Environmental Loss vs. Economic Gains: Evaluating the Sustainability of Hydraulic Fracking in the Marcellus Shale Region

Research Question: What are the environmental and economic impacts of Hydraulic Fracking in the Marcellus Shale Region, and can Hydraulic Fracking ever be done sustainably in this region?

Environmental Systems and Societies

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Introduction

The energy production industry in America is constantly evolving. Many different methods have been employed to find natural resources such as oil and gas, and as time passed, these methods became more and more efficient. From merely digging for these natural resources, to now using more efficient pumps to pull oil from under the ocean, the energy industry has become more efficient, yet more risky. The greatest example of this is hydraulic fracking. This is the most cost-efficient way to obtain natural gas, but the extreme nature of it leads to more drastic environmental impacts.[1] In the Marcellus Shale Region, Pennsylvania, for example, fracking has already done geological harm and made the area more prone to earthquakes.

So, what are the environmental and economic impacts of fracking in the Marcellus Shale Region, and can hydraulic fracking could ever be done sustainably in this region?

The evidence available implies that the environmental impacts of Hydraulic Fracturing to be far too harmful to risk for the economic gain that comes from doing it. Hydraulic fracking in the Marcellus Shale Region puts the environment and public health at risk in a number of ways. Firstly, the process of Fracking disrupts underground methane deposits which increases greenhouse gas emissions, leading to an increase in global warming. Hydraulic fracking can also increase Earthquake risk, as it greatly weakens the Shale layer of rock underground. Finally, it has been proven that hydraulic fracking can even lead to an increased risk of breast cancer among women, as the use of harmful chemicals and materials underground means that residential wells may be contaminated, and these harmful chemicals would be consumed.[2] Therefore, the potential long term environmental and social impacts of fracking are too negative and severe for fracking to be a sustainable method for producing energy in the future. It is important to acknowledge these negative impacts, because without awareness there is very little chance for action to be taken. Over time, the impacts of fracking will not only deteriorate ecosystems, but

[1]NPR Member Stations, "Study: Shale Gas Related Water Contamination Top-down, Not Bottom-up | Stateimpact Pennsylvania," NPR, October 13, 2015, https://stateimpact.npr.org/pennsylvania/2015/10/13/study-shale-gas-related-water-contamination-top-down-not-bottom-up/.

[2] NPR Member Stations, NPR, October 13, 2015, https://stateimpact.npr.org/pennsylvania/2015/10/13/study-shale-gas-related-water-contamination-top-down-not-bottom-up/.

will also impact all human life. Therefore, the significance of this issue lies within its future implications, which could be drastic. Through exploring these potential implications as well as observing the current effects of hydro-fracking in the Marcellus Shale Region, it will be possible to determine that the effects of hydro-fracking in the area are too negative and too detrimental to the environment for hydro-fracking to be considered sustainable.

Background

The process of hydraulic fracking uses changes in pressure caused by creating an upward vacuum which pulls fracking fluid to help pull natural gas (meaning naturally occurring gas that exists underground) out from the Shale layer underground. First, the horizontally drilled pipe that lies within the Shale Region is perforated, meaning that small charges are detonated along the outside of it in order to open up the Shale layer by making cracks in the rock, which allows natural gas to enter (as represented by diagram 1).[3] Once the cracks

[3]Ker Than, "Hydrofracking: A Ground Shaking Report," Infobase learning - login, 2015, https://tsof.infobase.com/articles/QXJ0aWNsZVRleHQ6NDg5NQ==.

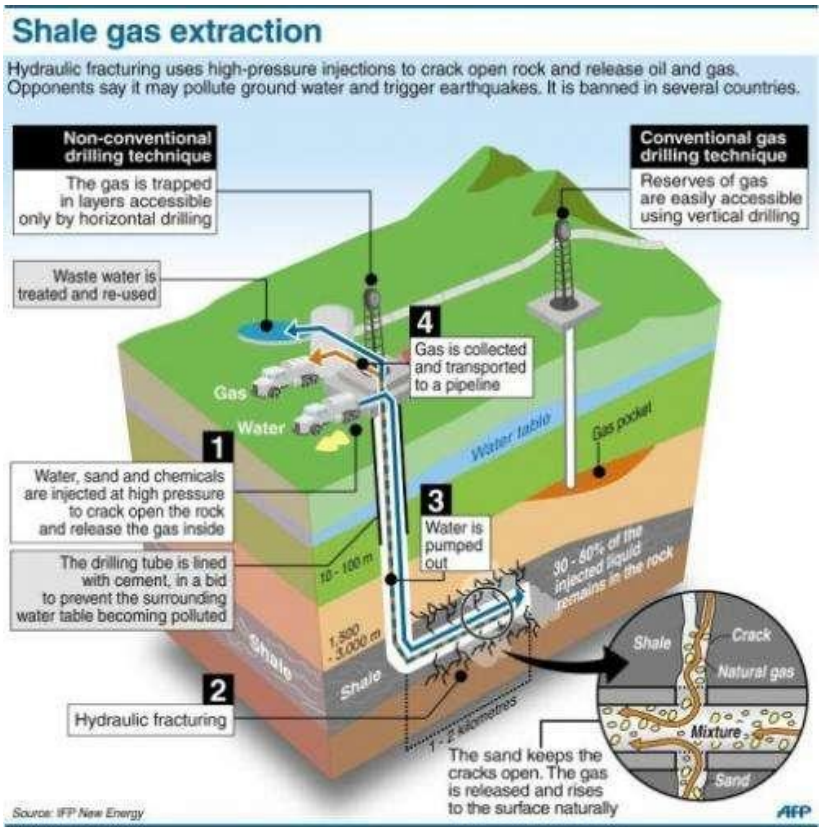

Figure 1: Diagram of Hydro-fracking[4]

