NATIONAL ENERGY TECHNOLOGY LABORATORY

Projecting the Economic Impact of Marcellus Shale Gas Development in West Virginia: A Preliminary Analysis Using Publicly Available Data

March 31, 2010

DOE/NETL- 402033110

ALL CONSULTING

U.S. DEPARTMENT OF ENERGY

DISCLAIMER

PROJECTING THE ECONOMIC IMPACT OF MARCELLUS SHALE GAS DEVELOPMENT IN WEST VIRGINIA: A PRELIMINARY ANALYSIS USING PUBLICLY AVAILABLE DATA

402/033110

FINAL REPORT

March 31, 2010

NETL Contact:

Anthony M. Zammerilli
General Engineer
Office of Systems Analyses and Planning

National Energy Technology Laboratory

www.netl.doe.gov

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

TABLE OF EXHIBITS

PREPARED BY:

Technology & Management Services (TMS)

All Consulting, LLC

DOE Contract #DE-AC26-04NT41817

Acknowledgements

This report was prepared by **ALL Consulting, LLC** under a **Technology and Management Services, TMS** site support contract for the United States Department of Energy's National Energy Technology Laboratory. This work was completed under DOE NETL Contract Number DE-AC26-04NT41817. This work was performed under TMS Subtask 41817-402.01.02. ALL Consulting, LLC logo used with permission.

The authors wish to acknowledge the excellent guidance, contributions, and cooperation of the NETL staff, particularly:

Anthony M. Zammerilli, NETL Technical Monitor

Timothy Skone

Joseph Dipietro

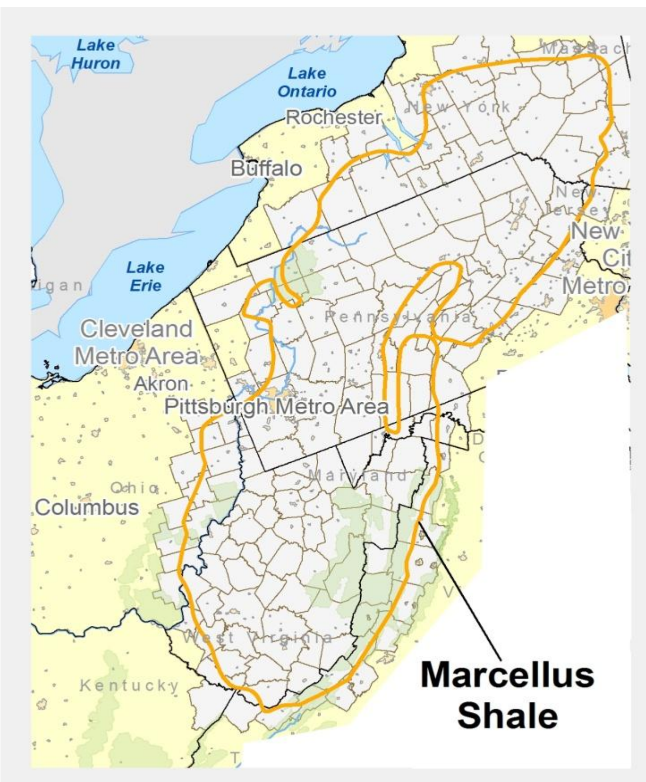
EXECUTIVE SUMMARY

Natural gas production from hydrocarbon rich shale formations, known as "shale gas," is one of the most rapidly expanding trends in onshore domestic oil and gas exploration and production today. Due to its high energy content, versatility, and low emissions, natural gas is a key component of the U.S. energy supply. Shale gas is already an important contributor to U.S. natural gas supply, and is predicted to have a significant and increasing role in the domestic energy portfolio in the future.

One of the most promising of the emerging shale gas plays is the Marcellus shale which covers an area of about 95,000 square miles, spanning six northeastern states (Exhibit ES-1). Recent estimates suggest that as much as 489 Tcf of gas may be recovered from the Marcellus, enough gas to meet the country's natural gas needs for more than 20 years at current consumption rates.

The Marcellus shale extends throughout most of West Virginia. While no formal resource assessments exist for the state, this study estimates that 100 to 150 Tcf may be recoverable from the Marcellus shale in West Virginia. Development of this substantial resource is expected to increase economic activity in the state and have far-reaching benefits.

EXHIBIT ES-1: MAP OF MARCELLUS PLAY



Source: ALL Consulting, Modified from USGS and WVG&ES, November, 2009

West Virginia is suffering an economic downturn, along with the rest of the country. Employment in both the goods and services sectors has decreased, the state budget is running a deficit, and the state, with the exception of one county, is losing population. The state economy is more reliant on mining than most states, and that sector faces regulatory uncertainty.

While Marcellus shale gas development in West Virginia is in its infancy, it is already making a positive contribution to the economy. In 2008, the industry drilled 299 gas wells in the Marcellus Shale. Through direct, indirect, and induced economic activity, these wells contributed $371 million in gross economic output, $189 million in value added, over 2,200 jobs, and $68 million in taxes (Exhibit ES-2).

EXHIBIT ES-2: CURRENT AND FUTURE IMPACTS OF SHALE GAS DEVELOPMENT ($MILLION)				
Year	**Gross Economic Output**	**Value Added**	**Jobs**	**Total Taxes**
2008	$371	$189	2,247	$68
2009	$989	$561	4,858	$199
2010	$1,161	$658	5,998	$266
2015	$1,874	$1,061	10,604	$531
2020	$2,896	$1,639	16,863	$872

Gross Economic Output *is the sum of direct, indirect and induced economic impacts.*

Value Added *is Gross Economic Output minus intermediate capital and labor. I t is often considered a more meaningful measure of true economic benefit from an activity.*

The pace of drilling for Marcellus Shale gas wells is expected to increase substantially in the future, growing to about 900 wells per year by 2020. As shown in Exhibit ES-2, this increasing level of drilling activity, with the accompanying industry expenditures in the state, is projected to contribute substantially to jobs, state taxes, and the overall economy in West Virginia. Through 2020, the cumulative production of shale gas in the state will total about 30 Tcf, worth more than $200 billion.

While these benefits are substantial and should provide some relief for a struggling economy, it should be noted that it is likely that these benefits are underestimated. This study has taken a conservative approach in estimating benefits. Where input data were not available or were not complete, this study either excluded those inputs or purposefully used conservative estimates to ensure that the benefits are not overstated. Similar studies in other states indicate the economic benefits of shale gas development in West Virginia will be even higher than those presented in this report.

LIST OF ACRONYMS

Bcf	billion cubic feet
Btu	British thermal unit
CO2	Carbon dioxide
EIA	Energy Information Administration
EUR	estimated ultimate recovery
Ft	foot/ feet
GHG	greenhouse gas
IOGA WV	Independent Oil and Gas Association of West Virginia
Mcf	thousand cubic feet
MIG	Minnesota IMPLAN Group, Inc.
MMcf/D	million cubic feet per day
NETL	National Energy Technology Laboratory
NGPA	Natural Gas Policy Act (1978)
Psi	pounds per square inch
PSU	Pennsylvania State University
Ro	Vitrinite Reflectance
Tcf	trillion cubic feet
Tcf/Y	trillion cubic feet per year
U.S.	United States
WVG&ES	West Virginia Geological and Economic Survey
WV OOG	West Virginia Department of Environmental Protection, Office of Oil and Gas

THIS PAGE INTENTIONALLY LEFT BLANK

INTRODUCTION

Natural gas production from hydrocarbon rich shale formations, known as "shale gas," is one of the most rapidly expanding trends in onshore domestic oil and gas exploration and production today.[1] In some areas, this has included bringing drilling and production to regions of the country that have seen little or no such activity in the past. New oil and gas developments bring change to the environmental and socio-economic landscape, particularly in those areas where gas development is a new activity. With these changes have come questions about the nature of shale gas development, the potential environmental impacts, and the potential economic impacts. Regulators, policy makers, and the public need an objective source of information on which to base answers to these questions as well as decisions about how to best manage the challenges that may accompany shale gas development.

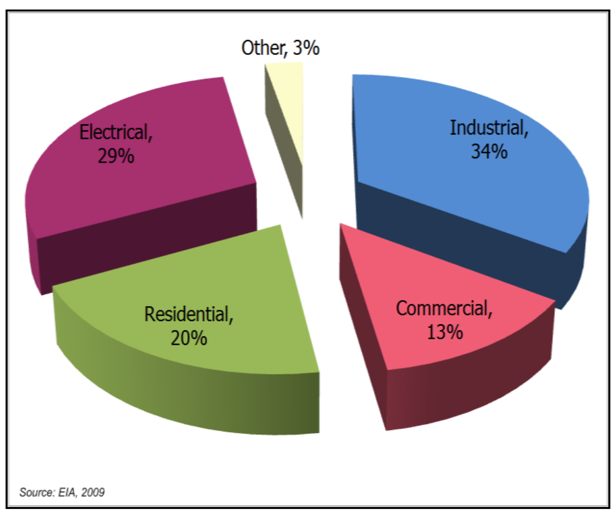
The National Energy Technology Laboratory (NETL) has previously published a separate report that discusses the technical and environmental aspects of shale gas development on a nationwide basis.[2] This study endeavors to provide information about the current and potential economic impacts of Marcellus shale gas development specific to West Virginia. It briefly describes the importance of shale gas in meeting the energy needs of the United States (U.S.), both now and in the future. This report also provides an overview of the Marcellus shale play and the potential for development in West Virginia. By providing such an overview and analysis, this report can serve as an instrument to facilitate informed public discussions and to support sound policy-making decisions.

Importance of Natural Gas

Natural gas plays a key role in meeting U.S. energy demands. Natural gas, coal and oil supply about 85% of the nation's energy, with natural gas supplying about 22% of the total.[3] The percent contribution of natural gas to the U.S. energy supply is expected to remain fairly constant for the next 20 years.

Natural gas use is distributed across several sectors of the economy (Exhibit 1[4]). It is an important energy source for the industrial, commercial and electrical generation sectors, and also serves a vital role in residential heating.[5] Although forecasts vary in their outlook on the future demand for natural gas, they all have one thing in common: natural gas will continue to play a significant role in the U.S. energy picture for some time to come.[6]

EXHIBIT 1: NATURAL GAS USE BY SECTOR



One reason for the widespread use of natural gas is its versatility as a fuel. Its high British thermal unit (Btu) content and a well-developed infrastructure facilitate its use in a variety of applications.

Another factor that makes natural gas an attractive energy source is its reliability. Eighty-four percent of the natural gas consumed in the U.S. is produced in the U.S., and ninety-seven percent of the gas used in this country is produced in North America.[7] Thus, the supply of natural gas is not dependent on unstable foreign countries and the delivery system is less susceptible to interruption.

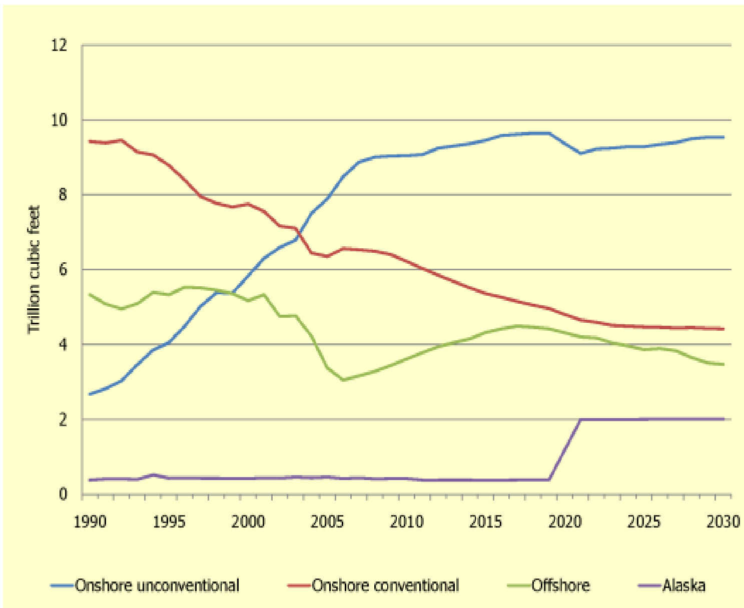
A key advantage of natural gas is that it is efficient and clean burning.[8] In fact, of all the fossil fuels, natural gas is by far the cleanest burning. It emits approximately half the carbon dioxide (CO_2) of coal along with low levels of other air pollutants.[9] Because natural gas emits only half as much CO_2 as coal and approximately 30% less than fuel oil, it is generally considered to be central to energy plans focused on the reduction of greenhouse gas (GHG) emissions.[10]

Additionally, the march towards sustainable renewable energy sources, such as wind and solar, requires that a supplemental energy source be available when weather conditions and electrical storage capacity prove challenging.[11] Such a backup energy source must not only be widely available, but also at near instantaneous supply. The availability of extensive natural gas transmission and distribution pipeline systems makes natural gas uniquely suitable for this role.[12] Thus, natural gas is an integral facet of moving forward with alternative energy options. With the current emphasis on the potential effects of air emissions on global climate change, air quality, and visibility, cleaner fuels like natural gas are an important part of our nation's energy future.[13]

Role of Shale Gas

The U.S. increased its natural gas reserves by 6% from 1970 to 2006, producing approximately 725 trillion cubic feet (Tcf) of gas during that period.[14] This increase is primarily a result of advancements in technology, resulting in an increase in economically recoverable reserves (reserves becoming proven) from unconventional natural gas reservoirs.[15] Unconventional gas fields are typically present as regionally extensive strata that are often of low permeability. In most cases the rock strata forming an unconventional play serve the function of both source rock and reservoir. A simple but useful way of looking at the evolution of the

