ATTACHMENT 21

The Economic Costs of Fracking in Pennsylvania

Revised May 14, 2019

Prepared for:

Delaware Riverkeeper Network

KOIN Center
222 SW Columbia Street
Suite 1600
Portland, OR 97201
503-222-6060

This page intentionally blank

Acknowledgments

For over 40 years ECONorthwest has helped its clients make sound decisions based on rigorous economic, planning, and financial analysis. For more information about ECONorthwest: www.econw.com.

ECONorthwest prepared this report for Delaware Riverkeeper Network. Other firms, agencies, and staff contributed to other research that this report relied on. That assistance notwithstanding, ECONorthwest is responsible for the content of this report.

Throughout the report we have identified our sources of information and assumptions used in the analysis. Within practical limits, ECONorthwest has made every effort to check the reasonableness of the data and assumptions and to test the sensitivity of the results of our analysis to changes in key assumptions. ECONorthwest has not independently verified the accuracy of all such information, and makes no representation regarding its accuracy or completeness. Any statements nonfactual in nature constitute the authors' current opinions, which may change as more information becomes available.

For more information about this report:

Dr. Mark Buckley

buckley@econw.com
KOIN Center
222 SW Columbia Street
Suite 1600
Portland, OR 97201
503-222-6060

Table of Contents

This page intentionally blank

Summary

Fracking or hydraulic fracturing has increased exponentially in Pennsylvania since 2008. Hydraulic fracturing involves a suite of support activities, including trucking, compressor plants, pipelines, and is highly water intensive. The boom of hydraulic fracturing in Pennsylvania has affected the state both locally and broadly. In this report we document and, where possible, value costs of fracking operations in Pennsylvania. Specifically, we evaluate the health, community, and environmental costs of fracking in the state.

Not all costs we considered are able to be monetized. In order to carry through the analysis to monetization the effect has to be clearly attributable to unconventional oil and gas production (fracking) only, meaning the cost would not have occurred but for the unconventional oil and gas activity. Not all effects have sufficient causal connections to be monetized. One of the reasons for missing information is that hydraulic fracturing in Pennsylvania is relatively new to the state. Due to this short time period some costs may not yet have manifested.

The estimated value and magnitude of the effects which are monetized are summarized in Table ES1. Annually, the costs of fracking in Pennsylvania are estimated as $1.5 billion per year. This estimated annual cost is roughly equivalent to 0.3 percent of the state's Gross Domestic Product. ***If fracking continues at current rates, the costs from fracking in Pennsylvania are estimated to be $54 billion over the next twenty years.***

ES Table 1: Summary of Costs from Hydraulic Fracturing Activities in Pennsylvania

Effect	Annual Cost	20-Year Present Value Cost
Health Costs		
Low Birth Weights	$25,200,000	$410,000,000
Asthma & Respiratory Afflictions	$1,200,000	$19,500,000
Sleep Disruption	$30,000	$488,000
Depression	$86,400,000	$1,400,000,000
Averting Behavior	$22,000,000	$358,000,000
Community Costs		
Lost Housing Value	N/A	$1,500,000,000
Road Wear and Tear	$11,000,000	$174,000,000
Environmental Costs		
Habitat Loss	$7,250,000	$115,000,000
GHG Social Cost	$1,300,000,000	$49,900,000,000
Total	**$1.5 billion**	**$54 billion**

Source: Created by ECONorthwest

Note: The present value calculation uses a three percent discount rate. For health costs, the present value adjusts for population growth of 0.25 percent per year, which is based on the Pennsylvania County Population Projections, 2010-2040 from Penn State Harrisburg.

Other costs from hydraulic fracturing activities are discussed qualitatively in this report. These types of costs are summarized in ES Table 2. While the magnitude of these costs is unknown, each also has real economic costs for Pennsylvania. Groundwater contamination is listed under all three categories because it will create health costs from exposure to pollutants, community costs to clean the water or find new water sources, and environmental costs due to the impact on the state's ecology. ***Groundwater contamination represents one of the largest potential future costs from fracking in Pennsylvania.***

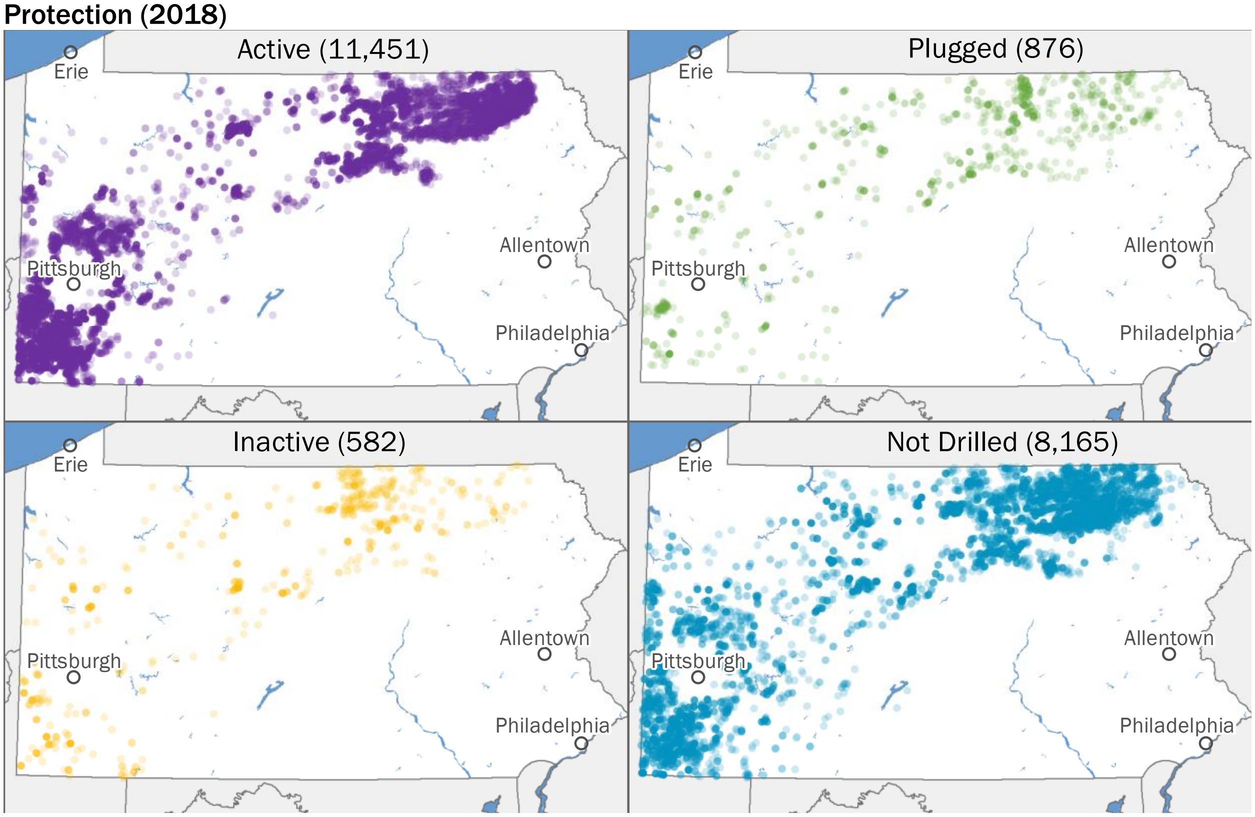
ES Table 2: Additional Unquantified Costs from Hydraulic Fracturing Activities in Pennsylvania

Health Costs	Community Costs	Environmental Costs
Cancer	Long Term Employment	Habitat Fragmentation
Cardiac Afflictions	Impacts to Other Industries	Habitat Pollution
Migraines & Sinus Afflictions	Housing Rents	Bioaccumulation
Afflictions of the Organs	Crime	Seismic Activity
Sexually Transmitted Diseases	Vehicle Crashes	Aesthetic Loss
Occupational Hazards	Bonding Losses	Groundwater Contamination
Groundwater Contamination	Groundwater Contamination	

Source: Created by ECONorthwest

Because many costs directly impact communities where fracking occurs, these costs are not evenly distributed throughout Pennsylvania. The northeastern and southwestern regions of the state have the highest concentration of hydraulic fracturing activities (ES Figure 1).

ES Figure 1: Unconventional Oil & Gas Wells Documented by PA Department of Environmental Protection (2018)



Source: Created by ECONorthwest with data from Pennsylvania Department of Environmental Protection "Open Data": http://data-padep-1.opendata.arcgis.com/
Note: "Not Drilled" wells are those which have been permitted but not yet drilled

While some costs like greenhouse gas emissions and habitat losses have wide geographic impacts, the health and community costs primarily impact only counties where hydraulic fracturing is occurring. To understand how these impacts are distributed, we estimated the annual costs of hydraulic fracturing at the county level based on the number of wells per county and by the number of people living within 2 miles of a well. ES Table 3 displays the ten counties with the highest costs from hydraulic fracturing based upon the number of wells in the county.

ES Table 4 displays the ten counties with the highest costs from hydraulic fracturing based upon the number of people living within 2 miles of a well.

ES Table 3: Top Ten Counties with Highest Annual Costs of Fracking from Number of Wells

Rank	County	Active Wells	Percent of Active Wells in State	Estimated Annual Costs in County based on Number of Wells
1	Washington	1906	17%	$24,273,000
2	Susquehanna	1624	14%	$20,682,000
3	Greene	1425	12%	$18,148,000
4	Bradford	1322	12%	$16,836,000
5	Lycoming	944	8%	$12,022,000
6	Tioga	842	7%	$10,723,000
7	Butler	610	5%	$7,768,000
8	Westmoreland	373	3%	$4,750,000
9	Fayette	326	3%	$4,152,000
10	Armstrong	293	3%	$3,731,000

Source: Created by ECONorthwest

ES Table 4: Top Ten Counties with Highest Annual Costs of Fracking from Number of People Living within Two Miles of Well (Active or Inactive)

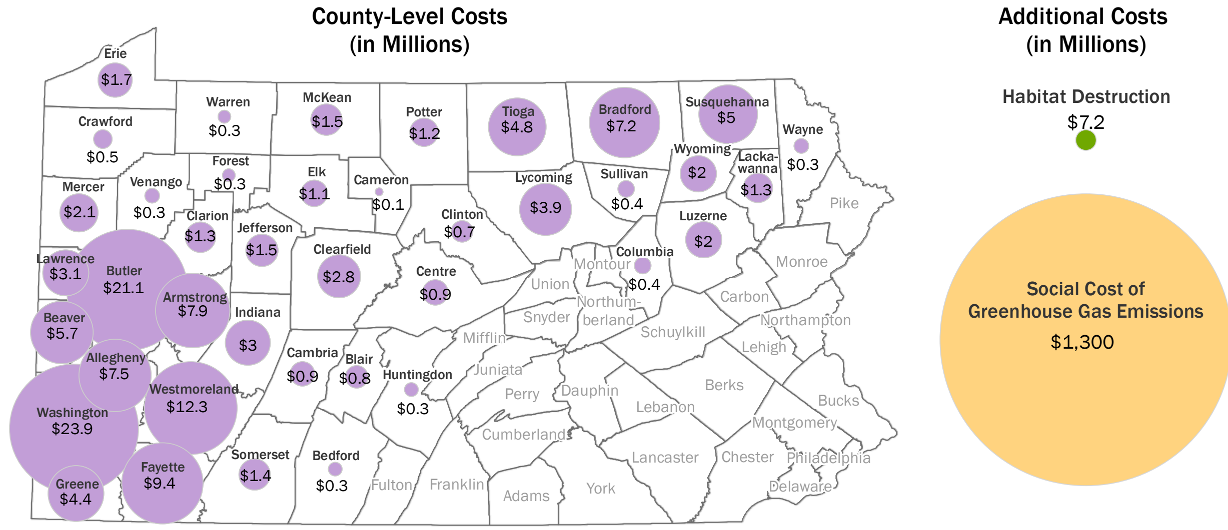
Rank	County	County Population	Number of People living within 2 miles of Well	Cost for people within 2 miles
1	Washington	207,820	155,865	$23,885,000
2	Butler	183,862	137,897	$21,131,000
3	Westmoreland	365,169	80,337	$12,311,000
4	Fayette	136,606	61,473	$9,420,000
5	Armstrong	68,941	51,706	$7,923,000
6	Allegheny	1,223,348	48,934	$7,499,000
7	Bradford	62,622	46,967	$7,197,000
8	Beaver	170,539	37,519	$5,749,000
9	Susquehanna	43,356	32,517	$4,983,000
10	Tioga	41,981	31,486	$4,825,000

Source: Created by ECONorthwest

The costs of fracking primarily affect vulnerable populations such as children, elderly, and low-income people, due to economic inequities and health risks. If fracking in Pennsylvania increases, then the total costs will also increase since they are rooted in per-well estimates. If fracking in Pennsylvania decreases these costs will decline, although some impacts like the loss of habitat will take years to restore. Even if fracking in Pennsylvania were to cease today, legacy wells will continue to pose risks to local communities and the broader region from health, community, and environmental impacts.

ES Figure 2 illustrates the annual costs of fracking by county and at the state-level. Although counties in the Southeast region of Pennsylvania do not have any wells, they are also subject to the environmental costs of fracking including habitat destruction and the social cost of greenhouse gas emissions, valued at approximately $1.3 billion per year.

ES Figure 2: Annual Costs of Fracking in Pennsylvania based on Number of People Living within 2 Miles of Well (In Millions of Dollars)



Source: Created by ECONorthwest
Note: The size of the circle is proportional to the number of people living within 2 miles of a well and therefore also proportional to the costs of fracking based on this population-weighted allocation. Environmental costs of fracking, habitat destruction and social cost of GHG emissions, are for the entire state because their effects are not limited to counties with wells.

In addition to the monetized costs, other economic costs should also be considered as resulting from UOGD in Pennsylvania. These non-monetized costs include:

- Potential for catastrophic groundwater contamination and associated health, community, and environmental costs;
- Increases in fatal traffic accidents, primarily in high well-density counties;
- Detrimental effects to the water resources of the state from the high volumes of fresh water and groundwater being used for extraction of natural gas;
- Long-term economic effects from lower educational attainment, primarily among men;
- Lack of economic resiliency from reliance on natural resource commodity subject to boom and bust economic cycles;
- Long-term health effects, including increased cancer rates;
- Environmental effects from the accumulation of chemicals and pollutants over time;
- Impacts to recreational hunters and fishermen due to declining wildlife populations;
- Fiscal risk to the state from inadequate bonding requirements which could transfer the costs of clean-up to the state;
- Loss of land for agriculture and recreation due to creation of well-pads and inadequate restoration once drilling is completed; and
- Perpetuation of reliance on U.S. energy on fossil fuels that delays and impedes transitions to renewable energy.

This page intentionally blank

1 Introduction

1.1 Purpose of Report

Pennsylvania has historically been a coal producing state, but in recent decades has transitioned to extracting a large amount of natural gas from the Marcellus Shale. New technology has allowed oil and gas firms to access shale deposits through horizontal drilling with hydraulic fracturing, commonly called fracking. Southwestern and Northeastern Pennsylvania have experienced the most drilling in the state.

The increased natural gas production has led to an assortment of costs in Pennsylvania. Some of the economic costs are related to the boom and bust nature of the economy and its relation to fuel prices and demand for natural gas, while others are focused on the environmental and health effects resulting from the production of natural gas. Many of these costs are spatially diffuse and have non-market values, making them difficult to quantify and properly value.

The Delaware Riverkeeper Network has engaged ECONorthwest to compile and analyze economic information about the costs of fracking in Pennsylvania. This information serves as a repository for the suite of costs associated with natural gas production. In addition to direct costs of fracking, this report focuses on external costs – costs not directly paid for by the natural gas producers or auxiliary firms who support the production of natural gas but rather by others in the community. Examples of some of these costs that are discussed in this report include:

- Economic uncertainty caused by the commodity market fluctuations in the natural gas industry;
- Natural gas production crowding out other economic activity (e.g. jobs for other industries, land use, and local resources);
- Costs attributable to adverse health effects resulting from water and air contamination;
- Environmental costs resulting from natural gas extraction activities; and
- Costs resulting from community disruptions.

This report estimates the costs of unconventional oil and gas development (UOGD) production in Pennsylvania. UOGD represent the activities involved with hydraulic fracturing, which allows access to “unconventional” oil and gas reserves that are not possible to extract without the horizontal drilling associated with hydraulic fracturing. While there are economic contributions to Pennsylvania from natural gas production in terms of jobs, tax revenue, and output, those revenues are not the focus of this report. Previous reports that have estimated the economic contributions of oil and gas industries have been sponsored by the industry, leading to criticisms of bias due to the data sources and assumptions.[1,2]

1.2 Terminology

There are a variety of different words used to describe activities related to fracking. We will primarily use the acronym UOGD to represent unconventional oil and gas development. This acronym is preferred to the terms *hydraulic fracturing* and *fracking* because it includes the support activities involved with well drilling, including compressors, pipelines, trucks, wastewater treatment facilities, and wastewater storage, as well as other support infrastructure and activities like maintenance and well-decommissioning.

The definitions for the terms used in this report are:

- **Unconventional Oil and Gas Development (UOGD):** The unconventional part of this term refers to the relatively new technological changes to hydraulic fracturing compared with conventional vertical well drilling techniques.[3] It is also referred to as "high volume hydraulic fracturing" due to the large amount of water used in the deeper well bores. UOGD includes all activities and infrastructure involved with the unconventional oil and gas extraction process, including well drilling.
- **Fracking/Hydraulic Fracturing:** This term refers to the horizontal well drilling technique for shale gas extraction.
- **Shale Gas:** Naturally occurring gases found in shale rock formations that are extracted through fracking/hydraulic fracturing.
- **Shale Play:** Shale rock formations that contain a significant accumulations of natural gas and which share similar geologic and geographic properties. In Pennsylvania the primary play is the Marcellus, but beneath the Marcellus also lies Utica Shale.

---

[1] Kinnaman, T. C. (2011). The economic impact of shale gas extraction: A review of existing studies. *Ecological Economics*, 70(7), 1243-1249.

[2] Barth, J.M. (2010). *Unanswered Questions About the Economic Impact of Gas Drilling in the Marcellus Shale: Don't Jump to Conclusions.* JM Barth & Associates, Inc. March.

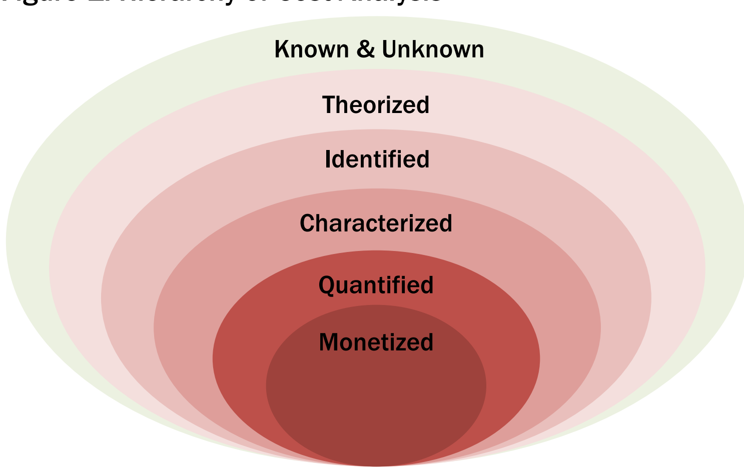
[3] The definition of unconventional wells according to the PA Department of Environmental Protection (Chapter 78A) is: "A bore hole drilled or being drilled for the purpose of or to be used for the production of natural gas from an unconventional formation." An unconventional formation is defined as "A geological shale formation existing below the base of the Elk Sandstone or its geologic equivalent stratigraphic interval where natural gas generally cannot be produced at economic flow rates or in economic volumes except by vertical or horizontal well bores stimulated by hydraulic fracture treatments or by using multilateral well bores or other techniques to expose more of the formation to the well bore".

1.3 Methods

Many of the costs created by UOGD represent externalities, meaning that the people who experience the costs are different than the people who enjoy the benefits. For UOGD in Pennsylvania, the population bearing the costs of the externalities are local citizens and the public at large, while the entities creating the costs and enjoying the benefits are the oil and gas companies. Because of this disconnect between who is experiencing the benefits and who is incurring the costs, distributional effects are important to consider as part of the cost analysis.

Cost analysis typically progresses from identification of costs to estimation of their monetary value. It is not feasible or appropriate to use dollar values for all potential costs of UOGD in Pennsylvania. Sufficient information is available to assign a dollar value to only a subset of the total costs incurred from UOGD activity in Pennsylvania. Other costs, such as non-market effects from boom and bust economic cycles or loss of some ecosystem goods and services, do not currently have sufficient data available to support quantification in physical and monetary terms. Still other costs are theorized to exist but cannot be identified and verified, such as in instances where no data has yet been collected. Figure 1 provides a visual aid for the set of costs that shows how as we move to more precise information on the value of these costs, the less complete we are able to be about the full set of costs, ranging from costs with limited information or that we don't even yet recognize ("Known and Unknown") to more precise and valued in dollars ("Monetized"). Many of the costs discussed herein cannot be represented at the quantified or monetized levels but can still be identified with scientific methods and characterized.

Figure 1: Hierarchy of Cost Analysis



Source: ECONorthwest

1.4 Organization of this Report

This report contains first a background of what has occurred in Pennsylvania to explain the increase in UOGD in the last decade. The costs of UOGD are then discussed based on the following categories:

- **Health Costs**: Description and quantification of the health costs associated with UOGD, with a focus on the health effects that have been documented in Pennsylvania.
- **Community Costs**: Characterization of how communities are impacted from UOGD operations, including impacts to housing, public safety, other industries, roads, and state and local fiscal budgets.
- **Environmental Costs**: Characterization of the impacts that UOGD has had on environmental amenities in Pennsylvania, including local effects such as habitat degradation and broad effects like greenhouse gas emissions.

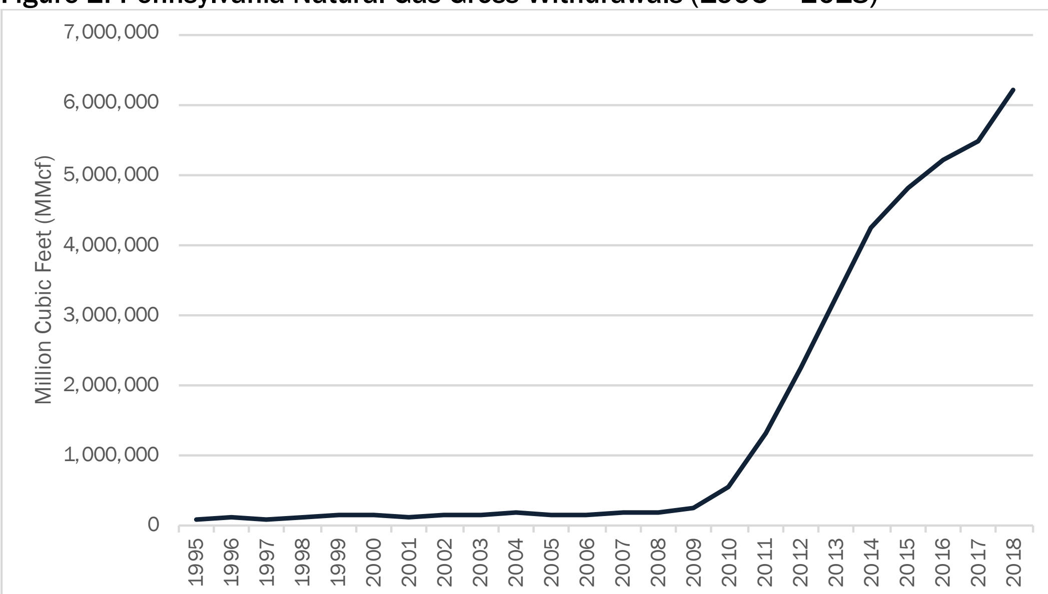
We then present a summary of the costs, with projections on how these costs might change under future scenarios of a moratorium or with increased UOGD in Pennsylvania.

2 Background Information

2.1 History of Fracking in Pennsylvania

Fracking or hydraulic fracturing is an oil and gas extraction technique that involves either vertical or horizontal drilling into rock formations and injecting water, chemicals, and sand at high pressures. In the late 1990s technological changes occurred which increased the productivity and lowered the costs of hydraulic fracturing wells. These technological changes, as well as higher oil and gas prices, made it feasible for firms to extract the shale gas in the Marcellus and Utica shale in Pennsylvania, New York, Ohio, and West Virginia. As a result, the intensity of shale gas extraction increased exponentially after 2008 in Pennsylvania (Figure 2).