open up in the Shale layer, a plug is fitted to the pipe so that gas will build up on one end.[5] Once enough gas is built up, the plug is removed, the accumulated natural gas rises, and then it is collected. This process is very reliant on the location of the fracking operation (as only an area with high levels of oil or natural gas will be profitable), and this is precisely why the fracking in the Marcellus Shale Region is done on such a great scale. The Marcellus Shale Region not only covers an area which spans 5 states, it is the world's second largest gas deposit (behind South Pars Field, located in Qatar and Iran).[6] This region contributes greatly to the US's natural gas energy production and thus has drawn a lot of investment, with over $54 Billion being invested into it in 2012.[7] Since then, it has contributed greatly to the US's energy production, as it helped to produce the 30 trillion cubic feet of natural gas that the US sells each

[4]DuPont, Veronique. "Fracking Brings Boom, Fears to Rural Us." Phys.org, April 22, 2012. https://phys.org/news/2012-04-fracking-boom-rural.html.
[5] Ker Than, "Hydrofracking: A Ground Shaking Report," Infobase learning - login, 2015, https://tsof.infobase.com/articles/QXJ0aWNsZVRleHQ6NDg5NQ==.
[6]Prud'homme, Alex. 2014. *Hydrofracking*. What Everyone Needs to Know. Oxford: Oxford University Press.
[7]Prud'homme, Alex. 2014. Oxford: Oxford University Press.

year.[8] Hydraulic fracking in the Marcellus Shale Region has not only helped the national economy, but also the local economy in Pennsylvania.[9] The very high yields that came with this new method of getting natural gas helped to change the local economy from one that had to import gas to one that exports it.[10] Fracking also provides a cleaner alternative to traditional coal-powered energy plants, as the emissions released during Fracking do not damage the atmosphere as much as those released by traditional coal plants.[11] However, while hydraulic fracking (hydro-fracking for short) is a better option than traditional coal plants, it is not without its faults. Hydro-fracking is a very invasive process, as it requires the Shale layer underground to be cracked and weakened over time, the pumping of water through these canals at high speeds, and the movement of potentially dangerous gasses and chemicals.[12] These effects that result from hydro-fracking are why many object to its widespread use across America, and as these Fracking projects continue to expand, more and more people will be subject to the negative effects of Fracking. Oftentimes, these are communities that are reliant on Fracking sites for employment. This brings the issue of Environmental Justice into the dialogue about Fracking.[13] Not only could hydro-fracking be detrimental for the environment, but without effective regulatory policy, Fracking projects could unfairly influence local governments through "lobbying".[14] As a whole, the long term sustainability of hydraulic fracking in the Marcellus Shale Region continues to be a disputed topic because of its long and short term economic and environmental impacts.

The Short Term Effects of Fracking

Hydraulic fracking in the Marcellus Shale Region is a very profitable venture due to the nature of the natural gas store, but the abundance of natural gasses at the fracking site also poses a significant problem for the companies who drill there.[15] Just as there are many natural gas

[8]Prud'homme, Alex. 2014. Oxford: Oxford University Press.
[9]Prud'homme, Alex. 2014. Oxford: Oxford University Press.
[10]Prud'homme, Alex. 2014. Oxford: Oxford University Press.
[11]Prud'homme, Alex. 2014. Oxford: Oxford University Press.
[12]New York Water Science Center, "Water Issues and Marcellus Shale Gas Development in New York," Water Issues and Marcellus Shale Gas Development in New York | U.S. Geological Survey, 2017, https://www.usgs.gov/centers/new-york-water-science-center/science/water-issues-and-marcellus-shale-gas-development-new#:~:text=Water%2Dresource%20issues%20associated%20with,with%20elevated%20radioisotopes%2C%20and%203.
[13]Warner, Barbara, and Jennifer Shapiro. 2013. "Fractured, Fragmented Federalism: A Study in Fracking Regulatory Policy." http://www.jstor.org/stable/42000297.
[14] Warner, Barbara, and Jennifer Shapiro. 2013. "Fractured, Fragmented Federalism: A Study in Fracking Regulatory Policy." http://www.jstor.org/stable/42000297.

