Extracting the Economic Benefits of Natural Resources in the Marcellus Shale Region

by

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ABSTRACT

My thesis seeks to explore the challenge of value capture from natural resources using the case of the Marcellus Shale in West Virginia and Pennsylvania as an exemplar. I examine the mechanisms in place to capture the economic benefits of shale gas extraction in these two states, performing a rough cost benefit analysis that attempts to quantify the economic impact of a single natural gas well drilled in each state. The thesis has two objectives: first, to determine whether or not drilling in the Marcellus Shale produces benefits that are captured and distributed in a way that accounts for the costs of natural gas extraction in Pennsylvania and West Virginia. Second, I hope to provide a cost benefit analysis framework that any locality considering allowing the shale gas industry to operate within its boundaries could utilize to recognize gaps in the distribution of costs and benefits early on, prior to the start of drilling.

In addition to performing a cost benefit analysis under normal operations, I also estimate the costs associated with a groundwater contamination rate of 1.2% of drilled shale gas wells in 2012 in both states. This analysis reveals that the costs of groundwater contamination exceed the level of funding allocated to address these potential costs by more than $1 billion in some scenarios.

In response to this lack of cost coverage, I suggest several policy solutions aimed at increasing the level of financial assurances states have in place to address the potential negative externalities resulting from the shale gas industry. By limiting the potential negative economic impact of the shale gas industry, these policy suggestions also support stronger value capture.

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Chapter 1

Introduction

Governing bodies and communities around the world have struggled to develop policies that allow their constituents to reap the economic benefits of natural resource extraction while limiting its costs. More specifically, stakeholders seek to avoid the "resource curse," a term used to describe a frequent occurrence in resource rich regions of the world—instead of benefiting from the resource in question, many resource rich regions end up worse off in terms of poverty and human development than if natural resources had never been discovered and/or exploited at all.

My thesis seeks to explore the challenge of value capture from natural resources using the case of the Marcellus Shale in West Virginia and Pennsylvania as an exemplar. I examine the mechanisms in place to capture the economic benefits of shale gas extraction in these two states. I perform a rough cost benefit analysis that attempts to quantify the economic impact of a single natural gas well drilled in each state. Beyond this analysis, I examine the distribution of costs and benefits, looking for gaps where there are uncovered costs (in spite of substantial other benefits in some cases). In summary, I have two objectives: first, to determine whether or not drilling in the Marcellus Shale produces benefits that are captured and distributed in a way that accounts for the costs of natural gas extraction in Pennsylvania and West Virginia. Second, I hope to provide a cost benefit analysis framework that any locality considering allowing the shale gas industry to operate within its boundaries could utilize to recognize gaps in the distribution of costs and benefits early on, prior to the start of drilling. Local policymakers and community members could in turn use this knowledge to make informed decisions about whether or not they want the shale gas industry and/or how the industry should be regulated to address costs incurred by the community.

There are a variety of factors that motivate my decision to use the Marcellus Shale in Pennsylvania and West Virginia as case studies. First, the development of the Marcellus Shale is a fairly recent occurrence. The first commercially viable natural gas well was drilled in the Marcellus Shale in Pennsylvania using hydraulic fracturing and horizontal drilling techniques just over a decade ago in 2003 ("Drilling & Mining: History of Drilling in Pennsylvania" 2014). In the years since, the volume of natural gas extracted from the Marcellus Shale play has increased rapidly.[1] Over a three-year period from 2008 to 2011 the volume of shale gas extracted in Pennsylvania grew from 9,757 million cubic feet (mcf) to 1,068,288 mcf ("Natural Gas Gross Withdrawals and Production" 2013). In West Virginia, shale gas extraction volumes increased significantly (though less dramatically than in Pennsylvania) from 53,436 mcf to 227,012 mcf in the same time period ("Natural Gas Gross Withdrawals and Production" 2013). These figures are an indication of the dramatic natural resource boom occurring on the ground in these two states at present, and thus the urgent need for policymakers and other local stakeholders to think critically about value capture and addressing the potential costs of natural gas extraction to communities and the environment.

Second, Pennsylvania and West Virginia share similar histories of natural resource development, which at various points in history generated significant economic benefits as well as long term costs to communities and the environment. Both states experienced booms in lumber and coal mining from the late 1700s through approximately the 1930s, which led to severe environmental damage (Pennsylvania

[1] Play in this case refers to a geographic area believed to contain natural gas reserves.

Department of Environmental Protection 2014)(West Virginia State Archives 2014). The current shale gas boom is seen as a second, third or even fourth chance, by stakeholders in these states to figure out how to maximize benefit capture from natural resources while limiting costs.

Another factor motivating my selection of West Virginia and Pennsylvania is the differences in policy mechanisms the two states use to capture and distribute the benefits of shale gas extraction. The states' differences in policy and regulation of the shale gas industry allow me to compare and contrast, going beyond determining which state captures the most economic benefit overall to examining which state is able to most efficiently distribute these benefits in a way that addresses the costs of shale gas extraction.

Finally, I have a personal connection to both of these states as a native Pennsylvanian, with roots in the Appalachian valleys of West Virginia. I grew up in a family of farmers (some of whom still operate farms in West Virginia today, though none that are impacted by shale gas drilling) and so wanted to develop a better understanding of the issues relevant to my home state and ultimately generate ideas around how we can responsibly prosper from our natural resources by first covering the costs of their extraction.

The remaining portion of this introductory chapter will provide a brief history of natural resource development in Pennsylvania and West Virginia in order for readers to become more familiar with the local context and historical relationship with natural resources in these states. This section will be followed by an overview of Marcellus shale natural gas development and summary of the drilling process currently employed there. These overviews will provide readers with the geological and technological background they need to understand the economic and environmental implications of shale gas extraction. The chapter will conclude with a brief overview of the results of my cost benefit analysis.

Moving beyond the introduction, Chapter 2 will describe the regulatory environments for shale gas extraction in Pennsylvania and West Virginia. Understanding the regulatory environment is essential to understanding the costs and benefits associated with shale gas extraction. Chapter 3 will examine the cost benefit analysis for a single shale gas well drilled in Pennsylvania and West Virginia in more detail by specifying the assumptions included in this analysis. Chapter 4 summarizes how the costs and benefits of shale gas extraction are aligned in terms of their distribution, highlighting areas where benefits fall short of addressing the costs of extraction. This final chapter also suggests policy solutions for increasing benefit capture relative to costs and improving the distribution of benefits in order to ensure that known costs of extraction are addressed.

History of Natural Resources in Pennsylvania and West Virginia

"We like to think technology is different, and we have different attitudes now about how people treat the land, but I guess it remains to be seen. We certainly have thought about that a lot. After the coal industry, the land was left with acid mine runoff we still deal with today. And after the lumbering, there were no trees left. Hopefully today it's different."

-Matt Carl, Historian, Bradford County Historical Society (Detrow 2012b)

While the boom in natural gas produced by the Marcellus Shale may be new to Pennsylvania and West Virginia, the two states have a long history of extracting natural resources for economic gain. In Pennsylvania, the coal industry sprouted first, developing in the late 1700s (Pennsylvania Department of Environmental Protection 2014). The industry was concentrated in western Pennsylvania around the city of Pittsburgh, which consumed more than 400 tons of coal per day for industrial use by 1830 (Pennsylvania

Department of Environmental Protection 2014). The coal industry peaked in 1918 when it employed 330,000 miners, producing 277 million tons of coal valued at $705 million at the time (Edmunds 2002). While still active today, the coal industry has been in decline in Pennsylvania ever since (Michael Wood and Sharon Ward 2009).

While this early coal boom supported job creation and economic development in Pennsylvania as well as became the impetus for the founding of entire towns, it came at a high cost. Before 1968, coal mine operators had few regulations to follow when operating around water (Michael Wood and Sharon Ward 2009). As a result, the mining process exposed large portions of Pennsylvania's water supply to pyrite, a waste byproduct of coal production. Pyrite polluted the state's water supply, increasing its acidity (Michael Wood and Sharon Ward 2009). As of 2009, Pennsylvania had "2,500 miles of streams polluted by acid mine drainage and 250,000 acres of unreclaimed surface mine land that [would] cost $15 billion to remediate" (Michael Wood and Sharon Ward 2009). Most of this remediation will occur at the expense of taxpayers as the mines' former owners and operators abandoned their holdings long ago (Michael Wood and Sharon Ward 2009).

The coal industry is still active in Pennsylvania today; though demand for cleaner burning fuels as well as more strict environmental regulations has led to a dramatic reduction in output and job loss in the sector. As recently as 2007, coal accounted for 50% of the United State's electricity generation (Silverstein 2013). At the time of writing it was down to 20-30% (Silverstein 2013).

Pennsylvania has felt the impact of weak demand for coal, with the state's coal production levels falling 80% since 2008 (Silverstein 2013). The state is expected to lose 3,000 jobs in the coming years due to the closure of coal plants (Bastasch 2012). The reality of a dying coal mining industry places greater emphasis on the hope that a growing natural gas industry focused on the development of the Marcellus Shale will lead to job creation, replacing some of the job loss occurring in the coal sector.

Beyond coal mining, which is perhaps the most well known natural resource industry in Pennsylvania historically, the state has also experienced significant exposure to the lumber and oil industries. The name "Pennsylvania" roughly translates to "Penn's Woods," named after the state's founder, William Penn, and in honor of the area's rich forestlands. It was these forests that attracted the attention of the lumber industry beginning in the 1890s (Detrow 2012b). Unlike the coal mining industry however, lumbering was short-lived in Pennsylvania dying out by 1930. Historian Matt Carl of the Bradford County, PA Historical Society says "They ran out of wood and stopped cutting" (Detrow 2012b). The lumbering industry was rapacious, "clear cutting mountain after mountain in northeast Pennsylvania" (Detrow 2012b). Similar to Pennsylvania's experience with coal mining, lumbering offered short term economic benefits in return for long term environmental damage.

A little known fact, Pennsylvania was home to the first oil well in the world, drilled in Titusville, PA in 1859 by Edwin Drake. Over the years that followed, the state experienced an oil boom defined by "boomtowns" such as Pithole City in northwestern Pennsylvania, which popped up seemingly over night in 1860 with the arrival of oil prospectors, workers, and merchants, and vanished just as quickly, ceasing to exist by 1880 after the oil supply dried up (ExplorePAhistory.com 2014a).

Similarly, Pennsylvania has prior experience with natural gas production. Drilling for natural gas occurred around the Pittsburgh area as early as the 1880s (ExplorePAhistory.com 2014b). In 1950, drillers in Leidy Township in Central Pennsylvania hit a natural gas well that produced up to 15 mcf daily and attracted more than 30 oil and gas companies and independent operators to the area (ExplorePAhistory.com 2014c). The well dried up within a decade (Kleinle 2012).

Similar to Pennsylvania, coal mining started in West Virginia in the late 1700s but did not become an essential component of the state's economic development until the 1880s (West Virginia Everettville Historical Association 2010). The earlier introduction of railroad lines in West Virginia in the 1850s and the industrial revolution, which supported growing demand for coal, led to a boom in the industry at that time (West Virginia Everettville Historical Association 2010).

Over the century that followed, the coal industry provided economic benefits to state residents, serving as an important source of employment, while also contributing to environmental damage. Like in Pennsylvania, West Virginia mining companies employ a mining process known as mountain top removal, which essentially involves "removing the top of a mountain in order to recover the coal seams contained there" (Copeland 2013). Mountain top removal mining is known to have a heavy negative impact on the environment, polluting nearby water supplies, eliminating streams, and impacting aquatic life (Copeland 2013).

Environmental disasters linked with coal production continue to occur in West Virginia today. As recently as January 2014, a chemical used to process coal leaked into the Elk River of West Virginia. In response, the National Guard came to deliver fresh water supplies to local residents (Biggers 2014).

In recent years, the coal mining industry of West Virginia has suffered from the same decline in demand for coal that impacts Pennsylvania. Coal production has decreased by 50% since 2008, leading to job loss (Silverstein 2013). There is a prevailing sense of hope among residents that natural gas extracted from the Marcellus Shale will help to replace some of these jobs.

In addition to coal, West Virginia was also home to a boom and bust lumber industry. The first band saw was introduced in the state in 1881 (Hiltz 2014). Over the decades that followed, the lumber industry's band saws were used to harvest an average of 17 acres of timber per day until approximately 1920 when the original forest was "completely depleted, except for a few isolated areas of small acreage" (Hiltz 2014).

West Virginia also began oil and gas production in the same year as Pennsylvania—1859. In the years that followed, production increased until peaking in 1900 (West Virginia Geological and Economic Survey 2004). Natural gas production began to grow around this time, reaching a peak in 1934 and then again in 1970 before slowing down until recently when the production of natural gas from shale formations began (West Virginia Geological and Economic Survey 2004).

In summary, both West Virginia and Pennsylvania have long and complicated histories with natural resources that provided fleeting but substantial economic benefits while causing long-term environmental damage, which in some cases is still being dealt with today. Natural gas extracted from the Marcellus Shale presents the states with yet another opportunity to try to get the equation right—to capture the maximum economic value of natural resources, using short-term returns to make long-term investments, while limiting the deleterious effects of their extraction on the natural environment and communities.

The Marcellus Shale

The Marcellus Shale is a sedimentary rock formation that materialized over millions of years from mud and organic materials (State Impact NPR 2014a). The shale formation, which also contains large deposits of natural gas, covers most of West Virginia, 60% of Pennsylvania, and most of the upper portion of New York state (Considine 2010).

Given the Marcellus Shale's location close to consumer markets, natural gas from the shale play is considered particularly valuable (Considine 2010).

There are various estimates available for the amount of natural gas reserves contained within the Marcellus. Early studies placed recoverable reserves at 489 trillion cubic feet (TCF) (Considine 2010). More recently, in 2012, the U.S. Energy Department reduced its estimate for the volume of recoverable natural gas to 141 tcf, based on drilling experience in the Marcellus Shale play to date (Buurma 2012). It is nonetheless, one of the largest natural gas deposits in the United States.

The natural gas contained in the Marcellus Shale is considered an "unconventional energy source" as it is typically more challenging to extract than conventional sources of oil and gas (Canadian Association of Petroleum Producers 2013). However, improvements in drilling technology have made the development of shale gas physically possible as well as commercially viable.[2]

It's important to note that the Marcellus Shale contains deposits of both "dry" and "wet" gas. Dry gas is composed almost entirely of methane, while wet gas is less than 85% methane and contains a variety of additional liquid natural gases like ethane and butane (U.S. Energy Development Corporation 2014). Most of the Marcellus Shale's wet gas is concentrated in southwestern Pennsylvania. At the time of writing, increased domestic use of methane had driven down its price, influencing drillers to focus their attention on deposits of wet gas containing substances like ethane that can be sold to petrochemical companies (State Impact NPR 2013b). Petrochemical companies use ethane crackers to

[2] More specifically, improvements in horizontal drilling technology, which allow operators to drilling horizontally for a mile or more, have been key to facilitating the growth of the shale gas industry.

transform the substance into ethylene, which is used in manufacturing plastic (State Impact NPR 2013b).[3]

Drilling in the Marcellus Shale is a fairly recent phenomenon. In 2005, only three wells each were drilled in Pennsylvania and West Virginia (Considine 2010). In 2007, 114 Marcellus shale gas wells were drilled in Pennsylvania; West Virginia experienced slightly more drilling with the introduction of 127 wells (Considine 2010). In 2008, Pennsylvania outpaced West Virginia in terms of drilling activity; drilling in both states became especially vigorous in 2009 (Considine 2010). According to data published by the Pennsylvania Department of Environmental Protection (DEP), in 2013 there were a total of 1,208 unconventional wells drilled in Pennsylvania. In the same year in West Virginia, 221 unconventional wells were drilled (see **Tables 8** and **9**).