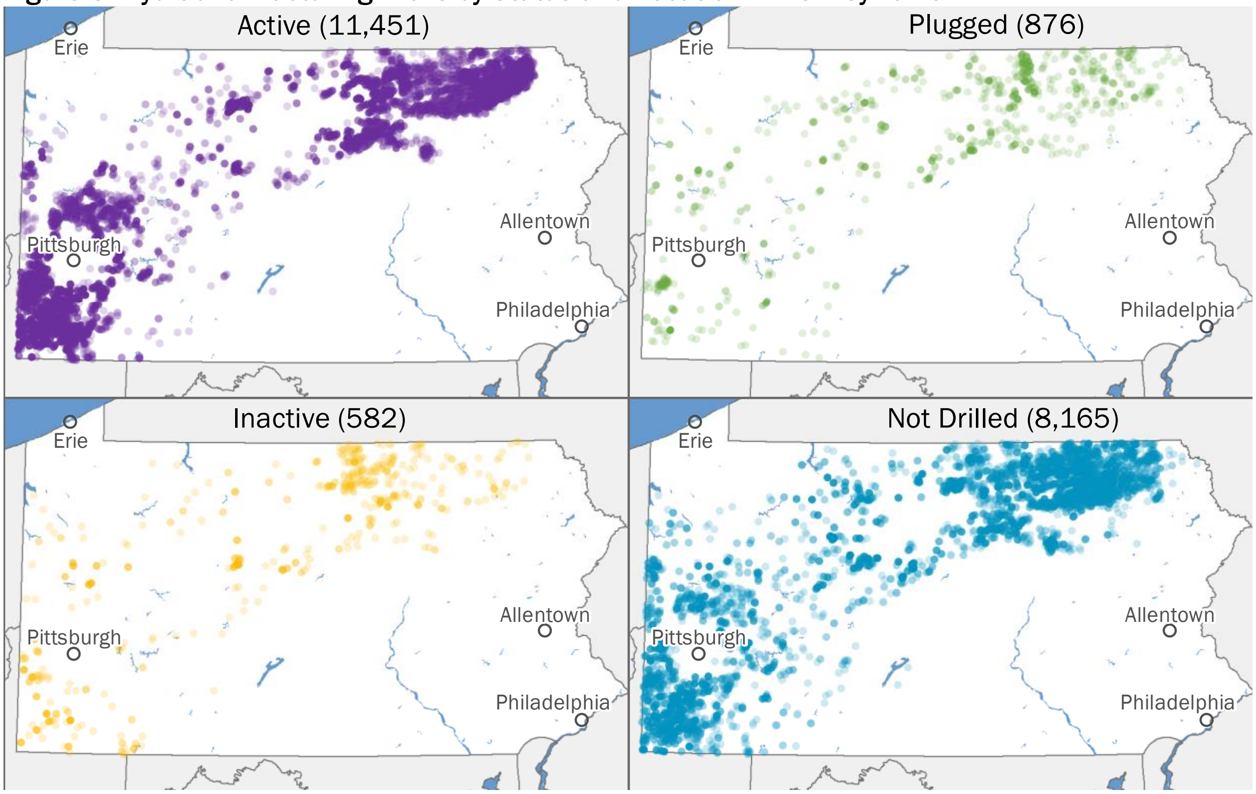
Figure 2: Pennsylvania Natural Gas Gross Withdrawals (1995 – 2018)



Source: ECONorthwest, with data from U.S. Energy Information Administration. (2019). Pennsylvania Natural Gas Gross Withdrawals. Retrieved from https://www.eia.gov/dnav/ng/hist/n9010pa2m.htm

The number of hydraulic fracking wells in Pennsylvania has similarly increased dramatically in the last decade. Drilling occurs primarily in the southwestern and northeastern parts of the state. According to the Pennsylvania DEP, there are currently 11,451 active wells, 876 plugged wells, 582 inactive wells, and another 8,165 wells that are permitted but not yet drilled (Figure 3).

Figure 3: Hydraulic Fracturing Wells by Status and Location in Pennsylvania



Source: Created by ECONorthwest with data from Pennsylvania Department of Environmental Protection "Open Data": http://data-padep-1.opendata.arcgis.com/

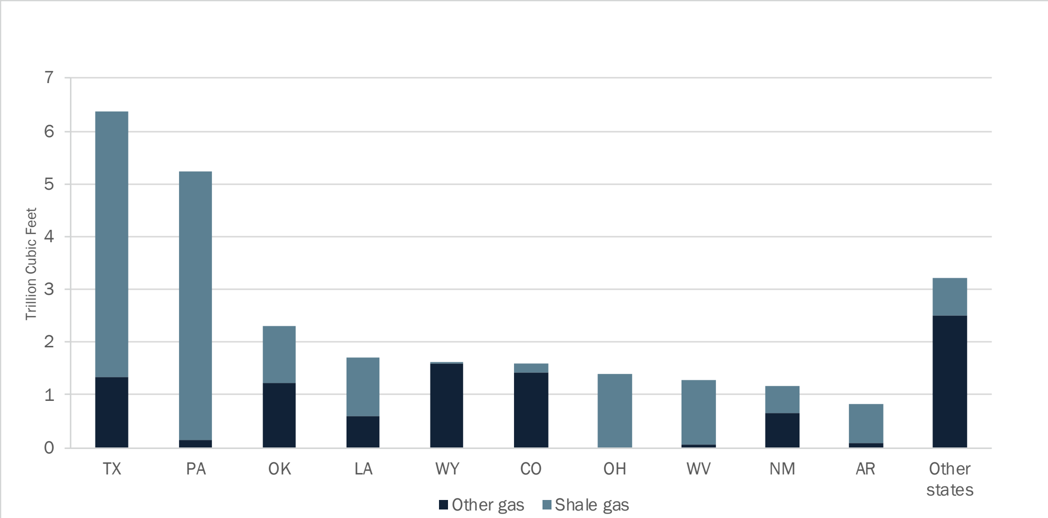
These values represent only unconventional wells (fracking wells) – the number of conventional wells (vertically drilled) is even larger. Orphaned and abandoned wells have historically been a problem in Pennsylvania since drilling has occurred since the 1800s before there were robust regulations. It is estimated that there are hundreds of thousands of orphaned and abandoned wells in the state.[4]

In July 2018, Pennsylvania alone produced 17 percent of total U.S. natural gas, while the Marcellus shale region overall produced 28 percent of the nation's natural gas.[5] Pennsylvania is second only to Texas in the amount of dry natural gas produced (Figure 4). Dry natural gas refers to gas that is primarily methane. The majority of natural gas from northeast and northcentral Pennsylvania is dry. Wet natural gas contains compounds like ethane and butane in addition to methane. The majority of natural gas from southwestern Pennsylvania is wet.

[4] Sisk, A. (2018). "State orders companies to plug more than 1,000 abandoned oil, gas wells". *StateImpact NPR*. July 25. Retrieved from https://stateimpact.npr.org/pennsylvania/2018/07/25/state-orders-companies-to-plug-1000-abandoned-oil-gas-wells/

[5] U.S. Energy Information Administration. (2019). *Natural Gas Gross Withdrawals and Production*. Retrieved from https://www.eia.gov/dnav/ng/NG_PROD_SUM_A_EPG0_FGW_MMCF_M.htm

Figure 4: Dry Natural Gas Production by Top-10-Producing States (2016)

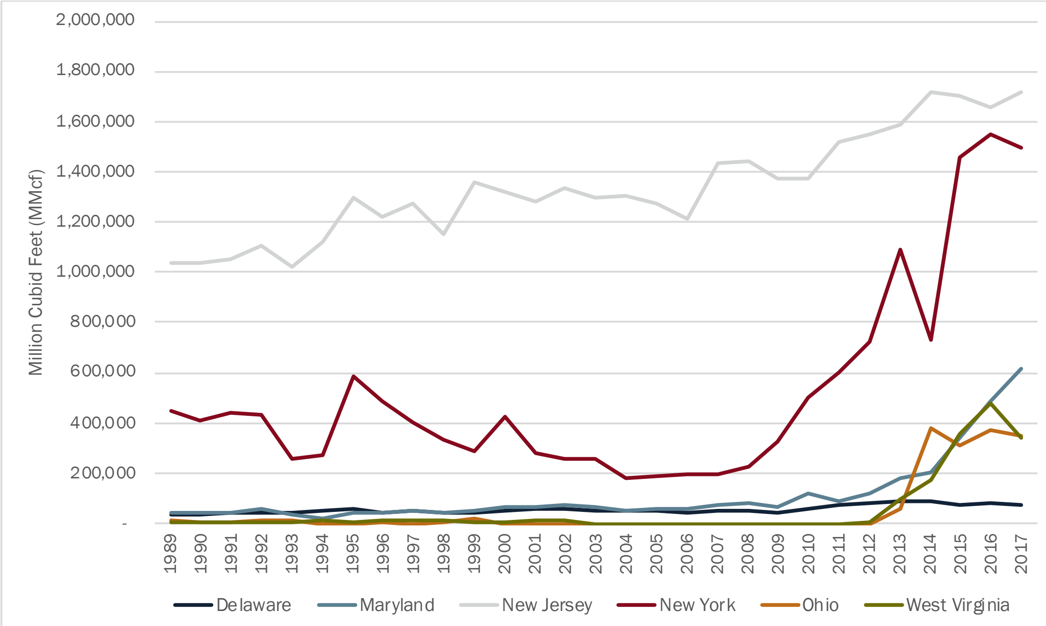


Source: Bureau of Labor Statistics. (2018.) Shale gas production and labor market trends in the U.S. Marcellus–Utica region over the last decade. *Monthly Labor Review*. August.
Note: TX = Texas, Pennsylvania = Pennsylvania, OK = Oklahoma, LA = Louisiana, WY = Wyoming, CO = Colorado, WV = West Virginia, NM = New Mexico, and AR = Arkansas.

Natural gas is being exported from Pennsylvania to other states, with the largest portions going to New Jersey and New York. Approximately 308,395 million cubic feet (MMcf) were imported into Pennsylvania in 2017, primary from West Virginia, while 4.6 million MMcf were exported.[6] Since 2008 exports to New York have sharply increased relative to exports to other states (Figure 5). Some of this increase is due to the increase in production in Pennsylvania, but some may also be due to the fracking bans and moratoria in New York which became statewide in 2014. Because New York is not producing its own natural gas, it has increased demand for natural gas from Pennsylvania.

[6] U.S. Energy Information Administration. (2019). *International & Interstate Movements of Natural Gas by State*. https://www.eia.gov/dnav/ng/ng_move_ist_a2dcu_SPA_a.htm

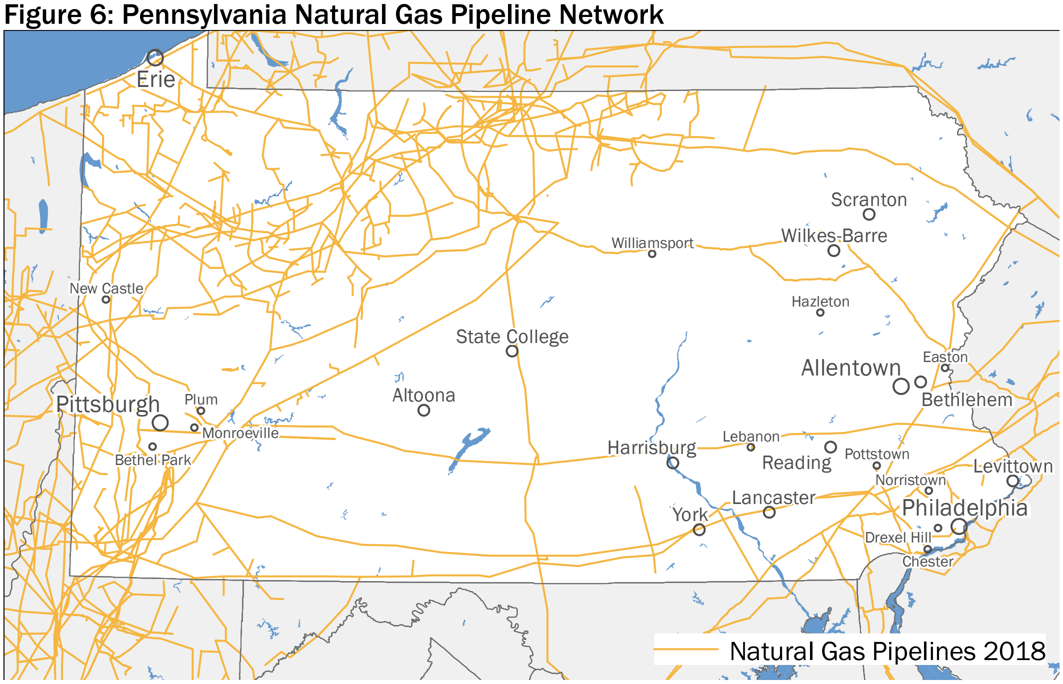
Figure 5: Natural Gas Interstate Deliveries from Pennsylvania (MMcf)



Source: ECONorthwest, with data from US Energy Information Administration. (2019). *International & Interstate Movement of Natural Gas by State*. Retrieved from https://www.eia.gov/dnav/ng/ng_move_ist_a2dcu_SPA_a.htm
Note: A small amount of Natural Gas was also delivered to Massachusetts from 2014 – 2016. Deliveries do not necessarily represent final consumption location.

Pipelines are required to transport the natural gas from the production area to processing and to market. The network of pipelines in Pennsylvania presented in Figure 6 illustrates the concentration of pipelines in north and western Pennsylvania. Pipelines exist throughout the state and cross over water resources including the Susquehanna River.

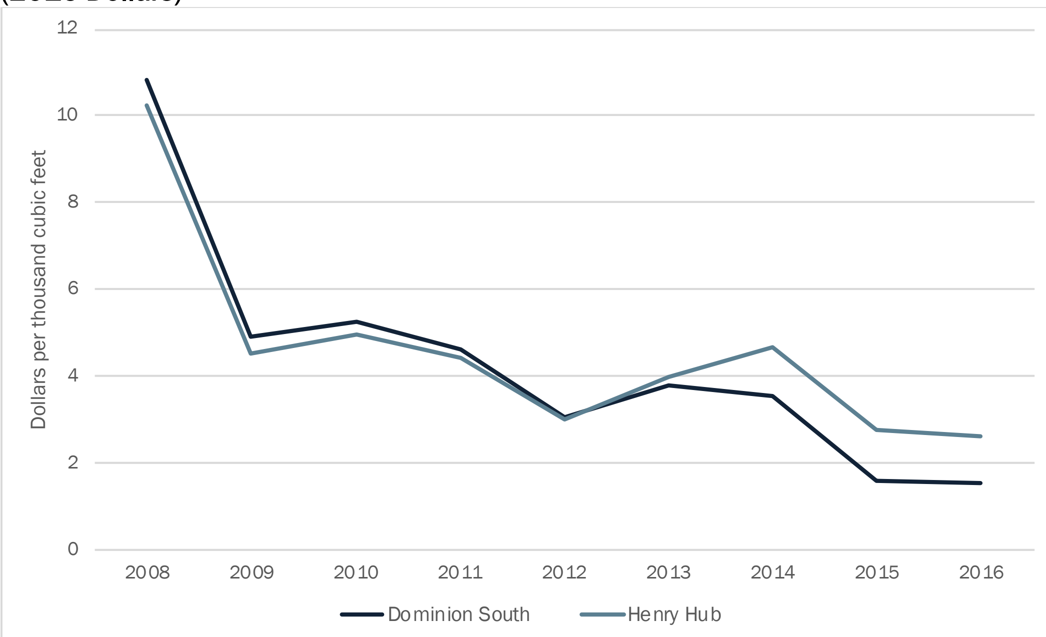
Figure 6: Pennsylvania Natural Gas Pipeline Network



Source: U.S. Energy Information Administration. (2019). *Layer Information for Interactive State Maps: Natural Gas Interstate and Intrastate Pipelines.* Retrieved from https://www.eia.gov/maps/layer_info-m.php

Since 2008, natural gas prices have declined due to the large influx of supply. The sharpest decline in prices was in 2009, with more gradual declines occurring in 2015 and 2016 (Figure 7). Dominion South prices are for Appalachia, which includes Pennsylvania, while the Henry Hub market is based in Louisiana. Since 2014 the Dominion South price has been lower than the Henry Hub.

Figure 7: Spot Price Comparison of Natural Gas: Henry Hub versus Dominion South (2007-2016) (2016 Dollars)



Source: U.S. Bureau of Labor Statistics. (2018). *Shale gas production and labor market trends in the U.S. Marcellus–Utica region over the last decade*. August. Retrieved from https://www.bls.gov/opub/mlr/2018/article/shale-gas-production-and-labor-market-trends-in-the-us-marcellus-utica-region-over-the-last-decade.htm
Note: Data for Dominion South were not available until mid-2007. Therefore, calculations begin with 2008 to prevent calculation based on a partial year.

2.2 Economics of Fracking in Pennsylvania

Complete and accurate economic information about the costs of UOGD in Pennsylvania is not available from a single source, which prompted this review. There are many studies that tell parts of the economic story or that present economic information without overall context. For example, some of the economic studies on the costs and benefits of hydraulic fracturing in the United States have been accused of bias or incompleteness because they are often sponsored by the oil and gas industry[7] or use input-output models which only consider spending on UOGD and not public costs.[8] Additionally, leakages (spending leaving the local region) and crowding

[7] Barth, J. (2010). *Unanswered Questions About the Economic Impact of Gas Drilling In the Marcellus Shale: Don't Jump to Conclusions*. JM Barth & Associates, Inc.

[8] Christopherson, S. & Rightor, N. (2011). *A Comprehensive Economic Impact Analysis of Natural Gas Extraction in the Marcellus Shale.* Working Paper Series, Cornell University.

out of other industries are often not included, which artificially inflates the economic impacts.[9] There have been some studies which consider both the benefits and costs of hydraulic fracturing, but many of these stop short of quantifying the non-market environmental and health impacts.[10]

Loomis and Haefele (2017) quantified the benefits and costs of hydraulic fracturing in the United States.[11] They found social benefits in the form of lower natural gas prices and environmental benefits from natural gas replacing coal. However, the authors also found substantial market and non-market costs, including $27.2 billion in health damages from air pollution, $3.8 billion in greenhouse gas emissions, $4 billion in wildlife habitat fragmentation, and $1 billion in pollution of private drinking water wells.

2.2.1 Employment

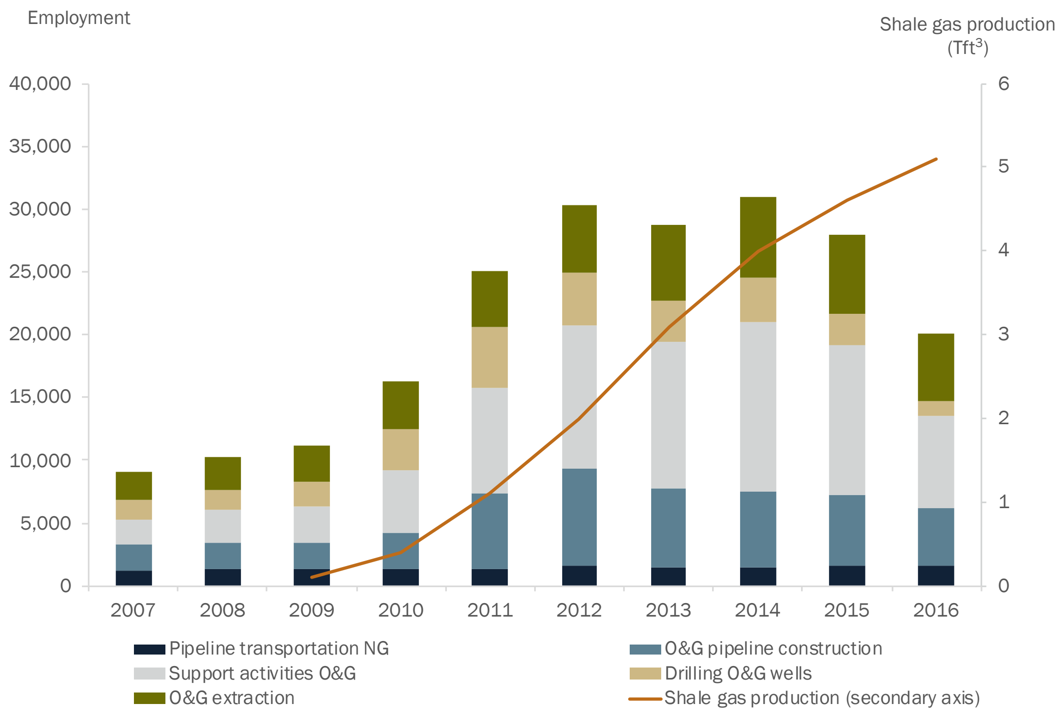
Employment in natural gas in Pennsylvania increased significantly from 2010 through 2016, but has since begun to decline as gas prices have fallen and automation has reduced some of the labor need. Figure 8 provides an overview of labor market trends in shale gas production in the Pennsylvania from 2007 to 2016. The majority of jobs are in oil and gas supporting industries, followed by extraction and pipeline construction.

[9] Krupnick, A.J., & Echarte, I. (2017). *Economic Impacts of Unconventional Oil and Gas* Development. Prepared for Resources for the Future as part of the as part of "The Community Impacts of Shale Gas and Oil Development Initiative".

[10] Sovacool, B. K. (2014). Cornucopia or curse? Reviewing the costs and benefits of shale gas hydraulic fracturing (fracking). *Renewable and Sustainable Energy Reviews*, 37, 249-264.

[11] Loomis, J., & Haefele, M. (2017). Quantifying market and non-market benefits and costs of hydraulic fracturing in the United States: a summary of the literature. *Ecological Economics*, *138*, 160-167.

Figure 8: Employment by Industry and Shale Gas Production (trillion cubic feet, Tft³), Pennsylvania (2007-2016)



Source: Bureau of Labor Statistics. (2018). *Shale gas production and labor market trends in the U.S. Marcellus–Utica region over the last decade.* August. Retrieved from https://www.bls.gov/opub/mlr/2018/article/shale-gas-production-and-labor-market-trends-in-the-us-marcellus-utica-region-over-the-last-decade.htm
Note: NG = natural gas and O&G = oil and natural gas.