EXHIBIT 2: NATURAL GAS PRODUCTION BY SOURCE (TCF/YEAR)



Source: EIA, 2008

oil and gas industry, which reflects this shift from conventional toward unconventional reservoirs, is to view it as moving from resources that are "hard to find, but easy to produce" to resources that are "easy to find, but hard to produce."[16]

EXHIBIT 3: UNITED STATES SHALE BASINS

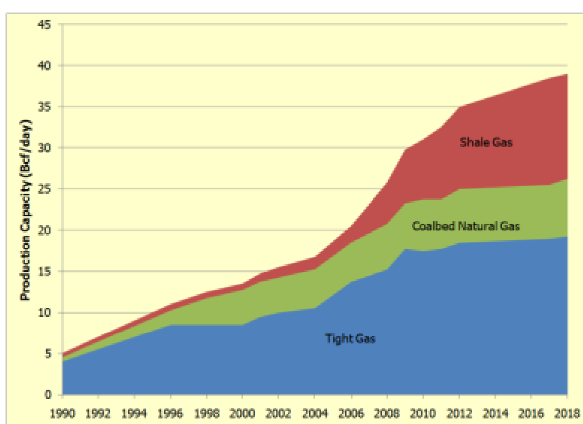
Source: Modified from USGS and other sources. March 2009[17]

Overall, unconventional natural gas is anticipated to become an ever-increasing portion of the U.S. proved reserves, while at the same time conventional gas reserves are declining.[18] Over the last decade, production from unconventional sources has increased almost 65%, from 5.4 Tcf per year (Tcf/Y) in 1998 to 8.9 Tcf/Y in 2007 (Exhibit 2). This means unconventional production now accounts for 46% of the total U.S. production.[19]

The lower 48 states have a wide distribution of organic-rich shales potentially containing vast resources of natural gas (Exhibit 3). Already, the fledgling Barnett Shale play in Texas produces 6% of all natural gas produced in the lower 48 states.[20]

Exhibit 4[21] shows that the projected contribution of shale gas is predicted to increase to about 38% of the

EXHIBIT 4: UNITED STATES UNCONVENTIONAL GAS OUTLOOK



overall unconventional gas production in the U.S. by 2018. Two technologic factors have come together in recent years to make shale gas production economically viable: 1) advances in horizontal drilling, and 2) advances in hydraulic fracturing. Analysts have estimated that by 2011 most new reserves growth (50% to 60%, or approximately 3 billion cubic feet (Bcf)/day) will come from unconventional shale gas reservoirs.[22]

SHALE GAS DEVELOPMENT IN THE UNITED STATES

Shale Gas History

Shale formations across the U.S. have been developed to produce natural gas in low, but continuous, volumes since the earliest years of gas development. Early supplies of natural gas were derived from natural gas seeps and shallow gas wells of relatively simple construction.[23] These wells and seeps typically produced the limited volumes of natural gas suitable for domestic use and also played a key role in bringing illumination to the cities and towns of the eastern U.S.[24,25] In fact, the first producing gas well in the U.S. was completed in 1821 in Devonian-aged shale near the town of Fredonia, New York, where it was used for lighting.[26,27]

The first field-scale development of shale gas occurred in the Ohio Shale at Big Sandy Field in Kentucky during the 1920s.[28] This field has recently experienced a resurgence of growth and currently encompasses five counties.[29] By the 1930s, gas from the Antrim Shale in Michigan had experienced moderate development; however, it was not until the 1980s that development began to expand rapidly to the point that it has now reached nearly 9,000 wells.[30] It was also during the 1980s that one of the nation's most active natural gas plays first kicked off in the area around Fort Worth, Texas.[31] The play was the Barnett Shale, and its success grabbed the industry's attention in a manner that has revolutionized the way we look at shale as a gas reservoir. Large-scale hydraulic fracturing, a process first developed in Texas in the 1950s, was first employed on a Barnett gas well in 1986; likewise, the first Barnett horizontal well was drilled in 1992.[32] In the ensuing two decades, the science of shale gas extraction has matured into a sophisticated process utilizing horizontal drilling and sequenced, multi-stage hydraulic fracturing technologies. As the Barnett Shale play has matured, natural gas producers have begun to export the lessons learned in the Barnett to the other shale gas formations present across the U.S. and Canada.[33]

The combination of sequenced hydraulic fracture treatments and horizontal well completions has been crucial in facilitating the expansion of shale gas development. Prior to the successful application of these two technologies, shale gas resources in many basins had been overlooked because production was not viewed as economically practicable.[34] The low natural permeability of shale had been the limiting factor to the production of shale gas resources because it only allows minor volumes of gas to flow naturally to a wellbore.[35] The characteristic of low-matrix permeability represents a key difference between shale and other gas reservoirs. For gas shales to be economically produced, these restrictions must be overcome.[36] The combination of reduced economics and low permeability of gas shale formations historically caused operators to bypass these formations and focus on other resources.[37]

Shale Gas Geology

Shale gas is natural gas produced from shale formations that typically function as both the reservoir and source for the natural gas. Thus, they are termed continuous autogenic (self-sourced), unconventional reservoirs.[38] Gas shales are organic-rich shale formations that were previously regarded only as source rocks and seals for gas accumulating in stratigraphically-proximal, conventional sandstone and carbonate reservoirs.[39]

Shale is a sedimentary rock that is predominantly comprised of consolidated clay-sized particles deposited as mud in low-energy depositional environments. During the deposition of these very fine-grained sediments, there can also be deposition of organic matter in the form of algae-, plant-, and animal-derived organic debris.[40] The naturally tabular clay grains tend to lie flat as the sediments accumulate and subsequently become compacted as a result of additional sediment deposition. This results in mud with thin laminar bedding that lithifies (solidifies) into thinly layered shale rock. The very fine sheet-like clay mineral grains and laminated layers of sediment result in a rock that has limited horizontal permeability and extremely limited vertical permeability. Typical unfractured shales have matrix permeabilities on the order of 0.01 to 0.00001 millidarcies.[41] This low permeability means that gas trapped in shale cannot move easily within the rock except over geologic expanses of time (millions of years).

EXHIBIT 5: MARCELLUS SHALE OUTCROP

Source: ALL Consulting, 2009

The natural layering and fracturing of shales can be seen in outcrop. Exhibit 5 shows a Marcellus shale outcrop which reveals the natural bedding planes, or layers, of the shale and near-vertical natural fractures that can cut across the naturally horizontal bedding planes.

The natural gas can reside in localized macro-porosity systems (i.e., fracture porosity) within the shale, or within the micro-pores of the shale itself.[42] It can also be adsorbed onto minerals or organic matter within the shale.[43] Wells may be drilled either vertically or horizontally and most are hydraulically fractured to overcome the challenges of natural low permeability and thus stimulate production.

Shale Gas Basins of the United States

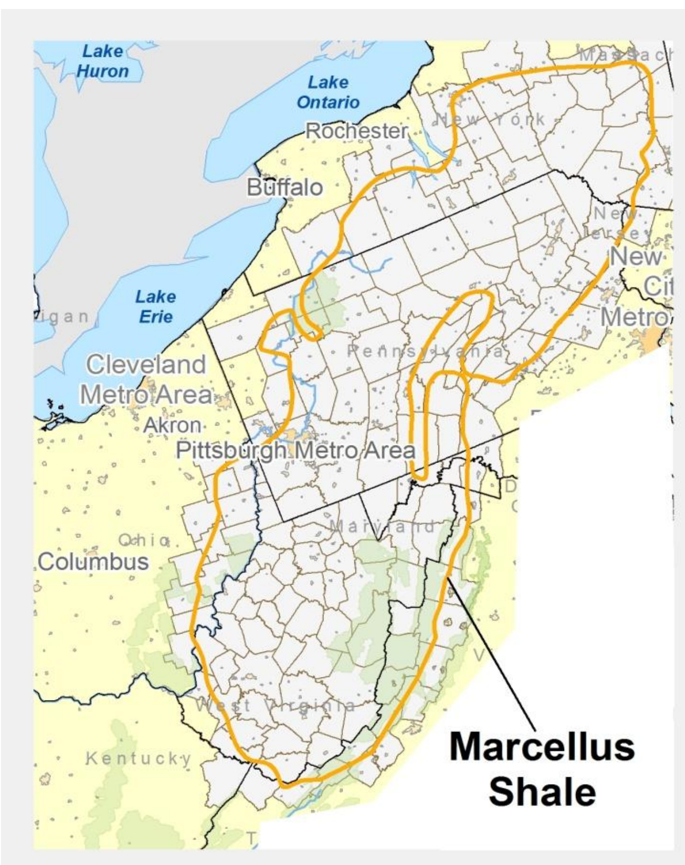
Shale gas is present across much of the lower 48 States. Exhibit 3 shows the locations of current producing gas shales and prospective shale basins. The most active shales to date are the Barnett Shale, the Haynesville/Bossier Shale, the Antrim Shale, the Fayetteville Shale, the Marcellus Shale, and the New Albany Shale. Each of these gas shale basins is different and each has a unique set of exploration criteria and operational challenges. Because of these differences, the development of shale gas resources in each of these areas faces potentially unique challenges. As new technologies are developed and refined, shale gas plays once believed to have limited economic viability are now being re-evaluated.

THE MARCELLUS SHALE

Marcellus Play Overview

The Marcellus Shale is the largest shale gas play in the U.S., spanning six northeastern states (Exhibit 6). The estimated depth of production for the Marcellus ranges from 4,000 ft to 8,500 ft.[44] The Marcellus Shale is a Middle Devonian-aged shale bounded above by shales of the Hamilton Group and below by limestones of the Tristates Group (Exhibit 7).

EXHIBIT 6: MAP OF MARCELLUS PLAY



Source: ALL Consulting, Modified from USGS and WVG&ES, November, 2009

The Marcellus Shale covers an area of approximately 95,000 square miles at an average thickness of 50 ft to 200 feet. It has been estimated that as much as 1,500 Tcf original gas in place may be present in the entire Marcellus play area.[45] The total amount of gas expected to be produced over the life of the play, referred to as the estimated ultimate recovery (EUR), for the Marcellus has recently been increased to 489 Tcf[46]; however, as with other shale gas plays, the Marcellus' potential estimates are frequently being revised upward due to its early stage of development.[47,48]

The Marcellus Shale is an organic-rich black shale deposited in the early developmental stages of the Appalachian foreland basin during the lower Middle Devonian. These sediments were deposited in a relatively deep marine setting between the Catskill Delta to the

EXHIBIT 7: STRATIGRAPHY OF THE MARCELLUS SHALE

Period		Group/Unit	
Penn		Pottsville	
Miss		Pocono	
Devonian	Upper	Conewango	
		Conneaut	
		Canadaway	
		West Falls	
		Sonyea	
		Genesee	
	Middle	Tully	
		Hamilton Group	Moscow
			Ludlowville
			Skaneateles
			Marcellus
		Onandaga	
	Lower	Tristates	
		Helderberg	

Source: Arthur et al, 2008[50]

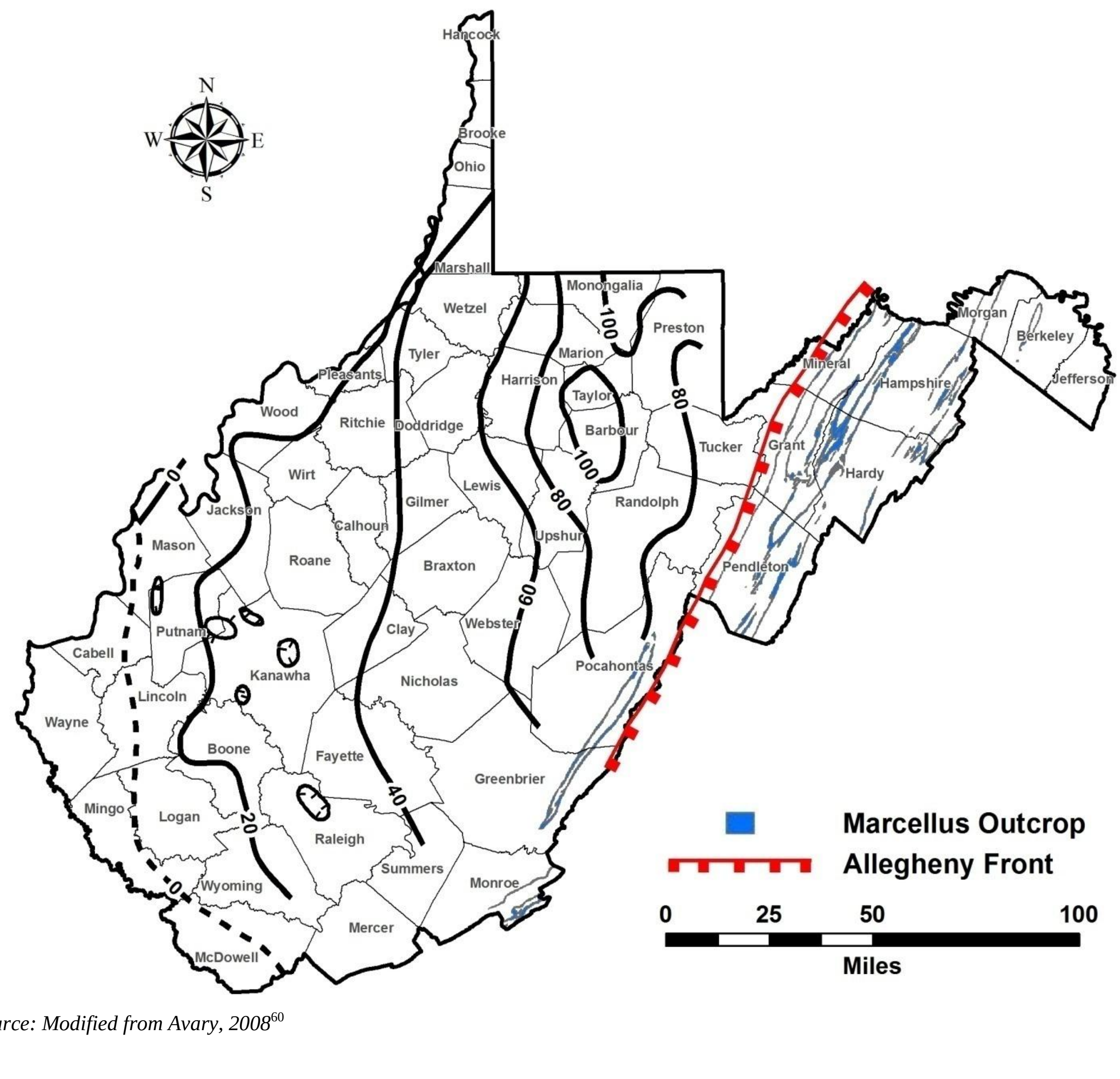
east and the carbonate platforms of shallow epeiric seas to the west. The Marcellus reaches a maximum thickness of 200 feet in central Pennsylvania. It is part of a much greater section of Middle and Upper Devonian basinal clastic sediments deposited seaward of the deltaic systems. These basinal clastics are dominated by shales, mudstones, and siltstones having a maximum combined thickness of up to 6,000 feet in central Pennsylvania. Minor limestones, such as the Tully Limestone, are also present within this sequence. However, it is the highly organic Marcellus that has the greatest promise as a source rock and reservoir for natural gas. The overall organic richness of the Marcellus decreases in a southwesterly direction towards West Virginia.[49]