Drilling for Unconventional Natural Gas

Natural gas is extracted from deposits in shale formations far below the Earth's surface, up to 10,000 feet or nearly two miles (Blackman 2013). Extraction in this case is a two-step process that entails first drilling into the shale formation using "horizontal drilling" technology. Horizontal drilling is a fairly new technological advance that came into use in the early 1990s (Blackman 2013). It allows drilling technicians to first drill into the Earth's surface vertically then use flexible piping and steerable drill bits to drill horizontally more than a mile through areas of promising shale formations. Next, large volumes of water are pumped through the drilled borehole at high pressure in order to fracture shale rock and release liquids such as petroleum and natural gas. This technique is known as hydraulic fracturing (or "fracking") and has been in use since 1947 (Maugeri

[3] Ethane cracker plants heat up the ethane from natural gas until it breaks into smaller components to create ethylene. Ethane crackers normally feed ethylene to other nearby plants to form additional products ("Frequently Asked Questions about Ethane Crackers" 2014).

2013). Sand and chemicals are normally mixed with the water injected into the borehole as well.[4] These serve to hold the fractures or fissures created open once the water has been removed from the well in order to allow for the gas deposits to be removed.

Hydraulic fracturing is an extremely controversial extraction technique due to its perceived environmental impacts and its scale—which at the time of writing is significant enough to overwhelm state regulatory capacity, resulting in increased risks to communities and the environment. Current research shows that there are two main perspectives on hydraulic fracturing. Industry advocates such as the Marcellus Shale Coalition claim that the technique allows for safe oil and gas extraction and that horizontal drilling limits environmental impact by eliminating the need to drill many vertical boreholes (Blackman 2013). Those opposed to the practice, including a variety of environmental groups and fracking protestors such as New Yorkers Against Fracking, claim that hydraulic fracturing pollutes ground water, threatens natural habitats, and poses a serious risk to public health.

The technical aspects of shale extraction are crucial to understand for this thesis insofar as their impact on economic outcomes. For example, Maugeri (2013) writes that in the conventional oil and gas sectors the technical demands of extraction require oil and gas companies to operate with a long-term business plan. It can take an average of 8-10 years for oil and gas companies to bring a new conventional discovery online (Maugeri 2013). Then once it comes online, there is very little opportunity to turn back as technical specificities make "turning off" a well infeasible.

[4] Hundreds of chemicals are used in the hydraulic fracturing process, including lead, uranium, mercury, ethylene glycol, radium, methanol, hydrochloric acid, and formaldehyde.

For shale drilling however, the opposite is true. According to Maugeri (2013), a shale well can be interrupted quickly "within a few months or even weeks" if commodity prices render it unprofitable. Similarly, shale drilling can be restarted again quickly in response to a sudden increase in commodity prices. These technical characteristics impact shale economics by making it clear that states like West Virginia and Pennsylvania must consider shale as a volatile new source of revenue utilizing and regulating it accordingly. According to **Tables 8** and **9** in Chapter 2, drilling activity has already begun to slow in Pennsylvania and West Virginia.

Similarly, the technical aspects of shale drilling affect the regulation and thus the economic impact of the industry by determining the players. Where traditional oil and gas normally attracts large, well-established companies willing to make long-term investments, shale oil and gas attracts many small players. Maugeri (2013) likens these small players to "guerilla groups," in comparison to large oil and gas companies that he calls "traditional armies." Within Pennsylvania alone there were 63 active oil and gas operators in 2012 (Nash 2013). The top 12 companies accounted for 85% of the shale gas extracted in the state, leaving 51 companies to account for the remaining 15% (Nash 2013). This breakdown of players indicates the challenges of applying economic or environmental regulation to a dispersed network of operators.

Cost Benefit Analysis of Shale Gas Industry in West Virginia and Pennsylvania

Due to a lack of data addressing costs on the aggregate level, this analysis is intended to estimate the potential costs and benefits of a single shale gas well drilled in either West Virginia or Pennsylvania. The potential costs to the community associated with drilling the well are very similar in both states (see **Table 1**). The primary challenge associated with estimating these costs is the variability and unknown quality of some measures, including property value loss and public health expenses. Further, the cost estimates associated with water contamination could quickly escalate depending on the number of incidents of contamination.

Table 1 - Costs and Potential Damages Resulting from Single Shale Gas Well

Road Damage	$18,000 over lifetime of well
Property Value Loss	8.5%
Water Testing	$700,000
Water Cleaning	$150,000
Water Replacement in 24 hours (delivery of 5 gallon water bottles)	$19,192 daily
Water Replacement in 72 hours (water delivery to tanks)	$300 daily
Permanent Water Replacement	$26,500 – Drilling a new well (per home), or $621,052 – Connecting to city water (per home)
Oil and Gas Inspectors	$1,150 annual (Pennsylvania), $1,630 annual (West Virginia)
Plugging Well	$80,000 one time fee
Site Remediation	$650,000 one time fee

The permitting and assurances and benefits are more easily determined than costs as they are primarily the result of regulations or known (or easily estimated) natural gas production quantities and employment data. There is more variation from state to state however, as a result of differing regulations (see **Tables 2,3,4,** and **5**).

Ideally, permitting and assurances should cover the costs the shale gas industry imposes on the public. The data presented here reveals that this is not the case. There is a significant gap between the costs of site remediation and site remediation bonds. There is also no provision in place to compensate property value loss or to guarantee that a natural gas operator covers the costs associated with potential water contamination.

Table 2 - Permitting and Assurances in Pennsylvania (per well)

Drilling Permit (per well)	$2,500
Site Remediation Bond	If well bore is less than 6,000 ft and there are less than 50 wells- $4,000 per well, more than 50 wells $35,000-$100,000 required in addition to individual well amount. If well bore is

	greater than 6,000 ft.- $10,000 per well bond required + lump sum for more than 25 wells ($140,000-$430,000)
Road Bond- Paved Road	$12,500 per mile
Road Bond – Unpaved	$6,000 per mile
Road Bond – District Blanket Bond	$10,000
Insurance	Not required
Road Maintenance Agreements	?
Heavy Load Transit Permitted	Approximately $30

Table 3 - Permitting and Assurances in West Virginia (per well)

Drilling Permit (first well)	$10,000
Drilling Permit (additional wells)	$5,000
Site Remediation Bond (single well)	$50,000
Site Remediation Blanket Bond	$250,000
Road Bond- Paved Road	$100,000 per mile
Road Bond – Tar and chipped Road	$35,000 per mile
Road Bond – District Blanket Bond	$250,000
Road Bond – State Blanket Bond	$1,000,000
Insurance	Not required
Road Maintenance Agreements	?
Heavy Load Transit Permit	Approximately $26

Table 4 - Economic Benefits in Pennsylvania (per well)

Employment	50 local jobs, 3-6 months in duration, with average salary of $75,000
Corporate Tax – Dry Well	$75,796 annual
Corporate Tax – Wet Well	$221,559 annual
Impact Fee	$50,000 first year, $310,000 over 15 years
Royalties – Dry Well	$790,955 annual
Royalties – Wet Well	$2,311,545 annual
Lease Payments	$6,388 one time payment, lease valid for 5 years
Damage Payments to Surface Owners	$1,600 one time payment
Total Value Added Estimate	$2,373,618 annual

Table 5 - Economic Benefits in West Virginia (per well)

Employment	50 local jobs, 3-6 months in duration, with average salary of $75,000
Corporate Tax – Dry Well	$49,317 annual
Corporate Tax – Wet Well	$144,157 annual
Property Tax	$160,727 annual
Severance Tax – Dry Well	$237,250 annual

Severance Tax – Wet Well	$693,500 annual
Royalties – Dry Well	$593,125 annual
Royalties – Wet Well	$1,733,750 annual
Lease Payments	$6,388 one time payment, lease valid for 5 years
Damage Payments to Surface Owners	$1,600 one time payment
Total Value Added Estimate	$2,373,618 annual

These findings are explored in greater detail in Chapter 3, which presents the cost benefit data provided here under a number of scenarios, estimating the potential impact of multiple water contamination incidents. Chapter 3 also includes more detailed descriptions of the assumptions behind these calculations.

Conclusion

Despite long and tumultuous histories of natural resource extraction, Pennsylvania and West Virginia residents are hopeful that new technologies and stronger environmental and economic regulation will allow the development of the Marcellus Shale to proceed successfully, with minimal damage to the environment and communities and maximum economic benefit. The next chapter discusses new regulations legislators in both states have put in place with the goal of meeting these objectives. Nonetheless, while there is great aspiration, the technical specificities of drilling in the Marcellus Shale present risks for environmental damage that will be challenging to regulate. Further, the nature of shale gas drilling makes it easy for gas companies to walk away quickly when natural gas prices fall too low; resulting in the risk that the Marcellus Shale will be little more than another quick resource boom for West Virginia and Pennsylvania, leaving little long-term economic impact.

The following chapter will detail the regulatory environment put in place in Pennsylvania and West Virginia to address some of these risks.

Chapter 2

Regulating the Shale Gas Industry in Pennsylvania and West Virginia

Introduction

The last chapter was intended to provide readers with an overview of the historical and geological context surrounding shale gas extraction in Pennsylvania and West Virginia, as well as introduce the cost benefit analysis method explored further later in the thesis. This chapter will focus on the regulatory context surrounding the shale gas industry in these two states.

Understanding the regulatory context is essential. Regulation informs the level of and distribution of costs and benefits that result from natural gas extraction. For example, if the state Department of Environmental Protection (DEP) is required to provide full-time well inspectors, the state DEP will incur the costs of the inspectors' recruitment, training, and salaries. To address these costs, the state will probably try to capture some of the economic benefits associated with natural gas extraction and funnel them to the DEP to pay the inspectors that regulate the industry. This could be accomplished by imposing fees or taxes on a number of different actors in various points in the extraction and distribution process. Key to understanding how costs and benefits align is examining the regulatory policies that generate (or attempt to reduce) revenue for the natural gas extraction industry and seek to minimize environmental and social costs to the communities involved.

This chapter will begin with a brief overview of federal policies that regulate natural gas extraction via hydraulic fracturing. Federal regulation of hydraulic fracturing, however, is limited. The bulk of the chapter will focus on state level regulation of shale gas drilling and production in Pennsylvania and West Virginia. The chapter will conclude with a discussion of regulatory enforcement. Even if a state has very strong regulations on the books, if they are not being enforced, gas drilling and production may result in much higher costs than would otherwise be the case.

Regulatory policies surrounding hydraulic fracturing for shale gas are still very much in flux at both the federal and state levels. At the time of writing, the Obama Administration was working with the Bureau of Land Management to draft a bill that would provide for greater regulation of drilling for shale gas on federal lands. Meanwhile, in November 2013, the House passed a bill that would block the Department of the Interior from regulating hydraulic fracturing in states that have their own regulations (Kasperowicz 2014). Needless to say, federal regulation of hydraulic fracturing is a controversial topic.

At the state level, lawmakers in Pennsylvania and West Virginia are still "playing catch up," updating their legislation under intense time pressure in light of the unexpected and rapid increase in drilling underway in these states. For example, West Virginia passed a new Horizontal Drilling Act in December 2011. Pennsylvania passed a new Oil and Gas Law (Act 13) in February 2012. In both cases, the laws were met with criticism from industry, environmental groups, and state residents. In fact, sections of Pennsylvania's Act 13 have been subject to state Supreme Court rulings and were on repeal at the time of writing.

I highlight the "newness" of these regulations as a disclaimer—the regulatory context described in this chapter, and thus the costs and benefits this regulation produces are still very fluid and subject to change.

Federal Regulation of Hydraulic Fracturing for Natural Gas

Federal regulation of the shale gas industry is primarily defined by a series of exemptions from major federal legislation intended to protect the environment and U.S.

residents. There are some efforts by the Obama administration currently taking place to extend the influence of federal regulation of shale gas extraction, but none of these efforts were successful at the time of writing.

The Clean Water Act and Safe Water Drinking Act provide the most extensive forms of federal regulation affecting the shale gas industry, though the industry is also subject to exemptions in the case of the Safe Water Drinking Act. Under the Clean Water Act, shale gas operators are required to obtain stormwater permits for the construction and operation of well pads and access roads that cover an area larger than one acre. Since most shale gas drilling and production sites are larger than one acre, this regulation applies in a majority of cases (Kansal 2012). In order to secure the permit, operators must provide the Environmental Protection Agency (EPA) with a stormwater pollution prevention plan "that serves to control the sedimentation of waterways near well pads and limit the quantity of pollutants, such as diesel and other chemicals that would enter waters due to leakage from equipment and general industrial activity" (Kansal 2012).

Further, the Clean Water Act restricts operators from discharging pollutants into bodies of water without a permit from the National Pollutant Discharge Elimination System (NPDES) program under the EPA's Office of Water Management (Kansal 2012). This regulation primarily applies to shale gas operators in regards to the disposal of fluids used in hydraulic fracturing.

The Safe Water Drinking Act was created "to protect drinking water aquifers from contamination associated with the injection of liquid waters into underground wells" (Spence 2014). Given this language alone, one may assume that hydraulic fracturing for natural gas would be a natural application of the law given the practice of injecting fluids into underground wells that is part of hydraulic fracturing. However, the 2005 Energy

Policy Act passed by Congress grants an exemption for hydraulic fracturing from the Safe Water Drinking Act.

According to the same 2005 Energy Policy Act, the Safe Water Drinking Act can only be applied to hydraulic fracturing in cases where diesel is used as a fracking fluid. While only a small percentage of hydraulic fracturing wells use diesel fuels (2% according to an EPA study), operators of these wells are required to obtain a permit from the EPA's underground injection control program (United States Environmental Protection Agency 2014).

Further, the Safe Water Drinking Act can be used to regulate the disposal of hydraulic fracturing waste in underground injection control wells (Kansal 2012). Underground wells used to store hydraulic fracturing waste are referred to as "Class II" disposal wells under EPA regulation. Class II disposal wells are commonly used to store salt water (brine) that is injected into the earth to stimulate oil and gas production and brought to the surface again during the extraction process. According to the EPA website, this brine can contain "toxic metals and radioactive substances;" it can also be "very damaging to the environment and public health if it is discharged to surface water or the land surface," thus the use of underground injection control wells to dispose of the waste (United States Environmental Protection Agency 2014). The EPA provides permits for the use of Class II disposal wells. States can also apply for supremacy to regulate Class II wells in the event the state can demonstrate to the EPA that it has permitting, inspection, monitoring, record keeping and reporting programs in place that comply with EPA regulations of Class II wells (United States Environmental Protection Agency 2014).

In summary, given that hydraulic fracturing is exempt from the Safe Water Drinking Act unless diesel fuel is used (which it is not in most cases), states are ultimately responsible to develop and enforce regulation that protects aquifers from damage linked with shale gas extraction.

At the time of writing, there was an ongoing effort by several senators, including Pennsylvania Senator Robert Casey, Jr. to pass the Fracturing Responsibility and Awareness of Chemicals Act (FRAC Act), which would require shale gas operators to disclose all the chemicals used in fluids for hydraulic fracturing and obtain permits before injecting fracking fluids underground (Goss 2013). The FRAC Act would essentially eliminate the exclusion of hydraulic fracturing for natural gas from the Safe Drinking Water Act. The bill was introduced to the Senate for the third time in July 2013 with little hope that it would pass through even the committee level (Goss 2013).

Similarly, hydraulic fracturing is exempt from the federal Emergency Planning and Community Right to Know Act. Under this act, firms are required to complete a "toxic chemical release form" that "[details] their use of chemicals" to the EPA (Spence 2014). If natural gas operators were required to comply with this Act they would have to report all of the chemicals used in the hydraulic fracturing process.