2.2.2 Lease & Royalty Payments to Landowners

Many Pennsylvanians have leased their land to allow for natural gas drilling. When they engage in this transaction, landowners are paid lease payments for the drilling opportunity and royalty payments based on the productiveness of the well. These terms are negotiated on a case-by-case basis and likely have significant variation from contract to contract. Because these are private transactions, the value of these payments is not available. Pennsylvania law requires that oil and gas developers pay 12.5 percent of the proceeds from production to landowners as royalties,[12] but recent lawsuits have lowered that amount by allowing companies to share transportation and processing costs with landowners, in some instances resulting in negative royalties.[13]

2.2.3 State Government Taxation

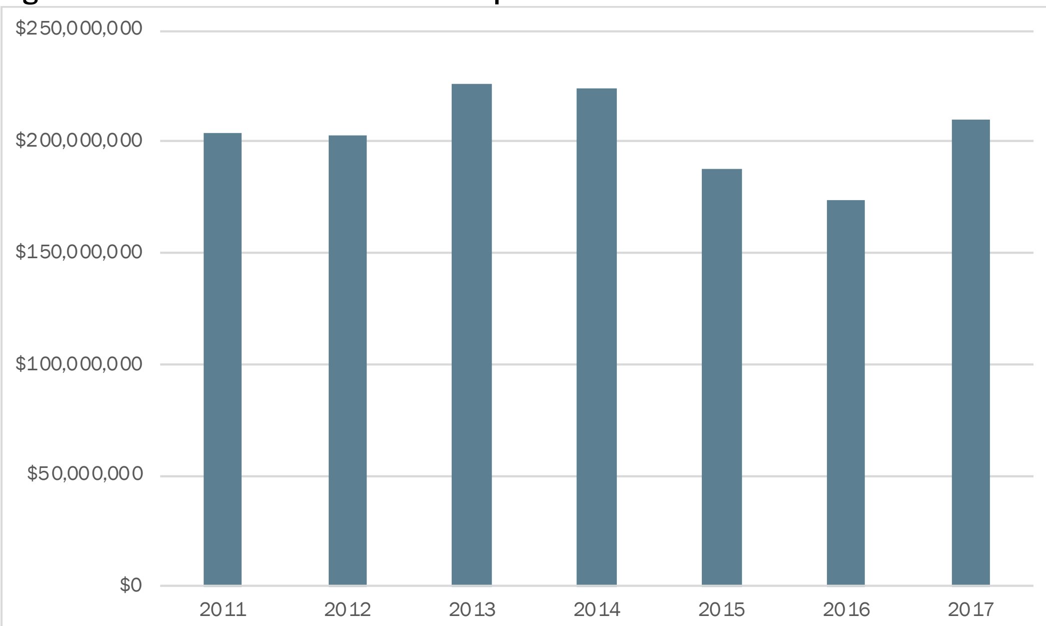
Unlike other states, Pennsylvania does not charge a severance tax for oil and gas extraction. Instead, the state levies an annual wellhead fee based on the number of wells drilled. The fee

[12] Pennsylvania General Assembly. (2013). *Oil and Gas – Leases to Remove or Recover*. P.L.473, No.66. Retrieved from https://www.legis.state.pa.us/WU01/LI/LI/US/HTM/1979/0/0060..HTM

[13] State Impact Pennsylvania. (No Date). *Shortchanged: the fight over gas royalties*. Retrieved from https://stateimpact.npr.org/pennsylvania/tag/royalties/

was created in 2012 with the passage of Act 13 and allows for the imposition of an unconventional gas well fee (also called an impact fee). Revenues from the fee are distributed to local and state governments. The fee is scaled based on the year the well was drilled and the price of natural gas.[14] State revenues from wellheads averaged $173 to $210 million per year between 2011 and 2017 (Figure 9).

Figure 9: Act 13 Disbursements and Impact Fees Revenues 2011-2017



Source: Act 13. Public Utility Commission. (No Date). *Disbursements and Impact Fees*. Retrieved from https://www.act13-reporting.puc.pa.gov/Modules/PublicReporting/Overview.aspx

Advocates for a severance tax argue that Pennsylvania obtains lower revenue compared with peer states and needs to rely on sales and income taxes more heavily. They also have concerns that the tax does not depend on the actual amount of the natural resource extracted.[15] Figure 10 provides a summary of state government taxation sources, showing that severance tax in Pennsylvania is much lower than other natural gas producing states. The well-head fee in Pennsylvania is included in the "other" taxation source of Figure 10. If Pennsylvania created a severance tax, it is estimated that state revenues would increase by $200 to $400 million per year.[16]

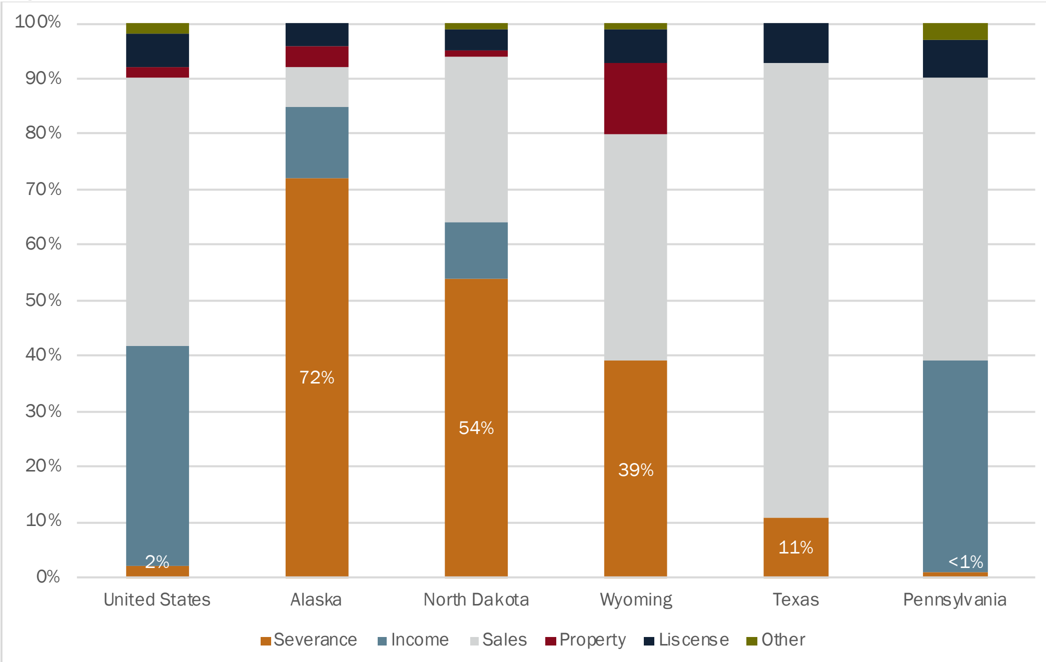
---

[14] The full fee schedule is available at: https://www.act13-reporting.puc.pa.gov/Modules/Disbursements/FeeSchedule.aspx

[15] Pennsylvania Budget and State Policy Center. (2018). *Governor Wolf's 2018 Severance Tax Proposal Could Bring in $1.7 Billion of Revenue Over the Next Five Years*. June 19. Retrieved from https://www.pennbpc.org/governor-wolf's-2018-severance-tax-proposal-could-bring-17-billion-revenue-over-next-five-years

[16] Pennsylvania Budget and State Policy Center. (2018). *Governor Wolf's 2018 Severance Tax Proposal Could Bring in $1.7 Billion of Revenue Over the Next Five Years*. June 19. Retrieved from https://www.pennbpc.org/governor-wolf's-2018-severance-tax-proposal-could-bring-17-billion-revenue-over-next-five-years

Figure 10: State Government Taxation Sources in 2014



Source: U.S Energy Information Administration. (2015). *Major fossil fuel-producing states rely heavily on severance taxes*. Retrieved from https://www.eia.gov/todayinenergy/detail.php?id=22612#
Note: Pennsylvania accesses a wellhead fee which is included in the "other" taxation source category

2.3 Policy History

A moratorium on fracking and water withdrawals has been in place since May 2010 in the Delaware River Basin. This moratorium was enacted by the Delaware River Basin Commission (DRBC), the regional body that manages the river system comprised of state governors.[17] Currently, DRBC is considering regulations to make the moratorium permanent, banning fracking in the basin. The Governors of New York, Pennsylvania, and Delaware demonstrated support for the fracking ban by their votes on a resolution to include the proposed ban in the draft regulations in 2017. Newly elected New Jersey Governor Phil Murphy announced his support for a ban after he took office in 2018. In January 2019, DRBC Chairman Governor Phil Murphy stated his support for prohibitions on the storage, processing, and discharge of wastewater produced by fracking within the basin and the export of water from the watershed to abet fracking elsewhere.[18]

In 2014 the state of New York enacted a ban on fracking for the entire state. New York does still import natural gas from neighboring states like Pennsylvania and has allowed new natural gas

---

[17] Delaware Riverkeeper Network. (No Date). *Shale Gas Extraction -- Drilling/Fracking*. Retrieved from http://www.delawareriverkeeper.org/ongoing-issues/shale-gas-extraction-drillingfracking

[18] State Impact Pennsylvania. (2019). *New Jersey governor: Ban fracking, all related activities in Delaware River Basin*. January 31. Retrieved from https://stateimpact.npr.org/pennsylvania/2019/01/31/new-jersey-governor-phil-murphy-fracking-ban-delaware-river-basin/

fired power plants.[19] New York was the second state to ban hydraulic fracturing, after Vermont which did so in 2012. Both states have cited health and environmental concerns as well as uncertainty as reasons for the bans.[20]

Fracking bans have also occurred internationally. By 2013, Bulgaria, the Czech Republic, France, and the Netherlands had enacted fracking bans.[21] Scotland enacted a moratorium and then permanently banned fracking in October 2017.[22]

2.4 Violations & Spills

While Pennsylvania has enacted regulations to protect the environment from some of the effects of UOGD, these protections are insufficient to avoid all environmental impacts and costs. Despite regulations, willful violations and accidents occur. Because the chemicals involved in fracking are known to be toxic, each year of violations and impacts from business-as-usual activities increase the bioaccumulation in the environment, meaning that impacts are worsening overtime with continuing UOGD activities.

In 2017, there were 821 violations at unconventional wells and 3,273 violations at conventional wells. Almost all (92 percent) of the unconventional well violations were environmental health and safety-related, including "failure to properly store, transport, process or dispose of a residual waste", "conducting an activity…without a permit or contrary to a permit issued by DEP", "failure to prevent gas flow in the well annulus", "failure to plug a well upon abandoning it", "conducting casing and cementing activities that failed to prevent pollution or diminution of fresh groundwater", and other violations.[23] The number of unconventional well violations for all wells (821) exceed the number of unconventional wells drilled in Pennsylvania in 2017 (810) (Figure 11). Well violations occur for wells at all stages of its lifespan.

[19]State Impact Pennsylvania. (2017). *New York's heralded fracking ban isn't all it's cracked up to be.* December 8. Retrieved from https://stateimpact.npr.org/pennsylvania/2017/12/08/new-yorks-heralded-fracking-ban-isnt-all-its-cracked-up-to-be/

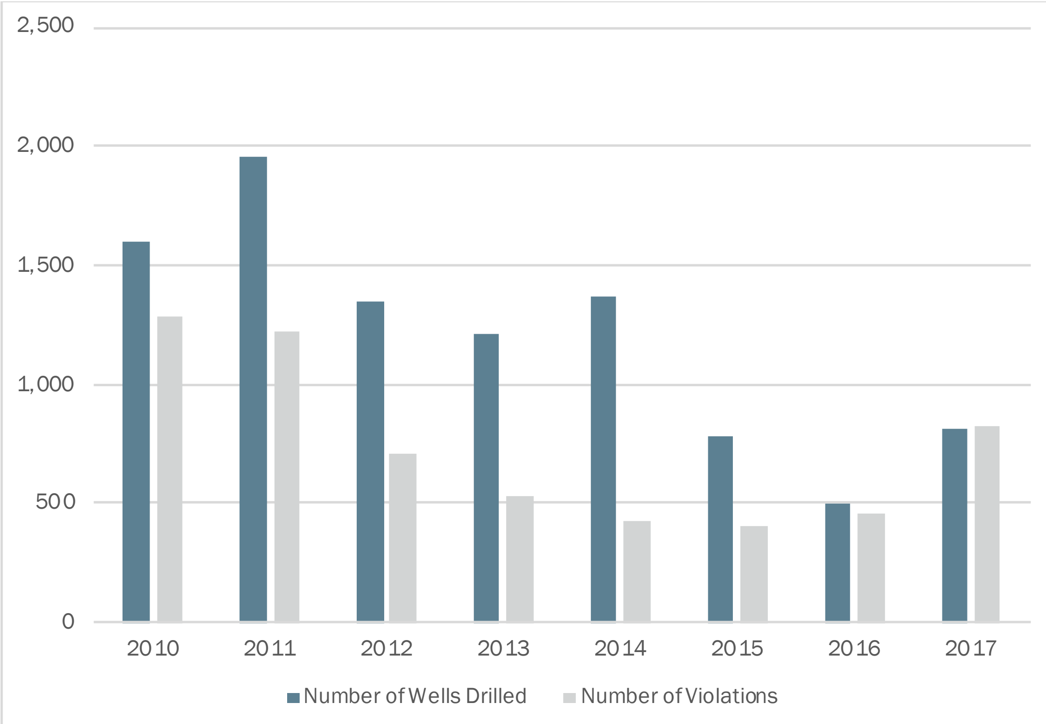
[20] Kaplan, T. (2014). "Citing Health Risks, Cuomo Bans Fracking in New York State". The New York Times. December 17. Retrieved from https://www.nytimes.com/2014/12/18/nyregion/cuomo-to-ban-fracking-in-new-york-state-citing-health-risks.html

[21] Sovacool, B. K. (2014). Cornucopia or curse? Reviewing the costs and benefits of shale gas hydraulic fracturing (fracking). *Renewable and Sustainable Energy Reviews*, 37, 249-264.

[22] Concerned Health Professionals of New York & Physicians for Social Responsibility. (2018). *Compendium of scientific, medical, and media findings demonstrating risks and harms of fracking (unconventional gas and oil extraction).*

[23] Pennsylvania Department of Environmental Protection. (2018). *2017 Oil and Gas Annual Report*. Retrieved from http://www.depgis.state.pa.us/2017oilandgasannualreport/

Figure 11: Number of Unconventional Wells Drilled vs Number of Unconventional Well Violations (2010-2017)



Source: Created by ECONorthwest with data from Pennsylvania Department of Environmental Protection. (2018). 2017 Oil and Gas Annual Report. Retrieved from http://www.depgis.state.pa.us/2017oilandgasannualreport/

In Pennsylvania from 2008 to 2013 violations occurred for 3.4 percent of wells.[24] Based on the limited data, the median volume of the spills is 120 gallons. The total volume of the reported spills from 2005 to 2014 is 0.26 million gallons in Pennsylvania.[25] The spatial distribution of violations corresponds to areas with high well density. The number of inspectors is also very low relative to the number of wells, which leads to poorly regulated wells.[26] The effect of violations, spills, and explosions endanger habitat. Untreated releases of fracking fluid have caused 100 percent mortality of some species in the area.[27, 28] Around 47 percent of the spills come from the wells that are repeat offenders.

---

[24] Vidic, R. D., Brantley, S. L., Vandenbossche, J. M., Yoxtheimer, D., & Abad, J. D. (2013). Impact of shale gas development on regional water quality. *Science*, 340(6134), 1235009.

[25] Patterson, L. A., Konschnik, K. E., Wiseman, H., Fargione, J., Maloney, K. O., Kiesecker, J., ... & Saiers, J. E. (2017). Unconventional oil and gas spills: Risks, mitigation priorities, and state reporting requirements. *Environmental Science & Technology*, 51(5), 2563-2573.

[26] Bosquez IV, T., Carmeli, D., Esterkin, J., Hau, M. K., Komoroski, K., Madigan, C., & Sepp, M. (2015). Fracking debate: the importance of pre-drill water-quality testing. *In American Bar Association Section of Litigation.*

[27] Adams, M. B., Edwards, P. J., Ford, W. M., Johnson, J. B., Schuler, T. M., Thomas-Van Gundy, M., & Wood, F. (2011). Effects of development of a natural gas well and associated pipeline on the natural and scientific resources of the Fernow Experimental Forest. *US Department of Agriculture Forest Service, Northern Research Station. General Technical Report NRS-76. Newtown Square, Pennsylvania.*

[28] Auchmoody, L. R., & Walters, R. S. (1988). Revegetation of a brine-killed forest site. *Soil Science Society of America Journal*, 52(1), 277-280.

2.5 Wastewater Treatment

Part of the water used in the drilling process will eventually come back to the surface after the pressure is released. The product of this process includes fracking fluid, and is known variously as drilling return water, drilling wastewater, flowback, or produced water, or stimulation fluid. The amount of wastewater returned to wellheads varies from five to twelve percent of the injected water, meaning that the majority of water used in drilling operations stays in the ground.[29] ***Water used for fracking in the Marcellus shale in Pennsylvania averages approximately 11.4 million gallons per well.***[30] The amount of water used per well has doubled in intensity since 2011 due to the drilling of longer well bores which require more water and sand.[31] From 2011 to 2017, FracTracker Alliance estimates that 51.4 billion gallons of water were used for fracking activities in Pennsylvania.[32] This amount of water is approximately equal to 10 percent of total annual water use in Pennsylvania.[33]

This increase in water use for wells has resulted in a dramatic increase in the amount of wastewater needed to be treated. According to the Susquehanna River Basin Commission, 86 percent of water used for wells is freshwater (3.8 million gallons) and 14 percent is reused water (0.6 million gallons).[34] From 2008 to 2011, the average amount of wastewater produced in Pennsylvania was 1.1 billion gallons per year, which is four times what it before the increasing drilling activities.[35] Because water use has increased dramatically since 2011, the amount of wastewater being treated now is at least double that amount.

Pennsylvania currently does not have the capacity to process all the wastewater produced by fracking wells. Wastewater is often pumped and transported to Ohio or West Virginia for storage in deep wells.[36,37] During the early stage of Marcellus Shale fracking extraction, fracking wastewater was primarily sent to publicly owned municipal sewage treatment plants or industrial wastewater treatment plants. The treated effluent is eventually release into surface

---

[29] Susquehanna River Basin Commission. (2018). *Comprehensive Plan for the Water Resources of the Susquehanna River Basin*. June 4. Retrieved from https://www.srbc.net/our-work/programs/planning-operations/docs/comp-plan-no-appendices.pdf

[30] FracTracker Alliance. (2018). *Potential Impacts of Unconventional Oil and Gas on the Delaware River Basin*. March 20.

[31] Ibid.

[32] Ibid.

[33] U.S. Geological Society. (2015). *Water Use Data for Pennsylvania*. Retrieved from https://waterdata.usgs.gov/pa/nwis/water_use/

[34] Susquehanna River Basin Commission. (2018). *Comprehensive Plan for the Water Resources of the Susquehanna River Basin*. Retrieved from https://www.srbc.net/our-work/programs/planning-operations/docs/comp-plan-no-appendices.pdf

[35] Wilson, J. M., & VanBriesen, J. M. (2012). Oil and gas produced water management and surface drinking water sources in Pennsylvania. *Environmental Practice*, 14(4), 288-300.

[36] Sovacool, B. K. (2014). Cornucopia or curse? Reviewing the costs and benefits of shale gas hydraulic fracturing (fracking). *Renewable and Sustainable Energy Reviews*, 37, 249-264.

[37] Akob, D. M., Mumford, A. C., Orem, W., Engle, M. A., Klinges, J. G., Kent, D. B., & Cozzarelli, I. M. (2016). Wastewater disposal from unconventional oil and gas development degrades stream quality at a West Virginia injection facility. *Environmental Science & Technology*, 50(11), 5517-5525.

water. Due to the increasing concentrations of bromides and total dissolved solids, in 2011 the Pennsylvania Department of Environmental Protection (DEP) issued a voluntary request to drilling companies to stop sending wastewater to municipal and public wastewater treatment plants.[38]

[38] Ferrar, K. J., Michanowicz, D. R., Christen, C. L., Mulcahy, N., Malone, S. L., & Sharma, R. K. (2013). Assessment of effluent contaminants from three facilities discharging Marcellus Shale wastewater to surface waters in Pennsylvania. *Environmental Science & Technology*, 47(7), 3472-3481.

3 Health Costs

3.1 How Fracking Impacts Health

Hydraulic fracturing primarily impacts human health through the pathways of reduced air quality, groundwater contamination, surface water contamination, occupational hazards, and soil/agricultural contamination. The drivers of these risks are the chemicals and materials used in the fracking process, as well as the subterranean materials brought to the surface through extraction. The support infrastructure to the fracking process including compressors, pipelines, and trucks also produces health impacts through air quality impacts, noise, and safety issues. The adverse health effects of UOGD are exacerbated by leaks, improper storage, and negligence associated with natural gas infrastructure, as well as by the intensity of nearby operations.[39] Health effects that have been linked to fracking include low birth weight, preterm births, infertility, asthma, respiratory diseases, cancer, liver damage, silicosis, cardiovascular diseases, migraines, anxiety, insomnia, depression, and other mental health problems.[40] The most commonly reported health symptoms of people living within one kilometer of a well include sleep disruption, headache, throat irritation, stress or anxiety, cough, shortness of breath, sinus problems, fatigue, nausea, and wheezing.[41]

Of the 685 papers published between 2008 and 2015 on fracking, 226 studies investigated the link between adverse health effects and fracking.[42] The exact causes of the illnesses are often unclear because of the unknown chemicals which are used in the fracking process.[43] In 2005, the U.S. Environmental Protection Agency (EPA) enacted regulations, commonly known as the "Halliburton Loophole", that exempts oil and gas companies from federal oversight under the Safe Drinking Water Act. This exemption means that oil and gas companies do not have to disclose the chemicals used in hydraulic fracturing production.

There are thousands of chemicals known to be used in the unconventional oil and gas development process. At least 29 of these chemicals used in the hydraulic fracturing process are

---

[39] ProPublica. (2009). *Officials in Three States Pin Water Woes on Gas Drilling*. ProPublica. Retrieved from www.propublica.org/article/officials-in-three-states-pin-water-woes-on-gas-drilling-426.

[40] Concerned Health Professionals of New York & Physicians for Social Responsibility. (2018). *Compendium of scientific, medical, and media findings demonstrating risks and harms of fracking (unconventional gas and oil extraction).*

[41] Weinberger, B., Greiner, L. H., Walleigh, L., & Brown, D. (2017). Health symptoms in residents living near shale gas activity: A retrospective record review from the Environmental Health Project. *Preventive medicine reports*, 8, 112-115.

[42] FracTracker Alliance. (2019). *Categorical Review of Health Reports on Unconventional Oil and Gas Development; Impacts in Pennsylvania.* FracTracker Alliance Issue Paper.

[43] Hays, J., & Shonkoff, S. B. (2016). Toward an understanding of the environmental and public health impacts of unconventional natural gas development: a categorical assessment of the peer-reviewed scientific literature, 2009-2015. *PloS one*, *11*(4), e0154164.

known or possible human carcinogens, regulated under the Safe Drinking Water Act for their risks to human health or listed as hazardous air pollutants under the Clean Air Act.[44]

For many of the chemicals used, the effects are largely unstudied and unknown because oil and gas companies are allowed to not disclose some chemicals by designating them as trade secrets. A 2018 report by the Partnership for Public Integrity found that secret fracking chemicals were used in 55 percent of wells drilled between 2013 and 2017.[45] Approval of chemicals by the EPA has also been questioned. For example, in response to a lawsuit, the EPA acknowledged that its existing formula for estimating emissions from flaring operations may dramatically underestimate the resulting levels of air pollutants.[46,47] The EPA has also approved chemicals for use despite health concerns. Between 2003 and 2014, an estimated 62 out of 109 chemicals identified by the EPA as potentially having adverse health effects were approved and used in drilling.[48]

Lawsuits have upheld assertions of direct human health impacts resulting from fracking. A family was awarded $2.8 million in Texas after suffering nosebleeds, vision problems, nausea, rashes, and blood pressure issues as a result of nearby fracking.[49] Many other lawsuits have had cash-settlements out-of-court, but details are not available because records are sealed and settlements are under gag-orders.[50] Eliza Griswold's book *Amity and Prosperity* recently won the Pulitzer Price for General Nonfiction for her account of the experiences of two families in Washington County, Pennsylvania who were exposed to illnesses due to fracking on their land and their subsequent legal battles.

3.1.1 Air Pollution

Many studies of the health effects of UOGD have focused on air pollution and emissions. Air pollution includes volatile organic compounds (VOCs) and ground-level ozone (smog) which occur due to drilling, flaring, finishing, and gas production stages in the development and

---

[44] U.S. House of Representatives. (2011). Chemicals use in hydraulic fracturing. Prepared for the Committee on Energy and Commerce.

[45] Horwitt, D. (2018). *Keystone Secrets: Records Show Widespread Use of Secret Fracking Chemicals are a Looming Risk for Delaware River Basin, Pennsylvania Communities*. Partnership for Policy Integrity.

[46] United States District Court for the District of Columbia. (2016*). Air Alliance Houston, et al. v. Gina McCarthy, Administrator, United States Environmental Protection Agency*. Consent decree. Case 1:16-cv01998. October 16. Retrieved from https://www.documentcloud.org/documents/3127584-Consent-Decree-on-Flares.html

[47] Hasemyer, D. (2016). "EPA agrees that its emissions estimates from flaring may be flawed". *InsideClimate News*. October 13. Retrieved from https://insideclimatenews.org/news/12102016/epa-natural-gas-oil-drilling- flaring-emissions-estimates-flawed-fracking

[48] Horwitt, D. (2018). *Keystone Secrets: Records Show Widespread Use of Secret Fracking Chemicals are a Looming Risk for Delaware River Basin, Pennsylvania Communities*. Partnership for Policy Integrity.