Following an increase in gas prices, triggered by the Natural Gas Policy Act (NGPA) of 1978, Devonian shale gas development rose in the early- to mid-1980s in the northeast, but decreasing gas prices resulted in uneconomical wells and declining production through the 1990s.[51] In 2003, Range Resources Corporation drilled the first economically producing wells into the Marcellus formation in Pennsylvania using horizontal drilling and hydraulic fracturing techniques similar to those used in the Barnett Shale formation of Texas.[52] Range Resources began producing from this formation in 2005. To date there are an approximate total of 1,772 gas wells that have been drilled to target the Marcellus Shale: 768 in Pennsylvania[53]; 957 in West Virginia[54]; and 47 in New York.[55] It is interesting to note that the earliest well to produce from the Marcellus in New York was drilled in 1880; however, until recently there has been only limited interest and drilling activity in the Marcellus as a producing interval.[56] No Marcellus wells have yet been drilled in Maryland; however, several permit applications to drill have recently been submitted to the Maryland Department of Environment, Minerals, Oil and Gas Division.[57]

West Virginia Marcellus Geology

The Marcellus Shale is present throughout most of West Virginia. It is absent in the southwestern-most counties and also in parts of the eastern-most counties where it also outcrops at surface in some areas.[58] The thickness of the Marcellus (mapped as high gamma ray response within the Hamilton section) varies across the state but is generally thickest in the northeast-central counties and thins to zero in the southwest (Exhibit 8).[59]

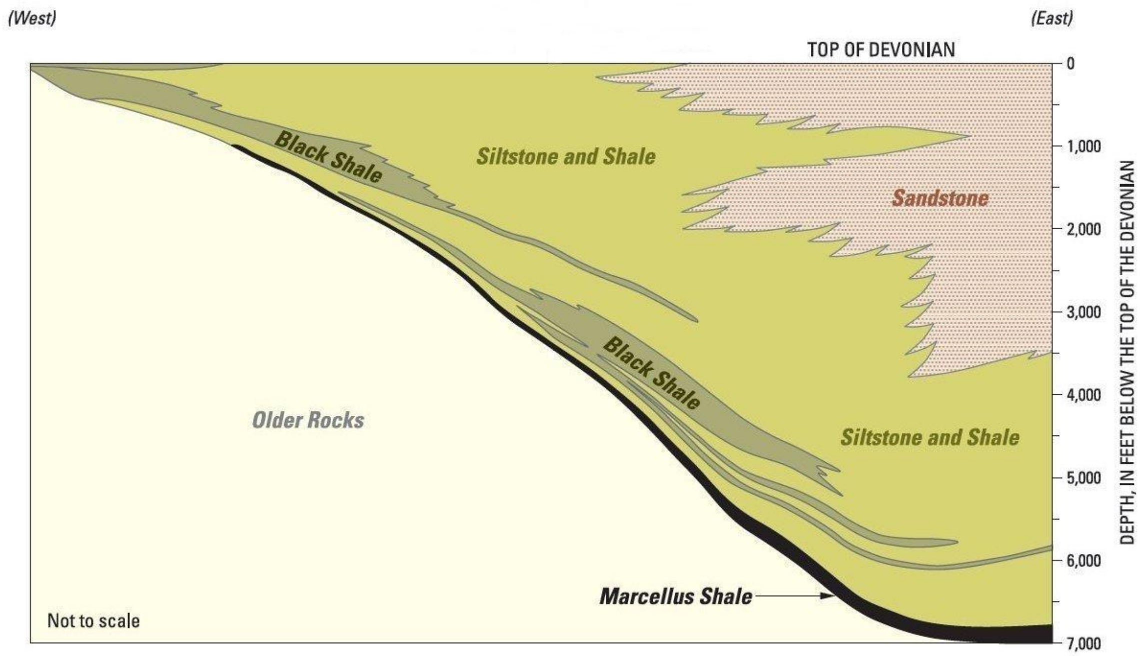
EXHIBIT 8: MARCELLUS THICKNESS (FEET)



Source: Modified from Avary, 2008[60]

A west-to-east cross-section demonstrates the significant thickening of Devonian sediments, including the Marcellus Shale, in the foreland basin between the North American craton to the west and the Appalachian Orogenic Belt to the east (see Exhibit 9). Moving further east and crossing the Allegheny Front (regional thrust fault associated with the Appalachian Orogenic Belt), the Marcellus has spotty presence, is more structurally complex, and present at shallow depth to outcropping at surface.[61]

EXHIBIT 9: TYPICAL MARCELLUS STRUCTURAL CROSS-SECTION

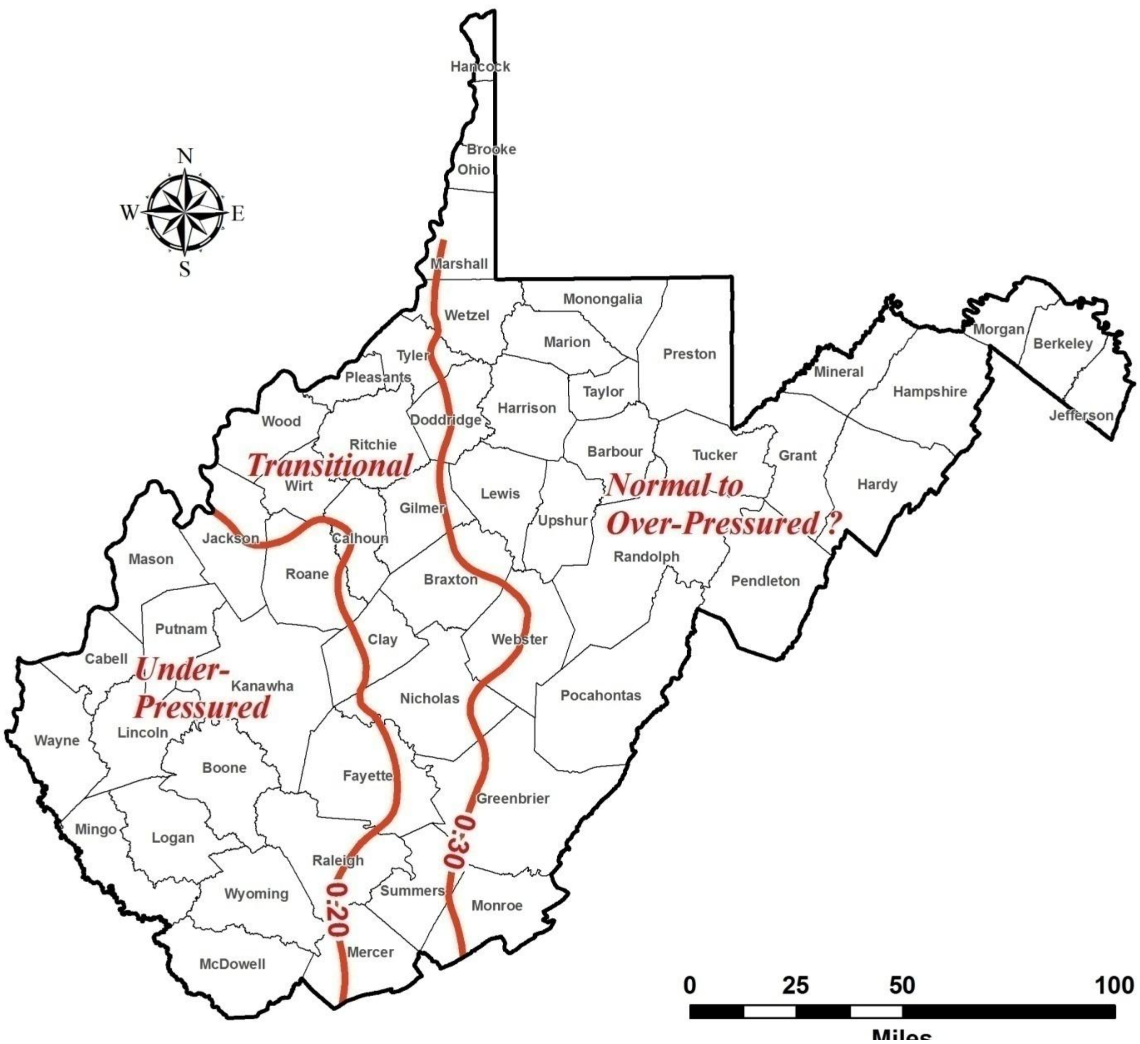


Source: Modified from Soeder and Kappel, 2009[62]

The Marcellus exhibits several different pressure regimes in West Virginia. Generally it is under-pressured to the southwest and, although there is insufficient data to be certain, it has been postulated to be normal to potentially over-pressured to the north-east with a transitional area in between. Exhibit 10shows these pressure regimes, with a question mark indicating the uncertainty associated with the normal to over-pressured area. It has been suggested that the highest ultimate recoveries will be from the normal to over-pressured areas. The presence of these separate pressure regimes necessitates different approaches to well stimulation: gas and foam fracture stimulations are commonly used in the under-pressured and transitional areas, whereas slickwater fracture stimulations are commonly used in the normal to over-pressured areas.[63]

EXHIBIT 10: MARCELLUS PRESSURE REGIMES

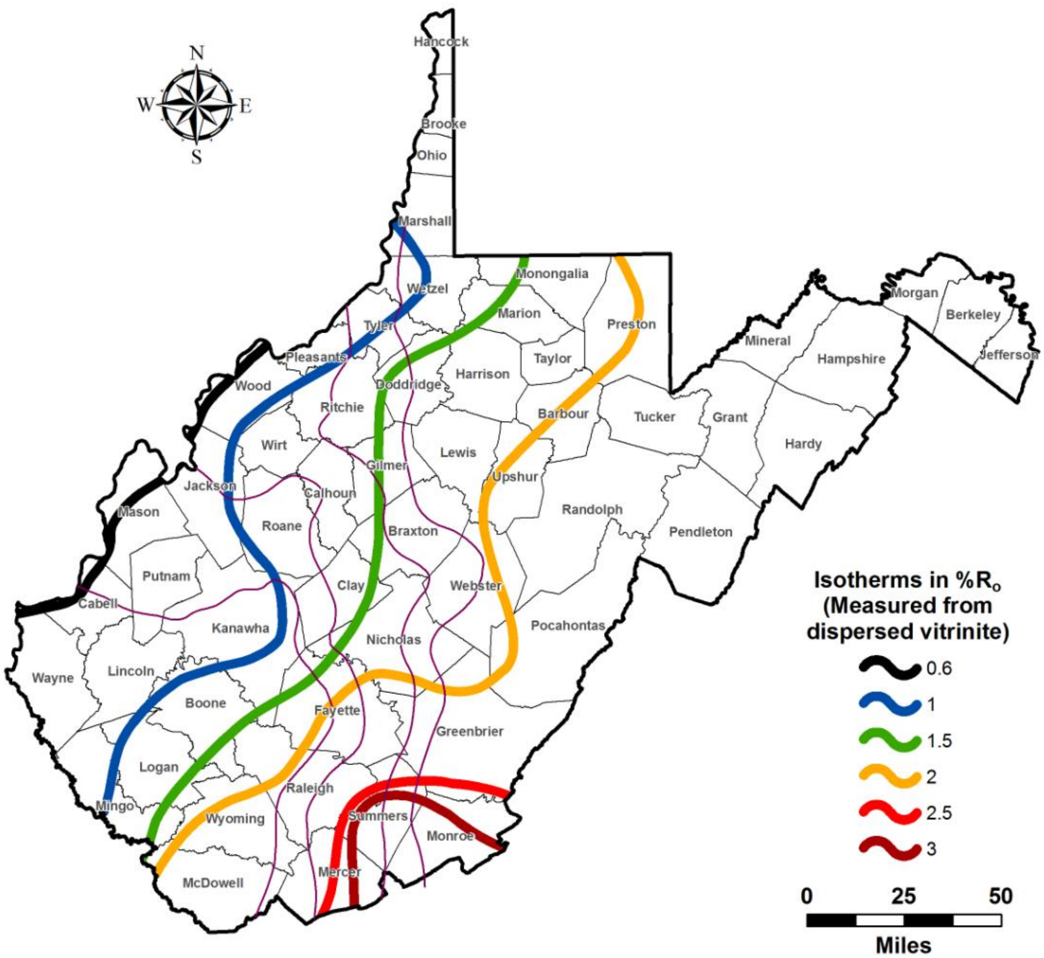
(Pressure gradient psi/ft. of depth)



Source: Modified from Wrightstone, 2009[64]

Thermal maturity, a measure of the heat-induced process of converting organic matter to oil or natural gas, can be determined by several means and converted to the universal standard of vitrinite reflectance (R_o). Economically viable shales frequently have R_o values in excess of 1.2%[65]. Shales with an R_o less than that will likely produce more oil than gas[66]. As one would anticipate based on the structural cross section (Exhibit 9), thermal maturity, as measured by vitrinite reflectance (R_o), is greatest towards the east in West Virginia (Exhibit 11).