Hydraulic fracturing is also exempt from the Resource Conservation and Recovery Act (RCRA), which was designed "to take a comprehensive approach to control hazardous wastes [...] from 'cradle to grave'"(Kansal 2012). In the late 1980s, the EPA decided "regulation of oil and gas wastes as hazardous wastes was 'unwarranted' due to both the significant costs that would be imposed on oil and gas producers [...] and the fact that state regulation of oil and gas waste was generally adequate" (Kansal 2012).

According to Spence (2014), "fracking fluids typically contain only trace elements of toxic constituents, some of those are listed as hazardous wastes under RCRA." Spence (2014) continues, "Under normal circumstances, that fact alone would subject the mixture to RCRA regulation;" if it were not for the RCRA exemption for the oil and gas industry, which Congress approved.

Further, natural gas operators are partially exempt from the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). This bill was established to "make liable those responsible for a spill or release of a hazardous substance into the environment" (Earthworks 2011). CERCLA includes a list of hazardous substances that should be regulated under the bill, but exempts these substances from regulation if they are found in natural gas or petroleum products. Operators are however, required to report spills of other hazardous substances used in hydraulic fracturing.

The Clean Air Act, which was created to reduce air pollution, has had little application to hydraulic fracturing for shale gas, which has traditionally been considered a "minor source" of emissions (Kansal 2012). EPA regulations of air emissions from shale gas operators are expanding, however. In April 2012, the EPA released new rules requiring shale gas operators "to control emissions of volatile organic compounds (VOCs) resulting from flowback by using 'green completions'" (Kansal 2012). Green completions require operators to capture gas immediately at the well head instead of allowing it to leak out into the air (Bunzey 2012). In March 2014, the White House announced that the EPA would "undertake a series of studies to determine the magnitude and prevalence of methane leaks from fracking sites, compressors, and gas pipelines" (Goldberg 2014). These studies may eventually result in additional regulation of emissions from shale gas operators.

In summary, federal regulations of hydraulic fracturing for shale gas are restricted to provisions from the Clean Water Act, Safe Water Drinking Act, and CERCLA. While there is a major push by environmental groups to expand federal regulation of the shale gas industry, at the time of writing most regulatory authority fell upon the states.

Act 13 and Regulation of the Natural Gas Industry in Pennsylvania

The Pennsylvania Oil and Gas Law, known as Act 13, consists of a set of amendments to older state legislation regulating the oil and gas industry. It was passed on February 8th, 2012. In addition to granting county governments the right to charge an impact fee on gas produced from wells within the county borders (more on this in Chapter 3), the Act also establishes a series of environmental regulations on natural gas drilling and production. Pennsylvania's Department of Environmental Protection (PA DEP) is the primary body in charge of enforcing these regulations (PennFuture 2012).

Act 13 faced immediate controversy with local governments going to court to dispute certain provisions of the Act with Pennsylvania Governor Corbett's administration. In particular, local governments were perturbed by Chapter 33 of the bill which allowed the state to "supersede local drilling ordinances and restrict local governments' ability to zone drilling operations" (Detrow 2012a). The Pennsylvania Commonwealth Court voided this section of the Act in July 2012 (Detrow 2012a). In December 2013, this ruling was upheld by the Pennsylvania Supreme Court, which found the restriction on local zoning in violation of Pennsylvania's constitution (Cusick 2013b). Chief Justice Ronald Castille determined that the preemptive zoning rules were in violation of the Pennsylvania Environmental Rights Amendment that guarantees state residents "the right to 'clean air, pure water, and to the preservation of the natural, scenic, historic and esthetic values of the environment'" (Cusick 2013a).

As of March 2014, some sections of the bill were still being debated in the Pennsylvania Commonwealth Court including the issue of "severability—essentially rather the rest of the law can stand without the portions that were struck down" (Cusick 2014). According to local news reports, as of March 2014, it appears that most of the law will remain intact and enforced despite the exclusion of Chapter 33 and some other issues that were still under debate, including private companies' ability to use eminent domain to seize private property for storing natural gas (Cusick 2014).

The following section provides a summary of environmental and other regulations that are currently enforced by the PA DEP under Act 13 and Act 66, a law passed in 2013 to govern pooling of land leases in the oil and gas production process.

Summary of Pennsylvania Regulations

Drilling Permits

All natural gas operators are required to obtain a permit from the PA DEP before drilling conventional or unconventional gas wells. The permit application consists primarily of a plat—a map "drawn to scale, showing the divisions of a piece of land" and "the location of the proposed well, [identified] water supplies within certain distances from the well and the acreage of the tract to be drilled, [depicting] the angle and direction of the well if it will not be vertical and [describing] any workable coal seams underlying the area to be drilled" (PennFuture 2012). Landowners, water purveyors, and gas storage operators located within 3000 feet of the proposed well bore must be notified of the permit application in addition to the owners and lessees of any coal seems beneath the proposed well site (PennFuture 2012) (Brannon and Shepard 2012). According to Michael Wood, Research Director at the Pennsylvania Center for Budget and Policy, drilling permits cost $2,500 per well on average (see **Table 1**).

Pooling

A new pooling law, known as Act 66, was passed in 2013. The law grants drilling companies the ability to combine oil and gas leases into production units without the permission of landowners, unless pooling without permission is prohibited under the lease signed with landowners ("Pennsylvania's New Pooling Law" 2014). The law, which is a subject of dispute among some mineral owners, states that "an operator has the right to develop multiple contiguous leases separately, the operator may develop those leases jointly by horizontal drilling unless expressly prohibited by a lease" ("Pennsylvania's New Pooling Law" 2014).

Well Spacing

In Pennsylvania, the DEP is responsible for handling well spacing orders (Brannon and Shepard 2012). However, there is no precise distance requirement for well spacing. Rather, the PA DEP considers each case individually in an attempt to ensure that wells are spaced sufficiently far away from one another to allow safe and efficient natural gas extraction (Penn State Univerisity Dickinson Law School 2006).

Setbacks

Unconventional natural gas wells must be located at least 500 feet from buildings and private water supply. They must be at least 1,000 feet from public water supply intake, 300 feet from wetlands greater than one acre in size and a well or well pad "may not be built in a floodplain if the well site will contain a pit or impoundment for drilling wastes. Wells and well pads may be built in a floodplain if wastes will be stores in tanks that are not located within the floodway section of the floodplain" (PennFuture 2012).

Bonding

Natural gas well operators are required to file a site remediation bond with the PA DEP and are subject to bond liability throughout the lifetime of the well, from the time it's drilled until it's plugged (Brannon and Shepard 2012). Brannon and Shepard (2012), provide a summary of the states bonding requirements:

> "If the well bore is less than 6,000 feet, and the number of wells operated is less than 50, then the bond amount is $4,000 per well. Once the number of wells operated exceeds 50, there is a lump sum (ranging from $35,000 to $100,000) required in addition to the individual well amount. The same conditions apply to

well bores of 6,000 feet or more, except that a $10,000 per well bond is required and lump sums are required once the number of wells operated exceeds 25 (ranging from $140,000 to $430,000)."

In the event that an operator fails to comply with its responsibility to plug the gas well and remediate the site, the bond will be forfeited to cover these costs.

In addition to the site remediation bond, operators are also required to provide road bonds and procure permits for heavy transport from the Pennsylvania Department of Transportation (Penn DOT). Some roads are determined by Penn DOT to be particularly susceptible to damage; these roads are classified as "posted." Operators using posted roads are required to post bonds in the amount of $12,500 per paved mile and $10,000 per unpaved mile. This applies at both the state and municipal level.

As operators use the road network, they are required to maintain it the way they found it. Road quality is inspected by Penn DOT staff and outside contractors hired specifically to assist with inspecting roads affected by Marcellus shale drilling. Roads are inspected on a bi-weekly or monthly basis. Penn DOT posts the results of its inspection on a webpage known as the "Bonded Roadway Condition Survey System.[5]" Operators can log into the system to verify the amount of damage they've done to the roads and the costs associated with the damage. Operators are required to cover these costs.

In some cases, operators may voluntarily upgrade the road at their own expense in order to ease operations. According to a Penn DOT representative, shale gas operators have voluntarily upgraded 400 miles of state roads in Pennsylvania.

[5] http://www.dot14.state.pa.us/ECMSMAR/

While the same bonding requirements apply at the municipal level, according to Penn DOT officials, municipalities have come up with their own ad-hoc techniques of dealing with (or not dealing with) natural gas operators and the damage they cause to roads. For example, instead of making commitments to maintain the road network, municipal leaders may come to a deal with the drilling company to provide some other sort of product or service (a community center, new fire truck, etc.) in return for looking the other way while the roads are destroyed.

It should be noted that operators are only required to post bonds for posted roads. According to representatives from Penn DOT, road bonds are rarely forfeited to cover the costs of road damage. At least bonded state roads have some level of financial assurances in place; un-posted roads at the state and municipal level and all municipal roads are at risk for costly damage with little recourse.

Well Casing and Cementing

After a well is drilled, steel pipes or cement are applied to the well to protect the well structure, ensure that gas and other fluids do not pollute groundwater, and prevent blowouts, which are defined as "uncontrolled fluid flows in the wellbore due to high pressures underground" (Kansal 2012). Pennsylvania requires casing for wells that penetrate through "fresh water strata" or through coal seams (Brannon and Shepard 2012). Casing should be installed "50 feet below the lowest fresh groundwater or 50 feet into consolidated rock, whichever is deeper" (Kansal 2012).

Failing to properly case or construct a well can result in water contamination. According to a report by Physicians, Scientists and Engineers for Healthy Energy, between 2010 and 2012, hydraulic fracturing wells in Pennsylvania had a 6-7% failure rate due to failures of structural integrity (Ingraffea 2013).

Chemical Disclosure

While Act 13 has introduced some chemical reporting requirements, it also allows for some exemptions. Operators are required to submit a well completion report to the PA DEP, which details a list of "chemicals and additives, and percent by mass of each, used to hydraulically fracture or 'stimulate' the well" (PennFuture 2012). However, operators can identify a portion of the report as a "trade secret" which disallows the PA DEP from disclosing this information (PennFuture 2012).

Water Management

All natural gas operators that withdrawal or use water for hydraulic fracturing are required to receive approval from the PA DEP, which may be granted after submission of a water management plan (Brannon and Shepard 2012). The PA DEP also requires operators to submit erosion and sediment plans ("Marcellus Shale Gas Well Drilling: Regulations to Protect Water Supplies in Pennsylvania" 2011). Act 13 also requires that natural gas operators replace any water supply that is polluted as a result of their operations. Further, the operator is automatically considered responsible for contamination of any nearby public or private drinking water supply within 1,000 feet of the gas well drilled, if the contamination is discovered within six months after the well was drilled ("Marcellus Shale Gas Well Drilling: Regulations to Protect Water Supplies in Pennsylvania" 2011). The only way an operator can prove that it is not responsible for water contamination is by showing evidence of pre-drilling water testing. Pre-drilling water tests are not required by law, but there are obviously large incentives for operators to conduct these tests in order to relieve themselves from potential future liability. Act 13 also includes provisions for addressing a "diminution" in water supply resulting from drilling; in this case, similar to contamination, operators must "restore or replace the affected water supply with an alternate source of water" ("Marcellus Shale Gas Well Drilling: Regulations to Protect Water Supplies in Pennsylvania" 2011).

Waste Storage and Disposal

The main forms of waste associated with hydraulic fracturing for natural gas include: drill cuttings, drilling fluids, flowback water, and produced water (Kansal 2012). Prior to disposal, waste may be stored at the drilling site. Under Pennsylvania law, pits storing hydraulic fracturing must be built using a "synthetic flexible liner" (Kansal 2012). Under Act 13, Pennsylvania requires that operators submit a waste containment plan for drilling sites. Operators are required to keep records of wastewater transport going back five years (Brannon and Shepard 2012). As stated previously, under federal regulations operators may also be required to obtain an NPDES permit to dispose of waste in bodies of water.

In Pennsylvania, the EPA has primacy over regulation of underground injection control wells. There are only 10 operating disposal wells in the state. According to Scott Perry, Deputy Secretary of the Office of Oil and Gas Management at the PA DEP, the Office does not currently have the human resources available to regulate disposal wells.

Air Quality Control

Act 13 does not place any restrictions on air pollutants but it does provide for a monitoring mechanism. Operators are required to submit annual reports to the PA DEP detailing the amount of pollutants emitted and describing the calculation methods used to arrive at that number (PennFuture 2012).

Contingency Planning and Spill Risk Management

Pennsylvania requires oil and gas operators to put in place a Preparedness, Prevention and Contingency Plan, which is intended both to prevent spills of hazardous materials and manage the consequences of spills when they do occur (State Review of Oil and Natural Gas Environmental Regulations, Inc. 2013). Unconventional well operators are also required to submit an Emergency Response Plan to the state, county, and local governments where they operate (State Review of Oil and Natural Gas Environmental Regulations, Inc. 2013). The state has a Hazardous Sites Cleanup Fund that the DEP can use to address spills by covering the costs of "regaining control of the well, controlling the perimeter of the well site, preparing water sprays, establishing trenches or dikes to capture the runoff fluids and providing the resources and equipment needs for the incident (State Review of Oil and Natural Gas Environmental Regulations, Inc. 2013). Under federal CERCLA regulation, operators are also required to report spills of any hazardous materials (except for oil and gas) and are responsible for the cleanup.

Abandoned Well Management

Operators are required to identify abandoned wells within 1,000 feet along from the surface of the full length of a horizontal well (State Review of Oil and Natural Gas Environmental Regulations, Inc. 2013). Act 13 requires operators to pay a $50 charge for new drilling permits that goes direct towards the state's Abandoned Well Plugging Fund. Gas well permits also come with an additional $200 charge for the Orphan Well Plugging Fund. The Act 13 Marcellus Legacy Fund is supposed to secure approximately $14 million annual to support various conservation projects, including plugging abandoned wells (State Review of Oil and Natural Gas Environmental Regulations, Inc. 2013). According to Susan Ghoweri, Plugging Chief at the PA DEP Office of Oil and Gas Management, there are approximately 8,300 known abandoned wells in Pennsylvania with no known operator. It's unclear how many of these abandoned wells can be attributed to the shale gas industry, but the number varies very little from year to year despite extensive well plugging efforts led by the state's Abandoned and Orphaned Well Program; this indicates a steady increase in abandoned wells while those in existence are being plugged and remediated.

In addition to identifying pre-existing abandoned wells, operators are also required to plug their own wells. At present, according to Ghoweri, there are no specific plugging requirements for horizontal wells.

In the past, many extractive industry operators have failed to comply with plugging and site remediation requirements resulting in bond forfeitures. For example, in Pennsylvania between 2001 and 2008, 227 mines in the state experienced bond forfeitures (Dutzik et al. 2013). Coal mines generally have longer lifespans than gas wells. If the shale gas industry is failing to appropriately plug abandoned wells and the sum of bonds is insufficient to address this issue, Pennsylvania taxpayers will have to take on the significant task of plugging wells or face pollution risks that could result in even greater costs to the environment and public health.