[49] Morris, J. (2014). "Texas family plagued with ailments gets $3M in 1st-of-its-kind fracking judgment". *CNN*. April 26. Retrieved from http://www.cnn.com/2014/04/25/justice/texas-family-wins-fracking-lawsuit/

[50] Efstathiou, J., Jr., & Drajem, M. (2013). "Drillers silence fracking claims with sealed settlements". *Bloomberg*. June 5. Retrieved from http://www.bloomberg.com/news/2013-06-06/drillers-silence-fracking-claims-with- sealed-settlements.html

production of a well pad.[51] VOCs include carcinogenic benzene and formaldehyde, among other pollutants. UOGD compressors are sources of the highest air pollution effects but flaring and truck exhaust are also contributors.[52] Because much of the air pollution caused by fracking occurs in rural areas, there is limited routine monitoring that has occurred, making clear linkages difficult to determine.[53]

Because of wind patterns, air pollution caused by fracking and associated adverse health effects have been observed more than two kilometers away from any UOGD operations.[54] Carcinogens such as formaldehyde have been found up to a half-mile from a wellhead.[55] Specific air pollutants that have been attributed to UOGD operations include benzene, hexane, toluene, carbon monoxide, nitrogen oxides, formaldehyde, xylene, particulate matter, diesel exhaust, and silica dust.[56, 57] Many of these compounds have been found to cause ground-level ozone (i.e.. smog).

Air pollution caused by UOGD pollutants has been linked to asthma, respiratory diseases, lung diseases such as silicosis, and lung cancer, especially among sensitive populations and on-site workers.[58] Benzene, toluene, ethylbenzene, and xylene (known as BTEX) are endocrine disruptors commonly found in ambient air that have the ability to interfere with human hormones. Ambient air pollution of these BTEX chemical compounds has been linked to sperm abnormalities, reduced fetal growth, cardiovascular disease, respiratory dysfunction, and asthma.[59] Increased cancer rates are also expected to occur in communities near UOGD

---

[51] Brown, D.R., Lewis, C. & Weinberger, B. I., *Human exposure to unconventional natural gas development: A public health demonstration of periodic high exposure to chemical mixtures in ambient air.* Journal of Environmental Science and Health, 2016. **50**(5): p. 460-472.

[52] Concerned Health Professionals of New York & Physicians for Social Responsibility. (2018). *Compendium of scientific, medical, and media findings demonstrating risks and harms of fracking (unconventional gas and oil extraction).*

[53] Ibid

[54] McCawley, M. A. (2017). Does increased traffic flow around unconventional resource development activities represent the major respiratory hazard to neighboring communities?: Knowns and unknowns. *Current Opinion in Pulmonary Medicine*, 23(2), 161-166.

[55] Macey, G. P., Breech, R., Chernaik, M., Cox, C., Larson, D., Thomas, D., & Carpenter, D. O. (2014). Air concentrations of volatile compounds near oil and gas production: a community-based exploratory study. *Environmental Health, 13*(82). doi: 10.1186/1476-069X-13-82

[56] Marrero, J. E., Townsend-Small, A., Lyon, D. R., Tsai, T. R., Meinardi, S., & Blake, D. R. (2016). Estimating emissions of toxic hydrocarbons from natural gas production sites in the Barnett Shale Region of Northern Texas. *Environmental Science & Technology*, 50(19), 10756-10764. doi: 10.1021/acs.est.6b02827

[57] Schade, G. W. (2017). "How has the US fracking boom affected air pollution in shale areas?". *The Conversation*. November 2. Retrieved from https://theconversation.com/how-has-the-us-fracking-boom-affected-air-pollution-in-shale-areas-66190

[58] Evans, R. B., Prezant, D., & Huang, Y. C. (2015). Hydraulic fracturing (fracking) and the Clean Air Act. *Chest, 148*(2), 298-300. doi: 10.1378/chest.14-2582

[59] Bienkowski, B. (2015). "Scientists warn of hormone impacts from benzene, xylene, other common solvents". *Environmental Health News*. April 15. Retrieved from http://www.environmentalhealthnews.org/ehs/news/2015/apr/endocrine-disruption-hormones-benzene-solvents

operations. Because cancer has a long latency it can take decades to manifest, so increases in cancer rates are believed to become more pronounced over time.[60]

In 2011, researchers calculated the annual economic cost of air pollution in Pennsylvania based on health and environmental damages using the "APEEP model" – they estimated the costs to Pennsylvania as between $8.3 to $37 million dollars per year.[61, 62] Of those damages, approximately 66 percent of the costs are estimated to occur throughout the lifetime of the wells and compressor facilities, meaning the majority of costs occur after a well is drilled and natural gas is processed.

The air pollution in Pennsylvania is not only caused by UCOG activities. Pennsylvania has extensive industrial activity, including oil refining, manufacturing and coal activities, which also contribute to toxic air pollutants. Five counties in Pennsylvania rank in the top 24 counties in the United States for the most year-round particulate pollution. These counties are Allegheny, Lancaster, Delaware, Philadelphia, and Lebanon.[63] Urban areas are also subjected to air pollution from UCOG. In Philadelphia, the oil refinery owned by Philadelphia Energy Solutions is the single largest source of particulate matter in the city and accounts for 16 percent of the city's carbon footprint (not including the fuels exported off site).[64]

3.1.2 Water Contamination

As of April of 2019, the Pennsylvania DEP officially acknowledges 339 cases of groundwater contamination caused by Marcellus Shale UOGD development.[65] Studies of health impacts from groundwater contamination are complicated by the fact that transport of pollutants takes much longer than surface water and because not all wells are sampled and the state DEP does not regulate private wells.[66] A 2016 EPA report found evidence that fracking activities impacted

---

[60] Macey, G. P., Breech, R., Chernaik, M., Cox, C., Larson, D., Thomas, D., & Carpenter, D. O. (2014). Air concentrations of volatile compounds near oil and gas production: a community-based exploratory study. *Environmental Health*, *13*(82). doi: 10.1186/1476-069X-13-82

[61] Litovitz, A., Curtright, A., Abramzon, S., Burger, N., & Samaras, C. (2013). Estimation of regional air-quality damages from Marcellus Shale natural gas extraction in Pennsylvania. *Environmental Research Letters*, *8*(1), 014017.

[62] Values have been inflated to 2019 dollars.

[63] American Lung Association. (2018). *State of the Air 2018*. Retrieved from https://www.lung.org/assets/documents/healthy-air/state-of-the-air/sota-2018-full.pdf

[64] The City of Philadelphia Office of Sustainability. (2017). *Powering our Future: A Clean Energy Vision for Philadelphia*. Retrieved from https://www.phila.gov/media/20171114102042/Powering-Our-Future.pdf

[65] Pennsylvania Department of Environmental Protection. (2019). *Water Supply Determination Letters*. Retrieved from http://files.dep.state.pa.us/OilGas/BOGM/BOGMPortalFiles/OilGasReports/Determination_Letters/Regional_Determination_Letters.pdf

[66] Pennsylvania Department of Environmental Protection. (No Date). *General Information About Private Wells*. Retrieved from https://www.dep.pa.gov/Citizens/My-Water/PrivateWells/Pages/default.aspx

drinking water from spills, injection of fracking fluids, discharge of fracking fluids into surface water, and reduction in the groundwater resource.[67]

Concentrations of high methane and ethane have been found in groundwater for homes within one kilometer from UOGD activity in Pennsylvania.[68, 69, 70, 71] In the town of Dimock, Pennsylvania a dozen domestic wells were found to have such high methane that they posed risks for fire and explosion.[72]

UGOD primarily contaminates water from spills, based on reported incidents.[73] In Pennsylvania there were at least 1,293 spills from 2005 to 2014. On average there are approximately five spills each year for every 100 wells.[74] In August 2014, the Pennsylvania DEP released documentation revealing that 243 private water supplies in 22 counties were either contaminated or lost flow due to fracking activities. This was the first time that the department linked fracking with the damage to local water resources.[75]

Besides the above, there were also fines and lawsuits against large gas companies in Pennsylvania for fracking-related water contamination. On May 17, 2011, Chesapeake Energy Corporation was charged $900,000 for contaminating the water of 16 residences in Bradford County.[76] In 2013, Exxon Mobil's subsidiary, XTO Energy Corporation was charged for a spill of drilling wastewater in 2010 and contaminating Susquehanna watershed. XTO paid a $100,000

---

[67] U.S. EPA. (2016). *Hydraulic fracturing for oil and gas: Impacts from the hydraulic fracturing water cycle on drinking water resources in the United States.* U.S. Environmental Protection Agency, Washington, DC, EPA-600- R-16-236Fa. Retrieved from https://www.epa.gov/hfstudy

[68] Osborn, S. G., Vengosh, A., Warner, N. R., & Jackson, R. B. (2011). Methane contamination of drinking water accompanying gas-well drilling and hydraulic fracturing. *proceedings of the National Academy of Sciences*, *108*(20), 8172-8176.

[69] Jackson, R. B., Vengosh, A., Darrah, T. H., Warner, N. R., Down, A., Poreda, R. J., ... & Karr, J. D. (2013). Increased stray gas abundance in a subset of drinking water wells near Marcellus shale gas extraction. *Proceedings of the National Academy of Sciences*, 110(28), 11250-11255.

[70] Sloto, R. A. (2013). Baseline groundwater quality from 20 domestic wells in Sullivan County, Pennsylvania, 2012 (p. 27). *US Department of the Interior, US Geological Survey*.

[71] Hill, E., & Ma, L. (2017). Shale gas development and drinking water quality. *American Economic Review: Papers & Proceedings*, 107(5), 522–525. doi: 10.1257/aer.p20171133

[72] U.S. Agency for Toxic Substances and Disease Registry (2016). *Health Consultation: Dimock Groundwater Site*. Retrieved from http://www.atsdr.cdc.gov/hac/pha/DimockGroundwaterSite/Dimock_Groundwater_Site_HC_05-24-2016_508.pdf

[73]Patterson, L., Konschnik, K., Wiseman, H., Fargione, J., Maloney, K. O., Kiesecker, J., ... Saiers, J. E. (2017). Unconventional oil and gas spills: Risks, mitigation priorities and states reporting requirements. *Environmental Science & Technology, 51*(5), 2563–2573. doi: 10.1021/acs.est.05749

[74] Ibid.

[75] Colaneri, K. (2014). *DEP publishes details on 248 cases of water damage from gas development*. August 29. Retrieved from https://stateimpact.npr.org/pennsylvania/2014/08/29/dep-publishes-details-on-248-cases-of-water-damage-from-gas-development/

[76] Levy, M. (2011). DEP fines Chesapeake $1 million. *The Ithaca Journal*. May 18. Retrieved from http://www.theithacajournal.com/article/20110517/NEWS01/105170345/DEP-fines-Chesapeake-1-million?

fine and agreed to improve its wastewater management system.[77] In 2014, a woman in Bradford County won her case against a gas corporation, Chesapeake Appalachia LLC, which she asserted contaminated her drinking water with methane. The court ordered the company to pay almost $60,000 for the damage.[78]

Over time, the infrastructure of wells (e.g. well casings) will deteriorate, which is likely to cause pollution into groundwater in the future. The impact of well drilling on groundwater resources will likely be one of the biggest legacy impacts of UOGD activity. Because these costs will arise in the future, the magnitude and extent of their impact is currently unknown and resists quantification. ***The potential for groundwater contamination represents one of the largest potential future costs of UOGD in Pennsylvania.***

As demonstrated in Figure 12, UOGD is concentrated in the Southwest and Northeast regions of Pennsylvania. This activity is occurring in close proximity to both large and small surface water resources in the state. There is limited information on the groundwater flow occurring in the subsurface of Pennsylvania land. However, groundwater is generally more abundant in areas with surface water and flow patterns are often similar, but groundwater can also be found far from surface water.[79]

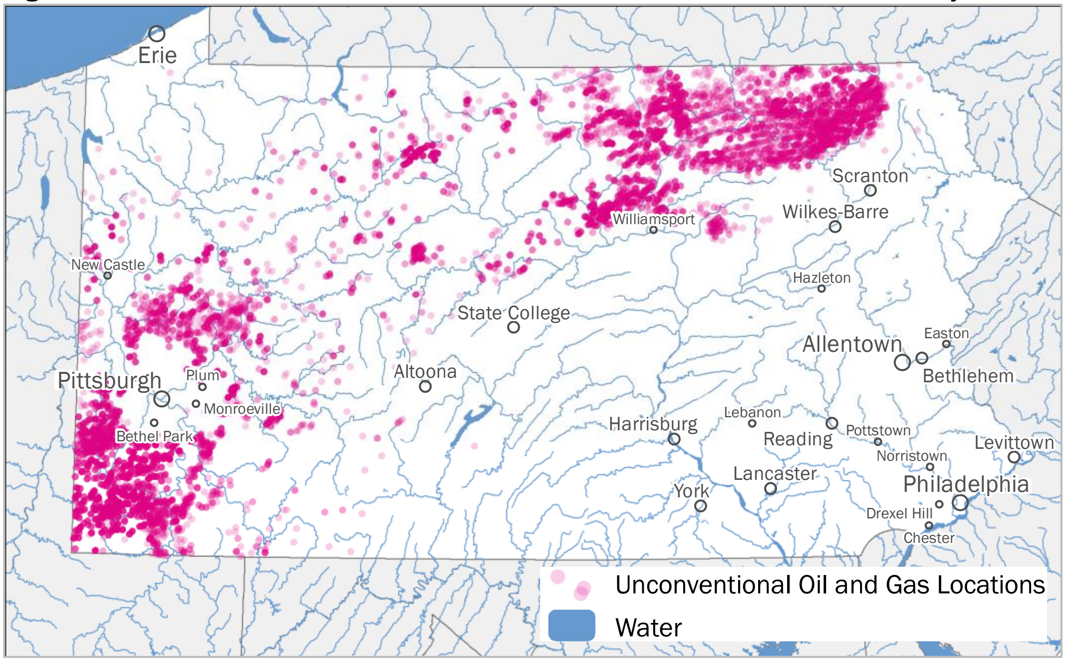
---

[77] Maykuth, A. (2013). Shale criminal charges stun drilling industry. *The Philadelphia Inquirer.* September 12. Retrieved from https://www.philly.com/philly/business/20130912_AG_s_criminal_charges_stun_drilling_industry.html

[78] Ernst, J. (2014). "Chesapeake pay Jacqueline Place of Terry Township, Bradford County Pennsylvania, $60,000 for temporary methane contamination". *Ernst v. EnCana Corporation.* February 19. Retrieved from https://www.ernstversusencana.ca/american-arbitration-association-commercial-arbitration-tribunal-orders-chesapeake-to-pay-jaqueline-place-of-terry-township-bradford-county-pa-60000-for-methane-contamination-of-water-after-fracing/

[79] U.S. Geological Survey. (1998). *Ground Water and Surface Water A Single Resource*. U.S. Geological Survey Circular 1139. Retrieved from https://pubs.usgs.gov/circ/circ1139/pdf/circ1139.pdf.

Figure 12: Unconventional Oil and Gas Wells and Water Resources in Pennsylvania



Source: Created by ECONorthwest using data from Pennsylvania Department of Environmental Protection

3.1.3 Radiation

When fracking brings oil and gas to the surface it also allows subsurface pollutants to rise to the surface. Radioactive material has been found in fracking wastewater from the Marcellus Shale that is over 200 times the drinking water standard limit.[80] Another study found elevated concentrations of radium as far as 12 miles downstream of a wastewater treatment plant and levels up to 200 times greater than background concentrations.[81] Radium has been shown to cause adverse health effects such as anemia, cataracts, fractured teeth, cancer and death.[82] Homes that use well water near fracking operations were found to have higher levels of radon, the gaseous form of radium.[83] Radon is the second leading cause of lung cancer, after cigarette smoking.[84]

[80] Rowan, E. L., Engle, M. A., Kirby, C. S., & Kraemer, T. F. (2011). *Radium content of oil- and gas- field produced waters in the northern Appalachian basin (USA)*. Retrieved from http://pubs.usgs.gov/sir/2011/5135/

[81] Burgos, W. D., Castillo-Meza, L., Tasker, T. L., Geeza, T. J., Drohan, P. J., Liu, X., ... Warner, N. R. (2017). Watershed-scale impacts from surface water disposal of oil and gas wastewater in Western Pennsylvania. *Environmental Science & Technology, 51*(15), 8851–8860. doi: 10.1021/acs.est.7b01696

[82] Agency for Toxic Substances and Disease Registry. (1990). *Public Health Statement for Radium*. Retrieved from https://www.atsdr.cdc.gov/phs/phs.asp?id=789&tid=154

[83] Casey, J. A., Ogburn, E. L., Rasmussen, S. G., Irving, J. K., Pollak, J., Locke, P. A., & Schwartz, B. S. (2015). Predictors of indoor radon concentrations in Pennsylvania, 1989–2013. *Environmental health perspectives*, *123*(11), 1130-1137.

[84] Centers for Disease Control and Prevention. (No Date). *Protect Yourself and Your Family from Radon*. Retrieved from https://www.cdc.gov/features/protect-home-radon/index.html

3.2 Methods for this Analysis

People living close to fracking operations have been found to be most at risk of adverse health impacts. FracTracker Alliance has calculated the number of people living within two-miles, one-mile and one-half-mile of well-sites in Pennsylvania. Their calculations used population data at the census tract level from the 2015 American Community Survey and intersected buffers for these three distances to determine the portion of the census tract within the buffers, and then estimated that population level based on that ratio.

Applying the FracTracker Alliance geospatial analysis, an estimated 170,232 individuals (3.4 percent of the total Pennsylvania population) live within a half-mile of a well. Living within 2 miles of well-sites are an estimated 582,395 people (11.6 percent of total Pennsylvania population). This analysis was also completed for well permit locations to reflect potential future drilling sites. Table 1 presents the results of FracTracker Alliance's analysis.

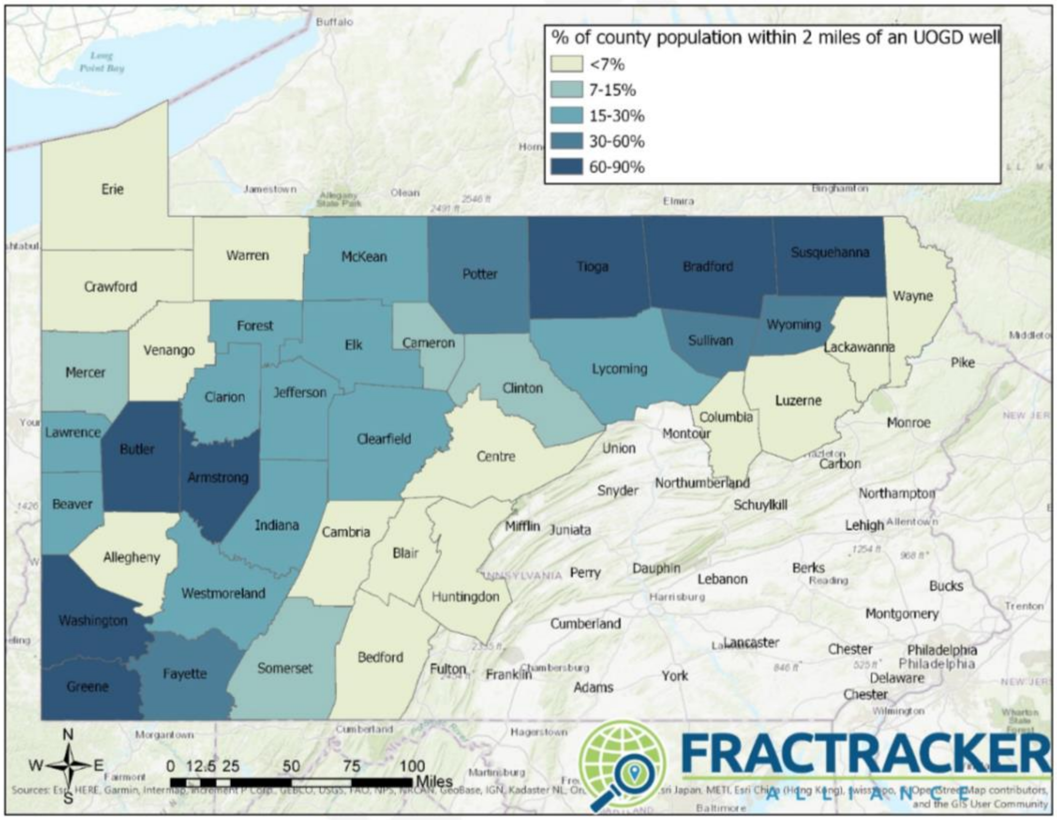
Table 1: Number of People Living Near UOGD Wells and Permits

	Affected Population Near Wells				Affected Population Near Permits			
Study Distance	Total Pop	Pct. Total	Under 18	Pct. Total	Total Pop	Pct. Total	Under 18	Pct. Total
0.5 Mile	170,232	3.4%	33,932	3.4%	226,521	4.5%	45,077	4.6%
1 Mile	446,891	8.9%	89,056	9.0%	582,395	11.6%	116,104	11.8%
2 Mile	954,728	19.1%	190,777	19.3%	1,229,198	24.6%	244,860	24.8%

Source: FracTracker. (2019). Categorical Review of Health Reports on Unconventional Oil and Gas Development; Impacts in Pennsylvania. FracTracker Alliance Issue Paper.

We use these estimates for the number of people living near wells to calculate the costs of illnesses associated with fracking. The health effects considered in this analysis include adverse birth outcomes, cancer, cardiac afflictions, asthma and respiratory disease, sleep disturbances, migraines and sinus afflictions, sexually transmitted diseases, occupational hazards, mental health costs, and non-human health impacts. Figure 13 provides a map by county of the percent of population living within 2 miles of wells. Counties with higher percentages of populations living near wells will have some of the highest health costs.

Figure 13: Percent of Populations Living Near Wells by County in Pennsylvania



Source: FracTracker. (2019). Categorical Review of Health Reports on Unconventional Oil and Gas Development; Impacts in Pennsylvania. FracTracker Alliance Issue Paper

3.3 Adverse Birth Outcomes

Many of the chemicals involved in fracking operations are known as endocrine disruptors which interfere with hormone production and organ functionality.[85] Multiple studies have found a link between proximity to UOGD and low birth weights.[86] Additional studies link infertility[87] and pre-term births with exposure to contaminants resulting from UOGD. In Pennsylvania, living within 1 mile of a UOGD well is associated with a 25 percent increase in probability of low-birth weights.[88] This same study found adverse effects of UOGD on birth

[85] Kassotis, C. D., Tillitt, D. E., Lin, C. H., McElroy, J. A., & Nagel, S. C. (2015). Endocrine-disrupting chemicals and oil and natural gas operations: potential environmental contamination and recommendations to assess complex environmental mixtures. *Environmental health perspectives*, 124(3), 256-264.

[86] Shaina, L. S., Brink, L. L, Larkin, J. D., Sadovsky, Y, Goldstein, B. C., Pitt, B. R., & Talbott, E. O. (2015). Perinatal outcomes and unconventional natural gas operations in southwest Pennsylvania. *PLoS One*, 10, e0126425. doi: 10.1371/journal.pone.0126425

[87] Endocrine Society. (2015). Fracking chemicals tied to reduced sperm count in mice. *ScienceDaily*. Retrieved from www.sciencedaily.com/releases/2015/10/151014134533.htm

[88] Currie, J., Greenstone, M., & Meckel, K. (2017). Hydraulic fracturing and infant health: New evidence from Pennsylvania. *Science Advances*, 3(12), e1603021. doi: 10.1126/sciadv.1603021. Retrieved from https://epic.uchicago.edu/sites/default/files/EPIC_121017_FrackingResearchSummary_Final.121317.pdf

outcomes up to three miles from a well. Birth defects, specifically congenital heart defects, are also correlated with well density.[89]

There were 137,771 live births in Pennsylvania in 2017.[90] Assuming that families closest to wells have the same birth rate as other parts of the state, we can estimate that 4800 babies were born in 2017 from the 446,891 people living within 1 mile of a well. Pre-term/low-birth weight babies incur hospital costs that are $20,932 higher than routine births.[91,92] Based upon these figures on the hospital costs and assuming 25 percent of the 4,800 babies born in Pennsylvania within one mile of a well have low birth weights, annual costs are estimated as $25.2 million dollars. ***Over twenty years, assuming similar rates of UOGD activity, the estimated costs of low birth weights from fracking in Pennsylvania has a present value of $410 million.***[93] This estimated number of births is likely high because there is evidence that fertility rates are lower within 1 mile of a well, but the calculation does not include the cost of fertility treatments or lifecycle costs for preterm/low-birth weight babies as they get older.