[15]DuPont, Veronique. "Fracking Brings Boom, Fears to Rural Us." Phys.org, April 22, 2012. https://phys.org/news/2012-04-fracking-boom-rural.html.

deposits in the MS (Marcellus Shale) Region, there are a lot of methane deposits near the Shale Layer, which is horizontally drilled and perforated.[16] There are many methane deposits in the MS Region, and these are often disrupted by the Hydrofracking being done there. These methane deposits are pockets of methane that exist around the Shale layer that is being horizontally drilled, and these deposits are being cracked open by the charges used in Fracking. Once these methane deposits are cracked open by the perforation, they release the methane gas upwards. It is when the methane gas travels upwards that it begins to have potentially harmful effects on humans. The first potential impact from this leakage of methane is that the gas will come in contact with groundwater and become dissolved by the groundwater. Studies show that as methane dissolves into the water, the salt levels of the water may be elevated as well as the metal content, and if this continues in the groundwater, it may lead to the contamination of drinking water in residential wells.[17] Other than potential water pollution, the leakage of methane from these underground deposits also contributes to global warming. Methane is a greenhouse gas, as it traps heat very effectively when present in the atmosphere. When more and more methane is released into the atmosphere, its heat trapping effects increase as well. This means that if more and more methane was released into the air due to the hydro-fracking, it would contribute to global warming and help accelerate climate change.

Going back to the aspect of hydro-fracking potentially polluting drinking water, there are more potential sources of pollution than methane. The first comes from a waste product of Fracking. When the Shale layer underground is chipped away at by the drilling as well as the charges used, black-shale drill cuttings are created. These have the potential to produce acidic, metals-rich drainage with elevated radioisotopes when they come in contact with water.[18] Simply put, this means that the black-shale drill cuttings that result from hydro-fracking would contaminate groundwater with heavy metals and radioactive materials if it came into contact with it.[19] Assuming that all hydro-fracking drilling projects that are happening in the MS Region are doing their due diligence to dispose of the drill cuttings in a safe manner, there is no risk of

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[16]Prud'homme, Alex. 2014. Oxford: Oxford University Press.
[17]"Methane," Methane Drinking Water Contamination Groundwater, accessed June 22, 2023, https://www.knowyourh2o.com/indoor-6/methane.
[18]New York Water Science Center, "Water Issues and Marcellus Shale Gas Development in New York," Water Issues and Marcellus Shale Gas Development in New York | U.S. Geological Survey, 2017, https://www.usgs.gov/centers/new-york-water-science-center/science/water-issues-and-marcellus-shale-gas-development-new#:~:text=Water%2Dresource%20issues%20associated%20with,with%20elevated%20radioisotopes%2C%20and%203.
[19]New York Water Science Center, "Water Issues and Marcellus Shale Gas Development in New York," Water Issues and Marcellus Shale Gas Development in New York | U.S. Geological Survey, 2017, https://www.usgs.gov/centers/new-york-water-science-center/science/water-issues-and-marcellus-shale-gas-development-new#:~:text=Water%2Dresource%20issues%20associated%20with,with%20elevated%20radioisotopes%2C%20and%203.

contamination for the groundwater. However, if any contamination of groundwater occurred, the subsequent build up of these radioactive and dangerous materials in residential wells would jeopardize the health of all residents near the hydro-fracking projects. Another potential source of water contamination comes with the leakage of Fracking Fluid in hydro-fracking projects. The Fracking Fluid is used to draw up the natural gasses that are brought into the horizontal pipe through the cracking done by the charges planted along the pipe. The fluid works by helping to create the fractures from which gas is pulled, as well as keeping them open as gas moves from the fractures to inside the pipe. In addition to containing particulates that help reduce friction in the pipes, Fracking Fluid is made up of chemicals that can be harmful when ingested, such as benzene, a known carcinogen, as well as acrylamide and formaldehyde.[20] These incredibly harmful chemicals are being put into the Earth in order to keep these fractures open for the natural gas to be extracted, which puts groundwater (which makes up residential wells) at risk of being contaminated. If traces of this Fracking Fluid are consumed by humans, it can lead to an increased risk of breast cancer in women.

While there are many environmental risks that come with hydro-fracking in the short term, the presence of these projects also help to boost the local economies of the drilled counties. In Tioga County (where hydro-fracking is being done on a large scale), the local economy has been greatly bolstered by the new investment in fracking.[21] From 2007-2012, there has been over a 250% increase in employment in Pennsylvania due to the expansion of the MS Region Fracking projects, as well as other Fracking Projects (as reflected by figure 3).[22]

[20] McHenry, Kristen Abatsis. "Fracking Women: A Feminist Critical Analysis of Hydraulic Fracturing in Pennsylvania." *International Journal of Feminist Approaches to Bioethics* 10, no. 2 (2017): 79–104. https://www.jstor.org/stable/90019563.
[21]U.S. Bureau of Labor Statistics, "The Marcellus Shale Gas Boom in Pennsylvania: Employment and Wage Trends : Monthly Labor Review," U.S. Bureau of Labor Statistics, 2014, https://www.bls.gov/opub/mlr/2014/article/the-marcellus-shale-gas-boom-in-pennsylvania.htm.
[22]U.S. Bureau of Labor Statistics, "The Marcellus Shale Gas Boom in Pennsylvania: Employment and Wage Trends : Monthly Labor Review," U.S. Bureau of Labor Statistics, 2014, https://www.bls.gov/opub/mlr/2014/article/the-marcellus-shale-gas-boom-in-pennsylvania.htm.