Table 6 - Permitting and Assurances in Pennsylvania (per well)

Drilling Permit (per well)	$2,500
Site Remediation Bond	If well bore is less than 6,000 ft and there are less than 50 wells- $4,000 per well, more than 50 wells $35,000-$100,000 required in addition to individual well amount. If well bore is greater than 6,000 ft.- $10,000 per well bond required + lump sums for more than 25 wells ($140,000-$430,000)
Road Bond- Paved Road	$12,500 per mile
Road Bond – Unpaved	$6,000 per mile
Road Bond – District Blanket Bond	$10,000
Insurance	Not required
Heavy Load Transit Permitted	Approximately $30

The Horizontal Well Control Act and Regulation of the Natural Gas Industry in West Virginia

Similar to Pennsylvania, West Virginia responded to a sudden increase in drilling for natural gas in the Marcellus shale by passing a new state law to regulate shale drilling activity and natural gas production. The Horizontal Well Control act was passed by the state legislature in "record time" in December 2011 ("WV Has New Marcellus Drilling Law in Record Time" 2012). Lawmakers took less than a year to draft the law and only four days to pass it after it was introduced to the congress in a special session.("WV Has New Marcellus Drilling Law in Record Time" 2012). The West Virginia Department of Environmental Protection (WV DEP) is the primary body in charge of enforcement of the new regulations.

Overall, the Horizontal Well Control Act appears to be less controversial in nature than Pennsylvania's Act 13. Several sections of the law were praised by industry critics, including a provision that increases well permitting fees in order to allow the WV DEP to hire more inspectors and improve regulatory enforcement. The law also increases natural gas drillers' obligations to notify surface land owners and modifies regulation surrounding water use and wastewater disposal (Dickerson 2011).

Some of the Act's more controversial points include new spacing requirements for horizontal wells, which are considered to be fairly weak by environmentalists and surface owners (West Virginia Surface Owners Rights Organization). Further, the law gives the WV DEP authority to override city and county zoning regulations. However, according to a report by the West Virginia Surface Owners Rights Organization, the zoning regulation is "a general provision of law, and it may be that the more specific provisions of law regarding zoning power, as well as any location restrictions mandated by federal law, would not be overridden."

The following section will detail some of the more specific environmental and pooling regulations in place in West Virginia under the Horizontal Well Control Act and other laws pertaining to the oil and gas industry.

Summary of West Virginia Regulations

Drilling Permits

The WV DEP grants drilling permits to natural gas operators. All permit applications for well sites with an area greater than three acres excluding pipelines, gathering lines and roads must include erosion control and construction plans certified by registered engineers (Brannon and Shepard 2012). Operators must provide a copy of their permit application and a surface use and compensation agreement (including an offer of compensation) to the surface owner on or before the day the application is filed with the WV DEP (West Virginia Surface Owners Rights Organization). The first horizontal well permit costs $10,000, every additional horizontal well is another $5,000 (see **Table 2**).

Pooling

The Horizontal Well Control Act does not include any provisions to alter West Virginia pooling law. While the state has a forced pulling statute in place it only applies to deep wells. Horizontal wells drilled in the Marcellus Shale would be considered shallow and therefore not subject to forced pulling (Wang 2012). Voluntary pooling is permitted, however (Brannon and Shepard 2012).

Well Spacing

There are no spacing requirements for horizontal wells in West Virginia (Brannon and Shepard 2012).

Setbacks

All wells drilled must be set back 250 feet from existing wells, 625 feet from an occupied dwelling, 100 feet from a stream, pond, or wetland, 300 feet from a trout stream, and 1,000 feet from a surface or ground water supply intake (Brannon and Shepard 2012) ("WV Has New Marcellus Drilling Law in Record Time" 2012). A report by the West Virginia Surface Owners notes that setback requirements can be waived at the consent of either the homeowner or the WV DEP.

Bonding

Natural gas operators are required to provide site remediation bonds in the amount of $50,000 per horizontal well or a blanket bond of $250,000 is available to cover all wells drilled per operator ("Oil & Gas: State by State Bonding Comparison" 2014).

West Virginia also requires additional bonds to cover the costs of potential road damage resulting from the transport of heavy equipment and large quantities of water used in the hydraulic fracturing process. Bonds only apply to "state local service" roads, not the interstate or prominent state roads (Mattox 2012). For operators who transport more than 5,000 barrels of liquids used for drilling activities, they are required to provide a $100,000 bond per paved mile, $35,000 per tar and chipped mile, and $25,000 per graveled mile (Mattox 2012). Alternatively operators with multiple wells can choose to provide a blanket bond for a maximum amount of $250,000 per district or $1,000,000 statewide (Mattox 2012). There are only 10 districts in the state, so operators present in multiple districts are likely to purchase the statewide bond.

Similar to Pennsylvania, natural gas operators in West Virginia must also procure permits for transporting heavy loads As of May 2012, approximately 3,000 miles of state roads out of a total network of 33,931 miles were in use by the natural gas industry (Efstathiou 2012).

Well Casing

West Virginia has a lengthy set of casing requirements for horizontal wells. In the case of drilling through freshwater strata, casing is required to extend a minimum of 50 feet below the deepest freshwater horizon and a maximum of 150 feet (West Virginia Department of Environmental Protection 2012). The casing can exceed 150 feet in the event that this is necessary to protect "workable" coal seams (West Virginia Department of Environmental Protection 2012). The WV DEP requires operators to have a "casing program" in place for each well that details the type of casing used. The WV DEP has authority to establish additional casing requirements depending on well specifications. Also, operators must promptly report any casing deficiencies to the WV DEP (Brannon and Shepard 2012).

Water Management and Chemical Disclosure

The Horizontal Well Control Act obligates operators who require more than 210,000 gallons of water withdrawals from the state of West Virginia to stimulate a well within a 30-day period to include a water management plan with their application for a well work permit. Among other things, the water management plan must include "a listing of anticipated additives that may be used in water utilized for fracturing or stimulating the well" (*Horizontal Well Control Act*). When the well is completed, the operator is required to provide a list of the additives that were actually used for inclusion in the completion log (*Horizontal Well Control Act*). Similar to Pennsylvania, if operators identify any of the fluids used in drilling to be "trade secrets," this information well be kept confidential by the WV DEP (Clark 2013).

Operators are not permitted to withdraw water beyond volumes that the waters can "sustain" (Brannon and Shepard 2012). Any water contamination that occurs within 1,500 feet of the center of a well pad is assumed to be a result of drilling operation. Operators can refute this charge by showing evidence that the pollution existed prior to drilling or that the operator was not permitted by the surface owner to test water quality (Brannon and Shepard 2012). If water contamination were to occur as a result of drilling activity, operators would be required to provide an emergency replacement water supply within 24 hours, a temporary water supply within 72 hours, and a permanent supply within 30 days (Clark and Bradley 2014).

Waste Storage and Disposal

All drill cutting and drilling mud must be disposed of in an approved solid waste facility unless the landowner allows for waste to be stored in pits onsite (Brannon and Shepard 2012).

West Virginia does have primacy over the EPA in regards to regulating underground injection control wells.

Air Quality

The Horizontal Well Control Act specifies that the WV DEP will study air pollution associated with drilling and apply regulations if deemed necessary (*Horizontal Well Control Act*).

Contingency Planning and Spill Risk Management

West Virginia law normally provides that hazardous waste generators pay an assessed fee that is funneled into a hazardous waste emergency response fund used to address spills and other accidents. However, "drilling fluids, produced waters, and other waters associated with the exploration, development or production of crude oil, natural gas, or geo-thermal energy" are excluded from this fee assessment (*Hazardous Waste Emergency Response Fund* 2014).

Abandoned Well Management

According to West Virginia state law (the "Abandoned Well Act"), any oil or gas well that has been inactive for 12 months must be plugged unless the operator can demonstrate a viable future use for the well.

Table 7 - Permitting and Assurances in West Virginia (per well)

Drilling Permit (first well)	$10,000
Drilling Permit (additional wells)	$5,000
Site Remediation Bond (single well)	$50,000
Site Remediation Blanket Bond	$250,000
Road Bond- Paved Road	$100,000 per mile
Road Bond – Tar and chipped Road	$35,000 per mile
Road Bond – District Blanket Bond	$250,000
Road Bond – State Blanket Bond	$1,000,000
Insurance	Not required
Road Maintenance Agreements	?
Heavy Load Transit Permit	Approximately $26

Regulatory Enforcement in Pennsylvania

The PA DEP Office of Oil and Gas Management is the primary body in charge of enforcing natural gas drilling and production regulation in the state. Enforcement essentially begins with oil and gas inspectors who are responsible for regularly inspecting natural gas operators' activities. A September 2013 report by the State Review of Oil and Natural Gas Environmental Regulations, Inc. (STRONGER), commends the PA DEP for using additional revenues generated by an increase in permit fees to significantly increase the number of employees in the Office of Oil and Gas Management from 64 in 2009 to 202 in 2013 (State Review of Oil and Natural Gas Environmental Regulations, Inc. 2013). 80% of the 2013 staff was assigned to working on "engineering, scientific or permit/inspection-related work," ultimately increasing the number of staff members dedicated to working on "permitting, compliance and enforcement" (State Review of Oil and Natural Gas Environmental Regulations, Inc. 2013). The increased hiring was undertaken in direct response to an increase in drilling in the Marcellus shale in the state and should, generally speaking, support an increase in the number of inspections occurring. According to Perry, the decision to hire more inspectors was based on inspection goals and projected drilling activity. At the time of writing, despite increased hiring the PA DEP is still unable to meet its inspection goals according to Perry who estimated that there may be a need to hire 10 more people at the Office of Oil and Gas Management going forward, depending upon drilling activity.

Table 8 - Pennsylvania Drilling Activity, Regulation, and Enforcement

	2009	2010	2011	2012	2013	Jan-Apr, 1st 2014
# Permits Issued for Unconventional Wells	1,984	3,314	3,553	2,627	2,930	843
# Inspections Conducted on Unconventional Wells	874	1,944	10,558	12,686	12,447	2,914
# of DEP Inspectors	35	65	x	x	x	83
# Violations	x	1,218	662	712	516	128
# of Violations Resulting in Enforcement Actions	x	305	251	262	181	43
# of Abandoned Wells	x	x	x	x	x	8,341
# Marcellus Wells Drilled	768	1,446	1,962	1,348	1,208	312

Sources: Pennsylvania Department of Environmental Protection,Earthworks, and "Regulation of Shale Gas Development: An Argument for State Preeminence with Federal Support" by Tushar Kansal

Of course, inspections are just one component of regulatory enforcement. The other equally critical component is taking enforcement action to correct violations discovered during the inspection process. According to a 2012 report by the Earthworks' Oil & Gas Accountability Project, despite an increase in violations since 2008 (likely resulting in part from an increase in the number of inspections occurring coupled with an increase in drilling activity) the percent of violations resulting in enforcement action was in decline over the same period (Earthworks 2012). Roughly 45% of violations resulted in enforcement action in 2008 compared to 20% between April and June 2012 (Earthworks 2012). This decline in enforcement may be due to data specifications, however. According to representatives at the PA DEP, one enforcement action often addresses multiple violations, indicating that there may not have been a decline in enforcement, rather an increase in the number of violations addressed by a single enforcement action.

Also, it's important to note that there are various types of violations. Some may pertain to a failure to submit necessary paperwork on time, while others may be more severe in that they result in actual damage to the environment. There is no way to tell, given the data available, what percentage of violations are related to paperwork or other more severe failures. Without this information, it's challenging to judge whether or not a state is appropriately addressing severe violations.

Among industry experts, Pennsylvania is known to charge the highest fines among states where shale gas development occurs (Soraghan 2011). Operators' with unconventional well violations in Pennsylvania can incur fines up to $75,000 plus $5,000 for each additional day the violation is not addressed, compared to a maximum fine of $1,000-$20,000 in most other states where shale gas extraction occurs (Earthworks

2012). Thus, while enforcement actions may be rare in comparison to the number of violations in Pennsylvania, when fines are issued they tend to be more severe in nature than they would be in other states.

In addition to having stronger fines, Pennsylvania's enforcement regime is also commendable for transparency in reporting inspections, violations, and enforcement actions. The PA DEP website offers an on-line database of compliance reports searchable by operator, municipality, county, region, and date. Also, in an unscheduled phone interview Perry was very forthcoming with information surrounding violations and enforcement and was extremely adamant that the PA DEP has one of the strongest regulatory regimes for the shale gas industry in the country.

STRONGER also compliments the state's efforts to develop specific regulations for unconventional drilling, including drilling in the Marcellus shale, which is unique in nature in comparison to conventional natural gas or oil wells and therefore presents distinct challenges. Examples of unconventional specific regulations include higher bonding requirements for unconventional gas wells and higher fines for operator violations (State Review of Oil and Natural Gas Environmental Regulations, Inc. 2013).

Pennsylvania is also known to have strong storm water management and abandoned gas well programs. In its Orphaned and Abandoned Well Program, the PA DEP actively involves individuals and environmental groups in searching for abandoned oil and gas wells (State Review of Oil and Natural Gas Environmental Regulations, Inc. 2013). STRONGER commends the PA DEP's storm water management program for requiring operators submit erosion and sediment control plans and conducting regular inspections of drilling and production sites to ensure compliance (State Review of Oil and Natural Gas Environmental Regulations, Inc. 2013).

Nonetheless, there may be some gaps in Pennsylvania's regulations surrounding shale gas development and related regulatory enforcement. For example, the impact of drilling waste on drinking water has been a major concern in the state (as well as most other states where shale gas drilling occurs). According to a 2011 report by the New York Times, a 2009 EPA report that was never published showed that some sewage treatment plants processing drilling waste in the state were "incapable of removing certain drilling contaminants and were probably violating the law," though regulators had not required drinking-water intake plants downstream from these sewage water treatment plants to test for radioactivity since before 2006, when the shale gas industry was inactive in the state (Urbina 2011a). However, PA regulators have on occasion used enforcements actions to address drinking water contamination. For example, in 2010, natural gas operator, Chesapeake Energy was fined $900,000 for contaminating the water supplies of 16 homes in Bradford County (Soraghan 2011). The contamination occurred when the casing and cementing surrounding gas wells failed, causing methane to leak into nearby groundwater resources (Kusnetz 2011)

According to representatives at Penn DOT, operators mostly pay what they owe for road damage. To date, Penn DOT officials report that they've only had to take advantage of bonds on a couple of occasions as operators normally comply with their requirements to maintain the road networks as they found them. There are on occasion disputes with shale gas operators who feel they are being overcharged for damages. Penn DOT routinely interacts with trade industry organizations like the Marcellus Shale Coalition and the Pennsylvania Independent Oil and Gas Association on these issues.

Overall, Pennsylvania's regulatory enforcement regime surrounding shale gas development is known to be more efficient and harsh (in terms of fines) than in other states where shale gas development is occurring. The state has taken concrete actions to boost the PA DEP's capacity to regulate the industry in light of increased drilling in the Marcellus Shale. While Perry says the PA DEP is still not able to meet its goals in terms of inspection, in an interview he was adamant about increasing the number of inspectors on staff in order to meet regulatory objectives.

Regulatory Enforcement in West Virginia

Similar to Pennsylvania, the WV DEP Office of Oil and Gas is the main body in charge of enforcing regulations surrounding shale gas drilling and production in West Virginia. The growth of the shale gas industry is known to have led to a serious shortage of inspectors at the WV DEP. In May 2012, WV DEP Secretary Randy Huffman told press that he had a "backlog of more than 250 [drilling] permits that needed to be processed" (Wowktv.com 2012). The West Virginia Horizontal Well Control Act attempted to address this issue by increasing permit fees from $400 to $10,000 in order to capture more revenue to hire more inspectors (Bradley 2013). This plan appears to have been effective. As of February 2013, the WV DEP Office of Oil and Gas hired eight employees for its Inspection and Enforcement Section, up from 17 previously (Bradley 2013). Leadership at the Office of Oil and Gas has expressed some concern that going forward regulations imposed by the Horizontal Well Control Act may make it difficult to fill inspector positions (The State Journal 2012). The Act requires that new inspectors have at least two years of "relevant experience" in the oil and gas industry (West Virginia Surface Owners Rights Organization).