3.4 Cancer

Because cancer takes years to manifest and the fracking boom in Pennsylvania began only 10 years ago, many of the effects may not have occurred yet. Benzene is the primary carcinogen of concern. Proximity to fracking is linked to increased instances of hematologic (blood) cancer, such as leukemia, as well as urinary, bladder, and thyroid cancer.[94] A study in Colorado found that children and young adults between the ages of 5 and 24 who were diagnosed with acute lymphocytic leukemia were 4.3 times more likely to live in the highest density areas for oil and gas production.[95] Mammal lab studies have also found links between malignant cells and exposure to fracking wastewater.[96] Lung cancer from radon and silicosis, primarily among workers exposed through their occupation, is also possible.

---

[89] McKenzie, L. M., Guo, R., Witter, R. Z., Savitz, D. A., Newman, L. S., & Adgate, J. L. (2014). Birth outcomes and maternal residential proximity to natural gas development in rural Colorado. *Environmental health perspectives*, 122(4), 412-417.

[90] Pennsylvania Department of Health. (2018). *Birth Statistics*. Retrieved from https://www.health.pa.gov/topics/HealthStatistics/VitalStatistics/BirthStatistics/Pages/birth-statistics.aspx

[91] This figure has been inflated from $14,500 in 2001 dollars to 2019 dollars.

[92] Russell, R. B., Green, N. S., Steiner, C. A., Meikle, S., Howse, J. L., Poschman, K., ... & Petrini, J. R. (2007). Cost of hospitalization for preterm and low birth weight infants in the United States. *Pediatrics*, 120(1), e1-e9.

[93] The present value calculation uses a three percent discount rate and accounts for population growth of 0.25 percent per year, which is based on the Pennsylvania County Population Projections, 2010-2040 from Penn State Harrisburg.

[94] Finkel, M. L. (2016). Shale gas development and cancer incidence in southwest Pennsylvania. *Public health*, 141, 198-206.

[95] McKenzie, L. M., Allshouse, W. B., Byers, T. E., Bedrick, E. J., Serdar, B., & Adgate, J. L. (2017). Childhood hematologic cancer and residential proximity to oil and gas development. *PloS one*, *12*(2), e0170423.

[96] Yao, Y., Chen, T., Shen, S. S., Niu, Y., DesMarais, T. L., Linn, R., . . . Costa, M. (2015). Malignant human cell transformation of Marcellus Shale gas drilling flow back water. *Toxicology and Applied Pharmacology*, 288, 121- 130. doi: 10.1016/j.taap.2015.07.011

The CDC Cost of Illness Calculator estimates the annual per person costs of cancer in Pennsylvania as $13,405 (2019 dollars), with total costs of $8.2 billion annually for all cancers for the entire state. If cancer rates only increase by 0.01 percent for all people in Pennsylvania due to fracking, then over 1,280 more people would be affected and the annual cost for these new cancer cases would be $17.2 million. The 0.01 percent estimate is being used for only demonstration purposes, since the increase in cancer due to fracking is unknown. These costs represent only direct annual costs, so totals including lifetime costs, absenteeism costs, and deaths would be much higher. ***The present value for cancer is not projected because of uncertainties regarding the percent of the population affected due to UOGD.***

3.5 Cardiac Afflictions

Studies have found increased instances of hospital admittance for cardiology problems from 2007 to 2011 associated with higher well densities.[97, 98] Wayne County, which did not have active wells from 2007 to 2011 served as a control in this study, which found that cardiology inpatient rates were increased by 27 percent as a zip code went from low to high well density. Health research has consistently linked air pollution, such as fine particulate matter and ground-level ozone, to cardiac hospital admissions and deaths.[99]

The CDC Cost of Illness Calculator estimates the annual per-person costs in Pennsylvania for congestive heart failure as $11,709 and coronary heart disease as $9,432. If we assume that fracking increases the rate of illness of these afflictions by 0.01 percent for all of Pennsylvania, that would lead to an additional 1280 people being afflicted. For congestive heart failure (heart attacks), an episodic illness, this increase would increase annual costs in Pennsylvania to $15 million. Because wells are being drilled near similar populations, we would not expect the same individuals to have heart attacks each year. For coronary heart disease, a chronic illness, increased instances for 0.01 percent of Pennsylvania's population would increase annual costs to $12.1 million. The 0.01 percent estimate is being used for only demonstration purposes because the increase in cardiac afflictions due to fracking is unknown. These costs represent only direct annual costs, so lifetime costs, absenteeism costs, and deaths would be much higher. The present value for cardiac afflictions is not projected because of uncertainties regarding the percent of the population affected due to UOGD.

---

97 Jemielita T., Gerton G. L., Neidell, M., Chillrud S., Yan B., Stute, M., . . . Panettieri, Jr., R. A. (2015), Unconventional gas and oil drilling is associated with increased hospital utilization rates. *PLoS ONE* 10(7), e0131093. doi: 10.1371/journal.pone.0131093

98 This study also found increased instances of hospital admittance for dermatology, neurology, oncology, and urology inpatient services were also correlated with higher well density.

99 American Heart Association. (2019). *Air Pollution and Heart Disease, Stroke*. https://www.heart.org/en/health-topics/consumer-healthcare/air-pollution-and-heart-disease-stroke

3.6 Asthma & Respiratory Afflictions

Studies have found that instances of asthma in Pennsylvania are linked to increased UOGD activity nearby.[100] One study found that pediatric asthma was found to increase by approximately 25 percent during the same quarter a well was drilled.[101] Children are believed to be especially vulnerable to air pollution due to the development of their respiratory system. A meta review of the literature on UOGD effects on children found that increased risks exist for asthma, chronic and acute respiratory symptoms, adverse lung function and development, and airway inflammation.[102] These symptoms are primarily attributed to ozone, particulate matter, silica dust, benzene, and formaldehyde resulting from UOGD operations.[103]

The per-person annual costs of asthma are estimated by the CDC Cost of Illness Calculator as $2,521 (2019 dollars) and on average 5.8 percent of the population suffers from asthma. From the portion of the population under the age of 18 living within 0.5 mile of a well, we would expect 1900 children who are afflicted by asthma. Based on the 25 percent increase in rates of asthma we would expect an additional 500 children would be afflicted. Based on the per person costs, the total average annual costs in Pennsylvania from asthma caused by UOGD in children living near wells is estimated at $1.2 million. ***Over twenty years, assuming similar rates of UOGD activity, the estimated costs of asthma from fracking in Pennsylvania has a present value of $19.5 million.***[104]

3.7 Sleep Disturbance

Sleep disruption was the most commonly reported symptom of people living within one kilometer of a UOGD well in Pennsylvania, with 43.1 percent reporting that they had been affected.[105] This study of self-reported illnesses excluded responses where there was another clear cause of the illness (for example, coughing among smokers). Disturbance to sleep has been attributed to noise and light from UOGD operations but may also be caused by other health

---

[100] Rasmussen, S. G., Ogburn, E. L., McCormack, M., Casey, J. A., Bandeen-Roche, K., Mercer, D. G., & Schwartz, B. S. (2016). Association between unconventional natural gas development in the Marcellus Shale and asthma exacerbations. *JAMA internal medicine*, 176(9), 1334-1343.

[101] Willis, M. D., Jusko, T. A., Halterman, J. S., & Hill, E. L. (2018). Unconventional natural gas development and pediatric asthma hospitalizations in Pennsylvania. *Environmental research*, *166*, 402-408.

[102] Webb, E., Hays, J., Dyrszka, L., Rodriguez, B., Cox, C., Huffling, K., & Bushkin-Bedient, S. (2016). Potential hazards of air pollutant emissions from unconventional oil and natural gas operations on the respiratory health of children and infants. *Reviews on Environmental Health*, 31(2), 225-243. doi: 10.1515/reveh-2014-0070

[103] Ibid.

[104] The present value calculation uses a three percent discount rate and accounts for population growth of 0.25 percent per year, which is based on the Pennsylvania County Population Projections, 2010-2040 from Penn State Harrisburg.

[105] Weinberger, B., Greiner, L. H., Walleigh, L., & Brown, D. (2017). Health symptoms in residents living near shale gas activity: A retrospective record review from the Environmental Health Project. *Preventive medicine reports*, 8, 112-115.

symptoms that interfere with sleep or by increased stress and anxiety. Sleep disturbance is most associated with lost productivity.

The National Safety Council reports that the national costs of fatigue in the workplace are $136 billion a year and are due to absenteeism, poor performance, occupational injuries, and workplace accidents. Applying this figure to 43.1 percent of the population in Pennsylvania living within 0.5 miles of a well (slightly less than 1 km), the estimated costs of fatigue are $30,000 per year. ***Over twenty years, assuming similar rates of UOGD activity, the estimated costs of sleep disruption from fracking in Pennsylvania for the workplace has a present value of $488,000.***[106] This does not include the cost of discomfort or other direct effects to the afflicted.

3.8 Migraines & Sinus Afflictions

Headaches are the second most common affliction reported by people living within one kilometer of a well in Pennsylvania (41.2 percent).[107] Throat irritation was reported by 39.2 percent and sinus problems are reported by 29.4 percent of the surveyed population.[108] Another study by researchers at Johns Hopkins found correlations between UOGD activity and migraines, fatigue, nasal and sinus afflictions.[109]

Like fatigue, migraines and sinus afflictions are associated with lost work productivity and absenteeism, in addition to health care costs. Migraines are estimated to affect 11–14 percent nationwide.[110] For migraines alone the per person direct and indirect annual costs range from $2,240 for episodic migraines to $9,880 for transformed (chronic) migraines.[111, 112] While there is strong evidence that people living near oil and gas wells have higher levels of migraines, the rate of increased prevalence is unknown.

---

[106] The present value calculation uses a three percent discount rate and accounts for population growth of 0.25 percent per year, which is based on the Pennsylvania County Population Projections, 2010-2040 from Penn State Harrisburg.

[107] Weinberger, B., Greiner, L. H., Walleigh, L., & Brown, D. (2017). Health symptoms in residents living near shale gas activity: A retrospective record review from the Environmental Health Project. *Preventive medicine reports*, 8, 112-115.

[108] Ibid.

[109] Tustin, A. W., Hirsch, A. G., Rasmussen, S. G., Casey, J. A., Bandeen-Roche, K., & Schwartz, B. S. (2017). Associations between unconventional natural gas development and nasal and sinus, migraine headache, and fatigue symptoms in Pennsylvania. *Environmental Health Perspectives*, 125, 189-197. doi: 10.1289/EHP281

[110] Burch, R. C., Loder, S., Loder, E., & Smitherman, T. A. (2015). The Prevalence and Burden of Migraine and Severe Headache in the United States: Updated Statistics From Government Health Surveillance Studies. Headache: The Journal of Head and Face Pain, 55(1), 21-34.

[111] These figures have been inflated to 2019 dollars from 2006 dollars.

[112] Munakata, J., Hazard, E., Serrano, D., Klingman, D., Rupnow, M. F., Tierce, J., ... & Lipton, R. B. (2009). Economic burden of transformed migraine: results from the American Migraine Prevalence and Prevention (AMPP) Study. *Headache: The Journal of Head and Face Pain*, *49*(4), 498-508.

3.9 Mental Health & Quality of Life

Stress and anxiety were reported by 37.3 percent of the surveyed population living within 1 km of a UOGD well in Pennsylvania.[113] Higher rates of UOGD development were associated with increased self-reported symptoms of depression by approximately 18 percent in Pennsylvania.[114] These reported mental health issues are believed to be due to "a range of complex stressor events that are clearly more multidimensional than simply the risk of damage to health or property" including "chemical exposure, water and air contamination, and the risk of large-scale disasters from new technologies used in the extraction process".[115, 116] Other research suggests that fracking creates social stress by disrupting residents' sense of place and identify.[117]

There have been multiple instances documented of neighbors infighting in Pennsylvania due to the emergence of UOGD operations in the community. Some of this infighting has been attributed to discrepancies in lease and royalty payments, with some landowners receiving more than others, or households incurring costs as a result of their neighbor's decision.[118] These leasing payments can also amplify wealth disparities, since only those who own the land benefit, but the externalities caused by UOGD operations impose costs on the entire community. There is also evidence that increased fracking is associated with increases in violent crime rates, even with increases in public safety expenditures.[119, 120]

In Pennsylvania the average annual cost per person of depression is $4,193 from the CDC Cost of Illness Calculator. Using the self-reported estimate that 18 percent of people living within 0.5 mile of UOGD wells experience depression (not including depression that goes unreported), minus the 5.9 percent average depression rate for Pennsylvania, we estimate that 20,500 people within 0.5 miles of a well experience depression due to UOGD. The total costs in Pennsylvania

---

[113] Weinberger, B., Greiner, L. H., Walleigh, L., & Brown, D. (2017). Health symptoms in residents living near shale gas activity: A retrospective record review from the Environmental Health Project. *Preventive medicine reports*, 8, 112-115.

[114] Casey, J. A., Wilcox, H. C., Hirsch, A. G., Pollak, J., & Schwartz, B. S. (2018). Associations of unconventional natural gas development with depression symptoms and disordered sleep in Pennsylvania. *Scientific reports*, 8(1), 11375.

[115] Jacquet, J. B. (2014). Review of risks to communities from shale energy development. *Environmental science & technology*, 48(15), 8321-8333.

[116] Bamberger, M., & Oswald, R. (2014). "The real cost of fracking: How America's shale gas boom is threatening our families, pets, and food". Boston: Beacon Press.

[117] Sangaramoorthy, T., Jamison, A. M., Boyle, M. D., Payne-Sturges, D. C., Sapkota, A., Milton, D. K., & Wilson, S. M. (2016). Place-based perceptions of the impacts of fracking along the Marcellus Shale. *Social Science & Medicine*, 27-37.

[118] Brasier, K. J., Filteau, M. R., McLaughlin, D. K., Jacquet, J., Stedman, R. C., Kelsey, T. W., & Goetz, S. J. (2011). Resident's perceptions of community and environmental impacts from development of natural gas in the Marcellus Shale: A comparison of Pennsylvania and New York Cases. *Journal of Rural Social Sciences*, 26(1), 32.

[119] Bartik, A., Currie, J., Greenstone, M., & Knittel, C. R. (2016). The local economic and welfare consequences of hydraulic fracturing. *MIT Center for Energy and Environmental Policy Research.*

[120] Price, M., Herzenberg, S., Ward, S., Wazeter, E., & Basurto, L. E. (2014). *The Shale Tipping Point: The Relationship of Drilling to Crime, Traffic Fatalities, STDs, and Rents in Pennsylvania, West Virginia, and Ohio.* December. Retrieved from: http://www.multistateshale.org/shale-tipping-point

of depression associated with UOGD is estimated at $86.4 million. This number is likely high because not all people may seek treatment for depression symptoms but does not include the pain and suffering of those afflicted. ***Over twenty years, assuming similar rates of UOGD activity, the estimated costs of depression from fracking in Pennsylvania has a present value of $1.4 billion.***[121]

3.10 Other Potential Health Impacts

3.10.1 Organ Afflictions

Rashes, hair loss, itchy skin, skin lesions/blisters have been reported by people living near UOGD activities.[122] Skin-related hospitalizations have also been found to increase in areas with high well densities.[123] This same study also found that kidney infections, kidney stones, and urinary tract infection increased in areas with high density UOGD activities.

3.10.2 Sexually Transmitted Diseases

There is evidence for increased instances of sexually transmitted diseases (STD) in areas with high UOGD.[124] Increased rates of gonorrhea (21 percent) and chlamydia (19 percent) were found in Ohio in regions with shale gas activity.[125] In Pennsylvania, counties with UOGD activity have 7.8 percent higher instances of gonorrhea and 2.6 higher rates of chlamydia than averages, as well as increased instances of prostitution.[126]

Reasons for these increases in STD rates have been hypothesized as being attributable a change in the composition of the labor population in counties with high UOGD activities, particularly non-locals who do not have friends and family in the vicinity. It is unclear if these infected people would have been infected in different locations if they did not come to work in the UOGD industry. However, the more infected people there are in an area the higher the risk that additional people will contract the disease who would not otherwise, suggesting that there has been a net new increase in STDs in regions with UOGD production.

---

[121] The present value calculation uses a three percent discount rate and accounts for population growth of 0.25 percent per year, which is based on the Pennsylvania County Population Projections, 2010-2040 from Penn State Harrisburg.

[122] Weinberger, B., Greiner, L. H., Walleigh, L., & Brown, D. (2017). Health symptoms in residents living near shale gas activity: A retrospective record review from the Environmental Health Project. *Preventive medicine reports*, 8, 112-115.

[123] Denham, A., Willis, M., Zavez, A., & Hill, E. (2019). Unconventional natural gas development and hospitalizations: evidence from Pennsylvania, United States, 2003–2014. *Public health*, *168*, 17-25.

[124] Komarek, T., & Cseh, A. (2017). Fracking and public health: Evidence from gonorrhea incidence in the Marcellus Shale region. *Journal of public health policy*, 38(4), 464-481.

[125] Deziel, N. C., Humeau, Z., Elliott, E. G., Warren, J. L., & Niccolai, L. M. (2018). Shale gas activity and increased rates of sexually transmitted infections in Ohio, 2000–2016. *PloS one*, 13(3), e0194203.

[126] Beleche, T., & Cintina, I. (2018). Fracking and risky behaviors: Evidence from Pennsylvania. *Economics & Human Biology*, 31, 69-82.

3.11 Occupational Hazards

Pipeline accidents have resulted in deaths and injury for those who work with natural gas. There are also occupational hazards associated with exposure to the chemicals used in UOGD production. Silica used as a proppant in fracking increases the risk of the lung disease known as silicosis in workers, which is caused by exposure to crystalline silica.[127] Silicosis causes difficulty breathing, coughing, chest pain, and other symptoms – it can also exacerbate other lung conditions. Inhalation of crystalline silica can also cause lung cancer, chronic obstructive pulmonary disease, kidney disease and autoimmune diseases.[128]

Because of the boom and bust nature of resource extraction, when downturns occur, they can affect the mental health of workers who might be laid off. There is evidence that rates of depression, substance abuse, and suicide increases during downturns. In Alberta, Canada, suicides rate increases of up to 30 percent were correlated with job losses due to drops in the price of natural gas.[129]

3.12 Non-Human Health Impacts

Health effects do not only impact humans, but also livestock, pets, and other living organisms exposed to contaminants. Increased instances of illness, especially skin conditions, have been documented in dogs living less than one km from a UOGD well.[130] Infertility has also been documented in animals exposed to UOGD spills, most commonly among cattle which impacts the revenues of ranchers.[131]

3.13 Averting Behavior

Another way to estimate the economic costs of health effects is to consider what people are willing to pay to avoid the perceived increased risk. Although there is debate about the systematic contamination of water resources, households in Pennsylvania do appear to practice

---

[127] Bang, K. M., Mazurek, J. M., Wood, J. M., White, G. E., Hendricks, S. A., & Weston, A. (2015), Silicosis mortality trends and new exposures to respirable crystalline silica – United States, 2001-2010. *Morbidity and Mortality Weekly Report*, 64(05), 117-120.

[128] Esswein, E. J., Breitenstein, M., Snawder, J., Kiefer, M., & Sieber, W. K. (2013). Occupational exposures to respirable crystalline silica during hydraulic fracturing. *Journal of Occupational and Environmental Hygiene*, 10(7), 347-356. doi: 10.1080/15459624.2013.788352

[129] Mouallem, O. (2015). "The boom, the bust, the darkness: suicide rate soars in wake of Canada's oil crisis". The Guardian. December 14. Retrieved from https://www.theguardian.com/world/2015/dec/14/canada-oil-production-crisis- suicide-alberta?CMP=share_btn_fb

[130] Slizovskiy, I. B., Conti, L. A., Trufan, S. J., Reif, J. S., Lamers, V. T., Stowe, M. H., Dziura, J., & Rabinowitz, P. M. (2015). Reported health conditions in animals residing near natural gas wells in southwestern Pennsylvania. *Journal of Environmental Science and Health, Part A: Toxic/Hazardous Substances and Environmental Engineering*, 50(5), 473-481, doi: 10.1080/10934529.2015.992666

[131] Phillips, S. (2011). Burning questions: Quarantined cows give birth to dead calves. *StateImpact*. September 27. Retrieved from http://stateimpact.npr.org/pennsylvania/2011/09/27/burning-questions-quarantined-cows-give-birth-to-dead-calves/

averting behavior (or avoidance behavior), suggesting many people believe there might be adverse health effects from drinking water contamination. Water filters, water delivery, other direct water purchases, and even selling one's home and moving is considered averting behavior. The costs incurred by the averting behavior represent costs associated with fracking, because they would not be occurring but for the nearby UOGD.

Using water purchase data from the Nielsen Corporation, the annual expenditures on averting behavior specific to bottled water purchases are estimated at $22 million in Pennsylvania.[132, 133] This value does not include other forms of averting behavior such as use of other sources of potable water or water treatment or moving costs. These expenditures represent the minimum perceived risk of drinking water contamination, since these consumers are willing to pay at least as much as these drinking water purchases to minimize their potential exposure to water contamination. ***Over twenty years the estimated costs of averting behavior associated with bottled water purchases due to fracking in Pennsylvania has a present value of $358 million.***[134]

[132] Inflated from a value of $19 million in 2010 dollars.

[133] Wrenn, D. H., Klaiber, H. A., & Jaenicke, E. C. (2016). Unconventional shale gas development, risk perceptions, and averting behavior: evidence from bottled water purchases. *Journal of the Association of Environmental and Resource Economists, 3*(4), 770-817. doi: 10.1086/688487

[134] The present value calculation uses a three percent discount rate and accounts for population growth of 0.25 percent per year, which is based on the Pennsylvania County Population Projections, 2010-2040 from Penn State Harrisburg.

4 Community Costs

For communities that have experienced the boom associated with fracking in Pennsylvania, there have been corresponding costs that arise with the expansion of drilling, some of which are projected to stay or worsen after the bust has occurred. One of the first changes that the fracking boom brought is an inflow of out-of-state workers to Pennsylvania. Although to a lesser extent than in states such as North Dakota, communities have changed due to these altered demographics. There is evidence that rents, property values, and compositions of industries have changed in areas with high UOGD. Costs from increased crime, traffic, and road wear and tear have also been cited. Many of the current and future costs are due to uncertainties involved with the UOGD process.

4.1 Long-Term Employment

When fracking began to increase in intensity in Pennsylvania beginning in 2008, there was an initial sharp increase in economic activity. However, like other non-renewable extraction industries, the initial boom can produce an equally large bust. In a collaboration between the Pennsylvania College of Technology and Penn State Extension, researchers estimated that 98 percent of natural gas exploration and development jobs are not needed after the well is drilled.[135] Researchers have also found that non-local workers primarily fill the new jobs created by increases in UOGD in Pennsylvania.[136]

Although many of the jobs are short term and filled by non-local workers, UOGD does affect the local labor force. Areas with increases in oil and gas production have experienced a one-percent increase in the rate at which males drop out from high school.[137] Because there are more short-term jobs available, which pushes wages up, students see the opportunity cost of school as higher and opt to drop out of school and enter the workforce. This phenomenon also affects college entrance and graduation rates. Studies of prior oil and gas booms have found that males are two percent less likely to attend college.[138] Other studies find that unconventional fracking activity increases the "rural brain drain" by decreasing the portion of the population with a college education.[139] There are also long-term implications for the local economies due to this

[135] Marcellus Shale Education & Training Center (MSETC). (2011). *Pennsylvania Statewide Marcellus Shale Workforce Needs Assessment.*

[136] Jorgensen, H. (2012). *Fracking Nonsense: The Job Myth of Gas Drilling*. Retrieved from http://cepr.net/blogs/cepr-blog/fracking-nonsense-the-job-myth-of-gas-drilling

[137] Cascio, E. U., & Narayan, A. (2015). *Who needs a fracking education? the educational response to low-skill biased technological change* (No. w21359). National Bureau of Economic Research.

[138] Kumar, A. (2017). Impact of oil booms and busts on human capital investment in the USA. *Empirical Economics*, 52(3), 1089-1114.

