natural gas and oil, both central tenets of the energy industry, banning fracking could hugely destabilize energy prices. However, if fracking is polluting our air and water, allowing it to continue could be even worse. To fully understand the controversy behind fracking, it is necessary to understand what it is and how it works.

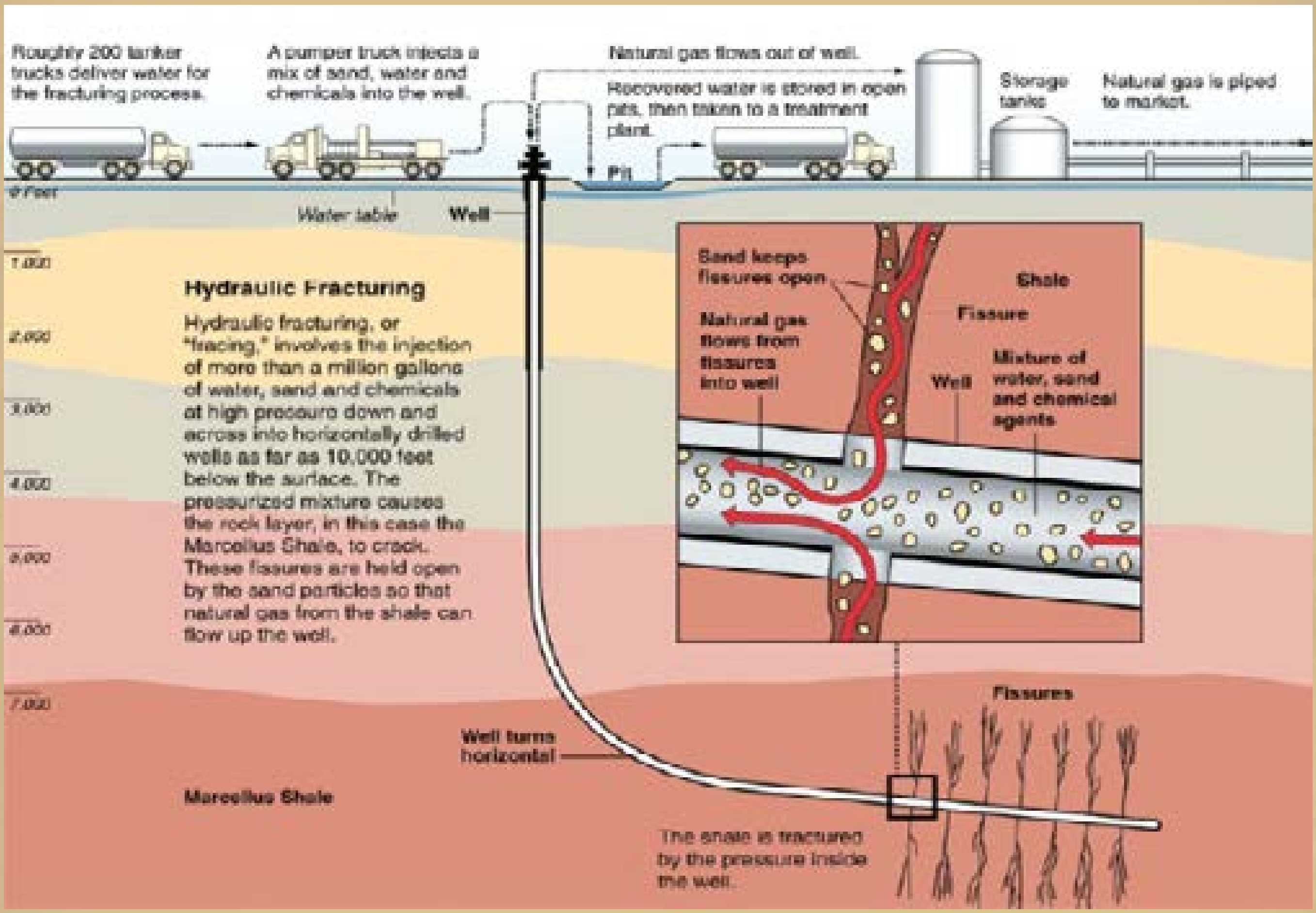
Hydraulic fracturing is a method of treating wellbores to increase the production rate and efficiency of collection of resources. It is most commonly used to increase the yields of natural gas or oil mining operations, though adapted versions of the process see insignificant amounts of usage harvesting more exotic resources (Brown, 2007). True to its name, it works by pumping highly pressurized fluid into a borehole, causing ruptures in the side of the well through which gas or oil can seep in, which are often wedged open using a granular "proppant" to facilitate flow through the fissures. While fracking has existed commercially since the 1960s, prototypical forms of the process date back to over a hundred years before that (Montgomery & Smith, 2010). In its long lifespan, fracking has been fine-tuned dozens of times by hundreds of innovative new processes, chemicals, and instruments that allow it to drastically increase the yields of wells. While many regulatory agencies have and continue to consider fracking a safe process, some recent studies (and indeed, reported contamination incidents) make it seem ever more likely that fracking is far from the golden boy of the energy industry that it was once thought to be. Even now, several governments around the world have passed legislation restricting or banning the use of fracking, and it is increasingly possible that we may see it phased out altogether.