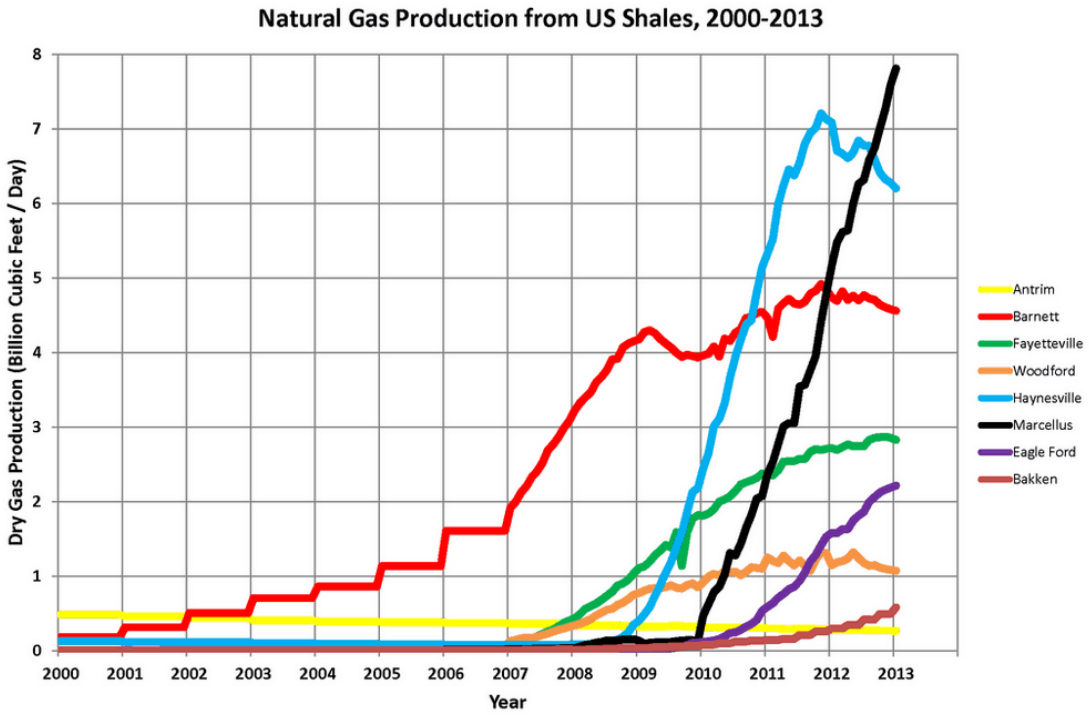

Figure 2: Graph Showing Rapid Increase in the Rate of Natural Gas Production from the MS Region[23]

[23]Michael Webber, "Pricing out Natural Gas," Highlights of 2012: Outlook on natural gas, 2012, https://www.earthmagazine.org/article/highlights-2012-outlook-natural-gas/.

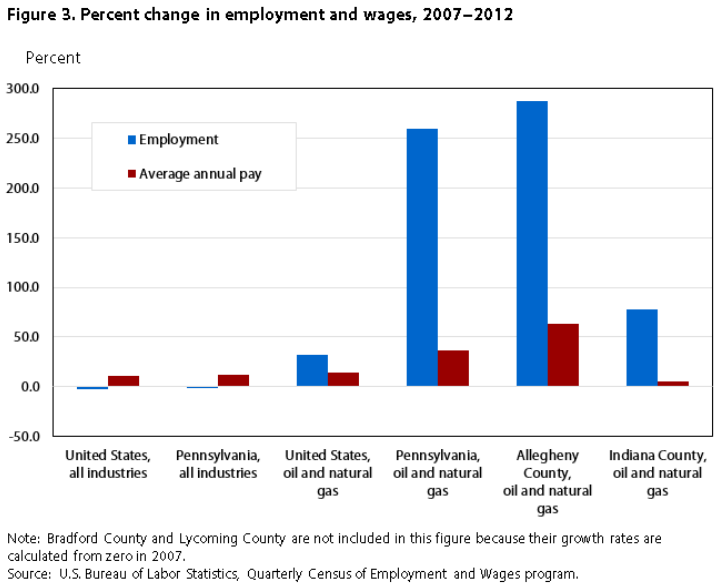

Figure 3: Percent Increase in Employment and Wages in the Natural Gas Industry[24]

However, some may argue that the economic impacts of the MS Region projects do not benefit the citizens of the county where the drilling is happening.[25] As explained by a study conducted by Penn State, this could be attributed to a few factors. For example, "leakage", which the study characterizes as "money immediately leaving the community, such as purchases from businesses outside the region or leasing and royalty dollars going to non- resident property owners".[26] The study goes on to explain that because of the "regional nature of the work", many workers are forced to commute from nearby counties or even states.[27] Applying this to the high percent increase in employment and wages shown in Figure 2 along with the increase in natural gas production from Figure 1, it is easy to see why many people think that the supposed "local economic growth" resulting from hydro-fracking is not real. They argue that even though this increase in natural gas production in the MS Region led to an overall increase in employment and wages across Pennsylvania, the presence of leakages in these small local economies (like the one of Tioga County) cancels out any local economic growth.The report expands on this, explaining that through observing local employment gains rather than increased employment by the companies carrying out the drilling, it is easy to see that this increase in income associated