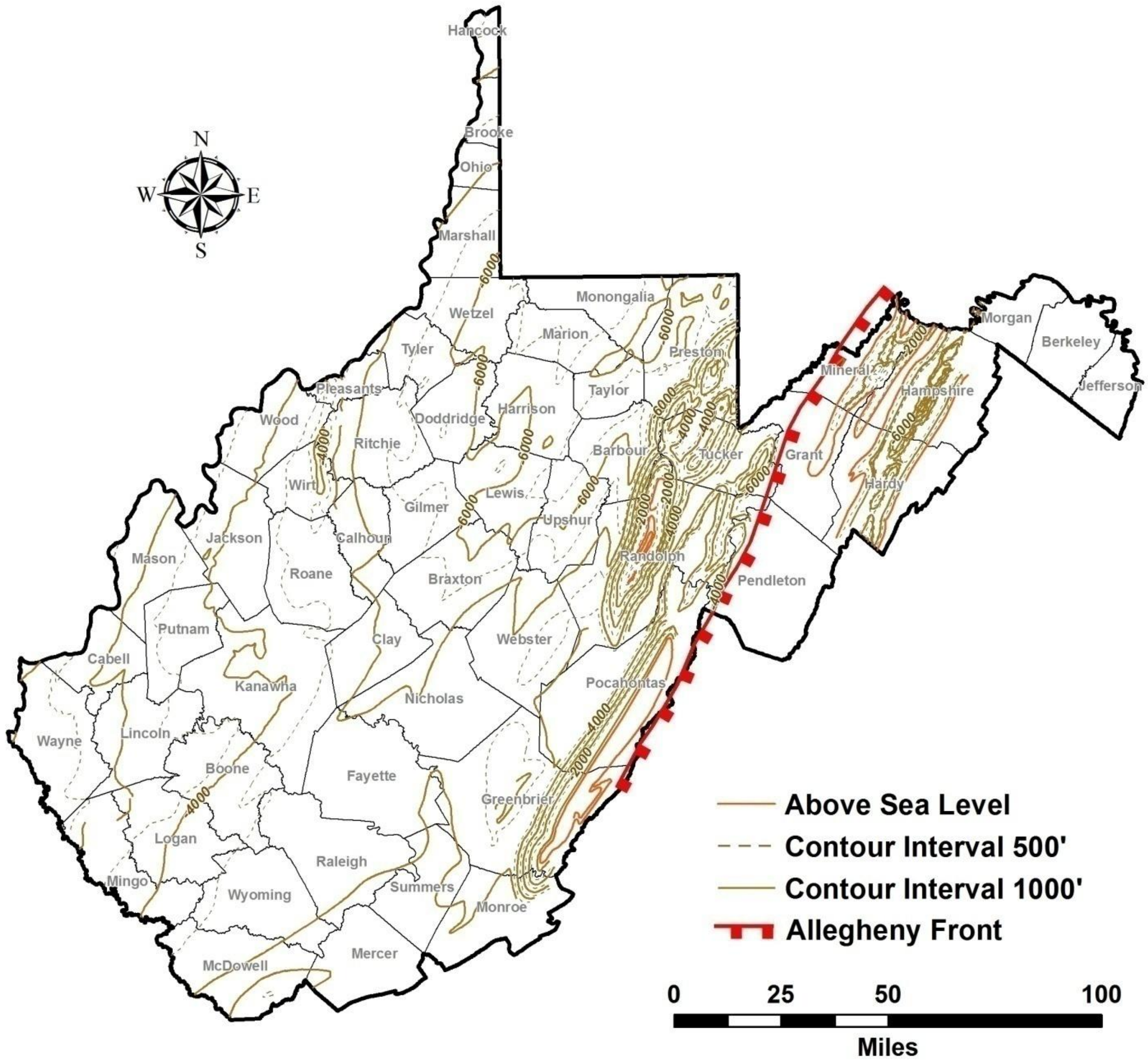
EXHIBIT 11: THERMAL MATURITY OF THE MARCELLUS



Source: Modified from Milici and Swezey, 2006[67]

Drilling depth to the bottom of the Marcellus section is mapped based on the top of the underlying Onondaga Formation (Exhibit 12). Depth to the Onondaga decreases towards the west (to approximately 5,000 ft), is greatest just west of the Allegheny Front on the east (approximately 7,000 to 8,000 ft), and is least in the area east of the structural front where the Marcellus outcrops.[68] A minimum depth of drilling for economic production from the Marcellus has yet to be determined in West Virginia.[69] However, according to the West Virginia Geological and Economic Survey (WVG&ES), some operators believe that the Marcellus must be greater than 10 feet thick in order to have any appreciable production potential.[70]

EXHIBIT 12: DRILLING DEPTHS TO BOTTOM OF MARCELLUS



Source: Modified from Cardwell 1982[71]

West Virginia Natural Gas and Marcellus Development History

The oil and natural gas industry in West Virginia began in the early- to mid-1800s with the first significant wells drilled in 1859 to 1860. As early as 1831, natural gas was transported in wooden pipes to the Kanawha area for use in heating/evaporating associated with salt manufacture. The wealth generated by the early producers was put to political use in establishing statehood for West Virginia during the Civil War. During the war, many oil fields were destroyed by Confederate forces. Following the Civil War these fields were revived and a boom in natural gas development ensued spreading across most West Virginia counties for the remainder of the century.[72]

According to the Gas Research Institute, drilling targeting Devonian black shales first began in West Virginia in 1981.[73] Data provided by the WVG&ES indicates that gas development specifically targeting the Marcellus Shale as a natural gas reservoir began in 2002. Through the end of 2008, 924 wells have been completed in the Marcellus in West Virginia, of these 883 are vertical wells and 41 are horizontal wells.[74] Based on similar development scenarios experienced in the Barnett Shale of Texas as well as the Marcellus Shale in Pennsylvania, it is anticipated that in the future the ratio of vertical to horizontal wells will shift towards greater use of horizontal wells.

Discussions with industry representatives indicate that vertical wells are typically drilled on an approximate equivalent to 40-acre spacing and horizontal wells are drilled on an approximate equivalent to 160-acre spacing assuming a lateral leg of 4,000 to 5,000 feet long. According to the WVG&ES, as many as 10 horizontal wells may be developed from a single well pad.[75]

West Virginia Marcellus Development Potential

The oil and gas industry typically examines formation properties (Exhibit 8, thickness and Exhibit 11, thermal maturity) in order to determine development potential. This appears to be the case for the Marcellus shale in West Virginia as industry activity correlates strongly with formation properties that indicate the fairway areas of greatest shale potential.[76]

The primary characteristics for defining the Marcellus fairway in West Virginia are:

- Net thickness of organic rich Marcellus Shale >30 ft
- Pressure gradient of 0.40 pounds per square inch (psi)/ft
- Thermal maturation >1.25% Vitrinite Reflectance(R_o)
- Depth >5,000 ft[77]

According to the WVG&ES, most Marcellus wells range in depth from 5,000 to 7,000 feet; with shallower production in Randolph County. East of the Allegheny thrust the Marcellus is present (e.g., in portions of Berkeley, Grant, Hampshire, Hardy, Morgan, Mineral, and Pendleton Counties)[78] at shallow depths with limited porosity, but it may be over-mature in this area and so non- or only marginally productive. There is little question that the Marcellus is much more structurally complex east of the Allegheny Thrust.[79] In this area some of the production may actually be from the Oriskany sandstone in combination with the Marcellus. Also, production in this area is often for private use rather than commercial use (e.g., a paper company in Mineral County operates several wells to serve their own natural gas needs, but not for commercial sale of the gas).[80]

Neither the West Virginia Department of Environmental Protection, Office of Oil and Gas (WV OOG), the WVGE&S, nor the Independent Oil and Gas Association of West Virginia (IOGA-WV) have prepared estimates of recoverable resources for the Marcellus in West Virginia.[81,82,83] We have attempted to estimate EUR using the following three simplified approaches:

- An often cited investment oriented article suggests an EUR of 2.5 Bcf per horizontal well, drilled on 80-acre spacing equivalent, for the Marcellus in general.[84] Based on a total Marcellus acreage of approximately 6,985,000 acres, assuming that 2.5 Bcf are indeed recoverable from an average 80-acre proration unit, and that up to 70% of such proration units are actually available for development, such an estimate would indicate more than 60,000 proration units with an EUR of approximately 150 Tcf for the Marcellus in West Virginia.
- Engelder has estimated that the EUR for the entire Marcellus play is 489 Tcf (at 50% probability and assuming 70% of proration units are available for development).[85] Based on a total acreage in the entire Marcellus play of approximately 34,500,000 acres, and 6,985,000 acres or approximately 20% of the total acreage of which are located in West Virginia, then approximately 98 Tcf could be attributable to the state.
- Using Chesapeake Energy's 2008 pro forma decline curve referenced by Engelder, that has also been used throughout this document, we calculate an EUR of approximately 3.6 Bcf per horizontal well (160-acre spacing equivalent) over 30 years. Using the estimated 6,985,000 acres for the Marcellus in West Virginia and assuming 70% of proration units (160-acre horizontal well) are available for development yields an estimated 30,500 proration units developed. This then provides an estimated EUR of approximately 110 Tcf for the Marcellus in West Virginia.

Therefore, the EUR for the Marcellus in West Virginia is estimated to be within the range of 98 Tcf to 150 Tcf.

This analysis is based first on a predicted future rate of Marcellus gas well drilling and second on the predicted resultant gas production rates from those wells. For simplicity in presentation, the discussion of Marcellus development potential is presented as a lead-in to the economic analysis methodology section below.

PHASES OF DEVELOPMENT

In order to understand how shale gas development affects the local economy, it is important to understand the process of drilling and producing shale gas wells. Exhibit 13 shows the major steps in shale development and provides a framework for understanding the wide variety of skilled labor, services, equipment, and supplies needed to develop a shale gas play.

EXHIBIT 13: PROCESS OF SHALE GAS DEVELOPMENT (DURATION)

Mineral Leasing

Companies negotiate a private contract or lease that allows mineral development and compensates the mineral owners. Lease terms vary and con contain stipulations or mitigation measures pertinent to protect various resources. (Several weeks to years)

Permits

The operator must obtain a permit authorizing the drilling of a new well. Surveys, drilling plans, and other technical information are frequently required for a permit application. The approved permit may require site specific environmental protection measures. Other permits such as water withdrawal or injection permits may also be required. (Several weeks to months)

Road and pad Construction

Once permits are received, roads are constructed to access the well-site. Well pads are constructed to safely locate the drilling rig and associated equipment during the drilling process. Pits may be excavated to contain drilling fluids. (Several days to weeks)

Drilling and Completion

A drilling rig drills the well and multiple layers of steel pipe (called casing) are put into the hole and cemented in place to protect fresh water formations (Weeks or months)

Hydraulic Fracturing

A specially designed fracturing fluid is pumped under high pressure into the shale formation. The fluid consists primarily of water along with a proppant (usually sand) and about 2% or less of chemical additives. This process creates fractures in rock deep underground that are "propped" open by the sand, which allows the natural gas to flow into the well. (Days)

Production

Once the well is placed on production, parts of the wellpad that are no longer needed for future operations are reclaimed. The gas is brought up the well, treated to a useable condition, and sent to market. (Interim Reclamation: days; Production: decades)

Workovers

Gas production usually declines over the years. Operators may perform a workover which is an operation to clean, repair and maintain the well for the purposes of increasing or restoring production. Multiple workovers may be performed over the life of a well. (Several days to weeks)

Plugging and Abandonments/Reclamation

Once a well reaches its economic limit, it is plugged and abandoned according to State standards. The disturbed areas, including well pads and access roads, are reclaimed back to the native vegetation and contours, or to conditions requested by the landowner. (Reclamation Activity: Days; Full Restoration: Years)

Source: Modified from ALL and GWPC 2009

THE WEST VIRGINIA ECONOMY

The West Virginia economy has been decelerating, following national trends that are driven by a recession and crises in the housing and financial sectors. The state is facing an estimated $100 million deficit for its General Revenue FY 2010 budget as reported November 2009.[87] After three years of job gains from 2004 to 2006, the goods-producing sector of the state economy experienced job losses in the following two years. Indeed, West Virginia University's Bureau of Business and Economic Research stated earlier this year that the state's manufacturing sector "continues to shed jobs at an alarming pace."