It is almost laughable to compare fracking in its historic sense to the modern usage of the term -- indeed, the sheer scale of the growth of the process boggles the mind. While early fracking treatments in the 1950s used on the order of 750 gallons of fluid to rupture the rock and 400 pounds of sand to prop open the fractures, some of the largest modern fracking treatments can exceed 1,000,000 gallons of fluid and 5,000,000 pounds of proppant (Montgomery & Smith, 2010). While much of this vast increase in scale is due to increased demand for fuel and larger wells, a large extent of it is due to a clearer understanding of the mechanics of fracking, a gradual and unending perfection of the process, and a better sense for the maximum amount of fracking that is cost-efficient. It is easy to think of modern fracking as a science, and like all sciences, fracking evolved from highly disorganized roots through careful observation and improvement.

In 1865, Lieutenant-Colonel Edward Roberts, inspired by memories of artillery from the Civil War, christened his "Explosive Torpedo", a gunpowder-filled iron shell with an explosive tip that would detonate upon a firm impact. By filling an oil well with water, then deploying and detonating a torpedo in the well, Roberts was able to utilize the power of the explosion to carve fissures into the rock well in a process he called "superincumbent fluid tamping" (Montgomery & Smith, 2010). In the years that followed, roughneck oil workers in New York, Pennsylvania, and West Virginia often employed nitroglycerine, a potent explosive, to increase the yields of shallow, hard oil wells. By disintegrating substantial portions of the oil-containing structures, the workers hoped to increase the flow of oil to the well and the total amount of oil that could be effectively recovered. This process, known as "shooting" an oil well, was incredibly dangerous, highly illegal, and above all, spectacularly successful in liberating black gold from its rocky prison. This process was artfully painted by John J. McLauren in his 1896 book *Sketches in Crude Oil — Some Accidents and Incidents of the Petroleum Development in all parts of the Globe*.

> "A flame or a spark would not explode Nitro-Glycerin readily, but the chap who struck it a hard rap might as well avoid trouble among his heirs by having had his will written and a cigar-box ordered to hold such fragments as his weeping relatives could pick from the surrounding district."

Despite the notorious and well-document risks, this prototypical form of fracking quickly became a standard in the incipient petroleum industry, due in no small part to increases in yield as high as 1200%. The practice also spread to similar industries, who found that "shooting" was equally effective in releasing gas and water from otherwise impermeable reservoirs. In the 1930s, experimentation with less explosive methods of well stimulation led to the development of acidization, a process in which strong acids capable of etching rock formations (but incapable of damaging the hydrocarbon reservoirs) are injected into wellbores, creating fractures that are less susceptible to collapse and "cleaning up" existing fractures such as to increase the flow of reservoir fluids. Acidization is still used today, as a way of purging the formation of rubble and unwanted chemical side products that are formed by previous treatments (Fjaer, 2008). Acidization, however, was only the first foray into nonexplosive fluid stimulation. In 1947, Floyd Farris of Stanolind Oil, noticing a correlation between treatment pressures of acidization and well productivity, first conceived of hydraulic fracturing as we know it today. In Kansas City later that year, the first experimental "Hydrafrac" treatment was performed, with 1000 gallons of napalm-thickened gasoline injected into a well in an attempt to rupture a natural gas formation through pure pressure as opposed more chemical means (Montgomery & Smith, 2010). Though the process



Fracking involves little more than the injection of vast quantities of pressurized water, sand, and chemicals to rupture fuel-containing rock layers.