[24] U.S. Bureau of Labor Statistics. "The Marcellus Shale Gas Boom in Pennsylvania: Employment and Wage Trends : Monthly Labor Review." U.S. Bureau of Labor Statistics, 2014. https://www.bls.gov/opub/mlr/2014/article/the-marcellus-shale-gas-boom-in-pennsylvania.htm.
[25]Timothy Kelsey et al., "Economic Impacts of Marcellus Shale in Tioga County: Employment and Income in 2010", 2010, Penn State.
[26]Timothy Kelsey et al., "Economic Impacts of Marcellus Shale in Tioga County: Employment and Income in 2010", Penn State.
[27]Timothy Kelsey et al., "Economic Impacts of Marcellus Shale in Tioga County: Employment and Income in 2010", Penn State.

with drilling is happening outside the drilled counties. The report reconciles this misled point of view, explaining that this increase in hydro-fracking does positively impact the economies of the drilled counties and can be seen in the increase in income for local landowners who have leased their land for well-drilling.[28] Through calculating each county's share of the Marcellus play's total land area in Pennsylvania by proportionately dividing the total income gained by leasing the land areas among each county, it was determined that "royalties paid in 2010 averaged $148,561 per well".[29] As a whole, the economic gains experienced by the drilled counties more than make up for the economic losses that come with running a natural gas hydro-fracking project. This adds to the question of whether or not hydro-fracking is sustainable for the Marcellus Shale Region, as these economic benefits might be worth the environmental risk.

The Long Term Effects of Fracking

Going back to the environmental effects of hydro-fracking, one that appears in the long term is geological degradation.[30] This primarily stems from the fluid injection that is used in the hydraulic-fracking projects.[31] The use of Fluid Injection means that the pressure will increase in the Shale Layer of the rock, which increases pressure in the rock formation.[32] Over time, this continual build up of pressure will make the area more susceptible to earthquakes in general because of the decrease in the Shale Layer's integrity.[33] This phenomena is called Fault Reactivation, where the newly elevated pressure can reactivate pre-existing faults in the rock layers.[34] Usually, these faults (where the tectonic plates meet) are locked together due to the presence of a lot of friction, but the newly added pressure from the Fluid Injection will help to overcome this friction and allow for more movement between the plates, resulting in an

[28]Timothy Kelsey et al., "Economic Impacts of Marcellus Shale in Tioga County: Employment and Income in 2010", Penn State.
[29]Timothy Kelsey et al., "Economic Impacts of Marcellus Shale in Tioga County: Employment and Income in 2010", Penn State.
[30]"How Is Hydraulic Fracturing Related to Earthquakes and Tremors?," How is hydraulic fracturing related to earthquakes and tremors? | U.S. Geological Survey, June 7, 2023, https://www.usgs.gov/faqs/how-hydraulic-fracturing-related-earthquakes-and-tremors#:~:text=Reports%20of%20hydraulic%20fracturing%20causing,injected%20into%20deep%20wastewater%20wells.
[31]"How Is Hydraulic Fracturing Related to Earthquakes and Tremors?," U.S. Geological Survey, https://www.usgs.gov/faqs/how-hydraulic-fracturing-related-earthquakes-and-tremors#:~:text=Reports%20of%20hydraulic%20fracturing%20causing,injected%20into%20deep%20wastewater%20wells, June 7, 2023.
[32] "How Is Hydraulic Fracturing Related to Earthquakes and Tremors?," U.S. Geological Survey, https://www.usgs.gov/faqs/how-hydraulic-fracturing-related-earthquakes-and-tremors#:~:text=Reports%20of%20hydraulic%20fracturing%20causing,injected%20into%20deep%20wastewater%20wells, June 7, 2023.
[33] "How Is Hydraulic Fracturing Related to Earthquakes and Tremors?," U.S. Geological Survey, https://www.usgs.gov/faqs/how-hydraulic-fracturing-related-earthquakes-and-tremors#:~:text=Reports%20of%20hydraulic%20fracturing%20causing,injected%20into%20deep%20wastewater%20wells, June 7, 2023.
[34] "How Is Hydraulic Fracturing Related to Earthquakes and Tremors?," U.S. Geological Survey, https://www.usgs.gov/faqs/how-hydraulic-fracturing-related-earthquakes-and-tremors#:~:text=Reports%20of%20hydraulic%20fracturing%20causing,injected%20into%20deep%20wastewater%20wells, June 7, 2023.