Table 9 - West Virginia Drilling Activity, Regulation and Enforcement

	2008	2009	2010	2011	2012	2013	Jan 1st- April 30th, 2014
# Permits Issued for Unconventional Wells	406	545	445	543	626	668	198
# Inspections of Unconventional Wells	x	x	x	315	327	684	x
# of DEP Inspectors	x	x	x	x	17	25	27
# Violations	3	18	21	88	26	38	24
# Enforcement Actions	x	8	12	28	15	14	14
# Marcellus Wells Drilled*	169	183	220	255	324	221	x

*Data for 2013 was not yet up-to-date at time of writing

Source: West Virginia Department of Environmental Protection

In regards to violations and enforcement, the number of violations for horizontal wells has not increased significantly over the years, despite increased permitting and drilling activity, with the exception of a spike in violations in 2011. James Martin, Chief of the Office of Oil and Gas at the WV DEP, was unable to explain the spike in violations in this year. Similar to Pennsylvania, the violation and enforcement data is difficult to assess as a single enforcement may address multiple violations.

In an interview with Bloomberg Businessweek, Gary Clayton, regional maintenance engineer for the West Virginia Department of Transportation (WV DOT) said, "In most cases outside of a few, we've been able to maintain the roads in near the original condition" (Efstathiou 2012). As of May 2012, the state had not pursued any enforcement actions against operators for failing to fulfill road maintenance agreements (Efstathiou 2012). However, Clayton also noted that some road repairs are not done as quickly as would be preferable (Efstathiou 2012). This may be due to the fact that operators who are continuously using the roads know that damage will continue to occur as long they're there and so may hold off on repairing the roads until they are almost ready to leave an area. In this scenario, operators' willingness to finance road repairs is a positive point but doing so in an untimely fashion is likely to generate externalities for residents such as costly vehicle damage and detours to avoid especially damaged roads.

While the PA DEP has received praise for its abandoned wells program, a recent audit report by the West Virginia Legislative Auditor revealed that the WV DEP Office of Oil and Gas is not enforcing requirements surrounding abandoned wells leading to an increase in their numbers. According to the report, the state has approximately 13,000 abandoned wells; 36.1% of which have no known operator (West Virginia Legislative Auditor 2012). When no operator can be linked with an abandoned well, the state must take on the costs of plugging the abandoned well, which the DEP estimates at $25,000 per well (West Virginia Legislative Auditor 2012).

Overall, while industry experts normally perceive West Virginia to be a more lax regulatory environment than Pennsylvania a lack of information surrounding regulatory enforcement in West Virginia makes it difficult to judge the effectiveness of the state's regulatory regime. The regulatory staff at the WV DEP is also generally less forthcoming with information than the PA DEP. There are a few examples of shortfalls of the WV DEP, such as the abandoned well program, but perhaps the most glaring shortfall of the regulatory regime is the lack of clear information that could be used to assess the effectiveness of the regulatory regime.

Conclusions

Both Pennsylvania and West Virginia have responded to an increase in shale drilling activity by attempting to adapt old oil and gas regulations to suit the modern day challenges of drilling in the Marcellus Shale. Both states regulatory regimes have strengths (an increase in inspectors) and weaknesses (water contamination, abandoned wells).

The next chapter will expand upon the information surrounding regulation and regulatory enforcement to estimate the costs and benefits of drilling in the Marcellus Shale to the environment and communities by looking at both the costs of regulatory enforcement (hiring inspectors) and the costs associated with a failure of regulatory enforcement (abandoned wells, contaminated water supplies, etc.).

Chapter 3

Estimating the Costs and Benefits of the Shale Gas Industry in Pennsylvania and West Virginia

Introduction

Many of the regulations discussed in the previous chapter were put in place to limit the shale gas industry's negative impact on the environment and communities. In addition to regulating against the potential negative impact of the shale gas industry, lawmakers in Pennsylvania and West Virginia have also implemented policies aimed at capturing the economic benefits of shale gas development, mostly in the form of taxes. Individual landholders also benefit economically from the industry by signing lease and royalty agreements with natural gas operators.

This chapter uses data provided by industry and policy experts and regulatory authorities to assess the costs and benefits of the shale gas industry for the two states included in the study—Pennsylvania and West Virginia. To begin, I estimate the costs and benefits of the industry per well in the two states, stating the assumptions used in this analysis. In the latter half of the chapter, I describe a scenario in which 1.2% of wells drilled in each state in 2012 result in water contamination. I estimate the resulting costs and compare these against the permits and assurances and overall economic benefits provided by each state to see what gaps may exist in terms of cost coverage.

As mentioned in the introductory chapter, ideally the permits and assurances put in place by the state should address the costs of the shale gas industry to the community. When permits and assurances fail to do so, the costs fall upon the state and its residents. The final section of this chapter uses the cost data provided here to demonstrate that there is a gap between costs and potential damages and permits and assurances in both Pennsylvania and West Virginia, ultimately indicating that state governments and residents of the two states included in the study may have to cover the costs of the shale gas industry when natural gas operators fail to fulfill their obligations.

Shale Gas Industry Costs

Whereas the benefits and permits and assurances surrounding the shale gas industry are relatively well known or easily estimated quantities, the costs of the industry are more difficult to dispel. There are a variety of reasons for this—first, the shale gas industry is young and studies surrounding its potential impact on air quality and groundwater pollution are still ongoing. Second, in interacting with a variety of regulatory authorities in both Pennsylvania and West Virginia I discovered a dearth of data describing reports of water contamination. While some municipal level town managers shared their belief that water contamination was occurring in their area as a result of the shale gas industry, there was simply a lack of reliable data available to confirm this assumption. Third, attempting to quantify in dollar amounts the negative impact of an industry on the environment and public health is always a challenging task.

In an effort to confront these challenges, I decided to focus on the economic costs of the shale gas industry that could be readily quantified including: road damage, property value loss, water contamination, regulatory costs, and well plugging and site remediation (see **Table 10**). It's important to note that while these costs are the most easily quantified they likely do not capture the full cost impact of hydraulic fracturing. For example, the chemicals used in hydraulic fracturing have been linked with a variety of health complications including cancer, immune system problems, and endocrine disruption (Dutzik et al. 2013). Air emissions from fracking are believed to have similar deleterious public health impacts (Dutzik et al. 2013). The cost of such ailments is challenging to quantify on a per well basis but could be significant. For example, in April 2014 a Texas family won a $3 million lawsuit against a natural gas operator after suffering from a variety of ailments ("Texas Family Plagued with Ailments Gets $3M in Fracking Judgement" 2014). Equally concerning is hydraulic fracturing's impact on the environment. The shale gas industry's heavy water usage can damage waterways, affecting aquatic habitats and displacing wildlife (Dutzik et al. 2013). While all of these impacts are significant, a lack of data makes it impossible to factor these costs into this thesis analysis.

In order to assess the aforementioned more tangible costs, I reached out to regulators at the PA and WV DEPs. I also spoke with individuals from the states' Departments' of Transportation, town managers in areas experiencing significant shale gas drilling, and industry experts from the West Virginia Oil and Natural Gas Association and Cabot Oil and Gas—one the largest operators in Pennsylvania. Where data was unavailable for Pennsylvania and West Virginia, I made reasonable estimates based upon data available from other states or general knowledge of the shale gas industry and its operations.

With the exception of the costs of oil and gas inspectors, there are no substantial differences in the cost of the shale gas industry to communities in Pennsylvania and West Virginia.

Table 10 - Costs and Potential Damages Resulting from Single Shale Gas Well

Road Damage	$18,000 annual
Property Value Loss	8.5%
Water Testing	$700,000 one time fee
Water Cleaning	$150,000 per acre, one time fee
Water Replacement in 24 hours (delivery of 5 gallon water bottles)	$19,192 daily
Water Replacement in 72 hours (water delivery to tanks)	$300 daily
Permanent Water Replacement	$26,500 – Drilling a new well (per home), or $621,052 – Connecting to city water (per home), one time fee
Oil and Gas Inspectors	$1,150 annual (Pennsylvania), $1,630 annual (West Virginia), annual

Plugging Well	$80,000 one time fee
Site Remediation	$650,000 one time fee

Road Infrastructure Damage

Hydraulic fracturing for natural gas places extreme stress on road infrastructure. Heavy truckloads of sand, water, and chemical mixtures, weighing approximately 80,000 lbs., must be transported to each drilling site, often along narrow, poorly paved rural roads that were not designed to handle such loads (Efstathiou 2012). According to a representative from the Texas Department of Transportation (TxDOT), "big trucks are often too wide to pass two-abreast on rural roads so they run off the pavement, eroding the roads' shoulder. Then there are the potholes..." (Fehling 2012). According to a study by TxDOT, the average well site required 1,200 truck trips to prepare it for production, which given the trucks' weight is equivalent to 3.5 million car trips in terms of the damage caused (Fehling 2012) (Dutzik et al. 2013). The road damage can be so severe that it causes damage to vehicles and/or influences drivers to take different, longer routes to get to where they need to go (Efstathiou 2012).

The costs associated with repairing this damage are significant. According to a 2010 congressional testimony provided by Scott Christie, deputy secretary for highway administration in Pennsylvania, the cost for repairing damage to Pennsylvania's road networks resulting from the shale gas industry is approximately $265 million (Christie 2010).

According to Sean O'Leary, a fiscal policy analyst at the West Virginia Center on Budget and Policy, the biggest cost imposed on the state by the shale gas industry is infrastructure damage. According to O'Leary, the state's road infrastructure was already in poor condition and the development of the Marcellus Shale has only served to exacerbate the problem.

In 2012, a Blue Ribbon Commission appointed by the governor of West Virginia to perform a needs assessment for the state's road infrastructure, concluded that over a 25 year period the state would need a budget of $463 million annually to improve highways and $101 million annually to work on bridges (Stafford and Hurst 2012). While it is not clear how much of this need can be attributed to damage caused by the shale gas industry, these figures are strongly indicative of a transportation network in need overall.

To estimate the amount of road damage resulting from each well, I relied on a 2014 study on the consumptive use costs of shale gas extraction on Pennsylvania roadways authored by researchers from the American Society of Civil Engineers. In order to arrive at an annual figure of road damage per well per year, the researchers first estimated that number of heavy truck trips required to build and operate a single well and the anticipated loss of road life resulting from these trips. Next, they estimated roadway life and reconstruction costs in Pennsylvania. Finally, the truck travel data was combined with the cost data to estimate the total road damage costs per shale gas well in Pennsylvania (Abramzon et al. 2014). The researchers arrive at an estimate of $13,000 to $23,000 per well for all roadway types (Abramzon et al. 2014). I averaged this range to arrive at $18,000 per well per year in roadway damage.

No similar study was available in the case of West Virginia, but in speaking with representatives from the Departments of Transportation from both states I was informed that there was no substantive reason to assume that road damage costs would vary significantly between the two states.

Property Value Loss

The impact of shale gas drilling activity on property values is controversial in nature. While significant drilling activity can lead to rapid economic development in an area and thus an increased demand for business and residential properties, it may also have a negative impact on property values as potential buyers may be hesitant to locate nearby drilling operations out of concern for the industry's impact on the environment in general and drinking water more specifically (Integra Realty Resources 2010).

I looked at several studies on the impact of shale gas drilling on property values in order to arrive at the estimated property value loss used in this thesis. A 2010 study by Integra Realty Resources of residential property values near natural gas drilling operations in Flower Mound, Texas revealed that homes valued at $250,000 or more located within 1,000 feet of drilling operations experienced a decrease in home value between 3 and 14% (Integra Realty Resources 2010). The assessed valued of homes valued at less than $250,000 or located further than 1,000 feet away from the drilling site appeared to be unaffected by drilling operations (Integra Realty Resources 2010).

A 2012 study by the National Bureau of Economic Research of property values in Washington County, Pennsylvania revealed a similarly negative impact on residential real estate values for homes located near shale gas drilling operations (Muehlenbachs, Spiller, and Timmins 2012). According to this study, the risk of groundwater contamination resulted in a 24% reduction in property values in the county (Muehlenbachs, Spiller, and Timmins 2012). Similarly in West Virginia, a survey of landowners with at lease one completed shale gas well drilled on their property revealed that 43.4% had seen their property values decline since the start of drilling (O'Leary 2014).

To arrive at the estimated property value loss included in this study, I decided to rely on the more conservative estimates proposed by the Flower Mound, Texas study. This study also concentrates on homes that are within 1,000 feet of drilling operations. The 1,000 feet limitation is important because natural gas operators are assumed to be responsible for any water contamination occurring within six months after the start of drilling activity for homes within 1,000 feet of a well pad in Pennsylvania and 1,500 feet in West Virginia. I took an average of the 3-14% range proposed by the study to arrive at a property value loss of 8.5%.

Drinking Water Contamination

One of the most controversial impacts of shale gas development is drinking water contamination. This can occur at several points in the drilling and production process and is typically the result of operational errors. More specifically, drinking water contamination can occur as the result of the spilling or leakage of fracking fluids, which are widely acknowledged to be detrimental to public health and the environment (Ridlington and Rumpler 2013). Fracking fluids could either spill from a truck traveling to and from the drilling sites or leak from surface equipment. Faulty well casing (recall the well casing regulations discussed in the previous chapter) can also lead to natural gas leaking into drinking water supplies. Finally, inappropriate disposal of fracking waste can also lead to water contamination. In this case, faulty waste pits, deep disposal and underground injection wells would be to blame. Water treatment plants processing fracking waste may also fail to appropriately remove all toxic elements of the waste water before releasing it into the environment (Ridlington and Rumpler 2013).

When an accident like one of those described above occurs, drinking water supplies must be temporarily replaced and treated over the long term. In some cases, long-term drinking water replacement sources must be found.

As described in the previous chapter, in Pennsylvania natural gas operators are automatically assumed to be responsible for the contamination of any public or private drinking water supply within 1,000 feet of the gas well drilled, if the contamination is discovered within six months after drilling ("Marcellus Shale Gas Well Drilling: Regulations to Protect Water Supplies in Pennsylvania" 2011). The only way an operator can refute theses charges is by providing evidence of pre-drilling water testing, which is not required by law.

According to a report by The Times Tribune, a Scranton, PA based news publication, a collection of nearly 1,000 letters written by DEP officials and obtained by a journalist at The Times Tribune revealed 161 incidents of damaged water supplies for PA homes, farms, churches, and businesses between 2008 and the fall of 2012 (Legere 2013). According to the same report, the PA DEP prefers to count broad incidents of water contamination from drilling as opposed to individual well impact. By PA DEP standards, there were 83 incidents of water contamination resulting from drilling over the same period (Legere 2013). Prior to 2008, the PA DEP confirmed 128 cases of water contamination resulting from drilling between 1987 and 2007 (Legere 2013).

This data reveals a water supply contamination rate of 32.2 cases per year according to The Times Tribune's count of individual incidents or 16.6 cases per year according to the PA DEP's count of broader incidents of water contamination. This marks a substantial increase in water contamination related to drilling activities in comparison to 1987-2007, when there were 6.4 cases per year.

According to The Times Tribune report, an increase in water contamination from drilling may result from drilling activities taking place in areas of the state that were traditionally untouched by the oil and gas industries like Central and Eastern Pennsylvania. Operators may need to experience a learning curve, dealing with the unique geology of these areas before arriving at the most appropriate well construction and casing techniques (Legere 2013). According to a report by Physicians, Scientists and Engineers for Healthy Energy, between 2010 and 2012, hydraulic fracturing wells in Pennsylvania had a 6-7% failure rate due to failures of structural integrity (Ingraffea 2013).