The overall job market in West Virginia began to decelerate significantly in 2006, both in the goods-producing and service sectors. The former experienced job losses in the last two years, while the service sector held on longer, but lost jobs in the past year. In the goods-producing sector, construction and manufacturing have suffered the most, while mining has continued to add jobs, although at a slower pace than in previous years. Reliance on the coal mining industry carries a certain amount of regulatory risk, as Congress contemplates climate change legislation, and there are increasing concerns about clean water and clean air.[88]

While West Virginia has added 5,000 residents since 2000, one county alone, in the eastern panhandle, had a population growth of 23,000. This means that without Berkeley County, which serves as a lower-cost suburb of the Washington, D.C., metropolitan area, the state would have lost 18,000 residents this decade. As might be expected, the housing slowdown has hit this county disproportionately hard. In addition, over the next five years, the state is forecast to gain population in only one age group: those 65 and older.[89]

ECONOMIC ANALYSIS

The phases of drilling activity described above lead to expenditures by the industry that contribute to economic activity in West Virginia. This section describes that impact as it positively affects many parts of the state's economy through payments to a number of industrial and commercial sectors, mineral-rights owners (which may include individual households), and state and local governments.

In the process of drilling and completing a well, a gas producer buys equipment and materials, pays staff, hires service companies and other support personnel, and pays taxes. The producer must also secure the lease before drilling and generally pays a lease bonus to the mineral-rights owner and perhaps a yearly rental. Once production begins, the producer must pay staff or contract personnel to maintain the well and equipment and he also pays the mineral owner a royalty on the revenue received for the produced gas, as well as severance taxes on that revenue and income tax on profits. All of these expenditures go into the state economy and generate economic activity.

However, these simple metrics do not fully represent the extent of the economic impact of shale gas drilling and production. These expenditures ripple through the economy, causing additional economic activity and benefits through a "multiplier effect." Economists define three types of economic impacts or effects from these industry expenditures: direct, indirect, and induced. Direct impacts are the initial, immediate economic activities (jobs and income) generated by a project or development. Direct impacts associated with the development coincide with the first round of spending in the economy, e.g., the expenditures for equipment, materials, services, payroll, and severance and corporate taxes described above. Indirect impacts are the production, employment and income changes occurring in other businesses and industries in the community that supply inputs to the project industry. This occurs as the suppliers and service companies that are paid by the gas producer must in turn buy supplies and services in order to conduct their business. Finally, induced impacts are the effects of spending by the households in the local economy as the result of direct and indirect effects from an economic activity. The induced effects arise when employees spend their new income in the community. [90]

The sum of the direct, indirect, and induced impacts is referred to as the gross economic output, and this is often used as a measure the economic benefit from an industry or sector. Value added is often considered a more meaningful measure of true economic benefit from an activity. It is the gross output of an industry or sector minus its intermediate capital and labor inputs.[91] It measures the value added by the actions of that industry or sector and effectively subtracts inter-industry purchases, which lead to double counting of value.[a]

This methodology has been used in economic impact studies for a wide variety of industries and projects, and, in particular, to assess the economic benefits of shale gas development in several basins and areas, including two other parts of the Marcellus Shale – Pennsylvania[92] and Broome County New York[93] – as well as in the Barnett Shale of Texas,[94] the Haynesville Shale of Louisiana,[95] and the Fayetteville Shale of Arkansas.[96] All of these studies use "input-output analysis" to estimate the three types of economic impacts described above.

Data on expenditures by an industry or sector are used as input to the models. These expenditures are categorized as payments to suppliers, payment to households and taxes. Payments to suppliers consist of any money spent with another company and this spending is broken down by the amount given to each type of company. Payments to households consists of worker salaries and lease payment to mineral owners. Taxes include s corporate income tax and severance taxes paid by the industry as well as the personal income taxes from salaries. Input-output models use large tables of economic data to depict inter-industry relationships in a national or regional economy, and thus, to predict the effect of changes in one industry on all the others. Using these data, the model calculates the gross economic output and the value added. The model also calculates the taxes that would result and the number of jobs that would be created. . A variety of input-output models are available for this purpose.

---

[a] To give a simplistic example, iron is mined and sent to the steel mill which produces steel ingots that are then used to fabricate steel products. The value added by the mine is the revenue from selling the ore minus what it cost to produce it. The value added by the steel mill is the revenue it gets from selling the ingots minus the cost of the ore and the capital and labor used to produce the product. A steel fabricator then makes steel parts or sheets from the ingots and its value added is the revenue from its products minus the cost of the ingots and the capital and labor used to produce them. Adding the value added from each step gives the total value of the end products and avoids triple counting the cost of the ore as one would if just adding the total revenue from all three operations.

This study of the economic impact of shale gas development in West Virginia takes this same input-output approach, employing one of the most commonly used modeling systems, described in the next section, as do the majority of studies cited above. It also follows the general approach of the Pennsylvania State University (PSU) study[97] since that analysis also addressed a state in the Marcellus shale, bordering on West Virginia and with similar industry and resource characteristics.

Methodology

The first step in this analysis is to establish the rate of Marcellus drilling in West Virginia to date and to predict the rate of future development. This was accomplished through several steps:

- The well database used for this analysis was compiled by the WVG&ES from original drilling permits and completion tickets cross-referenced against electric logs.[98] To determine the number of Marcellus Shale gas wells drilled in West Virginia through 2008, the WVG&ES database was analyzed to identify those wells for which the Marcellus Shale is identified as a pay zone. The data were then grouped by well type, i.e., vertical or horizontal (directional) wellbore. To develop the future rate of Marcellus well drilling in West Virginia, the predictive equation developed by PSU was used as a starting point. PSU's equation uses the known development of the Barnett Shale, as the best available and longest term surrogate for shale gas development, correlated to the historical Henry Hub natural gas commodity pricing to establish a rate curve with which to predict future development within the Barnett play.[99] The equation is stated as:

  $$\ln(Drilling) = 1.61 + 2.70 * \ln(Henry\ Hub\ Price)$$

  PSU then applied this equation, with an adjustment, to predict the rate of Marcellus development in Pennsylvania.

- In order to apply this equation to West Virginia, a correction factor was incorporated to compensate for the vast differences in area between the Barnett play in Texas and Marcellus play in West Virginia. To do so, the right side of the equation was multiplied by an adjustment coefficient equal to the area of the Marcellus in West Virginia (9,709,967 acres) divided by the area of the Barnett Shale in Texas (16,839,237 acres):

  $$\ln(Drilling) = (1.61 + 2.70 * \ln(Henry\ Hub\ Price)) * 0.577$$

- Future gas prices were then entered into the final equation to predict the rate at which future Marcellus drilling would occur in West Virginia. Future Henry Hub gas prices were obtained from the Energy Information Administration's (EIA) Annual Energy Outlook.[100]

- Similar to the PSU approach, ninety cents was also added to the Henry Hub price to account for the anticipated premium West Virginia Marcellus gas producers would receive because of their proximity to eastern markets.[101]

Historically, most wells drilled in West Virginia have been drilled vertically, but this is not the expected development trend. It is likely that the development of the Marcellus will increasingly rely on the use of horizontal wells. To account for this, the expected number of future wells was multiplied by a time-dependent ratio of horizontal to vertical wells to predict the relative future percentages of vertical and horizontal completions. This ratio begins in 2009 at the current horizontal to vertical ratio of Marcellus producers in West Virginia (3%) and increases linearly to the current horizontal to vertical ratio of producers in the Barnett shale (56%). The ratio increases over a 23 year period, which is the length of time it has taken to reach the current ratio in the Barnett Shale.

Once the forecast drilling scenario has been established, gas production from these wells over time must be estimated. To do this, thirty-year production forecasts were developed for both horizontal and vertical wells. The horizontal well production forecast used 4,552 thousand cubic feet (Mcf)/day as an initial production rate and the vertical well production forecast used 1,500 Mcf/day as initial production rate.[102] Both cases were assumed to decline at the same rate defined by the equation:

$$F(x) = 4.5522x^{-0.585}$$

Engelder presented this equation as a pro forma decline curve for the Marcellus based on actual Chesapeake production data.[103]

Schedules for future revenue generated from gas production were calculated using EIA's Henry Hub future gas price and the anticipated production volumes developed from the expected drilling and production forecasts.[104] The drilling and revenue forecast provided a measure of the anticipated royalty payments, payroll, payments to suppliers, and taxes as follows:

- For royalty payments, a 3/16 interest was assumed for landowners. [105]
- Payroll was calculated at 2.5% of revenue received by the gas producer.
- Payments to suppliers were calculated as the sum of drilling and operational costs.
- Drilling costs were assumed to be $3,500,000 for horizontal wells[106] and $800,000 for vertical wells.[107] Average operational costs over the life of a well were conservatively assumed to be $2,000 per month for horizontal wells and $1,000 per month for vertical wells.
- Severance taxes were calculated using the West Virginia rate of 4.7¢ per Mcf of natural gas produced plus 5% of produced gas value.
- State, corporate, and personal income taxes were set at the West Virginia rate of 8.5%.

Future expenditure and revenue calculations were generated through the year 2020 by multiplying the forecast number of horizontal and vertical wells by the expenditures and production for each well type. Expenditures were then sorted into three categories for input to the model:

- Payments to suppliers are the sum of drilling and operational costs each year.
- Payments to households are the sum of royalty payments and payroll.
- Total taxes are the sum of severance tax, corporate income tax, and personal income taxes.

To evaluate the impact of Marcellus Shale gas drilling and production on the economy of West Virginia, this project employed the IMPLAN economic modeling software, a product of the Minnesota IMPLAN Group, Inc. (MIG). IMPLAN is proprietary software that utilizes input-output analysis in combination with region-specific Social Accounting Matrices and Multiplier Models to provide a model for regional economic impact planning and analysis.[108]

To estimate the economic impact of development of West Virginia Marcellus, the payments to suppliers and personal spending described above were entered into IMPLAN. MIG also provided pertinent economic statistics for West Virginia that were used in the calculation presented herein.

To prepare the inputs for the IMPLAN model, several adjustments to the gross expenditure estimates were made. Not all expenditures for wells drilled in West Virginia are spent within the state. To account for out-of-state spending, payments to suppliers and payments to households were reduced by 5%. This is in conformance with the approach adopted by PSU in their Pennsylvania analysis and was assumed in the absence of similar available data for West Virginia. Personal income from payroll and royalties were also adjusted to account for the fact that not all income is spent. Some is paid out in taxes and some is saved. Personal income minus taxes paid is known as disposable income and is reported by the Bureau of Economic Analysis, U.S. Department of Commerce, by state. Disposable income minus savings is called personal outlays, which is the number that is appropriate when analyzing the state economic impact of personal spending. Therefore, the calculated payments to households from payroll and royalties were reduced by the ratio of personal income to disposable income in West Virginia in 2008,[109] and further by the national savings rate.[110] As a result, personal income was reduced by 12% to obtain personal outlays in 2008 and by 13% in future years where a slightly higher long-term savings rate was assumed.

While IMPLAN calculates taxes from the spending inputs, it does not account for severance taxes paid on gas production. In addition, since taxes are taken out of personal and corporate spending to obtain the figures for personal outlays and payments to suppliers that are input to the model, these taxes are also not accounted for in the model output. Thus, both state severance tax and state income tax were added to the model output to obtain the total state tax impacts reported in this analysis.

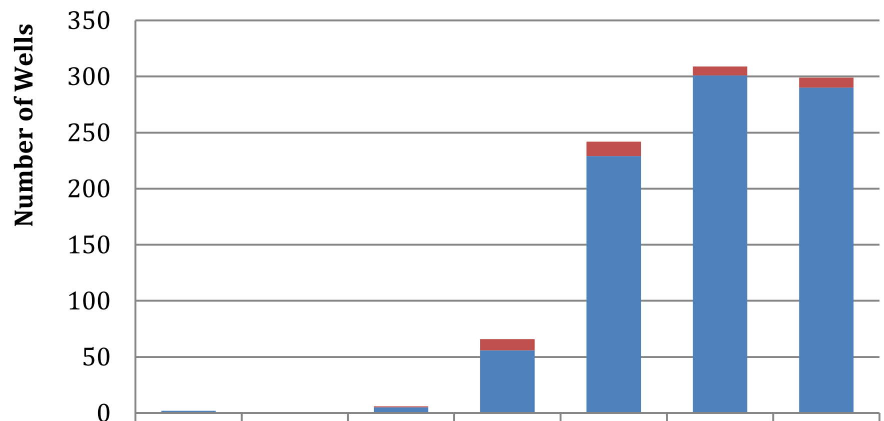
IMPLAN requires that expenditures be allocated to economic sectors in order to estimate the full economic impact of those expenditures. PSU conducted a survey to determine the approximate distribution of spending by Marcellus producers among the various sectors of the economy.[111] This study assumes the same proportional distribution of spending for payments to suppliers in West Virginia, based on the similarities of the industry and the resource in the two states. Personal spending was distributed separately among economic sectors according to personal consumption spending patterns for goods and services reported by the Bureau of Economic Analysis.[112]

IMPLAN provided estimates of the direct, indirect, and induced economic impacts in each specific sector resulting from the spending of personal income and the payments to suppliers. IMPLAN also provided an estimate of jobs created, total tax revenues, and value added to the regional economy.