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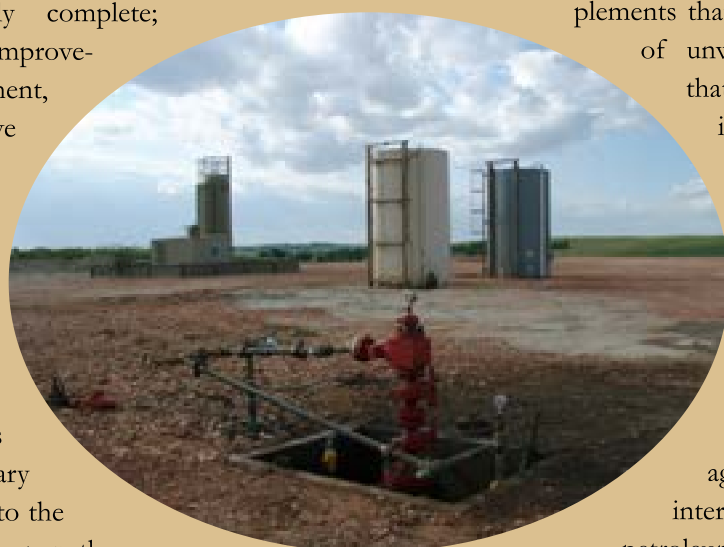
Understanding Fracturing Fluid

To create productive natural gas wells, companies force fluid thousands of feet below the surface at high pressure to crack shale rock and release trapped natural gas. This extraction technique is called hydraulic fracturing. The fluid used in the process is made up almost entirely of water and sand. However, it also includes a very small percentage of chemical additives that help make the process work.

did not significantly alter the output of the well, Hydrafrac continued to perambulate around Stanolind Oil until it papers about it were released to to the oil industry in 1948, culminating in Halliburton Oil acquiring an exclusive patent to the treatment. Halliburton performed the first commercial fracking treatments later that year, using crude oil and gasoline as a fluid and adding sand to the mixture in an attempt to wedge the hydraulic fractures open. After early treatments produced increases in production averaging 75%, fracking took the oil industry by storm, topping out at over 3000 treatments per month in the mid-1950s and drastically increasing the US oil supply (United States Department of Energy [US DoE], 2011). At this point, the concept behind fracking was fundamentally complete; however, since that time, improvements in the materials, equipment, and processes of fracking have continued to improve the efficacy of the treatment.

Modern fracking operations utilize powerful pumps and vast amounts of water and chemicals to liberate trapped gases and oils.

Possibly the most important component of any fracking treatment is the fluid used to rupture the rock. It is impossible to use basic fluids like water for this task, which lack the necessary viscosity to convey proppant to the formation that it might hold open the ruptures formed. The viscosity of the proppant also affects the properties of the breached well; high-viscosity fluids tend to form large, prominent fissures of large penetration, whereas lower-viscosity (also known as "slickwater") treatments tend to create numerous spread-out microfractures (Fjaer, 2008). For this reason, early treatments utilized crude oil, gasoline, or kerosene, which were inexpensive at the time and facilitated large volumes at low cost. Water was first used as a fracking fluid in 1953; through the use of various gelling agents, it can serve as a 'base' with which a suitable fluid is formed. Nowadays, acids, alcohols, brines, foams, gelling agents, and crosslinking agents all see usage to optimize the properties of the fracking fluid to perfectly fit the situation (Fjaer, 2008; Montgomery & Smith, 2010). Modern fracking fluid consists on average of 99.5% freshwater and sand and a mere 0.5% additives. These additives include, but are not limited to, guar gum (to thicken the fluid to allow it to suspend the proppant), isopropanol (to increase the viscosity of the fluid), various borate salts (to maintain viscosity independence with temperature), and hydrochloric acid (to dissolve rubble and facilitate the creation of fissures), along with a myriad assortment of supplements that serve to minimize the amount of unwanted chemical side reactions that take place. It is this fluid that is of supreme concern to opponents of fracking, as the principal environmental danger of fracking is that of these unwanted chemicals leaching into the surrounding ecosystem via water tables during the fracking process.