[139] Mayer, A., Malin, S. A., & Olson-Hazboun, S. K. (2018). Unhollowing rural America? Rural human capital flight and the demographic consequences of the oil and gas boom. *Population and Environment*, *39*(3), 219-238.

educational achievement deficit; research indicates that lower educational achievement is associated with negative social, health, and economic outcomes.[140]

Recently, there have been efforts to automate oil and gas activities, which will likely result in future job losses.[141] As oil and gas prices have decreased since recent highs in 2014 (Figure 14), profits have declined, as have financing opportunities.[142]

Figure 14: Henry Hub Natural Gas Spot Price

Source: Created with data from EIA (https://www.eia.gov/dnav/ng/hist/rngwhhdm.htm)

Ultimately, the reliance on fracking, which makes up 0.4 percent of Pennsylvania's employment, leaves the state vulnerable to future reductions in the industry and creates a situation where lower-educated workers are unable to reintegrate into the economy.[143] This vulnerability is especially pronounced in counties which have a high percentage of jobs in the oil and gas sector.

---

[140] Hanushek, E.A., Ruhose, J., & Woessmann, L. (2016). It Pays to Improve School Quality: States That Boost Student Achievement Could Reap Large Economic Gains. *Education Next*, *16*(3), 16-24.

[141] Blum, J. (2019). Schlumberger, Rockwell create joint venture for the digital, automated oilfield. *Chron*. Retrieved from https://www.chron.com/business/energy/article/Schlumberger-Rockwell-create-new-JV-for-the-13628114.php

[142] Olsen, B. and Elliot, R. (2019). "Frackers Face Harsh Reality as Wall Street Backs Away". *The Wall Street Journal*. February 24. Retrieved from https://www.wsj.com/articles/frackers-face-harsh-reality-as-wall-street-backs-away-11551009601

[143] Pickenpaugh, G.C., and Adder, J.M. (2018). "Shale gas production and labor market trends in the U.S. Marcellus–Utica region over the last decade," *Monthly Labor Review*. U.S. Bureau of Labor Statistics. Retrieved from https://doi.org/10.21916/mlr.2018.20.

4.2 Impacts on Other Industries

As discussed in the employment section, the increase in UOGD can change the structure of local economies and the composition of the workforce. Additionally, temporary employment gains in UOGD can disrupt labor supply for other industries such as construction, manufacturing, agriculture, tourism, and similar.[144] While there are short-term benefits to these demand shocks, longer term the composition of the economy makes it less resilient and less diverse if there is less UOGD activity. Researchers from Ohio State University have found that expansions in the oil and gas sector suppress self-employment, especially in rural communities.[145] UOGD operations can also crowd out tourism through landscape changes and increased prices for hotels, and crowd out agriculture from soil and water contamination. UOGD may also affect other industries by supporting other high-pollution potential manufacturing. For example, plastic manufacturing and petrochemical production that uses natural gas liquids (ethane, propane, butane, isobutane, and pentane) as inputs have increased in Pennsylvania.[146] Petrochemical processing and plastics manufacturing are even being promoted by the Pennsylvania Department of Community and Economic Development because of the advantages of being near abundant oil and gas production.[147]

4.2.1 Tourism

Researchers studying the effects of UOGD on local economies identified multiple effects on tourism, including:

> *strains on the available supply and pricing of hotel/motel rooms, shortfalls in the collection of room (occupancy) taxes, visual impacts (including wells, drilling pads, compressor stations, equipment depots, etc.), vastly increased truck and vehicle traffic, potential degradation of waterways, forests and open space, and strains on the labor supply that the tourism sector draws from.*[148]

These impacts alter the supply of tourism amenities both in quantity and quality of sustained amenities. Surveys have found that 38 percent of park users were unwilling to recreate near

---

[144] Christopherson, S., & Rightor, N. (2012). How shale gas extraction affects drilling localities: Lessons for regional and city policy makers. *Journal of Town and City Management*, 2(4), 1-20.

[145] Tsvetkova, A., & Partridge, M. (2017). The shale revolution and entrepreneurship: an assessment of the relationship between energy sector expansion and small business entrepreneurship in US counties. *Energy*, 141, 423-434.

[146] Pennsylvania Department of Community and Economic Development. (No Date). *Plastics*. Retrieved from https://dced.pa.gov/key-industries/plastics/

[147] IHS Markit. (2017). *Prospects to Enhance Pennsylvania's Opportunities in Petrochemical Manufacturing*. Prepared for Team Pennsylvania and Pennsylvania Department of Community and Economic Development. March.

[148] Christopherson, S (Ed.). (2011). *The economic consequences of Marcellus Shale gas extraction: Key issues*. Cornell University, Department of Development Sociology, Community and Regional Development Institute.

fracking operations.[149] In Pennsylvania, fracking has contributed to at least one fish kill incident.[150] Recreational fishing was a $1.6 billion industry in 2001.[151]

4.2.2 Agriculture

Soil and groundwater contamination has occurred in Pennsylvania due to UOGD. In 2014, the Pennsylvania DEP found three leaks from wastewater impoundments in Washington County that contaminated soil.[152] There has also been evidence that fracking increases the rate of invasive plant spread via the high traffic volumes, which can lead to removal costs for private and public landowners.[153, 154] Pipelines crossing agricultural land restrict certain farming practices, imposing costs on farmers. The threat of chemical contamination jeopardizes organic certification.[155] For dairies, there have been instances of cattle dying and not being able to reproduce because of suspected water contamination.[156] A list of the impacted farms and farmers in Pennsylvania was compiled by Pennsylvania Alliance for Clean Water and Air as of 2015 and includes 31 instances of livestock, human, or land impacts from fracking that adversely affected farms.[157]

4.3 Housing Market Disruptions

4.3.1 Short Term

Increased rental prices are caused by increased demand for rental housing which leads to short-term housing shortages and price increases. The effect of these prices increases often most

[149] Kellison, T. B., Bunds, K. S., Casper, J. M., & Newman, J. I. (2015). Fracking & parkland: Understanding the impact of hydraulic fracturing on public park usage. Retrieved from http://plaza.ufl.edu/tkellison/_/Fracking.html

[150] Lustgarten, A. (2011). Frack Fluid Spill in Dimock Contaminates Stream, Killing Fish. *ProPublica*. September 21. Retrieved from https://www.propublica.org/article/frack-fluid-spill-in-dimock-contaminates-stream-killing-fish-921

[151] Pennsylvania Fish and Boat Commission. (2012). *Economic Value of Fishing and Boating in Pennsylvania (fact sheet).* Retrieved from fishandboat.com/promo/funding/fact_ economic_impact.htm

[152] Hopey, D. (2014). State: Fracking waste tainted groundwater, soil at three Washington County sites. *Pittsburgh Post-Gazette.* Retrieved from https://www.post-gazette.com/local/washington/2014/08/06/Pa-finds-tainted-water-soil-at-three-Washington-County-shale-sites/stories/201408050198

[153] Barlow, K. M., Mortensen, D. A., Drohan, P. J., & Averill, K. M. (2017). Unconventional gas development facilitates plant invasions. *Journal of Environmental Management*, *202*, 208e216. doi: 10.1016/j.jenvman.2017.07.005

[154] Mulhollem, J. (2017). "Shale gas development spurring spread of invasive plants in Pa. forests". *PennState News*. Retrieved from http://news.psu.edu/story/475225/2017/07/20/research/shale-gas-development-spurring- spread-invasive-plants-pa-forests

[155] Potter County Today. (2015). "Shale gas impact on agriculture 'profound'". Retrieved from http://today.pottercountypa.net/shale-gas-impact-on-agriculture-profound/

[156] Ramanujan, K. (2012). "Study suggests hydrofracking is killing farm animals, pets". *Cornell Chronicle*. Retrieved from http://www.news.cornell.edu/stories/2012/03/reproductive-problems-death-animals-exposed- fracking

[157] Lisak, J. (2015). List of the Harmed PA Farms and Farmers. Pennsylvania Alliance for Clean Water and Air. Retrieved from https://pennsylvaniaallianceforcleanwaterandair.wordpress.com/list-of-the-harmed-pa-farms-and-farmers/

adversely impacts renters who are lower-income and more marginalized populations. [158] Estimates of increases in rental prices due to Marcelles Shale development range from 39 percent to 200 – 300 percent. [159, 160] In 2015, Pennsylvania lacked a quarter million affordable rental homes for people in poverty despite well fees being used for affordable housing.[161] Because of the natural gas slow-down since 2015 and there being time for the impacts of affordable housing investments to occur, this figure is likely lower now. However, for the impacted populations, the net loss in rental increases is likely more than the net gain from affordable housing or fracking operations.

4.3.2 Long Term

The impact of UOGD on residential housing prices depends on the water source for the home, being negative at close range with groundwater sources.[162] Converted to 2019 prices, the average annual loss for ground-water dependent homes within 1.5 kilometer of a well was $37,040 and the price decreases for these properties are between 10 and 22 percent.[163] A later study found smaller negative effects for homes near wells on groundwater, as well as near major highways.[164] Mortgages and property values may also be impacted from non-coverage of oil and gas activities by homeowners insurance.[165]

Approximately 446,891 Pennsylvanians live near wells. Dividing this by 2.58, the average US household size from the 2010 census, we can estimate an average of 173,213 households in Pennsylvania live within one mile of a fracking well. The median home price in Pennsylvania is currently $173,330.[166] ***Assuming that half of these homes are on groundwater, we estimate the effects at the low end (10 percent lost value) to be approximately $17,000 per home in lost value for a total of $1.5 billion in property value losses.***

---

[158] Kinnaman, T. C. (2011). The economic impact of shale gas extraction: A review of existing studies. *Ecological Economics*, 70(7), 1243-1249.

[159] Muehlenbachs, L., Spiller, E., Steck, A. & Timmins, C. (2015). *The Impact of the Fracking Boom on Rents in Pennsylvania*. Duke University. Retrieved from http://public.econ.duke.edu/~timmins/fracking_rents.pdf

[160] Williamson, J., and Kolb, B. (2011). *Marcellus Natural Gas Development's Effect on Housing In Pennsylvania*. Center for the Study of Community and the Economy (CSCE), Lycoming College.

[161] Cusick, M. (2015). Despite drilling slowdown, rents still high in fracking boomtowns. *StateImpact*. Retrieved from https://stateimpact.npr.org/pennsylvania/2015/12/08/despite-drilling-slowdown-rents-still-high-in- fracking-boomtowns/

[162] Muehlenbachs, L., Spiller, E., & Timmins, C. (2015). The housing market impacts of shale gas development. *American Economic Review*, 105(12), 3633-59.

[163] Ibid

[164] Gopalakrishnan, S., & Klaiber, H. A. (2013). Is the shale energy boom a bust for nearby residents? Evidence from housing values in Pennsylvania. *American Journal of Agricultural Economics*, *96*(1), 43-6

[165] Radow, E. L. (2014). At the intersection of Wall Street and Main: Impacts of hydraulic fracturing on residential property interests, risk allocation, and implications for the secondary mortgage market. *Albany Law Review, 77*(2), 673-704.

[166] Zillow. (2019). *Pennsylvania Home Prices & Values*. Retrieved from https://www.zillow.com/pa/home-values/

4.4 Crime

There is some evidence that crime rates increase in regions with higher UOCD. Methamphetamine use among workers, who are likely trying to stay awake to meet work demands, was found to increase in Northern and Western Pennsylvania.[167] Sex trafficking and prostitution has been linked to the fracking industry.[168, 169] In six counties in Pennsylvania, violent crime increased 17.7 percent in 2012, corresponding to about 130 more violent crimes in those counties – urban and rural non-drilling communities experienced a decrease in crime during this same period. [170] Property crime for these six counties was found to increase 10.8 percent, drug abuse rates rose 48 percent, and drunk-driving offenses rose 23 percent compared to rural areas with no drilling. [171] Some have suggested that this increase in crime is potentially due to an increase in population from non-local workers which reduces social ties.[172]

4.5 Traffic, Accidents, and Road Wear and Tear

Increases in UOCD involve significant truck activity to haul in and remove water, additives, equipment, and pipelines. Depending on the amount of water needed, a single well can require more than 1,000 truckloads.[173] The increased water use from the longer well bores has increased traffic by even more since 2011 to deliver the additional water and chemicals. The impact of this increased heavy traffic results in significant road wear and tear, in addition to dust and noise. In Pennsylvania, it has been estimated that each shale gas well causes between $5,400 and $10,000 in damage to state roads.[174] In Mercer County, Pennsylvania, the damage to bridges alone is estimated as $30 million over the next ten years.[175]

---

[167] Newberg, R. (2015). Meth use tied to fracking workers in Pennsylvania. *WIVB 4*. March 20. Retrieved from http://wivb.com/2015/03/20/meth-use-tied-to-fracking-workers-in-pennsylvania/

[168] Dalrymple, A. & Lymn, K. (2015). Trafficked Report: Sex for sale in the Bakken. January 4. *Forum News Service*. Retrieved from http://www.traffickedreport.com/?p=15

[169] Gaines, J. (2015). The oil boom in North Dakota now has a serious sex-trafficking problem. March 9. *Business Insider*. Retrieved from http://www.businessinsider.com/north-dakota-sex-trafficking-prostitution-oil-boom-police-raid-2015-3

[170] Price, M., Herzenberg, S., Ward, S., Wazeter, E., & Basurto, L. E. (2014, December). *The Shale Tipping Point: The Relationship of Drilling to Crime, Traffic Fatalities, STDs, and Rents in Pennsylvania, West Virginia, and Ohio.* Retrieved from: http://www.multistateshale.org/shale-tipping-point

[171] Ibid

[172] Jacquet, J. B. (2014). Review of risks to communities from shale energy development. *Environmental science & technology*, 48(15), 8321-8333.

[173] Christopherson, S (Ed.). (2011). *The economic consequences of Marcellus Shale gas extraction: Key issues.* Cornell University, Department of Development Sociology, Community and Regional Development Institute.

[174] Abramzon, S., Samaras, C., Curtright, A., Litovitz, A., & Burger, N. (2014). Estimating the consumptive use costs of shale natural gas extraction on Pennsylvania roadways. *Journal of Infrastructure Systems*. *20*(3). doi: 10.1061/(ASCE)IS.1943-555X.0000203, 06014001

[175] Poole, E. (2019). "Bridging the gap: Mercer County needs millions annually for repairs". *The Herald*. https://www.sharonherald.com/news/bridging-the-gap-mercer-county-needs-millions-annually-for-repairs/article_c92f2278-4c44-11e9-92e6-dbf25490425f.html

Using the low-end value of $5,400, for the 2,028 wells that were permitted to be drilled in 2017, the estimated average value of road wear and tear is estimated as $11 million per year.[176] ***Over twenty years the estimated costs of road wear and tear from fracking in Pennsylvania has a present value of $174 million.***[177]

Traffic accidents and fatalities also increase because of the heavier traffic. In Texas, commercial vehicle accidents are estimated to have increased by 50 percent due to increased UOGD activities. [178] First responders, hospitals, and law enforcement require additional resources to respond to these incidents. In Pennsylvania, there is not a clear relationship between heavy vehicle crashes and increases in UOGD because statewide these rates have not increased since 2008 when the boom began. However, from 2013 to 2017 counties with the highest numbers of wells do have higher levels of fatal vehicle crashes as a percent of the county population compared to the state average. Figure 15 shows the averages fatal crashes as percentage of population for the counties with the highest number of wells, all of which are higher than the state average.[179] In 2017, the total economic loss due to traffic crashes in Pennsylvania is estimated as $18.1 billion for all crash types.[180]

[176] Pennsylvania Department of Environmental Protection. (2018). *2017 Oil and Gas Annual Report*. Retrieved from http://www.depgis.state.pa.us/2017oilandgasannualreport/

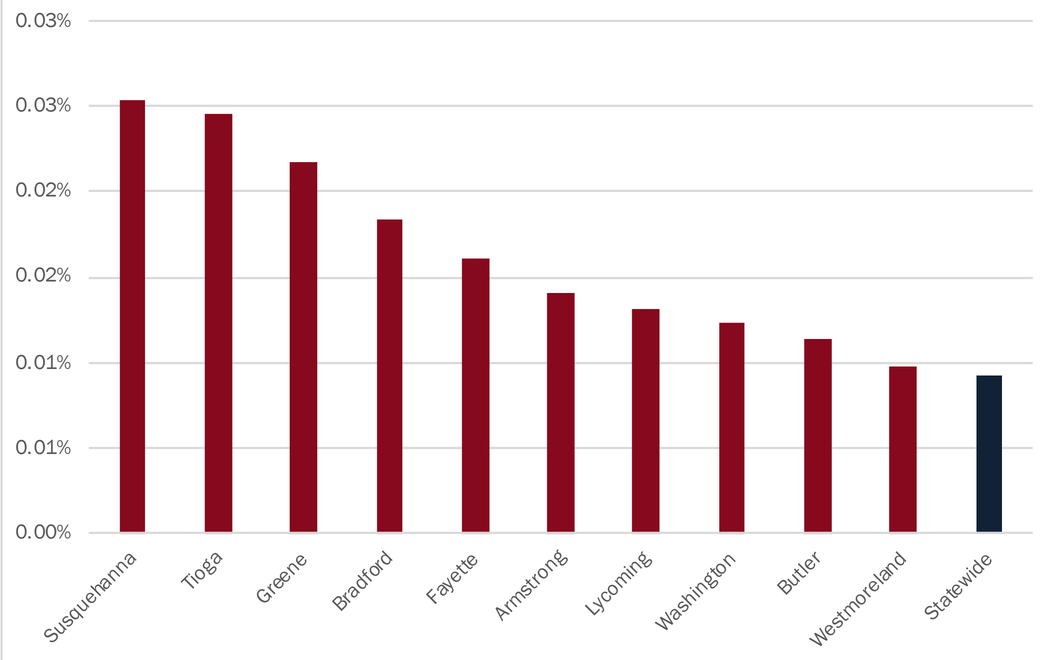
[177] The present value calculation uses a three percent discount rate.

[178] Schneider, A. (2014). In Texas, traffic deaths climb amid fracking boom. *National Public Radio*. October 12. Retrieved from http://www.npr.org/2014/10/02/352980756/in-texas-traffic-deaths-climb-amid-fracking-boom

[179] Pennsylvania Department of Transportation. (2017). *Pennsylvania Crash Facts and Statistics*. Retrieved from https://www.penndot.gov/TravelInPA/Safety/Documents/2017_CFB_linked.pdf

[180] Ibid.

Figure 15: Five Year Average Fatal Crashes as Percent of Population by County (2013 - 2017)



Source: Pennsylvania Department of Transportation. Crash Facts & Statistics for 2013 – 2017. Retrieved from https://www.penndot.gov/TravelInPA/Safety/Pages/Crash-Facts-and-Statistics.aspx

4.6 Fiscal Costs to Communities

When UOGD activities increase it brings in local revenue through the well fees in Pennsylvania. These funds are collected by the state and distributed to local communities for road maintenance, policing, health care demand, potential property value losses, and environmental costs. A survey of local governments in areas with high intensity UOGD found that 74 percent of local governments report net fiscal benefits, 14 percent say the effect has been neutral, and 12 percent reported net fiscal costs.[181] Of the communities which reported costs, infrastructure and staff costs have often outpaced increased revenues. In two of the 21 regions surveyed local governments also reported fiscal costs due to environmental issues.[182]

Because hydraulic fracturing is a natural resource commodity, it is subject to boom and bust cycles. When there are large drops in oil and gas prices, there have been instances of budget cuts in states dependent on these revenues.[183] In Pennsylvania, this is most likely to manifest through sales taxes, which will decline with the industry.

A 2015 report estimated that tax breaks and direct spending on fossil fuels in Pennsylvania resulted in an annual subsidy of $4.9 million (2019 dollars). The majority of this subsidy is tax breaks, which means that tax revenues are not being collected. The impact of this is that the

---

[181] Newell, R. G., & Raimi, D. (2018). The fiscal impacts of increased US oil and gas development on local governments. *Energy policy*, *117*, 14-24.

[182] Ibid.

[183] Ibid.

state may experience a budget deficit from not collecting these revenues or that the state would need to supplement the taxes with other revenue sources, such as sales taxes.

4.7 Uncertainties

Many of the costs from fracking arise due to uncertainties. For example, spills and leaks are common types of water pollution, but these instances are by definition unpredictable. Other sources of uncertainty from the UOGD process include:

1) Unknown chemical compounds and potency of chemicals used in UOGD;
2) Unknown long-term health effects;
3) Potential for leaks and spills throughout the extraction and distribution process;
4) Decommissioned and abandoned wells continuing to emit pollutants and pose safety hazards;
5) Potential for groundwater contamination and improper storage/dumping of UOGD wastewater;
6) Potential for contamination of surface water and sediments;
7) Unknown long-term effect of storage and disposal practices (landfill, spreading, and burying);
8) Unknown effects from pollutants/containments continuing to build up (biomagnification) in the environment (plants and animals) over time; and
9) Uncertainty regarding the amount of natural gas in the Marcellus.

4.7.1 Bonding

When an accident, negligence, or maleficence does occur, it is unclear if there are sufficient funds to perform remediation. There is a financial assurance requirement in Pennsylvania's bond system, but external investigations have described this system as a "pending disaster" because the bonds are set at such low levels, they will not be able to cover clean-up costs.[184] The average reclamation cost (plugging, site restoration and equipment removal) for wells in Pennsylvania was $100,000 in 2011, suggesting they are likely even higher now (the exact costs are not tracked). In 2010, Cabot Oil and Gas spent $2.19 million on plugging three wells, suggesting per well costs were over $700,000 each.[185] Bond levels are not sufficient to cover these direct costs, let alone the costs of other externalities like water contamination.[186] Bonds are

[184] McMahon, J. (2017). "Another Fracking Time Bomb Lurks Beneath U.S.". *Forbes*. Retrieved from https://www.forbes.com/sites/jeffmcmahon/2017/06/05/another-fracking-time-bomb-lurks-beneath-america/#3cfb27383ee9

[185] Cabot Oil & Gas Corporation. (No Date). *Exhibit B: Summary of Cabot's Good Faith Efforts*. Retreived from http://cabotog.com/pdfs/ExhibitB.pdf

[186] Mitchell, A. L., & Casman, E. A. (2011). Economic incentives and regulatory framework for shale gas well site reclamation in Pennsylvania. *Environmental science & technology*, 45(22), 9506-9514.

released in Pennsylvania after one year of plugging and reclaiming of the well.[187] Bonding requirements in Pennsylvania depend on the number of wells and the depth of the well:[188]

- For wells with a total well bore length less than 6,000 feet: $35,000 to $250,000
- For wells with a total well bore length of at least 6,000 feet: $140,000 to $600,000

The deficit of bonding requirements to potential damages will most likely affect the long-term costs of fracking, likely when the industry is in decline. There is evidence that profits in the UOGD industry have recently declined, as have financing opportunities.[189] In addition to the bonding, lawsuits may be possible if there are instances of neglect, but if companies are bankrupt, the timing may be such that when the health and environmental costs occur the companies no longer exist and the costs will have to be paid by the local population instead.

Pennsylvania is still recovering from prior oil and gas exploration activities. According to the Pennsylvania DEP, since the first commercial oil well was drilled in Pennsylvania in 1859, between 100,000 and 560,000 oil and gas wells remain unaccounted for in state records from before permitting and plugging requirements went into effect.[190]

---

[187] Dutzik, T., Davis, B., Van Heek, T., Rumpler, J. (2013). Who Pays the Costs of Fracking? PennEnvironment Research & Policy Center.

[188] Act of Feb. 14, 2012,P.L. 87, No. 13 Cl. 58 - OIL AND GAS (58 Pennsylvania.C.S.) - Omnibus Amendments. Retrieved from https://www.legis.state.pa.us/cfdocs/legis/li/uconsCheck.cfm?yr=2012&sessInd=0&act=13#

[189] Olsen, B. and Elliot, R. (2019). "Frackers Face Harsh Reality as Wall Street Backs Away". *The Wall Street Journal*. February 24. Retrieved from https://www.wsj.com/articles/frackers-face-harsh-reality-as-wall-street-backs-away-11551009601

[190] Pennsylvania Department of Environmental Protection. (2018). *Abandoned and Orphan Oil and Gas Wells and the Well Plugging Program*. Retrieved from http://www.depgreenport.state.pa.us/elibrary/PDFProvider.ashx?action=PDFStream&docID=1419023&chksum=&revision=0&docName=ABANDONED+AND+ORPHAN+OIL+AND+GAS+WELLS+AND+THE+WELL+PLUGGING+PROGRAM&nativeExt=pdf&PromptToSave=False&Size=411528&ViewerMode=2&overlay=0

5 Environmental Costs

In the United States, it is estimated that the annual ecological costs of fracking are over $1.52 billion per year.[191, 192] This value includes the economic value associated with "ecosystem services" that are damaged by UOGD. Ecosystem services are the benefits that natural capital provides to people, such as carbon sequestration, flood mitigation, food security, recreation, and genetic diversity. These benefits are not bought and sold in markets, but economists derive and measure their value using various methods, including estimating the cost to replace the service with built infrastructure, asking people about their willingness to pay to protect or enhance services, and revealed social preference based on regulatory costs and government spending to sustain and protect scarce resources.