Economic Impact of West Virginia Marcellus Shale Development in 2008

The first step in estimating the economic impact of shale gas development was to determine the number of gas wells drilled in 2008 that were completed in the Marcellus Shale formation, as discussed in the methodology section above. The earliest wells were drilled in 2002, with 299 wells drilled in 2008, nine of which were horizontal wells. Exhibit 14 shows the total number of reported Marcellus wells drilled in the state, divided into vertical and horizontal wells, since the modern period of shale gas drilling began.

EXHIBIT 14: MARCELLUS WELLS DRILLED IN WEST VIRGINIA



	2002	2003	2004	2005	2006	2007	2008
Horizontal	0	0	1	10	13	8	9
Vertical	2	0	5	56	229	301	290

Standard well cost profiles were used to estimate expenditures for payments to suppliers, payroll, and taxes. A capital cost of $3.5 million was used for horizontal wells[113] and $800,000 for vertical wells.[114] Estimated initial year production for 2008 wells was used to calculate royalty payments to landowners. Summing these payments across the number of horizontal and vertical wells drilled in 2008 resulted in total drilling expenditures. In 2008, payments to suppliers amounted to $254 million, payments to households totaled $86 million, and direct taxes paid by producers and employees were $51 million (Exhibit 15). These industry expenditures do not take into account the ripple effect through the economy that was described earlier. This will be addressed in the next part of the analysis.

EXHIBIT 15: TOTAL SPENDING BY CATEGORY	
Sector	**Amount ($ MILLIONS)**
Payments to Suppliers	**253.8**
Payroll	*8.5*
Payments to Landowners	*77.9*
Payments to Households	**86.4**
Severance Tax	16.9
Corp Income Tax	27.0
Personal Income Tax	6.6
Total Taxes	**50.5**

As shown in Exhibit 15, payments to households in this analysis consist of payroll and royalties on production (computed at 3/16 of gross value). This total leaves out a large and important component of payment to landowners, namely lease bonus payments. These bonus payments have been estimated in other studies through survey data. PSU reported over $2 billion in payments to landowners in Pennsylvania in 2008, the great majority of which is assumed to be lease payments[115], and a study of the Haynesville shale reported over $3 billion in lease payments alone in Louisiana in 2008.[116] Since the current study does not have survey data for West Virginia and lease payment data are not publicly available, there is no basis for estimating lease bonus payments in West Virginia and these payments are not included in this analysis. Thus, the estimated impact of Marcellus Shale development in 2008 found here is a very conservative number. The estimates for future years may not be

EXHIBIT 16: DISTRIBUTION OF PAYMENTS TO SUPPLIERS	
Spending by Sector in 2008	**Amount ($ MILLIONS)**
Ag, Forestry, Fish & Hunting	1.01
Mining 3 (oil, gas, and minerals)	99.07
Utilities	1.19
Construction	76.80
Manufacturing	1.90
Wholesale Trade	41.84
Transportation and Warehousing	7.74
Retail Trade	6.38
Information	0.09
Finance and Insurance	0.12
Real Estate and Rental	0.18
Professional Services - Scientific and Technical	14.38
Administrative & Waste Services	2.02
Educational Services	0.27
Health & Social Services	0.27
Arts - Entertainment & Recreation	0.12
Accommodations & Food Services	0.15
Other Services	0.27
Total Purchasing	**253.76**

as highly conservative since lease bonuses are one-time, up-front payments and future payments to landowners are likely to be dominated by royalties.

To find the total economic impact, the expenditures shown in Exhibit 15 were distributed across economic sectors, as described in the previous section, and input to IMPLAN. In distributing the $254 million in payments to suppliers, as may be expected, the largest payments go to the mining sector, which includes oil and gas drilling, but substantial expenditures are also made in construction, wholesale trade, and professional services (Exhibit 16). Household expenditures were distributed separately, according to how households purchase goods and services nationally.

IMPLAN uses these inputs and its database of cross-industry interactions specific to West Virginia to calculate how these expenditures are multiplied through the state economy. The inputs to IMPLAN lead to direct, indirect, and induced activity. Thus, as estimated by the model, the West Virginia Marcellus gas industry produces $267 million in direct spending which then circulates in the economy through subsequent rounds of spending and produces an additional $53 million in indirect economic output. This direct and indirect spending leads to additional income to households and thus induces another $52 million in purchases by those households. All told, the $267 million in direct spending results in a total of $371 million of total gross economic activity in the state (Exhibit 17).

Thus, for every one dollar spent by the industry, $1.39 of total economic activity is generated. This is in line with the findings of other studies of impacts of oil and gas activities, which found multipliers of $1.34 in Louisiana[117]and $1.43 in New Mexico.[118] However, it is somewhat lower than the $1.94 calculated by PSU for the Pennsylvania Marcellus industry.[119]

EXHIBIT 17: ECONOMIC IMPACT OF SHALE GAS DEVELOPMENT IN 2008 ($ MILLIONS)				
	Direct	**Indirect**	**Induced**	**Total**
Ag, Forestry, Fish & Hunting	1.01	0.01	0.00	1.02
Mining (oil, gas, and minerals)	99.07	0.82	0.05	99.94
Utilities	1.19	1.53	0.96	3.68
Construction	76.80	0.00	0.00	76.80
Manufacturing	1.90	0.02	0.00	1.92
Wholesale Trade	7.91	3.13	1.87	12.91
Transportation and Warehousing	9.81	0.89	0.36	11.06
Finance and Insurance	5.57	0.88	1.58	8.02
Retail Trade	8.16	0.17	1.44	9.76
Real Estate and Rental	12.57	1.85	1.77	16.19
Professional Services - Scientific and Technical	0.09	0.13	0.02	0.24
Management of Companies	14.38	0.49	0.13	15.00
Administrative and Waste Services	2.02	0.34	0.13	2.49
Educational Services	0.27	0.01	0.15	0.43
Health and Social Services	10.71	0.01	1.55	12.28
Arts - Entertainment & Recreation	2.69	0.02	0.15	2.86
Accommodation & Food Services	4.24	1.30	3.00	8.54
Other Services	6.42	0.06	0.13	6.60
Government and Other Institutions	1.87	32.44	31.12	65.43
Total	**266.65**	**52.65**	**51.87**	**371.17**

The economic activity in Exhibit 17 created a total of over 2200 jobs in 2008, distributed widely throughout the economic sectors (Exhibit 18). Oil and gas jobs in particular pay much more than the average wage earned by West Virginia's workforce. While the median household income in 2007 was about $37,000,[120] the average oil and gas industry wage in the state was about $70,000, almost twice as much.[121] Note that due to payments to households, in addition to industrial spending, many jobs are created in the real estate, hotel and restaurant, and health sectors.

EXHIBIT 18: JOBS CREATED IN 2008				
	Direct	**Indirect**	**Induced**	**Total**
Ag, Forestry, Fish & Hunting	8	0	0	8
Mining (oil, gas, and minerals)	229	2	0	231
Utilities	2	3	2	7
Construction	507	0	0	507
Manufacturing	4	0	0	4
Wholesale Trade	10	21	12	42
Transportation and Warehousing	67	7	3	77
Finance and Insurance	31	4	7	41
Retail Trade	46	2	22	70
Real Estate and Rental	137	20	19	177
Professional Services - Scientific and Technical	1	1	0	2
Management of Companies	99	3	1	104
Administrative and Waste Services	12	2	1	15
Educational Services	5	0	3	8
Health and Social Services	93	0	14	107
Arts - Entertainment & Recreation	27	0	2	29
Accommodation & Food Services	86	26	61	172
Other Services	88	1	1	90
Government and Other Institutions	15	241	300	557
Total	**1466**	**334**	**447**	**2247**

The economic output from the 2008 drilling activity ($371 million, as shown in Exhibit 17) translates into value added of $189 million in the West Virginia economy, (Exhibit 19). As discussed above, value added is the gross output of an industry or sector minus its intermediate capital and labor inputs and is often considered a more meaningful measure of the true economic benefit from an activity.[122] Intermediate capital and labor are calculated by IMPLAN.

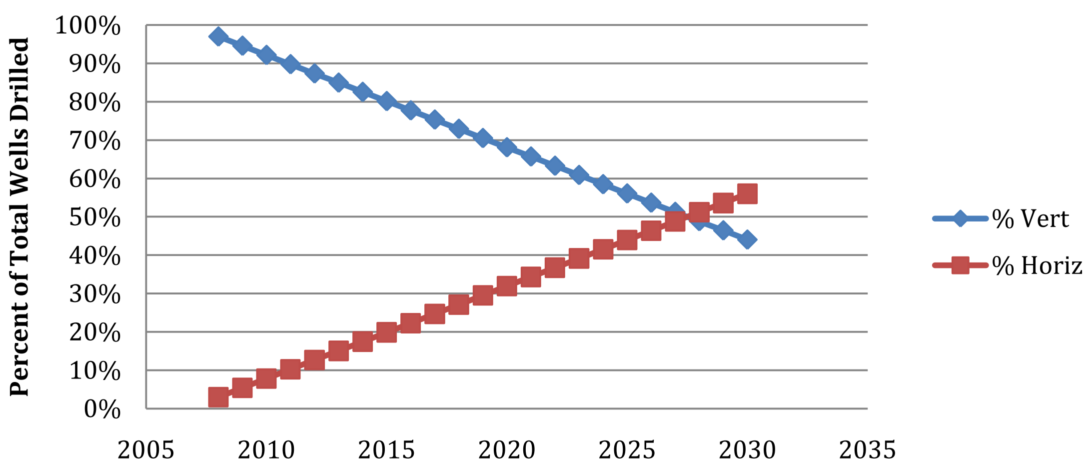
EXHIBIT 19: IMPACT OF 2008 MARCELLUS DRILLING EXPENDITURES	
Output ($ Millions)	$371
Value Added ($ Millions)	$189
Jobs	2,247
Total Taxes ($ Millions)	$68

Total state and local taxes consist of direct severance and state income taxes from drilling activity (Exhibit 15) plus additional taxes that result from the indirect and induced economic activity as computed by IMPLAN. Those taxes total $68 million in 2008. The direct, indirect and induced economic activity from Marcellus drilling investments resulted in 2,247 jobs in 2008.

Economic Activity from Future Development of Marcellus Shale in West Virginia

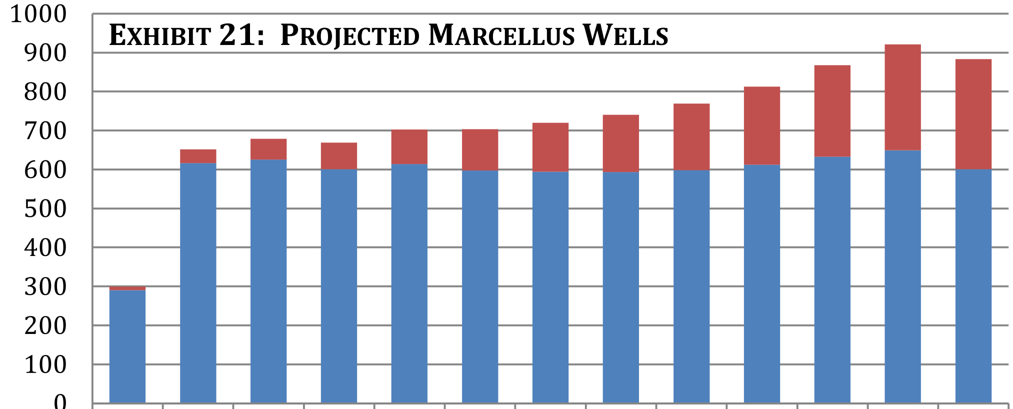
As discussed above, the estimation of the impact of future Marcellus development started with estimating the number of wells to be drilled each year. Those wells must also be divided into the number of vertical and horizontal wells that will be drilled. This approach resulted in a linear increase in the percentage of horizontal wells drilled each year and a corresponding decrease in vertical wells (Exhibit 20). Although this projection was done through 2030, mirroring the 20-year-plus history of the Barnett shale industry, the economic analysis was run only through 2020.

EXHIBIT 20: PROJECTED TRENDS IN HORIZONTAL AND VERTICAL WELLS



Using the algorithm for total wells drilled and the ratio of the types of wells resulted in a projection that about 900 wells will be drilled in each of the last two years of the forecast (Exhibit 21).