After a fracking operation, little remains except for vastly increased wellflow and -- according to some -- widespread environmental harm.

The propping agents, by contrast, are of far less interest to both environmentalists and petroleum engineers alike. The first fracking treatments used screened river sand or construction sand to wedge open crevices in sheet rock, and though many exotic, even unusual proppants have seen use over the years (ranging from metal shot or plastic pellets to glass beads or even rounded nutshells), ordinary sand has always been the most common propping agent. The usage of proppant has varied over the years, mainly due to changes in the propping fluid; the viscous oils and water-based gels of the 50s to mid-1960s tend toward lower concentrations of larger-grained particulate, whereas less viscous modern fluids necessitate much higher concentrations of sand. While early fracking treatments averaged approximately half a pound of sand per gallon of fluid, modern treatments range between 2 to 5 pounds of proppant per gallon, and can actually reach as high as 20 lbs/gal during some stages of the fracking process (Fjaer, 2008). Nevertheless, due to the relative ubiquity of sand as a propping agent, even the high volumes used do not make the propping agents of serious concern to those concerned about the environmental ramifications of fracking. Simultaneously, sand's low price and efficiency as a proppant mean that propping optimization is by and large not as important as fluid optimization when it comes to maximizing the efficacy of the fracking process.

However, there is a tertiary concern beyond the consumable resources applied during the process of fracking. In order to create the incredible pressures used to crumble brittle rock like dry toast, heavy machinery is needed. While early fracking treatments made do with existing acid- or cement-pumping equipment, specialized instruments were rapidly created to produce the necessary pressures and flow rates that fracking requires. Modern fracking equipment uses around 1500 horsepower to pump 800 gallons of fluid per minute at pressures of around 500 psi. Some of the largest equipment for the deepest wells can utilize in excess of 10,000 horsepower to pump more than 4200 gallons of fluid per minute at pressures that can exceed 20,000 psi (Fjaer, 2008). The amount of pollution and runoff that these instruments can produce makes them unexpected factors to fracking's environmental damage.

When it comes to the health risks of fracking, it is undisputable that several of the chemicals used in fracking fluids are known toxins and can be poisonous not just to local ecosystems but also nearby residents. Health and Safety Agencies in Colorado and New York found detectable and not insignificantly harmful concentrations of carcinogens such as benzene, toluene, and xylene (which are used as thickening agents), as well as and toxins like ethylene glycol (which is used to prevent the formation of limestone "scales" on the boreholes) in groundwater near fracking operations (Brown, 2007). In July 2011, the EPA released new emissions guidelines, stating that "previous standards...could lead to unacceptably high cancer risks for those living near drilling operations" (United States Environmental Protection Agency [US EPA], 2011). Fracking is also known to produce high emissions of greenhouse gases, both via uncaptured methane from fractured rock and emissions from fracking equipment (Brown, 2007). Fracking also consumes large volumes of water, only 30-70% of which is recovered after it is pumped into the well, and in an environmentally unusable state (US Energy Information Administration [US EIA], 2011). While much of this water is recycled, the simple fact that less is recovered than is needed means that fracking treatments will continually draw water while they are in progress. As if this laundry list of malignancies was not enough, fracking has also been shown to liberate or otherwise lose significant quantities of radioactive nuclides. While some of these radiation sources are naturally-occurring minerals like uranium or thorium that are freed during the fracking process, a significant quantity of the radioactive output is due to the loss of radioactive "tracers" that are used to map fractures in the rock and are subsequently leached into the surrounding area (Brown, 2007).