The data provided here on water contamination resulting from drilling is an estimate based on a DEP letter analysis and a word-of-mouth report by PA DEP spokesman, Kevin Sunday (Legere 2013). A phone interview with Scott Perry, Deputy for Oil and Gas Management for the PA DEP, the Office of Oil and Gas Management revealed that reports of water contamination resulting from oil and gas development are confidential information. In light of these constraints, it's not possible to determine the precise number of public or private drinking water resources that have experienced contamination resulting from the shale gas industry.

However, when such contamination does occur and can be verified through PA DEP testing, operators are required to replace or restore the water supply in question. Perry described the water replacement process as arduous task. All affected properties must be equipped with a water tank that is hooked up to the building's plumbing. These tanks must be cleaned periodically and in the winter they must also be insulated. In addition to providing the tanks, the operator must cover the cost of trucking water to the effected properties. This can be a costly process. For example, a natural gas well leak in West Divide Creek, Colorado resulted in the operator paying $350,000 to provide potable water deliveries and water systems to homes within a two-mile area of the leak for a period of two years (Dutzik et al. 2013). However, Perry reported that for large operators replacing the water supply of affected homes is "a minor cost in the grand scheme of things."

According to Perry, to date there has not been any incidents where a natural gas operator was found liable for water contamination and refused to take on the responsibility of providing water deliveries. This is not outside the realm of possibilities, however. If a minor operator were to cause major damage to the water supply it's not inconceivable that it would be unable to cover the full costs of water delivery and water treatment, leaving the costs to fall on property owners and the state.

One of the most widely publicized incidents of water contamination resulting from the shale gas industry in Pennsylvania took place in Dimock Township, Susquehanna County in 2009. Natural gas operator, Cabot Oil and Gas was found by the PA DEP to be responsible for three separate spills of a "water/liquid gel mixture" used in the hydraulic fracturing process (Pennsylvania Department of Environmental Protection 2009). The spill amounted to 8,000 gallons of waste which polluted the nearby Stevens Creek and a wetland (Pennsylvania Department of Environmental Protection 2009). According to Perry, Cabot Oil and Gas offered 19 homeowners in the surrounding area water treatment systems in addition to offering to purchase the homes at twice their appraised values. Homeowners instead requested that they be connected a public water supply. According to Perry, the cost for connecting the 19 homes to the public water supply would have been approximately $12 million. Cabot refused to make this investment and given the reasonable alternatives proposed by the operator the PA DEP could not force Cabot to connect homes to the public water supply. After the homeowners refused water treatment systems and the opportunity to sell their homes, the PA DEP allowed Cabot to discontinue water deliveries to the homes.

The United States Environmental Protection Agency (EPA) became involved in the dispute when residents requested that the agency come to test water contamination levels. From the time that Cabot stopped delivering water supplies and while the EPA was engaged in testing well water in the area, the EPA provided temporary water deliveries to residents. Upon completing the water testing the EPA determine that there were "not levels of contaminants present that would require additional action by the agency" (United States Environmental Protection Agency 2012). This example highlights how despite regulations that require operators to replace water supplies in the case of contamination, difficult negotiations between the operator and affected homeowners resulted in the EPA and American taxpayers temporarily shouldering the costs of replacing the water supply.

Similar to Pennsylvania, natural gas operators in West Virginia are required to provide temporary water supply in the event that the WV DEP finds water contamination resulting from drilling activities. The WV DEP can also deem it necessary for the operator to provide a permanent water supply replacement. As stated in the previous chapter, similar to Pennsylvania, any water contamination that occurs within 1,500 feet of a drill site within six months after drilling is assumed to be the responsibility of the oil and gas operator (West Virginia State Legislature).

The earliest case of water contamination resulting from hydraulic fracturing in West Virginia occurred in 1984, and was in fact one of the first documented cases of this type of contamination. A 1987 report by the EPA revealed that fracking fluids from the Kaiser Exploration and Mining Company had polluted a privately owned water well 600 feet away from the drilling area (Urbina 2011b). This discovery was significant in that it refuted earlier claims from the oil and gas industry that hydraulic fracturing had never contaminated underground drinking water (Urbina 2011b).

There is relatively little data available describing the number of documented water contamination cases resulting from shale gas industry activities in West Virginia. This is in part due to the fact that energy companies can legally settle disputes surrounding water pollution directly with landowners, keeping the specific dealings of these cases confidential; the case is similar in Pennsylvania where water contamination cases and complaints are also kept confidential by the PA DEP (Urbina 2011b).

In a phone interview, James Martin, Chief of the WV DEP's Office of Oil and Gas said there were no reports of drinking water contamination resulting from shale gas development in the state. However, a January 2014 report by the Associated Press revealed that in West Virginia there were 122 complaints of well water contamination from 2009-2013 (Berkman 2014). Drilling operators agreed to take corrective action in only four of these cases (Berkman 2014).

The estimates used in this analysis are based on data from a variety of sources. The public affairs department of Cabot Oil & Gas provided the water testing cost data. The company paid a total of $700,000 to conduct a series of water tests during the Dimnock, Pennsylvania water contamination incident. Data from the Dimnock incident was also used to estimate the costs of connecting to a city water supply. The estimated cost for Cabot Oil & Gas to connect 19 homes to the nearest city water supply in Dimnock, Pennsylvania was $11.8 million and required the construction of a 5.5 mile water main (Pennsyvlania Department of Environmental Protection September 30). I divided the total figure to get the cost per home. While this particular estimate may seem exorbitant, many shale gas drilling projects take place in very rural parts of Pennsylvania and West Virginia where constructing a piped connection to a public water supply would indeed be a costly ordeal.

The costs for water cleaning are based on estimates for "air sparging." Air sparging entails injecting air into ground water to force the removal of chemical contaminants. According to a report by Frontier Group, air sparging can cost between $150,000 and $350,000 per acre. I decided to be conservative and estimate the costs at $150,000 per acre (Dutzik and Ridl 2012).

According to Corky Demarco, executive director of the West Virginia Oil and Natural Gas Association, if water contamination were to occur as a result of shale gas drilling activity, operators would likely provide an emergency drinking water replacement supply consisting of home deliveries of 5-gallon water bottles. To estimate this cost, I took the price of 5-gallon water bottles at Wal-Mart ($23.99) and multiplied this by 80 bottles per home and 10 homes estimated to be included in a water contamination incident. This is once again, a conservative estimate as it does not include the costs of transporting the water or labor involved in the process.

For the temporary water replacement, at Demarco and Perry's advice I assumed a water delivery service would be used. I contacted an emergency water delivery service based in New Milford Township, Pennsylvania—an area experiencing significant drilling activity. The delivery service estimated the cost of delivering 80 gallons of water per day to ten homes located within several miles of one another at approximately $300 daily.

For the well replacement costs, I consulted a home repair forum, which estimated the cost of drilling a new well to be between $3,000 and $50,000 (Vincent 2014). I averaged these numbers.

Regulatory Costs

The previous chapter described many of the rules and regulations in place to monitor the shale gas industries in Pennsylvania and West Virginia. There are costs associated with enforcing these regulations. The DEPs in both states are responsible for maintaining a staff of oil and gas inspectors who visit drilling and production sites on a regular basis, monitoring to ensure that operators are operating within their legal limits. Both states have had to hire additional inspection staff in response to increased drilling activity. This results in additional costs to the state.

Between 2010 and 2014, the PA DEP Office of Oil and Gas Management increased the number of inspectors on staff from 65 to 83. These inspectors receive an average annual salary of $46,443. The PA DEP incurs $835,983 annually in increased payroll expenses resulting from shale gas development in the state.

Similarly, the WV DEP Office of Oil and Gas has increased the number of inspectors on staff from 17 to 27 between 2012 and 2014. According to the horizontal well control act, all oil and gas inspectors in the state must be paid a minimum annual salary of $40,000. This means that the WV DEP currently incurs $400,000 annually in additional payroll costs resulting from the shale gas industry.

To estimate the inspection costs associated with a single gas well, I looked at the number of unconventional permits issued, inspectors on staff, and estimated inspector salaries at the WV and PA DEPs in 2012. I multiplied the number of inspectors by their salaries and divided this by the number of permits issued to get the approximate inspection costs per well.

Well Plugging and Site Remediation

When a natural gas well reaches the end of its productive lifespan, the operator is normally responsible for plugging the well and conducting site remediation. Plugging the well entails removing the well casing and equipment and inserting a cement plug in the borehole. The plug prevents leftover drilling fluids or natural gas from migrating and potentially contaminating land, surface water, and groundwater (Dutzik et al. 2013).

Abandoned wells have been a problem historically in the United States. In 2006, there were 59,000 orphan oil and gas wells on waiting lists for remediation and plugging and another 90,000 wells with "undocumented" or "unknown" status (Dutzik et al. 2013). It's estimated that the total cost of plugging these wells is greater than $760 million (Dutzik et al. 2013).

As discussed in the first chapter, in the shale gas industry wells have a relatively short lifespan, indicating that there is a need to frequently plug non-productive wells while drilling new ones at a fairly high pace. Operators' failure to keep up with demands could result in environmental contamination and public health risks.

According to Susan Ghoweri, Plugging Chief at the PA DEP Office of Oil and Gas Management, there are approximately 8,300 known abandoned wells in Pennsylvania with no known operator. It's unclear how many of these abandoned wells can be attributed to the shale gas industry, but the number varies very little from year to year despite extensive well plugging efforts led by the state's Abandoned and Orphaned Well Program; this indicates a steady increase in abandoned wells while those in existence are being plugged and remediated.

In the past, many extractive industry operators have failed to comply with plugging and site remediation requirements resulting in bond forfeitures. For example, in Pennsylvania between 2001 and 2008, 227 mines in the state experienced bond forfeitures (Dutzik et al. 2013). Coal mines generally have longer lifespans than gas wells. If the shale gas industry is failing to appropriately plug abandoned wells and the sum of bonds is insufficient to address this issue, Pennsylvania taxpayers will have to take on the significant task of plugging wells or face pollution risks that could result in even greater costs to the environment and public health.

According to West Virginia state law (the "Abandoned Well Act"), any oil or gas well that has been inactive for 12 months must be plugged unless the operator can demonstrate a viable future use for the well. As stated in the previous chapter, according to a 2012 West Virginia legislative audit, the Office of Oil and Gas of the Department of Environmental Protection was not properly enforcing this regulation, resulting in an increase in abandoned wells in the state. At the time of the audit in October 2012, there were almost 12,500 abandoned wells in the state, up from 10,900 in 2007 (Office of Oil and Gas, West Virginia Department of Environmental Protection 2012). Auditors attributed the failure of the WV DEP to address this concern to a staff shortage. The WV DEP has since added staff members but the number of abandoned wells has remained relatively static at approximately 12,200 in April 2014, including many gas wells. Overall, it appears that the WV DEP's failure to enforce well plugging regulations in the state may leave taxpayers to cover the costs of plugging wells and/or facing the pollution and public health risks associated with abandoned wells.

The PA DEP estimates horizontal well plugging costs to be between $60,000 and $100,000 depending on the length of the wellbore (Mitchell and Casman 2011). I averaged this range to arrive at an estimate of $80,000 per horizontal well plug. The site remediation costs come from a report by the Frontier Group, which estimated site remediation, including the costs of reclaiming retention ponds and repairing public roads at the site to be between $500,000 and $800,000 (Dutzik and Ridl 2012). I averaged these figures to come up with $650,000.

Shale Gas Industry Economic Benefits

Capturing the economic benefits of the shale gas industry depends primarily on three factors: 1) the nature of the industry, which generates significant employment opportunities at the start of drilling that are later eliminated when the drilling is completed; 2) taxation policies in place at the state level; and 3) private contracts negotiated between natural gas operators and mineral rights and land owners.

This section of the chapter explores benefit capture in Pennsylvania and West Virginia looking at the following aspects: employment, taxation, private contracts (royalties, lease payments, and damages), and economic multipliers. Each section explains the assumptions behind the economic benefit calculation in **Tables 11** and **12**.

Table 11 - Economic Benefits in Pennsylvania (per well)

Employment	50 local jobs, 3-6 months in duration, with average salary of $75,000
Corporate Tax – Dry Well	$75,796 annual
Corporate Tax – Wet Well	$221,559 annual
Impact Fee	$50,000 first year, $310,000 over 15 years
Royalties – Dry Well	$790,955 annual
Royalties – Wet Well	$2,311,545 annual
Lease Payments	$6,388 one time payment, lease valid for 5 years
Damage Payments to Surface Owners	$1,600 one time payment
Total Value Added Estimate	$2,373,618 annual

Table 12 - Economic Benefits in West Virginia (per well)

Employment	50 local jobs, 3-6 months in duration, with average salary of $75,000
Corporate Tax – Dry Well	$49,317 annual
Corporate Tax – Wet Well	$144,157 annual
Property Tax	$160,727 annual
Severance Tax – Dry Well	$237,250 annual
Severance Tax – Wet Well	$693,500 annual
Royalties – Dry Well	$593,125 annual
Royalties – Wet Well	$1,733,750 annual
Lease Payments	$6,388 one time payment, lease valid for 5 years
Damage Payments to Surface Owners	$1,600 one time payment
Total Value Added Estimate	$2,373,618 annual

Employment

The employment figures surrounding Marcellus Shale gas development are controversial in nature. According to a November 2013 report by the Multi-State Shale Research Collaborative, "firms with an economic interest in the expansion of drilling in the Marcellus [...] have used a variety of tools and techniques to exaggerate the employment impacts of shale drilling" (Mauro et al. 2013). The report cites one incident of this exaggeration, in particular. At a July 2012 press conference held by the Pennsylvania Chamber of Business and Industry, the president and CEO of The Institute for 21st Century Energy, Karen Harbert, told reporters that the shale gas industry had created 300,000 jobs in the last two years. This figure conflicted sharply with the Department of Labor and Industry's estimate of 18,007 jobs in "core" Marcellus activities and 5,611 jobs in "ancillary" industries (such as steel making) (Mauro et al. 2013). The Chamber later revised its statement, claiming the shale gas industry had not created 300,000 jobs, rather it "supported" the creation of 180,000 jobs in natural gas and related industries (Mauro et al. 2013).

In an interview, Michael Wood, one of the authors of the study and a research director with the Pennsylvania Budget and Policy Center, confirmed that while there is no doubt that employment has increased in the shale gas industry, measuring the industry's impact on employment in "ancillary" services is challenging. "The Department of Labor and Industry looks at the sectors that are involved in shale gas and they have a giant list of all the ancillary industries. Some have tangential relationships to shale gas but there is steelmaking in every industry—not just natural gas." Wood's point being that attributing all increases in steelmaking employment to shale gas, can lead to exaggerated employment claims.

To overcome this inaccuracy in the data, I spoke with industry experts about job creation linked with a single well's development. Consensus was that at the start of drilling, there are approximately 100 individuals working on a well pad, of which 50% are likely to be local. The local workers, which are generally service workers engaged in trucking or similar activities, make an average salary of $75,000 per year, and are employed on a single site for three to six months depending upon the length of the borehole. It's important to highlight that only 50% of the workers are local, as these are the workers who are most likely going to spend their earnings locally, setting off the economic multiplier effect that is discussed in greater detail in the coming pages.

While I did not include employment in ancillary services in my employment impact estimate, the economic multiplier ("total value added") should capture employment.

Taxation

Both Pennsylvania and West Virginia apply a corporate (business tax) to the shale gas industry. The corporate tax rate in West Virginia is 6.5%. In Pennsylvania it is 9.99%. To generate the corporate tax per well figures shown in **Tables 11** and **12**, I multiplied the average revenue per day for dry gas wells ($13,000) and wet gas wells ($38,000) by an estimated profit margin of 15.99% (corporate tax is generally paid on profits) (O'Leary 2014). I multiplied the estimated profit per well by the corporate tax rate for both states. The profit margin estimate is based on Cabot Oil & Gas' overall profit margin as of April 2014 (Schiavo 2014). Cabot's profit margin exceeds that of the industry, meaning that the economic benefits estimated here may be slightly exaggerated, thus providing for a conservative estimate of the economic losses associated with the water contamination scenario described later in the chapter.