earthquake.[35] This induced earthquake effect is called “Induced Seismicity”, and some of these earthquakes can reach larger magnitudes.[36] Going back to the Fluid Injection, the water and chemicals that are used in the hydro-fracking process return to the surface of the Earth as wastewater, which is called “flowback” or “produced water”.[37] Once this wastewater reappears, it is injected into underground disposal wells in order to get rid of the waste.[38] As more and more wastewater is injected into these underground disposal wells, there is an increase in pressure that can contribute to more seismic activity, much like the Fault Reactivation that occurs when there is Fluid Injection.[39] There is already evidence that hydro fracturing can lead to more Earthquakes.[40] Take for example an article from YaleEnvronmental360 on the progression of hydro fracturing in Texas, Kansas, and Oklahoma. They state that in Oklahoma, the average number of earthquakes per year went from 2 to 800 (these earthquakes were both large and small), and that the earthquake rate for Texas has already “increased six-fold” this year.[41] The article also shows how these new earthquakes were entirely caused by induced seismicity, as they interview a Southern Methodist University seismologist who states that these earthquakes are happening along fault lines that have not had activity in the past 300 years.[42] This carries over to the Marcellus Shale Region in the sense that the continued hydraulic fracturing will have the same effects there as it did in Texas and Oklahoma. Therefore, the longevity of hydraulic fracturing in the MS Region is very limited.

Observing the progression of the issue of groundwater contamination, it is plain to see that any area that undergoes hydraulic fracturing over a long period of time is more susceptible

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[35] “How Is Hydraulic Fracturing Related to Earthquakes and Tremors?,” U.S. Geological Survey, https://www.usgs.gov/faqs/how-hydraulic-fracturing-related-earthquakes-and-tremors#:~:text=Reports%20of%20hydraulic%20fracturing%20causing,injected%20into%20deep%20wastewater%20wells, June 7, 2023.
[36] “How Is Hydraulic Fracturing Related to Earthquakes and Tremors?,” U.S. Geological Survey, https://www.usgs.gov/faqs/how-hydraulic-fracturing-related-earthquakes-and-tremors#:~:text=Reports%20of%20hydraulic%20fracturing%20causing,injected%20into%20deep%20wastewater%20wells, June 7, 2023.
[37] “How Is Hydraulic Fracturing Related to Earthquakes and Tremors?,” U.S. Geological Survey, https://www.usgs.gov/faqs/how-hydraulic-fracturing-related-earthquakes-and-tremors#:~:text=Reports%20of%20hydraulic%20fracturing%20causing,injected%20into%20deep%20wastewater%20wells, June 7, 2023.
[38] “How Is Hydraulic Fracturing Related to Earthquakes and Tremors?,” U.S. Geological Survey, https://www.usgs.gov/faqs/how-hydraulic-fracturing-related-earthquakes-and-tremors#:~:text=Reports%20of%20hydraulic%20fracturing%20causing,injected%20into%20deep%20wastewater%20wells, June 7, 2023.
[39] “How Is Hydraulic Fracturing Related to Earthquakes and Tremors?,” U.S. Geological Survey, https://www.usgs.gov/faqs/how-hydraulic-fracturing-related-earthquakes-and-tremors#:~:text=Reports%20of%20hydraulic%20fracturing%20causing,injected%20into%20deep%20wastewater%20wells, June 7, 2023.
[40] Judith Lewis Mernit et al., “Fracking Activity Linked to Increase in Texas Quakes, According to New Study,” Yale E360, November 27, 2017, https://e360.yale.edu/digest/fracking-linked-to-increase-in-texas-quakes-according-to-new-study.
[41] Judith Lewis Mernit et al., “Fracking Activity Linked to Increase in Texas Quakes, According to New Study,” Yale E360, 2017, https://e360.yale.edu/digest/fracking-linked-to-increase-in-texas-quakes-according-to-new-study.
[42] Dave Blehi, “Research Links Shale Gas, Legacy Energy Development to Groundwater Contamination,” Penn State University, 2022, https://www.psu.edu/news/earth-and-mineral-sciences/story/research-links-shale-gas-legacy-energy-development-groundwater/.

to groundwater contamination than an undisturbed area.[43] Earlier, the issue of potential groundwater contamination through the release of methane into the water table was discussed. In 2013, a Duke engineer found methane in 115 of 141 residential drinking water wells in the Marcellus Shale Region counties of Pennsylvania.[44] Through observing the presence of ethane in the methane that was contaminating the wells, it was determined that the methane in the wells did not result from microbial activity, but rather that it was pushed to the groundwater layer by heat and pressure thousands of feet downward in the Marcellus Shale, where the hydraulic fracturing was occurring.[45] This movement of methane to groundwater can be attributed to the lack of sub-surface integrity that is only exacerbated through the continued drilling of natural gas.[46] That is why in observing the issue of groundwater contamination in the long term, it can be determined that it will only get worse. This trend can be observed in a study conducted in 2022, which shows that there has been an "increase in groundwater chloride nearby unconventional wells in southwestern Pennsylvania where the Marcellus Shale play overlaps with a long legacy of oil, gas and coal extraction", with the increase in chloride being attributed to leaking caused by changing subsurface features.[47] This overlap in location for the groundwater chloride, natural gas extraction, and groundwater methane is not a coincidence. Since 2013, the continued degradation of subsurface integrity (caused by more and more cracks being opened up by the perforation necessary for hydraulic fracturing to occur) has contributed to the leakage of chemicals into groundwater, and thus has furthered the contamination of residential wells. This continual degradation of subsurface integrity combined with the issues that come with incorrectly disposing of wastewater pose a significant threat to public health, as their effects only build upon each other over time.