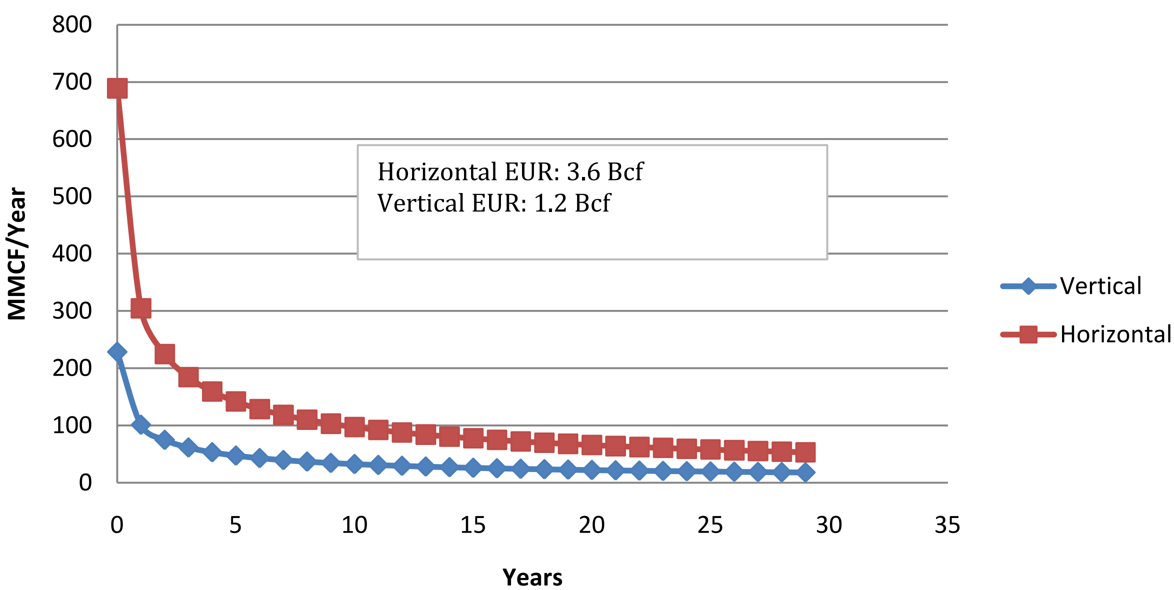
EXHIBIT 21: PROJECTED MARCELLUS WELLS



	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Horiz Marcellus	9	35	53	68	89	106	126	147	171	201	235	272	282
Vert Marcellus	290	616	625	600	614	597	594	593	598	612	633	650	601

Next, gas production from these wells was estimated using standard decline curves. Separate curves were used for the two types of wells, along with corresponding estimated ultimate recovery for each type of well: 1.2 Bcf for vertical wells and 3.6 Bcf for horizontal wells (Exhibit 22). The wells were then "vintaged," i.e., in any given future year the production from the wells drilled that year plus that year's production from all wells drilled in previous years were added to determine the total annual gas production. This production was combined with EIA price forecasts to calculate total production revenue which in turn served as the basis for royalties and severance and other taxes.

EXHIBIT 22: SHALE GAS WELL DECLINE CURVES



The annual gas production over the forecast period reaches about 5,000 Bcf in volume, worth $40 billion annually by 2020 (Exhibit 23). The cumulative volume over the analysis period totals over 30 trillion cubic feet of gas worth more than $200 billion (Exhibit 24).

EXHIBIT 23: PROJECTED ANNUAL MARCELLUS SHALE GAS PRODUCTION AND VALUE

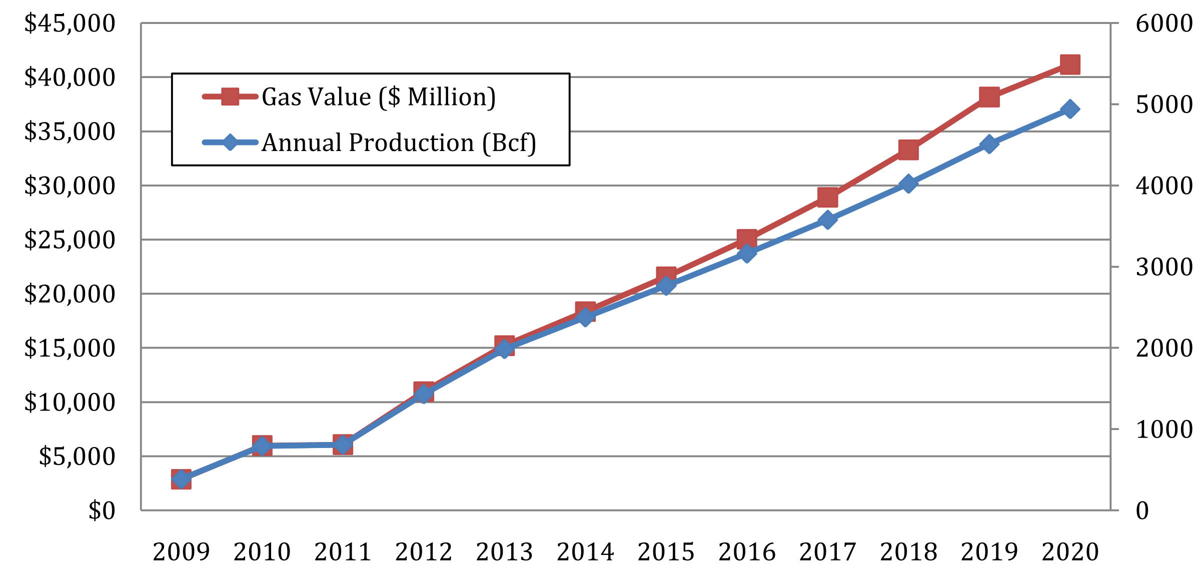
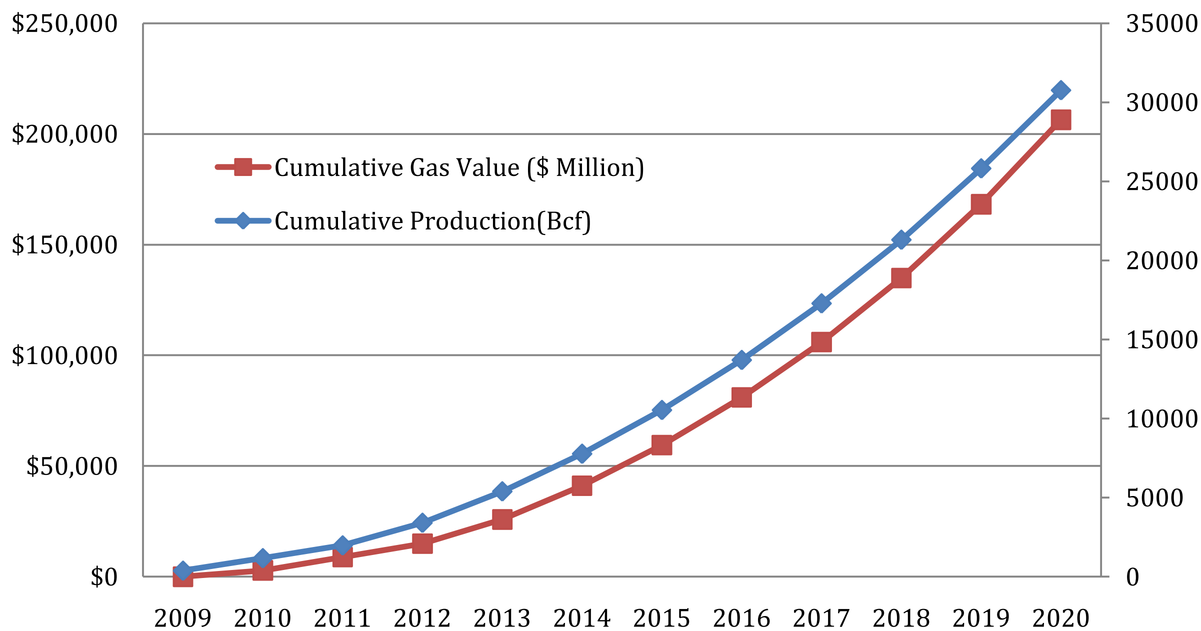


Exhibit 24: PROJECTED CUMULATIVE MARCELLUS SHALE GAS PRODUCTION AND VALUE



The expenditures for the wells drilled in future years were calculated similarly to those that were drilled in 2008. Total payments to suppliers, payroll, and taxes were calculated for the total number of wells, with costs for vertical and horizontal wells computed separately. By 2020, payments to suppliers approach $1.5 billion and royalties reach $1.2

billion. Industry payroll is more than $117 million and direct state and local taxes are just short of $700 million annually (Exhibit 25).

EXHIBIT 25: FUTURE EXPENDITURES RESULTING FROM MARCELLUS DRILLING AND PRODUCTION ($ MILLIONS)				
Year	**Payments To Suppliers**	**Royalties**	**Payroll**	**State and Local Taxes**
2009	$624.90	$213.95	$23.18	$138.53
2010	$695.97	$302.49	$32.77	$195.57
2015	$1,005.92	$648.49	$70.25	$417.40
2020	$1,492.96	$1,202.95	$117.58	$697.25

These expenditures will significantly benefit the West Virginia economy. Future Marcellus Shale gas drilling and production adds to both gross economic output and value added, as explained earlier, as well as jobs generated and state and local taxes paid (Exhibit 26). The impacts increase throughout the period. By 2020, the annual value added by Marcellus shale activity in West Virginia is over $1.6 billion based on gross economic output of $2.9 billion. In that year, almost 17,000 jobs are generated and about $870 million are paid in total state and local taxes.

EXHIBIT 26: IMPACTS OF SHALE GAS DEVELOPMENT ($ MILLIONS)				
Year	**Output**	**Value Added**	**Jobs**	**Total Taxes**
2009	$989	$561	4,858	$199
2010	$1,161	$658	5,998	$266
2015	$1,874	$1,061	10,604	$531
2020	$2,896	$1,639	16,863	$872

The estimate of taxes paid consists of several components (Exhibit 27). Direct taxes from Marcellus activity include severance taxes on production and personal and corporate taxes from the drilling and production activities. These direct taxes will total almost $700 million in 2020. In addition, induced taxes of $175 million are generated in 2020 from the drilling expenditures and personal spending by those receiving royalties and wages.

EXHIBIT 27: STATE AND LOCAL TAX IMPACTS ($ MILLIONS)				
	2009	**2010**	**2015**	**2020**
Severance Tax	$46.37	$65.55	$140.53	$235.21
Corp Income Tax	$73.98	$104.30	$221.74	$369.78
Personal Income Tax	$18.19	$25.71	$55.12	$92.26
Induced Taxes from Drilling	$49.62	$55.26	$79.87	$118.54
Induced Taxes from Personal Spending	$11.06	$15.63	$33.52	$56.09
Total Induced Taxes	$60.67	$70.89	$113.38	$174.63
State and Local Taxes	$138.53	$195.57	$417.40	$697.25
Total Taxes	$199.20	$266.46	$530.78	$871.88

Why This Analysis May Be Conservative

There are three main reasons why this analysis may underestimate the economic impact shown from Marcellus Shale gas drilling and production in West Virginia. First, as discussed above, lease bonus payments to landowners are not included because of lack of data on such payments. Surveys in other states have shown that these payments can be very large. While there is evidence to suggest that both the number and size of lease bonuses may be smaller in West Virginia than in neighboring Pennsylvania,[123] where PSU survey data reported over $2 billion in lease bonuses in 2008,[124] they are still likely to be much larger than royalty payments in 2008. Adding such bonus expenditures would increase the economic impact accordingly.

Secondly, the Barnett and Marcellus Shales may ultimately have different ratios of vertical to horizontal wells. Much of the horizontal drilling and high-volume hydraulic fracturing technologies used in shale gas development today were perfected in the Barnett. Marcellus producers, being at an earlier stage in the development of the basin, could reach a similar level of evolutionary development earlier in the play's history than did the Barnett, and, indeed, progress beyond it. This would be a result of the Marcellus industry benefitting from the technological and scientific advances made in the Barnett. Since horizontal wells cost more and are more productive than vertical wells, a larger proportion of horizontal wells than forecast here would produce a greater economic impact.

Finally, the pace of Marcellus Shale development may be faster than in the Barnett Shale on which the pace of future development in this analysis is modeled. It appears that some of the larger Marcellus operators are shifting their exploration dollars away from other conventional and unconventional plays, including the Barnett, and concentrating them within the Marcellus. This could lead to an increase in Marcellus drilling relative to what took place in the Barnett. Therefore, future development in the Marcellus, including West Virginia, may exceed the pace predicted in this analysis.

CONCLUSIONS

It is important to understand that this analysis examined only the economic stimulus provided by the Marcellus Shale natural gas play activities. The Marcellus is but a portion of the entire oil and gas activity in West Virginia. Those other oil and gas plays (e.g., Coal Bed Natural Gas, Ohio Shale, Trenton-Black River, etc.) have and will continue to contribute to the State's economy. West Virginia is currently the only state east of the Mississippi River that is a net exporter of natural gas.[125] Development of the Marcellus shale will have a significant and positive impact to the overall economy of the state that will be in addition to the State's ongoing oil and gas development.

West Virginia is suffering an economic downturn, along with the rest of the country. Employment in both the goods and services sectors has decreased, the state budget is running a deficit, and the state, with the exception of one county, is losing population. The state economy is more reliant on mining than most states, and that sector faces regulatory uncertainty.

In contrast, shale gas development in the state promises to increase economic activity and have far-reaching benefits. In 2008, the industry drilled 299 gas wells in the Marcellus Shale. Through direct, indirect, and induced economic activity, these wells contributed

$371 million in gross economic output, $189 million in value added, $86 million in direct payments to households, over 2200 jobs, and $68 million in taxes.

The pace of drilling for Marcellus Shale gas wells is expected to increase substantially in the future, growing to about 900 wells per year by 2020. This level of drilling activity, with the accompanying industry expenditures in the state, is projected to have the following economic impacts in 2020:

- $2.9 billion in gross economic activity;
- $1.6 billion in value added;
- $1.3 billion direct payments to households through royalties and industry payroll;
- Almost 17,000 additional jobs; and
- Over $870 million in state and local taxes.

All told, about 30 trillion cubic feet of shale gas will be produced by 2020, worth more than $200 billion.