Further, shale gas industry representatives in both states reported widespread use of tax credits that helped to alleviate operators' tax burden. West Virginia, for example, offers a strategic research and development tax credit that may be applied to research on natural gas drilling or production equipment (Muracca, Brown, and DeVore 2012). These tax credits are not included in the estimate, providing again for a more conservative estimate of losses associated with water contamination in the scenario described at the end of this chapter.

In addition to the corporate tax, natural gas reserves in West Virginia are also subject to a property tax. According to a 2009 study of the shale gas industry's economic impact on West Virginia, natural gas holdings generated $88.4 million in property tax that year. To arrive at the amount of property tax revenue resulting from a single well, I divided this figure by the total number of Marcellus Shale wells permitted for that year. Pennsylvania does not have a property tax on natural gas reserves.

Both states have put their own taxation policies in place specific to natural gas production. West Virginia employs a typical severance tax of 5% on natural gas production. 90% of the revenue generated from this tax goes into the state general fund. The remaining 10% is distributed to the counties. Every county gets a portion of this revenue based on their population and producing counties get an extra share based on their rate of natural gas production. Similar to the exercise I performed with the corporate tax, I simply multiplied the severance tax rate by the dry and wet well revenues.

Pennsylvania is the largest natural gas producing state in the country without a severance tax. Rather, Pennsylvania, through Act 13, applies an impact fee to natural gas production. The impact fee is based on the average annual price of natural gas and production rates. 60% of the revenue generated from the fee goes to the "Unconventional Gas Well Fund," which distributes the revenues to counties and municipalities with gas wells. The remaining 40% goes to the Marcellus Legacy Fund. 15% of this revenue is distributed to all counties in the state to support environmental initiatives (Pennsylvania Public Utility Commission 2012). To estimate the impact fee per well, I relied on calculations provided by Michael Wood from the Pennsylvania Budget & Policy Center, which estimated the impact fee revenue generated from a single well at $310,000 over a 15-year period.

Private Contracts

Royalty and lease agreements are normally negotiated individually between mineral rights owners and natural gas operators. Both Pennsylvania and West Virginia have minimum royalty payment laws in place. In West Virginia, the minimum royalty payment by law is 12.5% of gross production value. A 2006 court case, Tawny vs. Columbia Natural Resources, made it illegal for operators in West Virginia to deduct postproduction costs (transportation, taxes, etc.) from royalty payments.

The minimum royalty law in Pennsylvania is more challenging to decipher. According to Wood, the law provides that mineral rights owners receive 1/6th—1/6th of what exactly is unclear. "If you're an intelligent landowner you will sign a royalty agreement that entitles you to 1/6th of the gross production value," said Wood. Unfortunately, not all landowners have signed royalty agreements that were appropriately in their favor. Additionally, unless otherwise specified in the royalty agreement, natural gas operators in Pennsylvania are able to deduct postproduction costs from royalty payments. These deductions have been controversial among mineral rights owners who feel they are being underpaid (Cusick 2013a).

For both Pennsylvania and West Virginia, I estimated the royalty revenue per well by multiplying the minimal royalty law for both states by estimated revenues per well for dry and wet wells. For Pennsylvania, this estimate is likely exaggerated due to the aforementioned lack of clarity surrounding the minimum royalty payment law and operators' practice of deducting postproduction costs from royalty payments.

Lease payments are provided to mineral rights owners in return for the opportunity to develop natural gas on their property for a period of 5 years normally, though the length of the lease can vary. According to a report by Sean O'Leary from the West Virginia Center on Budget and Policy, lease payments normally vary between $750 and $2,900 per acre. To produce the estimated lease revenue per well, I averaged these figures and multiplied them by 3.5—the number of acres included in a typical Marcellus drilling site ("The Basics - Operations"). Researchers in Pennsylvania confirmed that this was a reasonable estimate for PA as well.

For both royalty and lease payments, it's important to note that these revenues go to the mineral rights owner associated with the natural gas reserves, NOT the land owner. In West Virginia, in particular, it is often the case that the mineral rights are severed from the surface rights to the property. According to one study, more than 10% of all the oil and gas well granted in the state since 2010 were on land owned by one logging company, Dallison Lumber (O'Leary 2014). Another 10% of permits were for land owned by state agencies (O'Leary 2014). In total, 25% of oil and gas permits are on land owned by two lumber companies, the state, a private university and an energy company (O'Leary 2014). When royalty and lease payments are directed towards large landholders that in some cases have no local presence whatsoever at the site of drilling, these revenues may never enter into the local economy.

Surface right owners who do not also own the mineral rights are normally entitled to one-time damage payments. While damage payment agreements would be negotiated privately on an individual basis and are therefore subject to variation, according to Demarco, landowners could be compensated for the value of timber removed from their property to make way for operations or they could receive $1-10 per foot of pipeline laid on their property. For my calculations, I estimated damage payments at $10 per foot pipeline for 160 feet of pipeline across a single property, resulting in a onetime damage fee of $1,600.

Economic Multiplier

In addition to the direct economic impact shale gas wells produce through generating tax, lease, and royalty revenues and employment, the industry also has an indirect affect on economic growth when shale gas workers or mineral rights' owners spend their earnings in the local community, leading to more job creation and economic benefit capture. A 2009 study of economic impacts of the Marcellus Shale in Pennsylvania estimates that if 50% of non-resident employee income stays in Pennsylvania and 15.4% minerals rights are owned out of state, total value added from a single well is $2,373,618 (Kelsey et al. 2011). I decided to use this estimate in my analysis as it is the only per well economic multiplier I could find that also took into account the fact that a portion of employee and mineral rights owner spending would take place outside of the state. The figure used may be a generous estimate in the case of West Virginia where the division of mineral rights and surface owner rights is more common.

Water Contamination Scenario

Overall, any single natural gas well in Pennsylvania and West Virginia should normally be managed in a way that allows for substantial profit generation. If this were not the case, then there would be no justification for the industry's existence. **Tables 13** and **14** demonstrate that a single well in Pennsylvania or West Virginia should generate more than $25 million in economic benefits (minus the aforementioned costs) over a 10-year period. However, despite the industry's profit making potential, drilling and production accidents can and do occur; and these accidents have the potential to greatly diminish the economic gains associated with any natural gas well. This section of the chapter will focus on the potential economic consequences associated with groundwater contamination resulting from shale gas industry activity.

Table 13 – One Dry Natural Gas Well in Pennsylvania over 10 Years

Costs	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Total
Road Damage	$ 18,000	$ 18,000	$ 18,000	$ 18,000	$ 18,000	$ 18,000	$ 18,000	$ 18,000	$ 18,000	$ 18,000	$ 180,000
Property Value Loss*	$ 212,500	x	x	x	x	x	x	x	x	x	$ 212,500
Oil and Gas Inspectors*****	$ 1,150	$ 1,150	$ 1,150	$ 1,150	$ 1,150	$ 1,150	$ 1,150	$ 1,150	$ 1,150	$ 1150	$ 11,500
Plugging Well	x	x	x	x	x	x	x	x	x	$80,000	$ 80,000
Site Remediation	x	x	x	x	x	x	x	x	x	$650,000	$ 650,000
										Total Costs	$ 1,134,000

Benefits	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Total
Corporate Tax – Dry Well	$ 75,756	$ 45,453	$ 29,545	$ 20,681	$ 14,477	$ 10,134	$ 7,094	$ 4,966	$ 3,476	$ 2,433	$ 214,015
Impact Fee	$ 50,000	$ 28,889	$ 28,889	$ 28,889	$ 28,889	$ 28,889	$ 28,889	$ 28,889	$ 28,889	$ 28,889	$ 310,000
Royalties – Dry Well	$ 790,955	$ 474,573	$ 308,472	$ 215,931	$ 151,152	$ 105,806	$ 74,064	$ 51,845	$ 36,291	$ 25,404	$ 2,234,493
Lease Payments	$ 63,888	x	x	x	x	$ 63,888	x	x	x	x	$ 127,776

Damage Payments to Surface Owners	$ 1,600	x	x	x	x	x	x	x	x	x	$ 1,600
Total Value Added Estimate	$ 23,73,618	$ 2,373,618	$ 2,373,618	$ 2,373,618	$ 2,373,618	$ 2,373,618	$ 2,3736,18	$ 2,373,618	$ 2,373,618	$ 2,373,618	$ 23,736,180

Total Economic Benefits		$ 26,624,064

Total Economic Gains		$ 25,490,064

Table 14 - One Dry Natural Gas Well in West Virginia over 10 Years

Costs	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Total
Road Damage	$ 18,000	$ 18,000	$ 18,000	$ 18,000	$ 18,000	$ 18,000	$ 18,000	$ 18,000	$ 18,000	$ 18,000	$ 180,000
Property Value Loss*	$ 212,500	x	x	x	x	x	x	x	x	X	$ 212,500
Oil and Gas Inspectors*****	$ 1,630	$ 1,630	$ 1,630	$ 1,630	$ 1,630	$ 1,630	$ 1,630	$ 1,630	$ 1,630	$ 1,630	$ 16,300
Plugging Well	x	x	x	x	x	x	x	x	x	$ 80,000	$ 80,000

Site Remediation	x	x	x	x	x	x	x	x	x	$ 650,000	$ 650,000
										Total Costs	$ 1,138,800
Benefits	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**	**Total**
Corporate Tax – Dry Well	$ 49,317	$ 29,590	$ 19,234	$ 13,464	$ 9,425	$ 6,597	$ 4,618	$ 3,233	$ 2,263	$ 1,584	$ 139,324
Severance Tax	$ 237,350	$ 142,410	$ 92,567	$ 64,797	$ 45,358	$ 31,750	$ 22,225	$ 15,558	$ 10,890	$ 7,623	$ 670,527
Property Tax	$ 160,727	$ 96,436	$ 62,684	$ 43,878	$ 30,715	$ 21,500	$ 15,050	$ 10,535	$ 7,375	$ 5,162	$ 454,063
Royalties – Dry Well	$ 593,125	$ 355,875	$ 231,319	$ 161,923	$ 113,346	$ 79,342	$ 55,540	$ 38,878	$ 27,214	$ 19,050	$ 1,675,612
Lease Payments	$ 63,888	x	x	x	x	$ 63,888	x	x	x	x	$ 127,776
Damage Payments to Surface Owners	$ 1,600	x	x	x	x	x	x	x	x	x	$ 1,600
Total Value Added Estimate	$ 2,373,618	$ 2,373,618	$ 2,373,618	$ 2,373,618	$ 2,373,618	$ 2,373,618	$ 2,373,618	$ 2,373,618	$ 2,373,618	$ 2,373,618	$ 23,736,180

Total Economic Benefits		$ 26,805,083

Total Economic Gains		$ 25,666,283

As stated previously, data on incidents of water contamination in both Pennsylvania and West Virginia was sparse with regulatory authorities from both states claiming that either a) there were no incidents of shale gas related water contamination (West Virginia) or b) that any information surrounding complaints of water contamination was confidential (Pennsylvania and West Virginia). The Dimnock township methane leak into drinking water supplies and the 1984 drilling related water contamination incident in West Virginia do however confirm that water pollution is a potential outcome of drilling for shale gas and that when it does occur, it can be very costly to fix.

In this section of the chapter, I demonstrate the potential economic impact of water contamination resulting from shale gas industry activity in both states. According to one study that looked at the natural gas industries in New Mexico and Colorado, groundwater contamination incidents occur at a rate of 1.2-1.8 incidents per every 100 producing gas wells (Bishop 2011). In this scenario, I imagine that 1.2% of permitted shale gas drilling projects in 2012 in Pennsylvania and West Virginia result in groundwater contamination. I chose 2012 because both Act 13 (Pennsylvania) and the Horizontal Well Control Act (West Virginia) were in force by this date, put in place to keep pace the shale gas industry and protect residents from potential negative externalities of the industry. I compare the economic costs of water contamination with the permitting and assurance data from Chapter 2 as well as the economic benefit data described in this chapter, ultimately searching for any gaps in cost coverage.

Pennsylvania Water Contamination Scenario

Table 15 demonstrates that if water contamination were to occur at a rate of 1.2% of permitted wells in 2012 in Pennsylvania it could result in $1.31 billion in costs with well replacement and almost $1.41 billion in expenses if city water connections became necessary. Meanwhile **Table 16** demonstrates that the assurances and permits put in place to address this type of disaster are insufficient, maxing out at $492 million if no blanket bonding mechanism is used. **Table 17** shows the total gap in cost coverage under a variety of scenarios. By all accounts, the gap is significant ranging from $858 million to $1.4 billion depending on whether or not a bonding mechanism is put in place and/or whether the construction of a city water connection is necessary to provide a permanent replacement water supply.

Table 18 demonstrates that even excluding direct employment benefits (which are incorporated into the model tangentially via the "total value added" estimate), the economic benefits (approximately $5 billion) associated with drilling in the Marcellus Shale in Pennsylvania in 2012 outweigh the costs, even taking a 1.2% rate of water contamination into account. However, there are several important caveats to keep in mind. First, none of the permitting and assurance fees are intended to address water contamination. In fact, there is no "safety net" in place to address water contamination. While natural gas operators in Pennsylvania are required by law to provide a temporary and replacement water supply in the event that they are held liable for water contamination, there is no bonding requirement that sets aside monies to address this concern, nor is there a legal requirement that operators carry an insurance policy to address costs associated with water contamination. If an operator were to suddenly become insolvent or have insufficient funds to address a major water contamination issue, there is simply no safety net—the costs would fall on the state.

Second, while the state is generating significant tax revenues from the shale gas industry, even these, which exceed $217 million including the impact fee, are insufficient to address water contamination issues. Revenues would have to be diverted from other perhaps equally important purposes in order to address the costs associated with natural gas operators' errors. Private landowners would also have to shoulder some of the costs.

Finally, the scenario described here describes only the normal costs of drilling (inspection, well plugging, site remediation) and damage costs associated with water contamination. Other types of damage (public health, natural habitat destruction) could generate much higher cost levels for communities affected by the shale gas industry. If the permitting and assurance fees in place no do not even cover the costs associated with a 1.2% rate of water contamination, they would certainly be insufficient to address more widespread damage of different varieties.

Table 15 - Costs and Potential Damages Resulting from Shale Gas Wells in Pennsylvania in 2012, assuming water contamination rate of 1.2%

Road Damage	$18,000 over lifetime of well	$24,264,000
Property Value Loss*	8.50%	$286,450,000
Water Testing**	$700,000	$11,323,200
Water Cleaning	$150,000	$8,492,400
Water Replacement in 24 hours (delivery of 5 gallon water bottles)***	$19,192 daily	$931,349
Water Replacement in 72 hours (water delivery to tanks)****	$300 daily	$436,752
Permanent Water Replacement	$26,500 – Drilling a new well (per home), or $621,052 – Connecting to city water (per home)	$42,866
		$100,461,372
Oil and Gas Inspectors*****	$1,150 annual (Pennsylvania), $1,630 annual (West Virginia)	$1,550,200
Plugging Well	$80,000 one time fee	$107,840,000
Site Remediation	$650,000 one time fee	$876,200,000
	Total Costs with Well Replacement	$1,317,530,768
	Total Costs with City Water Connection	$1,417,949,273

*Assumes 10 houses within 1,000 feet of well, each valued at $250,000

**Assumes 3.5 acre clean up area

***Assumes 3 days of emergency water deliveries, 400 gallons per home per day for 10 homes affected by groundwater contamination per incident

****Assumes 90 days of water deliveries

*****Assumes 35 inspectors with a salary of $46,443 for 1,348 wells permitted in 2012

Table 16 - Permitting and Assurances in Pennsylvania in 2012

Drilling Permit (per well)	$2,500	3,370,000
Site Remediation Bond*	If well bore is less than 6,000 ft and there are less than 50 wells- $4,000 per well, more than 50 wells $35,000-$100,000 required in addition to individual well amount. If well bore is greater than 6,000 ft.- $10,000 per well bond required + lump sum for more than 25 wells ($140,000-$430,000)	9,436,000
Road Bond- Paved Road**	$12,500 per mile	454,950,000
Road Bond – Unpaved**	$6,000 per mile	24,264,000
Road Bond – District Blanket Bond***	$10,000	180,000
Insurance	Not required	
Road Maintenance Agreements	?	
Heavy Load Transit Permitted****	Approximately $30	40,440
	Total Permitting and Assurances with Individual Road Bonding	492,060,440
	Total Permitting and Assurances with Road District Blanket Bonds	13,026,440

*Assumes 50% of wells are 6,000 ft or less and 50% are greater than 6,000 ft. No blanket bond.