[43]Dave Blehi, "Research Links Shale Gas, Legacy Energy Development to Groundwater Contamination," Penn State University, 2022, https://www.psu.edu/news/earth-and-mineral-sciences/story/research-links-shale-gas-legacy-energy-development-groundwater/.
[44] Mark Fischetti, "Groundwater Contamination May End the Gas-Fracking Boom," Scientific American, September 1, 2013, https://www.scientificamerican.com/article/groundwater-contamination-may-end-the-gas-fracking-boom/.
[45]Mark Fischetti, "Groundwater Contamination May End the Gas-Fracking Boom," Scientific American, https://www.scientificamerican.com/article/groundwater-contamination-may-end-the-gas-fracking-boom/, 2013.
[46]Mark Fischetti, "Groundwater Contamination May End the Gas-Fracking Boom," Scientific American, https://www.scientificamerican.com/article/groundwater-contamination-may-end-the-gas-fracking-boom/, 2013.
[47]Dave Blehi, "Research Links Shale Gas, Legacy Energy Development to Groundwater Contamination," Penn State University, 2022, https://www.psu.edu/news/earth-and-mineral-sciences/story/research-links-shale-gas-legacy-energy-development-groundwater/.

Evaluating the Sustainability of Fracking

Taking these long and short term impacts (both economic and environmental) into account, it is important to consider whether hydro fracturing itself causes these negative impacts, or if these negative impacts come from the malfunctioning of hydraulic fracking projects. This all depends on if the current hydro-fracking projects in the MS Region are being run with all necessary safety precautions in mind. This would be something like making sure that the flowback (wastewater) is being controlled and not affecting nearby wells.[48] As the EPA details in their FAQ sheet, there are many protocols in order to minimize the impact that hydraulic fracturing has on the local communities and environment.[49] For example, under the CWA (Clean Water Act), the discharge from hydro fracturing is not allowed to be discharged into any body of water in the US unless issued a permit by the EPA (Environmental Protection Agency) or an authorized state agency.[50] Because the issues of groundwater pollution occur even though the Marcellus Shale Region is not illegally dumping, it can be concluded that the hydro fracturing projects either need better technology to control pollutants in their waters (which they may be allowed to pour flowback into), or they need to change their approach to waste disposal. However, the FAQ sheet goes on to explain that the Marcellus Shale Region needs to follow the dumping prohibition, which means that the water chlorination and increasing levels of methane in the water are occurring even though the MS Region projects are trying to prevent this.[51] As the EPA is independently monitoring these projects through making sure they are following the prohibition, it can be assumed that the current protocol is ineffective (thus making hydro-fracking unsustainable).[52] However, this information also gives those fracking companies a direction to pursue in order to make the hydro fracking sites more sustainable. It shows that the problem lies within the fluid they use, so they can make corrections to fix this.

Another facet of the impact of hydraulic fracturing is the issue of environmental justice. According to an article from Ecology Law Quarterly, the impacts of hydraulic fracturing are

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[48]James Hanlon, "Natural Gas Drilling in the Marcellus Shale: Frequently Asked Questions," Natural Gas Drilling in the Marcellus Shale NPDES Program Frequently Asked Questions, 2011, https://www3.epa.gov/npdes/pubs/hydrofracturing_faq.pdf.
[49]James Hanlon, Natural Gas Drilling in the Marcellus Shale NPDES Program Frequently Asked Questions, 2011, https://www3.epa.gov/npdes/pubs/hydrofracturing_faq.pdf.
[50]James Hanlon, Natural Gas Drilling in the Marcellus Shale NPDES Program Frequently Asked Questions, 2011, https://www3.epa.gov/npdes/pubs/hydrofracturing_faq.pdf.
[51]James Hanlon, Natural Gas Drilling in the Marcellus Shale NPDES Program Frequently Asked Questions, 2011, https://www3.epa.gov/npdes/pubs/hydrofracturing_faq.pdf.
[52]James Hanlon, Natural Gas Drilling in the Marcellus Shale NPDES Program Frequently Asked Questions, 2011, https://www3.epa.gov/npdes/pubs/hydrofracturing_faq.pdf.

most felt in poorer rural communities.[53] The article compares the per capita income, population density, number of wells, and number of well violations of all the different counties in Pennsylvania.[54] Through comparing the average per capita income to the number of well violations for each different tier of county, the study revealed that poorer counties are more likely to have hydraulic fracturing projects, and thus be more impacted by the negative effects of these projects.[55]

TABLE A: Pennsylvania Counties

	No. of Counties [59]	Avg. per Capita Income [60]	Avg. Pop. Density [61]	No. of Wells [62]	No. of Counties with Wells[63]	No. of WSDs [64]	No. of Well Violations [65]
Tier I	22	$30,043	675	1610	5	8	268
Tier II	23	$23,906	645	2337	12	75	1698
Tier III	22	$21,552	74	3162	17	161	1914