Despite reported contamination incidents of many of these scenarios in Colorado, Pennsylvania, Texas, and many other states, the drilling industry maintains its position that properly maintained and secured fracking operations pose a negligible risk to the environment, a position that is largely supported by the official EPA stance that fracking contributions to pollution, both atmospheric and groundwater, were negligible comparative to more significant emission sources. After a 16-month investigation, EPA regulators concluded that high methane levels in Franklin Forks, Pennsylvania, were unrelated to local natural gas drilling, and were instead the product of local geothermal anomalies. The head of the EPA, Lisa Jackson, stated during Senate testimony that "[She was] not aware of any proven case where the fracking process itself has affected water" (US EPA, 2011). An EPA report published in 2011 reiterated this stance, stating:

> "Advocates state that fracturing has been performed safety without significant incident for over 60 years, although modern shale gas fracturing of two mile long laterals has only been done for something less than a decade. Opponents point to failures and accidents and other environmental impacts, but these incidents are typically unrelated to hydraulic fracturing per se and sometimes lack supporting data about the relationship of shale gas development to incidence and consequences."

Despite this stance, however, environmental health and

Background picture: The Kern River Oil Field in California is one of the most densely-developed oilfields in the continental United States.

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safety commissions in Colorado, Ohio, and California have proposed or imposed moratoriums on hydraulic fracturing, and the EPA is compiling a definitive study on fracking's effects on groundwater, to be released in 2014.

Because, on a very fundamental level, fracking breaks down barriers between the resource-rich environment and mining operations, it is inevitable that it will conversely break down barriers between pollutant-ridden mining operations and the environment in the process.

Ultimately, the most important decision that regulatory agencies must make about fracking is not whether or not it is eminently harmful, but whether it has the potential to do more harm than good. Due to the comparatively gigantic increases in yield that fracking is able to squeeze out of oil and gas wells, it is a huge contributor to the energy economy, and thereby the stability of the the entire energy market. A Yale University Energy Study Group performed a cost-benefit analysis on natural gas fracking, and calculated that the direct economic benefit of hydraulic fracturing in the US totaled over $100 billion per year (Ames, 2012). In North Dakota and South Texas, where fracking contributes hugely to the local oil and gas industries, household income rose during the 2008 recession, leaving the states comparatively unscathed by the economic crisis (US EIA, 2011). Fracking has greatly reduced US dependence on foreign oil imports -- which fell 19% in the first half of 2013 -- which functionally lowered the country's trade deficit by $31.6 billion. More importantly, the oil and gas industry -- mostly through fracking -- has produced 2.1 million new jobs since the recession (US DoE, 2011). Increasing regulations on fracking would inevitably lead to a decrease in national oil production, and -- depending on whom you talk to -- could put the energy industry into a slump as demand for oil and gas far outstrips their supply. In this sense, the time is simply not right for fracking restrictions and moratoriums, with an unstable economy that is probably unable to cope with the added stress of losing half of its oil and gas production and is certainly not ready to make the transition to more viable alternative energy sources so quickly. From this standpoint, it is not just a matter of environmental safety but also of economic viability whether fracking should be allowed to exist. While increased containment and pollution regulations are possible, widespread moratoriums (or even outright bans) on fracking as a practice are unlikely simply because they upset the status quo too much. Fracking is far too vital to the energy industry for it to disappear without long-lasting and far-reaching consequences.

The most important question we must ask is not if fracking will go away, but when. While there are innumerable reports of fracking contamination, many studies on individual contamination incidents are skewed by confounding variables, and as a result few cases can clearly show a documented correlation. Despite this, the fact that there is no clear scientific consensus on the issue makes a strong case for increased regulations -- after all, it only takes one major spill to make fracking a serious environmental concern. Unfortunately, while increased regulations can certainly decrease the risk of contamination and seepage, the simple fact remains that fracking is difficult to contain by its very nature. Because, on a very fundamental level, fracking breaks down barriers between the resource-rich environment and mining operations (and, more importantly, does so in a crude, uncontrollable manner), it is inevitable that it will conversely break down barriers between pollutant-ridden mining operations and the environment in the process. However, fracking is simply too important to the integrity of the current energy ecosystem for us to expect it to become obsolete in the near future. Because of the multiplicative returns it induces upon fuel sources that are now higher in demand than they have ever been, banning fracking is a poor economic decision. While environmental regulations and restrictions are clearly necessary to limit the consequences of reckless fracking, until there is a fundamental restructuring of the energy economy -- a true green revolution -- fracking is here to stay.

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