UOGD directly impacts water and air resources, producing many of the health and community effects described in previous sections. It also affects the integrity of ecological systems, which in turn reduces the quantity and quality of terrestrial and aquatic habitat. People derive value both from the species that depend on the habitat, and from its aesthetic character. Greenhouse gas emissions impose costs on human communities now and in the future. Geologic destabilization produces increased risks to physical infrastructure. This section of the report discusses each of these costs.

5.1 Habitat Degradation

UOGD can lead to habitat degradation from the conversion of land and the potential for water contamination. Beyond the area close to fracking sites specifically, impacts to habitat are largely through the use of water, release of treated wastewater and accidents related to transportation of natural gas and fracking fluid. UOGD also causes impacts to habitat through air quality declines, light and noise pollution, and through spills. These impacts generally are associated with areas adjacent to fracking, fracking fluid storage locations, and treated wastewater outfalls and adjacent waterways since habitat within the footprint is already entirely degraded. These impacts have varying levels of intensity and occur on different timescales.

5.1.1 Land Habitat

Infrastructure built to enable fracking results in direct conversion of land and potential habitat to developed areas. Though not all fracking results in land conversion, major sources of land for fracking come from forested land and agricultural land, both of which provide at least some

[191] The original 2015 values have been inflated to 2019 dollars.

[192] Moran, M. D., Taylor, N. T., Mullins, T. F., Sardar, S. S., & McClung, M. R. (2017). Land-use and ecosystem services costs of unconventional US oil and gas development. *Frontiers in Ecology and the Environment*, 15(5), 237–242. doi: 10.1002/fee.1492

level of habitat.[193, 194] Fracking has a generally smaller footprint than many other extractive industries, such as coal mining or even conventional drilling since horizontal drilling makes it possible to access reserves that are not directly underneath the drilling site. However, fracking infrastructure development causes habitat loss and the prevalence of fracking can result in large impacts.

While wells are functioning, habitat at these sites may be completely eliminated.[195] After a well site is no longer active, it is expected to be remediated and returned to its pre-drilling state. However, there is little oversight of remediation efforts and most regulations are not specific in the level of restoration required. This creates a conflict of interest since the companies are responsible for both determining the level of effort necessary and the associated cost.[196] The absence of oversight may result in lower levels of restoration because firms are profit seeking and may simply determine that a low level of effort is necessary in order to avoid paying high costs. Because this remediation cannot be counted on to return to pre-fracking conditions, these impacts may be long lasting.

Other associated infrastructure built to accommodate fracking includes the construction of roads, power grids, pipelines, produced water storage tanks, and water-extraction systems and water storage basins, all of which may increase habitat degradation and fragmentation through their footprint.[197, 198, 199] To the extent that fracking requires development of infrastructure to accommodate an influx of employees (new housing, hotels etc.), habitat is impacted when these developments convert land from forest or agriculture areas.

To value the conversion of land to fracking, we consider the ecosystem services that the land can no longer provide. Based on conversion trends, about 24–38 percent of new wells affect

---

193 Caldwell, J. A. (2015). *A policy and impact analysis of hydraulic fracturing in the Marcellus Shale region: a wildlife perspective.* Doctoral dissertation, University of Delaware.

194 Arthur, J., Langhus, B., & Alleman, D. (2009). *Modern shale gas development in the United States: a primer*. US Department of Energy, Office of Fossil Energy, Washington, DC.

195 Vengosh, A., Jackson, R. B., Warner, N., Darrah, T. H., & Kondash, A. (2014). A critical review of the risks to water resources from unconventional shale gas development and hydraulic fracturing in the United States. *Environmental science & technology*, 48

196 Caldwell, J. A. (2015). *A policy and impact analysis of hydraulic fracturing in the Marcellus Shale region: a wildlife perspective.* Doctoral dissertation, University of Delaware.

197 Burton, G. A., Basu, N., Ellis, B. R., Kapo, K. E., Entrekin, S., & Nadelhoffer, K. (2014). Hydraulic "fracking": are surface water impacts an ecological concern?. *Environmental Toxicology and Chemistry*, 33(8), 1679-1689.

198 Bosquez IV, T., Carmeli, D., Esterkin, J., Hau, M. K., Komoroski, K., Madigan, C., & Sepp, M. (2015). Fracking debate: the importance of pre-drill water-quality testing. *In American Bar Association Section of Litigation.*

199 Harleman, M. (2018). A Cost Benefit Analysis of Shale Gas Well Bonding Systems in Pennsylvania.

forested land and 49–62 percent convert agricultural land.[200,201] Between 1 and 5 percent convert already disturbed areas and the remaining land is forest edge. There are varied estimates of the total land damaged by fracking but assuming average impacts per 1.2–3.55 hectare (ha) in direct footprint conversion and an additional 2.3 ha for associated land conversion per well pad, the total converted lands is 3.56–5.85 ha per well pad. Based on an estimated 13,000 total wells in Pennsylvania and the average number of wells per well pad in 2011 of 2.2, approximately 6,200 well pads result in 21,000 to 34,000 ha of cleared land.[202, 203] Increasing the number of wells per well pad to 10 based on assumptions of increasing well density results in 4,600 to 7,600 ha (11,400 to 18,800 acres) of cleared land.[204] Of this land cleared, 24–38 percent is forest resulting in a low estimate of impacts at 1,100 ha (2,700 acres) and a high estimate of 13,100 ha (32,300 acres). These values represent between 0.01 to 0.1 percent of the total land in Pennsylvania.[205] Agricultural land converted also includes some ecosystem services loss and loss of agricultural quality soils due to compaction and lack of full restoration after fracking occurs. Using similar calculation methods, the amount of lost agricultural land from well pads is between 2,300 ha (5,700 acres) as a low estimate and 21,000 ha (52,000 acres) as a high estimate. This agricultural land converted represents between 0.02 to 0.18 percent of the total land in Pennsylvania.

Since ecosystem services are often viewed as public goods, their value can be best estimated by public investments for their protection or improvement. Eco-prices look specifically at investments to improve ecosystem services in order to estimate the value of those services. Using this method, the annual value of ecosystem services for forests are estimated to be $5,767 per ha.[206] This estimate includes carbon sequestration, storm water runoff, groundwater recharge, nutrient uptake, erosion prevention and wildlife habitat. Based on the range of forested land converted above, the lost ecosystems services value since 2008 is estimated as $6 million to $75 million. This is equivalent to a value of approximately $4 million per year in lost ecosystem services due to UOGD. ***Over twenty years, assuming similar rates of UOGD***

---

[200] Drohan, P. J., Brittingham, M., Bishop, J., & Yoder, K. (2012). Early trends in landcover change and forest fragmentation due to shale-gas development in Pennsylvania: a potential outcome for the Northcentral Appalachians. *Environmental management*, 49(5), 1061-1075.

[201] Johnson, N., Gagnolet, T., Ralls, R., Zimmerman, E., Eichelberger, B., Tracey, C., Kreitler, G., Orndorff, S., Tomlinson, J. & Sargent, S. (2010). *Pennsylvania Energy Impacts Assessment Report 1: Marcellus Shale Natural Gas and Wind*. The Nature Conservancy.

[202] Pennsylvania Department of Environmental Protection. (2018). *2017 Oil and Gas Annual Report.* Retrieved from http://www.depgis.state.pa.us/2017oilandgasannualreport/

[203] Drohan, P. J., Brittingham, M., Bishop, J., & Yoder, K. (2012). Early trends in landcover change and forest fragmentation due to shale-gas development in Pennsylvania: a potential outcome for the Northcentral Appalachians. *Environmental management*, 49(5), 1061-1075.

[204] Johnson, N., Gagnolet, T., Ralls, R., Zimmerman, E., Eichelberger, B., Tracey, C., Kreitler, G., Orndorff, S., Tomlinson, J. & Sargent, S. (2010). *Pennsylvania Energy Impacts Assessment Report 1: Marcellus Shale Natural Gas and Wind*. The Nature Conservancy.

[205] The total area of Pennsylvania is 11.928 million hectares.

[206] Campbell, E. T. (2018). Revealed social preference for ecosystem services using the eco-price. *Ecosystem Services*, 30, 267-275.

activity, the estimated loss of ecosystem services from fracking in Pennsylvania has an estimated present value of $64 million.[207]

While the footprint of a fracking site directly decreases habitat it also creates more edges to existing habitat and breaks up contiguous habitat. These edges are associated with an increase in nest predation and brood parasitism (laying of eggs in the nest of another bird), putting bird species in particular at risk.[208,209] Small mammals, reptiles, and amphibians are especially susceptible to barriers imposed by new roads which then limit their habitat range.[210, 211, 212, 213] Vehicle collisions also directly cause mortality, especially for slower moving species and species that seek the increased sun on roads.[214, 215] Estimates per well pad are an increased 8.5 ha of new edge habitat per well pad in a forested context.[216] Another issue in creating pipeline and road routes is the increased spread of invasive species which can have negative impacts on ecosystems.[217] Regulation does not require mitigation of invasive species.

5.1.2 Water Habitat

Water Quantity

Perhaps the most direct impact that UOGD has on Pennsylvania's environment is due to the high volumes of water that are used in the extraction process. Fracking is a water-intensive process and the water is obtained from local watersheds. A typical Marcellus Shale well requires 11.4 million gallons of water, typically delivered and removed by truck.[218] For the

---

207 The present value calculation uses a three percent discount rate.

208 Bosquez IV, T., Carmeli, D., Esterkin, J., Hau, M. K., Komoroski, K., Madigan, C., & Sepp, M. (2015). Fracking debate: the importance of pre-drill water-quality testing. *In American Bar Association Section of Litigation.*

209 Caldwell, J. A. (2015). *A policy and impact analysis of hydraulic fracturing in the Marcellus Shale region: a wildlife perspective*. Doctoral dissertation, University of Delaware.

210 Caldwell, J. A. (2015). *A policy and impact analysis of hydraulic fracturing in the Marcellus Shale region: a wildlife perspective*. Doctoral dissertation, University of Delaware.

211 Clark, B. K., Clark, B. S., Johnson, L. A., & Haynie, M. T. (2001). Influence of roads on movements of small mammals. *The Southwestern Naturalist*, 338-344.

212 Merriam, G., Kozakiewicz, M., Tsuchiya, E., & Hawley, K. (1989). Barriers as boundaries for metapopulations and demes of *Peromyscus leucopus* in farm landscapes. *Landscape Ecology*, 2(4), 227-235.

213 Marsh, D. M., Milam, G. S., Gorham, N. P., & Beckman, N. G. (2005). Forest roads as partial barriers to terrestrial salamander movement. *Conservation biology,* 19(6), 2004-2008.

214 Caldwell, J. A. (2015). *A policy and impact analysis of hydraulic fracturing in the Marcellus Shale region: a wildlife perspective*. Doctoral dissertation, University of Delaware.

215 Fahrig, L., & Rytwinski, T. (2009). Effects of roads on animal abundance: an empirical review and synthesis. *Ecology and society*, 14(1).

216 Johnson, N., Gagnolet, T., Ralls, R., Zimmerman, E., Eichelberger, B., Tracey, C., Kreitler, G., Orndorff, S., Tomlinson, J. & Sargent, S. (2010). Pennsylvania Energy Impacts Assessment Report 1: Marcellus Shale Natural Gas and Wind. The Nature Conservancy.

217 Caldwell, J. A. (2015). *A policy and impact analysis of hydraulic fracturing in the Marcellus Shale region: a wildlife perspective*. Doctoral dissertation, University of Delaware.

218 FracTracker Alliance. (2018). *Potential Impacts of Unconventional Oil and Gas on the Delaware River Basin*. March 20.

initial drilling phase of each well, delivering water and drilling or fracturing equipment, along with other additives, needs half of the total 625 to 1,148 truckloads from water sources to the site.[219]

Aquatic habitats are impacted through the overdrawing of water resources, especially from smaller sources or during periods of low flow. This can result in negative impacts to ecosystems from warmer water temperatures and lower flows.[220, 221, 222, 223] Over use of water resources can cause increases in sedimentation and change water chemistry which results in lower biodiversity.[224] In Pennsylvania, a large portion of water needed for fracking comes from surface water sources: from mid-2008 to mid-2010, 71 percent of water used for fracking in the Susquehanna River Basin came from surface water sources.[225] This can greatly reduce flows and the overall health of ecosystems.[226]

Aquatic habitats can also be impacted through the release of treated fracking fluid that has high levels of total dissolved solids and salts.[227, 228, 229, 230] Wastewater treatment plants in Pennsylvania generally are not equipped to deal with such high levels of salts and reduced water quality in terms of total dissolved solids and radioactive material downstream of these facilities has been

[219] Christopherson, S. (2013). *The economic consequences of Marcellus Shale Gas Extraction: Key Issues.* Cornell University Department of City and Regional Planning ed. Robin M. Blakely-Armitage. CaRDI Reports, Community & Regional Development Institute (14).

[220] Vengosh, A., Jackson, R. B., Warner, N., Darrah, T. H., & Kondash, A. (2014). A critical review of the risks to water resources from unconventional shale gas development and hydraulic fracturing in the United States. *Environmental science & technology*, 48

[221] Rahm, B. G., & Riha, S. J. (2012). Toward strategic management of shale gas development: Regional, collective impacts on water resources. *Environmental Science & Policy*, 17, 12-23.

[222] Bosquez IV, T., Carmeli, D., Esterkin, J., Hau, M. K., Komoroski, K., Madigan, C., & Sepp, M. (2015). Fracking debate: the importance of pre-drill water-quality testing. *In American Bar Association Section of Litigation.*

[223] Caldwell, J. A. (2015). A policy and impact analysis of hydraulic fracturing in the Marcellus Shale region: a wildlife perspective (Doctoral dissertation, University of Delaware).

[224] Ibid.

[225] Ibid.

[226] Ibid.

[227] Gregory, K. B., Vidic, R. D., & Dzombak, D. A. (2011). Water management challenges associated with the production of shale gas by hydraulic fracturing. *Elements*, 7(3), 181-186.

[228] Olmstead, S. M., Muehlenbachs, L. A., Shih, J. S., Chu, Z., & Krupnick, A. J. (2013). Shale gas development impacts on surface water quality in Pennsylvania. *Proceedings of the National Academy of Sciences*, 201213871.

[229] Ferrar, K. J., Michanowicz, D. R., Christen, C. L., Mulcahy, N., Malone, S. L., & Sharma, R. K. (2013). Assessment of effluent contaminants from three facilities discharging Marcellus Shale wastewater to surface waters in Pennsylvania. *Environmental science & technology*, 47(7), 3472-3481.

[230] Warner, N. R., Christie, C. A., Jackson, R. B., & Vengosh, A. (2013). Impacts of shale gas wastewater disposal on water quality in western Pennsylvania. *Environmental science & technology*, 47(20), 11849-11857.

shown to be an issue.[231,232] Ecosystems are likely to suffer from these releases as species are not adapted to such high salt levels.[233, 234] There is also evidence that fracking brine has been released with illegal dumping in some cases.[235] Aside from salt concentrations, endocrine disruptors were found in elevated levels in surface and ground water potentially as a result of fracking activity.[236] These chemicals can result in negative impacts to wildlife and ecosystems through changes in hormonal regulation.

A study done by the Nature Conservancy in 2010 included the negative impact on cold and cool water species due to streamflow reductions in small streams.[237] Besides the harm on the watershed and ecology, this might diminish the tourism and recreation value of the watershed.[238] A team of researchers developed an index to measure surface water sensitivity and the Marcellus Shale region is marked as vulnerable to the impact of fracking.[239]

In 2012, the 3634 million gallons of water used represented 75 percent of total consumptive water use in the Susquehanna basin.[240] Most water used in fracking is surface water. In Pennsylvania, at least 70 percent of the water comes from local surface water. From 2010 to 2012, the SRBC reported that 70 to 80 percent of fracking water withdrawals comes from surface water sources in its basin.[241] Fracking withdrew an average of 8 million gallons of surface water

---

[231] Olmstead, S. M., Muehlenbachs, L. A., Shih, J. S., Chu, Z., & Krupnick, A. J. (2013). Shale gas development impacts on surface water quality in Pennsylvania. *Proceedings of the National Academy of Sciences*, 201213871.

[232] Warner, N. R., Christie, C. A., Jackson, R. B., & Vengosh, A. (2013). Impacts of shale gas wastewater disposal on water quality in western Pennsylvania. *Environmental science & technology*, 47(20), 11849-11857.

[233] Vengosh, A., Warner, N., Jackson, R., & Darrah, T. (2013). The effects of shale gas exploration and hydraulic fracturing on the quality of water resources in the United States. *Procedia Earth and Planetary Science*, 7, 863-866.

[234] Kaushal, S. S., Groffman, P. M., Likens, G. E., Belt, K. T., Stack, W. P., Kelly, V. R., ... & Fisher, G. T. (2005). Increased salinization of fresh water in the northeastern United States. *Proceedings of the National Academy of Sciences*, 102(38), 13517-13520.

[235] States, S., Cyprych, G., Stoner, M., Wydra, F., Kuchta, J., Monnell, J., & Casson, L. (2013). Marcellus Shale drilling and brominated THMs in Pittsburgh, Pa., drinking water. *Journal-American Water Works Association*, 105(8), E432-E448.

[236] Kassotis, C. D., Tillitt, D. E., Davis, J. W., Hormann, A. M., & Nagel, S. C. (2014). Estrogen and androgen receptor activities of hydraulic fracturing chemicals and surface and ground water in a drilling-dense region. *Endocrinology*, 155(3), 897-907.

[237] DePhilip, M., & Moberg, T. (2010). *Ecosystem flow recommendations for the Susquehanna River basin*. The Nature Conservancy: Harrisburg, Pennsylvania, USA.

[238] Mitchell, A. L., Small, M., & Casman, E. A. (2013). Surface water withdrawals for Marcellus Shale gas development: Performance of alternative regulatory approaches in the Upper Ohio River Basin. *Environmental science & technology*, 47(22), 12669-12678.

[239] Entrekin, S. A., Maloney, K. O., Kapo, K. E., Walters, A. W., Evans-White, M. A., & Klemow, K. M. (2015). Stream vulnerability to widespread and emergent stressors: a focus on unconventional oil and gas. *PloS one*, 10(9), e0137416.

[240] Susquehanna River Basin Commission. (2018). *Comprehensive Plan for the Water Resources of the Susquehanna River Basin*. Retrieved February 6, 2019, from https://www.srbc.net/our-work/programs/planning-operations/docs/comp-plan-no-appendices.pdf

[241] Susquehanna River Basin Commission. (2018). *Comprehensive Plan for the Water Resources of the Susquehanna River Basin*. Retrieved February 6, 2019, from https://www.srbc.net/our-work/programs/planning-operations/docs/comp-plan-no-appendices.pdf

withdrawal per day in Pennsylvania from 2010 to 2017.[242] Besides fresh surface water, the industry also uses reused water for fracking. Approximately 12 percent of the water used for fracking is reused water. This number varies among wells; some reach 25 percentage while others have none.[243]

Water Quality

Degradation of water quality due to UOGD quality can also change habitat quality and ecosystem health. There is limited monitoring that occurs of non-drinking water resources so the extent of water quality degradation due to UOGD is largely unknown. However, there have been specific instances of water quality pollution adversely impacting species and habitats.

In June 2009, a fracking pipe in Washington County's Cross Creek Park leaked wastewater into the tributary of Cross Creek Lake. The leaking damaged the habitat and killed various wildlife such as fish, salamanders, crayfish and so on.[244]

5.1.3 Air Pollution

The mechanism by which UOGD impacts air quality is addressed in Section 3.1.2 of this report. Species and habitats are also impacted by air quality, primarily from increased truck traffic as well as emissions from wells that may include fracking fluid. Truck traffic can increase dust and erosion, both of which can have negative impacts on plants as sun blocking and can decrease habitable areas. Dust and erosion also impact aquatic species. Well sites also produce increased levels of ground-level ozone which has health risks for local wildlife.[245] Silica dust used in the drilling process can also cause adverse health effects in wildlife and contributes to air pollution. Other air pollutants include volatile organic compounds (VOCs) that contribute to ozone and others that are linked to central nervous system, neurological, and reproductive impacts, such as benzene.[246] These VOC compounds are released through the drilling process as well as venting during storage and transport.

---

[242] Hill, M. (2018). *Water Use in Pennsylvania.* Water Resources Advisory Committee Meeting, November 29, 2018. Pennsylvania Department of Environmental Protection. Retrieved from http://files.dep.state.pa.us/PublicParticipation/Advisory%20Committees/AdvCommPortalFiles/WRAC/2018/WaterUseinPennsylvania.pdf

[243] Mitchell, A. L., Small, M., & Casman, E. A. (2013). Surface water withdrawals for Marcellus Shale gas development: Performance of alternative regulatory approaches in the Upper Ohio River Basin. Environmental science & technology, 47(22), 12669-12678.

[244] Pittsburgh Post-Gazette. (2009). *Waste from Marcellus shale drilling in Cross Creek Park kills fish*. June 4. Retrieved from https://www.post-gazette.com/local/washington/2009/06/05/Waste-from-Marcellus-shale-drilling-in-Cross-Creek-Park-kills-fish/stories/200906050136

[245] Bosquez IV, T., Carmeli, D., Esterkin, J., Hau, M. K., Komoroski, K., Madigan, C., & Sepp, M. (2015). Fracking debate: the importance of pre-drill water-quality testing. *In American Bar Association Section of Litigation.*

[246] Concerned Health Professionals of New York & Physicians for Social Responsibility. (2018). *Compendium of scientific, medical, and media findings demonstrating risks and harms of fracking (unconventional gas and oil extraction).*

5.1.4 Noise and Light Pollution

Noise and light pollution can also impact the environments surrounding active well sites and affect wildlife activities.[247] Compressors are the primary source of noise pollution from UOGD activities. Impacts to song birds can also be severe as their mating calls are affected up to 700 m into the interior of forests along active roads and pipelines.[248, 249] Gas flaring from hydraulic fracturing wells produces light pollution in non-urban areas that would otherwise be much darker. These effects affect migration paths and sleep patterns of birds and other species.[250]

5.2 Emissions

Natural gas, before it is burned, is primarily methane, a greenhouse gas 86 times more efficient at warming the atmosphere than carbon over a 20-year time frame.[251] Approximately 25 percent of U.S. methane emissions are attributable to natural gas systems,[252] of which approximately 19 percent comes from Pennsylvania.[253] When natural gas is released into the atmosphere it is essentially a direct release of methane. Between 3.6 and 7.9 percent of the methane in natural gas is released into the atmosphere from production, transportation, and leaks throughout the lifecycle of a well.[254, 255] Although atmospheric methane has a relatively short half-life (7 years) compared with carbon dioxide (27 years) it is estimated to be 86 times more potent over 20 years, meaning that it contributes much more to climate change.[256] Methane is more potent because its chemical structure allows it to be more efficient at trapping heat.

The sources of methane emissions from fracking operations are largely unavoidable since venting, release of methane into the air, occurs at multiple stages of the fracking operations. These methane emissions that occur during the extraction period for natural gas are why the life

---

[247] Saunders, P. J., McCoy, D., Goldstein, R., Saunders, A. T., & Munroe, A. (2016). A review of the public health impacts of unconventional natural gas development. *Environmental geochemistry and health*, 1-57.

[248] Caldwell, J. A. (2015). *A policy and impact analysis of hydraulic fracturing in the Marcellus Shale region: a wildlife perspective.* Doctoral dissertation, University of Delaware.