Figure 4: Comparison of Counties and their Wells in 2015[56]

As depicted in Figure 4, areas with more well violations and wells had a lower average per capita income.[57] Some may argue that this is simply a coincidence, as cheaper areas would be more favorable for real estate for fracking. A case could also be made that the lower population densities are what made these areas more favorable for hydraulic fracking, and that it had nothing to do with the average per capita income of the area. However, the article goes on to explain that there is in fact a direct correlation between the average income of an area's population and the presence of hydraulic fracking. The article states that the presence of hydraulic fracturing prevents government programs like the Rural Housing Service Program and FHA-insured mortgages from operating in the area, which threatens the financial stability of many people living in these more rural areas.[58] Just as the article explains, the lack of these programs due to the presence of hydraulic fracturing directly prevents low-income individuals ability to

[53]Elena Pacheco, "It's a Fracking Conundrum: Environmental Justice and the Battle to Regulate Hydraulic Fracturing." *Ecology Law Quarterly* 42, 2015, http://www.jstor.org/stable/43920950.

[54]Elena Pacheco, *Ecology Law Quarterly* 42, 2015, http://www.jstor.org/stable/43920950.

[55]Elena Pacheco, *Ecology Law Quarterly* 42, 2015, http://www.jstor.org/stable/43920950.

[56]Elena Pacheco, *Ecology Law Quarterly* 42, 2015, http://www.jstor.org/stable/43920950.

[57]Elena Pacheco, *Ecology Law Quarterly* 42, 2015, http://www.jstor.org/stable/43920950.

[58]Elena Pacheco, *Ecology Law Quarterly* 42, 2015, http://www.jstor.org/stable/43920950.

achieve economic independence.[59] Taking this into consideration, the question of whether or not it would simply be fair to have hydraulic fracturing continue in these areas emerges. The answer to this question is no, as there are significant economic gains that come from hydraulic fracturing, but these benefits go to those who live outside of these rural areas, meaning that the inhabitants of these fracked areas do not get any compensation for the damage to their environment. However, some may argue that because natural gas is a finite resource, the ecosystems and environment of these fracked areas will simply recover after fracking stops. They may take this information, and that eventually all environmental damage will balance out, and the people in these areas will simply be able to move on as the assistance programs will return. However, even if the programs will return, the long term environmental damage that results from hydraulic fracking will not be resolved. Specifically, the higher risk for induced seismicity will remain, and thus disproportionately affect impoverished communities.

Conclusion

Taking these impacts into account, it can be concluded that hydraulic fracturing is not sustainable in the Marcellus Shale region. Since the introduction of hydraulic fracturing to the Marcellus Shale Regions in Pennsylvania, there have been quite a few economic improvements.[60] In Pennsylvania as a whole, employment numbers and wages have been continually rising due to the gas boom.[61] It is easy to see that the continual economic growth resulting from the gas boom in Pennsylvania will continue to help the state's economy develop and prosper, but will also contribute to the overall deterioration of the environment. This continual use of hydraulic fracturing and the continual search for more wells will only further damage the integrity of the subsurface rocks.[62] The second layer of the problem when it comes to hydro fracturing and sustainability is the fact that the intense resulting environmental degradation will not be equitably experienced in the state. Those who are working at these sites and getting paid to deteriorate a local ecosystem are not the ones who need to live there.[63] Therefore, the ultimate deciding factor when it comes to whether hydro fracking in the MS Region is sustainable is not only the environmental impacts, but how equitably the effects of these impacts are shared. It is the ultimate unfairness that results from exploiting one region's natural resources but only subjecting that area's people to the environmental impacts that makes it unethical for hydro-fracturing to occur. If those profiting from these fracking

[59]Elena Pacheco, *Ecology Law Quarterly* 42, 2015, http://www.jstor.org/stable/43920950.

[60]Prud'homme, Alex. 2014. Oxford: Oxford University Press.

[61]U.S. Bureau of Labor Statistics, U.S. Bureau of Labor Statistics, 2014. https://www.bls.gov/opub/mlr/2014/article/the-marcellus-shale-gas-boom-in-pennsylvania.htm.

[62]New York Water Science Center, Water Issues and Marcellus Shale Gas Development in New York | U.S. Geological Survey, 2017, https://www.usgs.gov/centers/new-york-water-science-center/science/water-issues-and-marcellus-shale-gas-development-new#:~:text=Water%2Dresource%20issues%20associated%20with,with%20elevated%20radioisotopes%2C%20and%203.

[63]Elena Pacheco, *Ecology Law Quarterly* 42, 2015, http://www.jstor.org/stable/43920950.

projects were the ones who had to use the polluted residential wells and risk drinking something as toxic as formaldehyde, then it would be up to those people what they do with their land. But because the long term environmental damage that will occur in this region (like increased risk of earthquakes and worse air quality) will only affect those living there, these fracking projects must be further regulated and restricted by the federal government in order to ensure that the inhabitants of the fracked areas have a voice.

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