**Assumes 30 miles of bonded roaded per well, 90% paved, 10% unpaved

***Assumes one bond for each congressional district

**** Assumes one heavy load permit per drilling site

Table 17- Cost and Potential Damages vs. Permitting and Assurances in Pennsylvania in 2012

	Total Permitting and Assurances with Individual Road Bonding	Total Permitting and Assurances with Road District Blanket Bonds
Total Costs with Well Replacement	-$825,470,328	-$1,304,504,328
Total Costs with City Water Connection	-$925,888,833	-$1,404,922,833

Table 18 - Economic Benefits in Pennsylvania in 2012

Corporate Tax – Dry Well*	$75,796 annual	$76,629,756
Corporate Tax – Wet Well*	$221,559 annual	$74,665,383
Impact Fee	$50,000 first year, $310,000 over 15 years	$67,400,000
Royalties – Dry Well*	$790,955 annual	$799,655,505
Royalties – Wet Well*	$2,311,545 annual	$778,990,665
Lease Payments	$6,388 one time payment, lease valid for 5 years	$8,611,024
Damage Payments to Surface Owners	$1,600 one time payment	$2,156,800
Total Value Added Estimate	$2,373,618 annual	$3,199,637,064
	Total Economic Benefits	$5,007,746,197

*Assumes 75% dry wells an 25% wet wells, and a profit margin of 15.99%

West Virginia Water Contamination Scenario

Very similar results are evident in the case of West Virginia, where a drinking water contamination rate of 1.2% would generate $316 million in expenses with well replacement and $340 million in expenses with the need to construct a city water connection (see **Table 19**). **Table 20** demonstrates that if no bonding mechanisms were used, West Virginia would have enough permitting and assurance revenue to address the challenges of water contamination. However, conversations with regulators and Demarco revealed that many operators take advantage of blanket bonding opportunities in West Virginia. **Table 21** reveals the serious lack of cost coverage if water contamination were to occur, ranging from $292 - $324 million. While the overall economic benefits of shale gas wells in 2012 (**Table 22**) would be sufficient to cover this cost gap, the same caveats apply as in the case of Pennsylvania. First, none of the permitting or assurance fees are intended to address water contamination, nor is there a legal requirement that operators carry an insurance policy to address these risks. Second, the tax revenues generated by the shale gas industry (approximately $187 million) would be insufficient to address the water contamination issues. Once again, public funding would have to be diverted from other equally worthy programs.

According to Sean O'Leary, a fiscal policy analyst at the West Virginia Center on Budget and Policy, much of the additional tax revenue generated by the shale gas industry is currently being used by the state to address budget shortfalls resulting from cutbacks in federal funding, meaning there are no additional funds available for addressing damage resulting from natural gas operators. Private landowners may be left to cover some of the costs of drinking water contamination on their own properties in the event that operators failed to take responsibility.

As is the case in Pennsylvania, if West Virginia does not have the capacity to address even a 1.2% rate of water contamination then it will not have the capacity to address the costs of the shale gas industry that are still unknown.

Table 19 - Costs and Potential Damages Resulting from Shale Gas Wells in West Virginia in 2012, assuming water contamination rate of 1.2%

Road Damage	$18,000 over lifetime of well	$5,832,000
Property Value Loss*	8.50%	$68,850,000
Water Testing	$700,000	$2,721,600
Water Cleaning**	$150,000	$2,041,200
Water Replacement in 24 hours (delivery of 5 gallon water bottles)***	$19,192 daily	$223,855

Water Replacement in 72 hours (water delivery to tanks)****	$300 daily	$104,976
Permanent Water Replacement	$26,500 – Drilling a new well (per home), or $621,052 – Connecting to city water (per home)	$10,303
		$24,146,502
Oil and Gas Inspectors	$1,150 annual (Pennsylvania), $1,630 annual (West Virginia)	$528,120
Plugging Well	$80,000 one time fee	$25,920,000
Site Remediation	$650,000 one time fee	$210,600,000
	Total Costs with Well Replacement	$316,832,055
	Total Costs with City Water Connection	$340,968,253

*Assumes 10 houses within 1,500 feet of well, each valued at $250,000
**Assumes 3.5 acre clean up area
***Assumes 3 days of emergency water deliveries, 400 gallons per home per day for 10 homes affected by groundwater contamination per incident
****Assumes 90 days of water deliveries
*****Assumes 17 inspectors with a salary of $40,000 for 324 Marcellus wells drilled in 2012

Table 20 - Permitting and Assurances in West Virginia in 2012

Drilling Permit (first well)	$10,000	$3,240,000
Drilling Permit (additional wells)	$5,000	
Site Remediation Bond (single well)	$50,000	$16,200,000
Site Remediation Blanket Bond*	$250,000	$8,100,000
Road Bond- Paved Road**	$100,000 per mile	$874,800,000
Road Bond – Tar and chipped Road**	$35,000 per mile	$34,020,000
Road Bond – District Blanket Bond***	$250,000	$2,500,000
Road Bond – State Blanket Bond****	$1,000,000	$5,000,000
Insurance	Not required	

Road Maintenance Agreements	?	
Heavy Load Transit Permit*****	Approximately $26	$8,424
	Total Permitting and Assurances with Individual Well Permits, No Blanket Bonding	$928,268,424
	Total Permitting and Assurances with Individual Well Permits, Site Remediation Blanket Bond	$920,168,424
	Total Permitting and Assurances with Individual Well Permits, Road District Blanket Bonds	$21,948,424
	Total Permitting and Assurances with Individual Well Permits, Road State Blanket Bond	$24,448,424
	Total Permitting and Assurances with Individual Well Permits, Site Remediation Blanket Bond, and Road State Blanket Bond	$16,348,424

*Assumes 10 wells per blanket bond

**Assumes 30 miles of bonded roadway per drilling site, 90% paved and 10% tar and chipped

***Assumes one bond for each district

****Assumes five largest operators each purchase one state blanket bond

*****Assumes one heavy load permit per drilling site

Table 21- Cost and Potential Damages vs. Permitting and Assurances in West Virginia in 2012

	Total Permitting and Assurances with Individual Well Permits, No Blanket Bonding	Total Permitting and Assurances with Individual Well Permits, Site Remediation Blanket Bond	Total Permitting and Assurances with Individual Well Permits, Road District Blanket Bonds	Total Permitting and Assurances with Individual Well Permits, Road State Blanket Bond	Total Permitting and Assurances with Individual Well Permits, Site Remediation Blanket Bond, and Road State Blanket Bond
Total Costs with Well Replacement	$611,436,369	$603,336,369	-$294,883,631	-$292,383,631	-$300,483,631
Total Costs with City Water Connection	$587,300,171	$579,200,171	-$319,019,829	-$324,619,829	-$324,619,829

Table 22 - Economic Benefits in West Virginia in 2012

Corporate Tax – Dry Well*	$49,317 annual	$11,984,031
Corporate Tax – Wet Well*	$144,157 annual	$11,676,717
Property Tax	$160,727 annual	$52,075,548
Severance Tax – Dry Well*	$237,250 annual	$57,651,750
Severance Tax – Wet Well*	$693,500 annual	$56,173,500
Royalties – Dry Well*	$593,125 annual	$144,129,375
Royalties – Wet Well*	$1,733,750 annual	$140,433,750
Lease Payments	$6,388 one time payment, lease valid for 5 years	$2,069,712
Damage Payments to Surface Owners	$1,600 one time payment	$518,400
Total Value Added Estimate	$2,373,618 annual	$769,052,232
	Total Economic Benefits	$1,245,765,015

*Assumes 75% dry wells an 25% wet wells, and a profit margin of 15.99%

Conclusions

The data presented in this chapter demonstrates that while there are significant economic benefits associated with shale gas extraction, these benefits may fall short of addressing potential damage associated with the industry's activities. This is true for both Pennsylvania and West Virginia where tax revenues to the state would be insufficient to address the costs associated with a water contamination rate of 1.2%.

There are two important caveats to these findings. First, it's unlikely that every natural gas operator found responsible for groundwater contamination would fail to fulfill its responsibilities to address the associated costs (water testing, water replacement, etc.). It would more likely be the case that only a minor percentage of operators responsible for water contamination would fail to address these costs. Nonetheless, the objective of the water contamination scenario is to describe the total scale of potential costs associated with a water contamination rate of 1.2%. In this regard, the estimates provided here are accurate. Second, while permits and financial assurances may fail to address the full costs of water contamination and an operator may fail to take responsibility for these costs initially, the state could ultimately employ litigation against the responsible operator in order to attempt to recoup some of these costs. However, litigation is a time consuming and costly process that states should seek to avoid.

The following chapter suggests several policy solutions for addressing this gap in cost coverage without having to resort to litigation.

Chapter 4

Addressing the Costs of the Shale Gas Industry to Communities

Introduction

The last chapter used a simulation of water contamination to highlight the existing gaps in cost coverage for shale gas industry activities and potential damages. This chapter provides recommendations to increase permitting and assurances in order to be able to address the costs of the industry to communities and the environment and to reduce the potential costs. It focuses on six primary recommendations:

1. Making insurance for operators a requirement by law.
2. Making blanket-bonding opportunities more conservative.
3. Increasing the amount per site remediation bond.
4. Creating a water bond.
5. Improving enforcement.
6. Commissioning more extensive studies of the impact of the shale gas industry on public health and natural habitats.

Recommendations

Making Insurance a Requirement by Law

Natural gas operators in Pennsylvania and West Virginia are not required by law to carry insurance that would address the costs associated with water contamination or other environmental disasters. According to Corky Demarco, Executive Director of the West Virginia Oil and Natural Gas Association, many operators do carry insurance to address these risks, but again it's not required. This means that if an accident were to occur and the operator involved did not have the financial means to address the damages, there would be no other recourse but to rely on the financial resources of the state or individuals impacted by the damages. As demonstrated in the previous chapter, the state may even have insufficient revenues to address damages, meaning private residents will really be left to pay the bill. This is unacceptable. Requiring operators obtain liability insurance policies would pass the responsibility on to insurance companies and provide assurance that damages would be addressed, even if the operator responsible did not have the financial capacity on its own to address the problem (Dutzik et al. 2013). Mandatory insurance policies are particularly crucial given the nature of the shale gas industry in Pennsylvania and West Virginia, where there are many small operators with relatively small operating budgets (Maugeri 2013).

Making Blanket Bonding Opportunities More Conservative

As the scenarios in Chapter 3 demonstrate, blanket bonding, which allows an operator to submit one site remediation or highway bond for an unlimited number of well sites based in a geographic area, significantly reduces the amount of financial assurances available to the state to address damages perpetrated by the industry. Logically, one site remediation bond, even of a high value ($100,000+) could be insufficient to address an unlimited number of drilling sites. Created to incentivize drilling activity, the way blanket bonding is currently in practice is irresponsible and could lead to saddling the state and its residents with the significant costs associated with damages from the shale gas industry.

Going forward, blanket-bonding policies should force operators to provide financial assurances fully in line with their activities; or it should at the very least be more limited in the sense that one blanket bond could be used to address a maximum number of wells.

Increase the Amount per Site Remediation Bond

The last chapter provided data from the PA DEP, estimating the cost to plug horizontal wells in Pennsylvania to be $60,000-$100,000. At present, site remediation bonds in West Virginia and Pennsylvania have a maximum value of $50,000 to $100,000, respectively. In addition to introducing more conservative blanket bonding, both states should increase the amount per site remediation bond in order to be able to undertake well plugging in the event that a natural gas operator fails to do so. The frequency of drilling associated with the shale gas industry could make the costs of abandoned wells in the industry an astronomical burden for the state to bear unless bonding requirements are increased.

Creating a Water Bond

At present, none of the permitting or financial assurances in place in either state is intended to address the potential costs of water contamination. Either in addition to or in lieu of requiring operators carry insurance policies to cover the costs associated with water contamination, states could also create a water-bonding scheme similar in nature to road or site remediation bonds. Operators would be required to put forth a bond sufficient to cover the potential costs of water contamination including water testing, cleaning, and replacement. This bond would help the state to address these costs in the event that the operator responsible for the accident failed to fulfill its obligations to the community.

Improving Enforcement

Representatives from both the PA and WV DEPs cited a shortage of personnel as a challenge for inspection and enforcement. Concerted efforts must be taken to increase the human resource capacity of these agencies in order to keep pace with the booming shale gas industry.

Another proposal for improving enforcement is increasing the availability and clarity surrounding enforcement data. As mentioned in Chapter 2, at present it's challenging to see how many violations result in enforcement actions given the nature of the data, which lumps multiple violations into a single enforcement action. In addition to the lack of clear data surrounding enforcement actions, there is an absolute dearth of data surrounding water contamination. Regulators in both West Virginia and Pennsylvania hesitated to comment on complaints of water contamination and emphasized the confidentiality of such incidents. There is no reason that water contamination that poses a danger to public health should be kept confidential. Efforts should be made by both state DEPs to provide comprehensive information on the number of water contamination reports and resulting actions.

Further, additional data on violations may help the state DEPs to be able to determine when a drilling or production error is likely to occur, and thus when and where inspectors should be sent, thereby optimizing the use of limited human resources.

In summary, I recommend a two-pronged approach to improving regulatory enforcement. First, both states should invest in hiring more inspection and regulatory staff personnel. Second, both state should prioritize creating inspection, violation, and enforcement data that can be more readily interpreted while also creating more transparency around reports of water contamination.

Commissioning More Extensive Studies of the Costs of the Shale Gas Industry

This thesis focused on assessing some of the most tangible costs of the shale gas industry to communities: road damage, water contamination, property value loss, and regulatory costs. As mentioned in the previous chapter, the costs of the industry may actually be much more substantial if one takes into account potential public health costs or natural habitat loss. As an example, in April 2014, a Texas family won a $3 million judgment against a natural gas operator in their area after suffering a variety of negative health impacts believed to be related to the operator's drilling and production activities ("Texas Family Plagued with Ailments Gets $3M in Fracking Judgement" 2014). More efforts should be taken at both the state and federal level to assess and quantify the negative impacts of the shale gas industry on public health and natural habitats. Developing more comprehensive and accurate data around these costs will allow state level policymakers to make more informed decisions about how to regulate the shale gas industry.

Conclusions

This thesis demonstrates that while the shale gas industry offers significant economic benefits to residents of Pennsylvania and West Virginia it also comes at a significant cost. At present the financial assurances in place to address the costs of the industry are insufficient. Going forward, if Pennsylvania and West Virginia hope to not repeat the mistakes of the past in confronting yet another natural resource boom, both states need to make concerted efforts to increase the financial assurances required of natural gas operators while improving enforcement actions.

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