[249] Bayne, E. M., Habib, L., & Boutin, S. (2008). Impacts of chronic anthropogenic noise from energy-sector activity on abundance of songbirds in the boreal forest. *Conservation Biology*, 22(5), 1186-1193.

[250] Raap, T., Pinxten, R., & Eens, M. (2015). Light pollution disrupts sleep in free-living animals. *Scientific reports*, 5, 13557.

[251] IPCC (2013). *Climate Change 2013: The Physical Science Basis*. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

[252] U.S. Environmental Protection Agency. (2018). *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990 – 2016*. Retrieved from https://www.epa.gov/sites/production/files/2018-01/documents/2018_complete_report.pdf

[253] U.S. Energy Information Administration. (2018). *Pennsylvania's natural gas production continues to increase.* Retrieved from https://www.eia.gov/todayinenergy/detail.php?id=35892

[254] Howarth, R. W., Santoro, R., & Ingraffea, A. (2011). Methane and the greenhouse-gas footprint of natural gas from shale formations. *Climatic Change*, 106(4), 679.

[255] Jiang, M., Griffin, W. M., Hendrickson, C., Jaramillo, P., VanBriesen, J., & Venkatesh, A. (2011). Life cycle greenhouse gas emissions of Marcellus shale gas. *Environmental Research Letters*, 6(3), 034014.

[256] IPCC. (2013). *Climate Change 2013: The Physical Science Basis*. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

cycle emissions of natural gas can be as high as for coal.[257] When considering the full lifecycle of natural gas, estimates are that the greenhouse gas (GHG) footprint is more than 20 percent greater than coal over twenty years and roughly equivalent over 100 years.[258] Because of these impacts, some have called for the immediate end to methane releases from natural gas extraction.[259]

According to a 2018 EPA report, on average from 2012 to 2016 annual methane emissions from natural gas systems in the United States was 6.54 million metric tons (Table 2). This value was slightly lower in 2012 but has remained relatively constant since 2013.

Table 2: Methane Emissions from Natural Gas Systems (Thousand Metric Tons)[a]

Stage	2012	2013	2014	2015	2016
Exploration	101	119	39	42	30
Production	4,261	4,276	4,313	4,322	4,272
Processing	401	430	441	441	448
Transmission and Storage	1,125	1,237	1,292	1,365	1,311
Distribution	496	490	488	481	480
Total	**6,384**	**6,553**	**6,572**	**6,651**	**6,541**

Source: U.S. Environmental Protection Agency. (2018). Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990 – 2016.
[a] These values represent CH_4 emitted to the atmosphere. CH_4 that is captured, flared, or otherwise controlled (and not emitted to the atmosphere) has been calculated and removed from emission totals.
[b] Exploration includes well drilling, testing, and completions.
[c] Gathering and boosting includes gathering and boosting stations, gathering pipeline leaks, and gathering and boosting station episodic events.
Note: Totals may not sum due to independent rounding.

Carbon dioxide is also released throughout the lifecycle of natural gas production, with the majority of emissions occurring due to combustion (power generation). Before combustion, carbon dioxide emissions are primarily from processing before transmission and storage.[260] In 2016, carbon dioxide emissions due to natural gas were estimated as 25.5 million metric tons from non-combustion and 1,476.1 million metric tons from combustion (power plant processing).[261] If combusted efficiently, natural gas emits 50 to 60 percent less carbon dioxide compared with emissions from a typical new coal plant.[262] Unlike coal and other power sources, natural gas does not add to air pollution from particulate matter.

[257] Alvarez, R.A., S.W. Pacala, J.J. Winebrake, W.L. Chameides, and S.P. Hamburg. (2012). Greater focus needed on methane leakage from natural gas infrastructure. *Proceedings of the National Academy of Sciences* 109:6435–6440.

[258] Howarth, R. W., Santoro, R., & Ingraffea, A. (2011). Methane and the greenhouse-gas footprint of natural gas from shale formations. *Climatic Change*, 106(4), 679.

[259] Dr. Robert Howarth, Cornell University, https://www.youtube.com/watch?v=1NPuYr1LGMI

[260] U.S. Environmental Protection Agency. (2018). *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990 – 2016*. Retrieved from https://www.epa.gov/sites/production/files/2018-01/documents/2018_complete_report.pdf

[261] U.S. Environmental Protection Agency. (2018). *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990 – 2016*. Retrieved from https://www.epa.gov/sites/production/files/2018-01/documents/2018_complete_report.pdf

[262] National Energy Technology Laboratory (NETL). (2010). *Cost and performance baseline for fossil energy plants, Volume 1: Bituminous coal and natural gas to electricity*. Revision 2. November. DOE/NETL-2010/1397. United States Department of Energy.

The EPA has estimates for the value of social costs of GHGs, which represent the long-term costs based on damages due to GHG-caused changes in agricultural productivity, human health, property damages from increased flood risk, and changes in energy system costs.[263] The effects of climate change in Pennsylvania include changes in precipitation and runoff that will increase flooding and drought, as well as increases in temperature and frequency of temperature extremes.[264] Additionally, water resources will be impacted by sea level rise which could cause salt water intrusion to Delaware River Estuary water supplies, the drinking water source for millions of people. Salt water intrusion, floods, and droughts will also lead to loss of habitat and degradation of water quality. Agricultural costs and health costs are also anticipated to be large due to climate change in Pennsylvania. Using a three-percent discount rate, the social cost of carbon is $39, and the social cost of methane is $1,088.[265]

Pennsylvania accounted for 19 percent of total U.S. marketed natural gas production in 2017.[266] Applying that percentage to the total U.S. natural gas emissions for methane and carbon dioxide emitted in 2016 (the most recent data available*)*.

Table 3 provides a summary of Pennsylvania's contributions to the U.S. total social costs. ***The estimated annual cost due to natural gas production in Pennsylvania are estimated as $1.3 billion for methane and $11.2 billion for carbon dioxide.***

Table 3: Social Cost of Carbon and Methane from Natural Gas Production (2016)

Greenhouse Gas	Social Cost ($/metric ton)	Million Metric Tons (US)	U.S. Cost (Million)	Million Metric Tons (PA)	PA Cost (Million)
Methane	$1,088	6.50	$7,070	1.24	$1,343
Carbon Dioxide	$39	1,502	$58,798	285.30	$11,172

Source: Created by ECONorthwest with data from the U.S. Environmental Protection Agency [267, 268]
Note: All costs are in 2019 dollars

The values in Table 3 represent only the costs from one year of emissions in 2016. The net cumulative emissions from greenhouse gases over time from oil and gas are therefore much higher. The EPA estimates that the social cost of GHGs will increase over time due to the cumulative effects. ***If Pennsylvania continues to produce a similar level of natural gas as in 2016, in twenty years that production is estimated to result in a social cost of methane of $28.4***

[263] U.S. Environmental Protection Agency. (2017). The Social Cost of Carbon. Retrieved from https://19january2017snapshot.epa.gov/climatechange/social-cost-carbon_.html

[264] Union of Concerned Scientists. (2008). *Climate Change Impacts and Solutions for Pennsylvania*. Retrieved from https://www.ucsusa.org/sites/default/files/legacy/assets/documents/global_warming/Exec-Summary_Climate-Change-in-Pennsylvania.pdf

[265] These values represent the 2015 numbers inflated to 2019 dollars.

[266] U.S. Energy Information Administration. (2018). *Pennsylvania's natural gas production continues to increase.* Retrieved from https://www.eia.gov/todayinenergy/detail.php?id=35892

[267] U.S. Environmental Protection Agency. (2018). *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990 – 2016*. Retrieved from https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2016

[268] U.S. Environmental Protection Agency. (2017). The Social Cost of Carbon. Retrieved from https://19january2017snapshot.epa.gov/climatechange/social-cost-carbon_.html

billion and a social cost of carbon dioxide of $21.5 billion.[269] These estimates for the social costs of GHG emissions are lower bound estimates. Research suggests that by 2025 GHG emissions from Pennsylvania's natural gas sector will be at least three times higher than emissions in 2012.[270] Social costs of GHG emissions also increase over time as the cumulative level of GHGs in the atmosphere increases.[271]

5.3 Bioaccumulation

Fracking mobilizes some chemicals including heavy metals and naturally occurring radioactive materials that bioaccumulate in ecosystems.[272] The release of these chemicals, usually from either inadequately treated wastewater or accidental releases/spills or casing failures poses a threat to ecosystems in the long term and cannot be addressed through simple dilution of wastewater.[273] An example is the naturally occurring radioactive material that can be found in wastewater and has accumulated in stream sediments downstream of some facilities in western Pennsylvania, even though the releases may have been within regulations, the accumulated radioactive material can cause harm.[274, 275]

5.4 Seismic Activity

Seismic impacts from fracking are caused by rock formations destabilized by drilling and injections of fracking fluid. The underlying geologic structure plays a large role in determining the risk of causing seismic activity that can be felt at the surface. Studies of various areas in the United States show differing results on the impact of fracking on seismic activity. Within

---

[269] Net present values are discounted using a three percent discount rate and are in 2019 dollars.

[270] Physicians, Scientists and Engineers (PSE) for Healthy Energy. (2017). *Greenhouse Gas Emissions Associated with Projected Future Marcellus Shale Development*. January 18.

[271] U.S. Environmental Protection Agency. (2017). *The Social Cost of Carbon*. Retrieved from https://19january2017snapshot.epa.gov/climatechange/social-cost-carbon_.html

[272] Warner, N. R., Christie, C. A., Jackson, R. B., & Vengosh, A. (2013). *Impacts of shale gas wastewater disposal on water quality in western Pennsylvania*. *Environmental science & technology*, 47(20), 11849-11857.

[273] Adams, M. B., Edwards, P. J., Ford, W. M., Johnson, J. B., Schuler, T. M., Thomas-Van Gundy, M., & Wood, F. (2011). Effects of development of a natural gas well and associated pipeline on the natural and scientific resources of the Fernow Experimental Forest. *US Department of Agriculture Forest Service, Northern Research Station. General Technical Report NRS-76. Newtown Square, Pennsylvania.*

[274] Vengosh, A., Jackson, R. B., Warner, N., Darrah, T. H., & Kondash, A. (2014). A critical review of the risks to water resources from unconventional shale gas development and hydraulic fracturing in the United States. *Environmental science & technology*, 48

[275] Warner, N. R., Christie, C. A., Jackson, R. B., & Vengosh, A. (2013). Impacts of shale gas wastewater disposal on water quality in western Pennsylvania. *Environmental science & technology*, 47(20), 11849-11857.

Pennsylvania, and the Marcellus Shale reservoir generally, microseismic activity caused by fracking is not felt at the surface in part due to low levels of natural seismic activity.[276, 277, 278]

A single incident of seismic activity was felt in Youngstown, Ohio that was induced by deep well injection taking place in western Pennsylvania. The series of earthquakes took place in 2011 and 2012, the strongest being ranked as a 4.0 on the movement magnitude scale with no significant damages reported.[279] Other areas of the country with UOGD have been impacted by these human caused earthquakes, including in Oklahoma and Texas, both of which have experienced more significant impacts.[280]

5.5 Aesthetic Loss

While the geographic footprint of unconventional gas wells is relatively small compared to other forms of extraction such as coal, the cumulative impacts of fracking development may cause noticeable degradation of views and recreation sites. Decreases in biodiversity based on habitat reduction and fragmentation also may impact the quality of recreational opportunities.[281] Though individual land owners may have control over leases on their own land, adjacent owners may still be impacted by the aesthetic loss but do not receive payments from the lease. The extent of aesthetic loss in Pennsylvania is not well documented in the literature.

[276] Vengosh, A., Jackson, R. B., Warner, N., Darrah, T. H., & Kondash, A. (2014). A critical review of the risks to water resources from unconventional shale gas development and hydraulic fracturing in the United States. *Environmental science & technology*, 48

[277] Ellsworth, W. L. (2013). Injection-induced earthquakes. *Science*, 341(6142), 1225942.

[278] Rutqvist, J., Rinaldi, A. P., Cappa, F., & Moridis, G. J. (2013). Modeling of fault reactivation and induced seismicity during hydraulic fracturing of shale-gas reservoirs. *Journal of Petroleum Science and Engineering*, 107, 31-44.

[279] Kim, W. Y. (2013). Induced seismicity associated with fluid injection into a deep well in Youngstown, Ohio. *Journal of Geophysical Research: Solid Earth*, 118(7), 3506-3518.

[280] Ellsworth, W. L. (2013). Injection-induced earthquakes. *Science*, 341(6142), 1225942.

[281] Caldwell, J. A. (2015). *A policy and impact analysis of hydraulic fracturing in the Marcellus Shale region: a wildlife perspective*. Doctoral dissertation, University of Delaware.

6 Summary of Costs

The annual costs of fracking in Pennsylvania are estimated as $1.5 billion per year. This estimated annual cost is roughly equivalent to 0.3 percent of the state's Gross Domestic Product. ***If fracking continues at current rates, the costs for Pennsylvania are estimated to be at least $54 billion over the next twenty years.*** Table 4 summarizes the costs by type.

Table 4: Summary of Costs from Hydraulic Fracturing Activities in Pennsylvania

Effect	Annual Cost	20-Year Present Value Cost
Health Costs		
Low Birth Weights	$25,200,000	$410,000,000
Asthma & Respiratory Afflictions	$1,200,000	$19,500,000
Sleep Disruption	$30,000	$488,000
Depression	$86,400,000	$1,400,000,000
Averting Behavior	$22,000,000	$358,000,000
Community Costs		
Lost Housing Value	N/A	$1,500,000,000
Road Wear and Tear	$11,000,000	$174,000,000
Environmental Costs		
Habitat Loss	$7,250,000	$115,000,000
GHG Social Cost	$1,300,000,000	$49,900,000,000
Total	**$1.5 billion**	**$54 billion**

Source: Created by ECONorthwest

The present value calculation uses a three percent discount rate. For health costs, the present value adjusts for population growth of 0.25 percent per year, which is based on the Pennsylvania County Population Projections, 2010-2040 from Penn State Harrisburg.

Although several of the costs we considered were able to be monetized, many of the effects from UOGD in Pennsylvania did not have sufficient causal relationships or quantitative information to be monetized. We qualitatively discuss the costs that we did not quantify in this report and reference other studies which have researched the effect of the cost from hydraulic fracturing activities. Table 5 summarizes each unquantified cost of UOGD in Pennsylvania by type. While the magnitude of these costs is unknown, we do anticipate that there are real economic costs for each in Pennsylvania. Groundwater contamination is listed under all three categories because it will create health costs from exposure to pollutants, community costs to clean the water or find new water sources, and environmental costs due to the impact on the state's ecology. It is likely that groundwater contamination from UOGD activities will increase in frequency in the future as infrastructure deteriorates – ***groundwater contamination represents one of the largest potential future costs of fracking in Pennsylvania.***

Table 5: Additional Unquantified Costs from Hydraulic Fracturing Activities in Pennsylvania

Health Costs	Community Costs	Environmental Costs
Cancer	Long Term Employment	Habitat Fragmentation
Cardiac Afflictions	Impacts on Other Industries	Habitat Pollution
Migraines & Sinus Afflictions	Housing Rents	Bioaccumulation
Afflictions of the Organs	Crime	Seismic Activity
Sexually Transmitted Diseases	Vehicle Crashes	Aesthetic Loss
Occupational Hazards	Bonding Losses	Groundwater Contamination
Groundwater Contamination	Groundwater Contamination	

Source: Created by ECONorthwest

7 County-Level Total Fracking Costs

The costs presented thus far in the report represent statewide costs. The monetized costs are calculated based on per-person and per-well estimates, so they can be distributed based on the geographic frequency of wells and people living near wells. Using these individualized estimates, we apply the costs of UOGD to individual counties in Pennsylvania to more precisely describe how these costs are distributed across the state. Because UOGD occurs primarily in the northeast and southwest regions of the state, counties there experience higher costs. This does not mean that counties without wells experience no costs, because they are also impacted by the social cost of greenhouse gases and some habitat degradation costs. Because these costs have broader impacts than just the county, we have excluded the environmental costs from the individual county costs. The values used to calculate the county-level costs are as follows:

- Annual Health and Community Costs: $145,830,000
- Annual Environmental Costs: $1,307,000,000
- Number of Active Wells in Pennsylvania: 11,451
- Per Well Cost: $12,735
- Number of People Living within 2 Miles of Well (Active or Inactive): 951,641
- Per Person Cost: $153

By dividing the annual health and community costs by the number of active wells in Pennsylvania, we get a cost per active well of approximately $12,735. To estimate how this cost is distributed by county, we take the number of active wells in each county and multiply them by this per well cost. Table 6 presents the results of these calculations for counties with more than 1 percent of the state total active wells. Washington County has the highest number of active wells and therefore the highest annual costs in the state.

Table 6: Counties with Highest Annual Costs of Hydraulic Fracturing based on Number of Wells

Rank	County	Active Wells in County	Percent of State Active Wells	Estimated Annual Costs in County based on Number of Wells
1	Washington	1906	17%	$24,273,000
2	Susquehanna	1624	14%	$20,682,000
3	Greene	1425	12%	$18,148,000
4	Bradford	1322	12%	$16,836,000
5	Lycoming	944	8%	$12,022,000
6	Tioga	842	7%	$10,723,000
7	Butler	610	5%	$7,768,000
8	Westmoreland	373	3%	$4,750,000
9	Fayette	326	3%	$4,152,000
10	Armstrong	293	3%	$3,731,000
11	Wyoming	280	2%	$3,566,000
12	Allegheny	205	2%	$2,611,000
13	Elk	181	2%	$2,305,000
14	Beaver	163	1%	$2,076,000
15	Sullivan	162	1%	$2,063,000

Rank	County	Active Wells in County	Percent of State Active Wells	Estimated Annual Costs in County based on Number of Wells
16	McKean	121	1%	$1,541,000
17	Clearfield	103	1%	$1,312,000
18	Potter	102	1%	$1,299,000
19	Clinton	84	1%	$1,070,000
20	Cameron	60	1%	$764,000
21	Lawrence	58	1%	$739,000

Source: Created by ECONorthwest

Similarly, we also estimate a cost per number of residents living within 2 miles of a well (active or inactive) for each county based on the differences in this population size. The average costs per person living near a well of $153 is multiplied by the number of people in the county residing near wells to estimate the annual cost based on the number of wells. Table 7 presents the twenty counties with the highest costs based on the population living near wells.

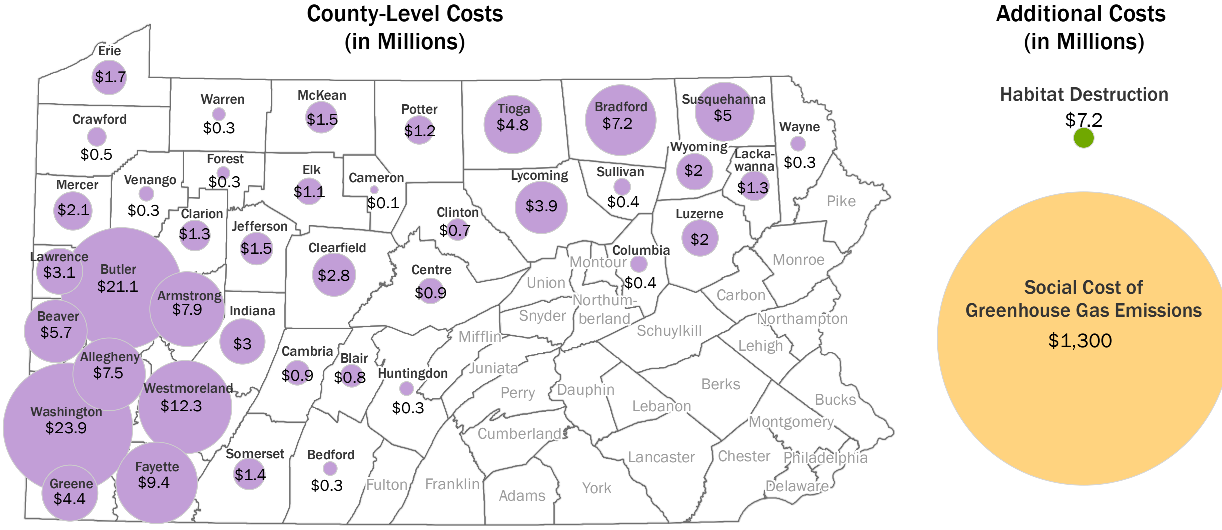
Table 7: Counties with Highest Annual Costs of Hydraulic Fracturing based on Population

Rank	County	Number of People living within 2 miles of Well	Cost based on people living within 2 miles
1	Washington	155,865	$23,885,000
2	Butler	137,897	$21,131,000
3	Westmoreland	80,337	$12,311,000
4	Fayette	61,473	$9,420,000
5	Armstrong	51,706	$7,923,000
6	Allegheny	48,934	$7,499,000
7	Bradford	46,967	$7,197,000
8	Beaver	37,519	$5,749,000
9	Susquehanna	32,517	$4,983,000
10	Tioga	31,486	$4,825,000
11	Greene	29,015	$4,446,000
12	Lycoming	25,544	$3,914,000
13	Lawrence	20,044	$3,072,000
14	Indiana	19,554	$2,996,000
15	Clearfield	17,961	$2,752,000
16	Mercer	13,997	$2,145,000
17	Luzerne	12,837	$1,967,000
18	Wyoming	12,724	$1,950,000
19	Erie	11,223	$1,720,000
20	Jefferson	9,944	$1,524,000

Source: Created by ECONorthwest

The costs in Table 7 are demonstrated spatially by county and at the state-level in Figure 16. Although counties in the Southeast region of Pennsylvania do not have any wells, they are also subject to the environmental costs of fracking including habitat destruction and the social cost of greenhouse gas emissions, valued at approximately $1.3 billion per year.

Figure 16: Annual Costs of Fracking in Pennsylvania based on Number of People Living within 2 Miles of Well (In Millions of Dollars)



Source: Created by ECONorthwest
Note: The size of the circle is proportional to the number of people living within 2 miles of a well and therefor also proportional to the costs of fracking based on this population-weighted allocation. Environmental costs of fracking, habitat destruction and social cost of GHG emissions, are for the entire state because their effects are not limited to counties with wells.

8 Conclusions

UOGD in Pennsylvania has transformed the state in a relatively short amount of time. While this boom is creating economic activity in the state, it is doing so by imposing large and long-term costs on residents. If fracking continues at current rates, the economic, social, and environmental costs for Pennsylvania are estimated to be at least $54 billion over the next twenty years. Increases in the rates of fracking in the state will increase these costs.

Not all costs from UOGD can be monetized. For many effects there is not sufficient data or information to estimate costs. Some of this lack of information is due to secrecy created by the oil and gas companies. For example, some of the chemicals used in the fracking process are able to not be disclosed as trade secrets. Lawsuit settlements that include non-disclosure agreements are another mechanism to restrict information, leading to many of the instances of oil and gas affecting water or health of residents not being publicly available.

In addition to the monetized costs, other economic costs should also be considered as resulting from UOGD in Pennsylvania. These non-monetized costs include:

- Potential for catastrophic groundwater contamination and associated health, community, and environmental costs;
- Increases in fatal traffic accidents, primarily in high well-density counties;
- Detrimental effects to the water resources of the state from the high volumes of fresh water and groundwater being used for extraction of natural gas;
- Long-term economic effects from lower educational attainment, primarily among men;
- Lack of economic resiliency from reliance on natural resource commodity subject to boom and bust economic cycles;
- Long-term health effects, including increased cancer rates;
- Environmental effects from the accumulation of chemicals and pollutants over time;
- Impacts to recreational hunters and fishermen due to declining wildlife populations;
- Fiscal risk to the state from inadequate bonding requirements which could transfer the costs of clean-up to the state;
- Loss of land for agriculture and recreation due to creation of well-pads and inadequate restoration once drilling is completed; and
- Perpetuation of reliance on U.S. energy on fossil fuels that delays and impedes transitions to renewable energy.

The costs of fracking in Pennsylvania are highest in regions with the higher amounts of UOGD activity but do affect the entire state and have broad and long-term impacts. The continued extraction of natural gas from the Marcellus and Utica shales will continue to disrupt landscapes, communities, and the environment, imposing further costs at more intensive levels of development. Many of these costs will persist even if fracking were to stop today, such as long-term health risks, but most all could be remedied somewhat quickly with a moratorium on UOGD activities in the state.