Finally, these results may well be conservative for three reasons: 1) lease bonus payments, a significant industry expense, were not included in this analysis due to lack of data; 2) Marcellus producers may take advantage of technological and operating advances developed elsewhere to increase the proportion of horizontal wells drilled beyond what has occurred in the areas where shale gas production was pioneered; and 3)the pace of Marcellus Shale development may be faster than in other basins on which this analysis is modeled as large producers shift their exploration dollars away from other basins. All of these factors would result in higher economic impacts than have been estimated in this report.

REFERENCES

[1] ALL Consulting and GWPC 2009. *Modern Shale Gas Development in the United States: A Primer*. Prepared for the Department of Energy Office of Fossil Energy and National Energy Technology Laboratory, Washington, DC. April.

[2] Ibid.

[3] EIA. 2008. *Annual Energy Outlook 2008 with Projections to 2030*. http://www.eia.doe.gov/oiaf/aeo/pdf/0383(2008).pdf. June.

[4] EIA. 2009. *March 2009 Monthly Energy Review, Table 4.3.* http://www.eia.doe.gov/emeu/mer/natgas.html. March.

[5] EIA. 2008. *Annual Energy Outlook 2008 with Projections to 2030*. http://www.eia.doe.gov/oiaf/aeo/pdf/0383(2008).pdf. June.

[6] EIA. 1999. *Natural Gas 1998: Issues and Trends*. http://www.eia.doe.gov/pub/oil_gas/natural_gas/analysis_publications/natural_gas_1998_issues_trends/pdf/it98.pdf. April.

[7] EIA. 2008. *Annual Energy Outlook 2008 with Projections to 2030*. http://www.eia.doe.gov/oiaf/aeo/pdf/0383(2008).pdf. June.

[8] EIA. 2007. *International Energy Outlook 2007, Chapter 4: Natural Gas*. May. http://tonto.eia.doe.gov/FTPROOT/forecasting/0484(2007).pdf.

[9] EIA. 1999. *Natural Gas 1998: Issues and Trends*. April. http://www.eia.doe.gov/pub/oil_gas/natural_gas/analysis_publications/natural_gas_1998_issues_trends/pdf/it98.pdf.

[10] American Clean Skies Foundation. *Natural Gas Myth vs. Fact*. http://www.cleanskies.org/. Accessed September 2008.

[11] Independent Petroleum Association of Mountain States (IPAMS). America's Independent Natural Gas Producers. *Producing Today's Clean Energy, Ensuring Tomorrow's Innovation*. http://www.ipams.org/media/docs/Callupdraft10.pdf. Accessed September 2008.

[12] Public Lands Advocacy. 2008. *Energy Insecurity*. Presentation at Public Lands Advocacy NEPA-Permitting Seminar/2008 Annual Meeting. June 11. http://www.publiclandsadvocacy.org/presentations.htm.

[13] American Clean Skies Foundation. *U.S. Fuel Goals*. http://www.cleanskies.org/. Accessed September 2008.

[14] BP. 2008. *Statistical Review of World Energy – 2008. Natural Gas*. http://www.bp.com/subsection.do?categoryId=9023762&contentId=7044550. Accessed September 2008.

[15] Navigant Consulting. 2008. *North American Natural Gas Supply Assessment*. Prepared for American Clean Skies Foundation. July 4.

[16] Tinker, S. 2008. Bureau of Economic Geology, University of Texas-Austin. *Global Energy*: *Myths, Realities and Paradoxes*. Presentation to the American Association of Petroleum Geologists, July 2008.

[17] ALL Consulting modified from USGS and other sources. March 2009.

[18] EIA. 2008. *Annual Energy Outlook 2008 with Projections to 2030*. June. http://www.eia.doe.gov/oiaf/aeo/pdf/0383(2008).pdf.

[19] Navigant Consulting. 2008. *North American Natural Gas Supply Assessment*. Prepared for American Clean Skies Foundation. July 4.

[20] EIA. 2008. *Is U.S. Natural Gas Production Increasing*? http://tonto.eia.doe.gov/energy_in_brief/natural_gas_production.cfm. June 11.

[21] American Clean Skies Foundation. 2008. *Natural Gas Planet*. Summer.

[22] Ibid.

[23] NY DEC. 1992. Division of Mineral Resources. Final Generic Environmental Impact Statement on the Oil, Gas and Solution Mining Regulatory Program.

[24] Harper, J. 2008. *The Marcellus Shale – An Old "New" Gas Reservoir in Pennsylvania*. v. 28, no 1. Published by the Bureau of Topographic and Geologic Survey, Pennsylvania Department of Conservation and Natural Resources. Pennsylvania Geology. Spring.

[25] Ibid.

[26] Ibid.

[27] Schlumberger. 2005. *Shale Gas White Paper*. 05-OF299. Modified from: J. K., Frantz and V. Jochen. Schlumberger Marketing Communications. October.

[28] Engelder, T., and G. G. Lash. 2008. *Marcellus Shale Play's Vast Resource Potential Creating Stir in Appalachia*. The American Oil & Gas Reporter. May.

[29] Williams, P. 2005. *Big Sandy: Kentucky's Big Sandy Field Remains a Locus of Exploration Activity, More than 90 years after its Discovery*. Oil and Gas Investor. August.

[30] Harrison, W. 2006. Production History and Reservoir Characteristics of the Antrim Shale Gas Play, Michigan Basin. Western Michigan University.

[31] Hayden, J., and D. Pursell. 2005. Pickering Energy Partners, Inc. *The Barnett Shale. Visitor's Guide to the Hottest Gas Play in the US.* October.

[32] Ibid.

[33] Ibid.

[34] Harper, J. 2008. *The Marcellus Shale – An Old "New" Gas Reservoir in Pennsylvania*. v. 28, no 1. Published by the Bureau of Topographic and Geologic Survey, Pennsylvania Department of Conservation and Natural Resources. Pennsylvania Geology. Spring.

[35] Ameri, S., K. Aminian, J. A. Miller, D. Doricich, and A. B. Yost. *A Systematic Approach for Economic Development of the Devonian Shale Gas Resources*. SPE 14504.

[36] Halliburton Energy Services. 2008. *U.S. Shale Gas: An Unconventional Resource*. Unconventional Challenges.

[37] Airhart, M. Geology.com. *The Barnett Shale Gas Boom: Igniting a Hunt for Unconventional Natural Gas Resources.* http://geology.com/research/barnett-shale-gas.shtml. Accessed September 2008.

[38] Milici, R. C., and C. S. Swezey. 2006. Assessment of Appalachian Basin Oil and Gas Resources: Devonian Shale – Middle and Upper Paleozoic Total Petroleum System. U.S. Geological Survey, Open File Report Series: 2006-1237. http://pubs.usgs.gov/of/2006/1237/.

[39] Schlumberger. 2005. *Shale Gas White Paper*. 05-OF299. Modified from J. K., Frantz and V. Jochen. Schlumberger Marketing Communications. October.

[40] Davis, R., Jr. 1992. *Depositional Systems: An Introduction to Sedimentology and Stratigraphy*. Prentice Hall. 2nd Edition.

[41] Freeze, R., and J. Cherry. 1979. *Groundwater*. Prentice Hall.

[42] Frantz, J.K., and V. Jochen. 2005. Schlumberger. *Shale Gas White Paper*. 05-OF299. Schlumberger Marketing Communications. October.

[43] Geology.com. *Marcellus Shale- Appalachian Basin Natural Gas Play: New Research Results Surprise Everyone on the Potential of this Well-known Devonian Black Shale*. http://geology.com/articles/marcellus-shale.shtml. Accessed September 2008.

[44] ALL Consulting and GWPC. 2009 *Modern Shale Gas Development in the United States: A Primer*. Prepared for the Department of Energy Office of Fossil Energy and National Energy Technology Laboratory, Washington, DC. April.

[45] Ibid.

[46] Engelder, T. 2009. Marcellus 2008: *Report card on the breakout year for gas production in the Appalachian Basin*. Fort Worth Basin Oil & Gas Magazine. August. http://www.geosc.psu.edu/~engelder/references/link155.pdf.

[47] ALL Consulting and GWPC. 2009 *Modern Shale Gas Development in the United States: A Primer*. Prepared for the Department of Energy Office of Fossil Energy and National Energy Technology Laboratory, Washington, DC. April.

[48] Duncan, D. 2009. Statement of Douglas Duncan Research Geologist, U.S. Geological Survey, U.S. Department of the Interior before the Committee on Natural Resources Subcommittee on Energy and Mineral Resources. June 4.

[49] Milici, R.C., and C.S. Swezey. 2006. *Assessment of Appalachian Basin Oil and Gas Resources: Devonian Shale – Middle and Upper Paleozoic Total Petroleum System*. U.S. Geological Survey, Open File Report Series: 2006-1237. http://pubs.usgs.gov/of/2006/1237/.

[50] Arthur, J.D., B. Bohm, and M. Layne. 2008. ALL Consulting. *Hydraulic Fracturing Considerations for Natural Gas Wells of the Marcellus Shale*. Presented at the GWPC Annual Forum in Cincinnati, OH. September.

[51] West Virginia Geological and Economic Survey. 1997. *Enhancement of the Appalachian Basin Devonian Shale Resource Base in the GRI Hydrocarbon Model*. Prepared for Gas Research Institute. December.

[52] Harper, J. 2008. Published by the Bureau of Topographic and Geologic Survey, Pennsylvania Department of Conservation and Natural Resources. Pennsylvania Geology. *The Marcellus Shale – An Old "New" Gas Reservoir in Pennsylvania*. v. 28, no 1. Spring.

[53] PDEP. 2009. Weekly Workload Report – Week of 11/09/2009 to 11/13/2009. Available on the Pennsylvania Department of Environmental Protection, Bureau of Oil and Gas Management website: http://www.dep.state.pa.us/dep/deputate/minres/oilgas/new_forms/marcellus/marcellus.htm.

[54] WVGES. 2009. Personal Communication: Marcellus Shale well database. West Virginia Geological and Economic Survey. November 5.

[55] NYDEC. 2009. Wels Data Search. New York State Department of Environmental Conservation website: http://www.dec.ny.gov/cfmx/extapps/GasOil/search/wells/index.cfm. Accessed November 2009).

[56] NYSERDA. Undated. New York's Natural Gas and Oil Resource endowment: Past, Present and Potential. New York State Energy research and Development Authority. http://www.dec.ny.gov/docs/materials_minerals_pdf/nyserda5.pdf. Accessed November 2009.

[57] Wheeler, T. 2009. First permits sought to drill in Marcellus shale deposits. The Baltimore Sun. November 13. http://www.baltimoresun.com/features/green/bal-shale-1113,0,6708719.story.

[58] Avary, K.L. Undated. Geology of the Marcellus Shale. PowerPoint presentation available on the West Virginia Geological and Economic Survey website: http://www.wvgs.wvnet.edu/www/datastat/WVGES_GeologyMarcellusShale.pdf. Accessed November 2009.

[59] Ibid.

[60] Ibid.

[61] Wrightstone, G. 2009. Marcellus Shale Geologic Controls on Production. Independent Oil and Gas Association West Virginia Winter Meeting, Charleston, WV, February 26. http://www.iogawv.com/pdfs/Wrightstone_For_Distribution_IOGAWV_2009.pdf.

[62] Soeder, D.J., and W.M. Kappel. 2009. *Water Resources and Natural Gas Production from the Marcellus Shale.* U.S. Geological Survey Fact Sheet 2009-3032. May. http://md.water.usgs.gov/publications/fs-2009-3032/.

[63] Wrightstone, G. 2009. *Marcellus Shale – Geologic Controls on Production*. American Association of Petroleum Geologists Annual Convention, Denver CO, June. http://www.searchanddiscovery.net/documents/2009/10206wrightstone/index.htm.

[64] Wrightstone, G. 2009. Marcellus Shale Geologic Controls on Production. Independent Oil and Gas Association West Virginia Winter Meeting, Charleston, WV, February 26. http://www.iogawv.com/pdfs/Wrightstone_For_Distribution_IOGAWV_2009.pdf.

[65] Cluff, R.M., Shanley, K.W., and Miller, M.A. 2007. Discovery Group. *Three Things We Thought We Understood About Shale Gas, but Were Afraid to Ask*. April 2007.

[66] Montgomery, S.L., Jarvie, D.M., Bowker, K.A., and Pollastro, R.M. 2005. *Mississippian Barnett Shale, Fort Worth Basin, North-central Texas: Gas Shale Play with Multi-trillion Cubic Foot Potential*. AAPG Bulletin. v 89. no 2. pp 155 – 175. 2005.

[67] Milici, R.C., and C.S. Swezey. 2006. *Assessment of Appalachian Basin Oil and Gas Resources: Devonian Shale – Middle and Upper Paleozoic Total Petroleum System*. U.S. Geological Survey, Open File Report Series: 2006-1237. http://pubs.usgs.gov/of/2006/1237/.

[68] Ibid.

[69] Wrightstone, G. 2009. *Marcellus Shale – Geologic Controls on Production*. American Association of Petroleum Geologists Annual Convention, Denver CO, June. http://www.searchanddiscovery.net/documents/2009/10206wrightstone/index.htm.

[70] WVG&ES. 2009. Personal Communication. West Virginia Geological and Economic Survey. October 30.

[71] Cardwell, D.H. 1982. *Oriskany and Huntersville Gas Fields of West Virginia*. West Virginia Geological and Economic Survey, Mineral Resources Series MRS-5A. GIS data for top of Onondaga Limestone map provided by WVGE&S.

[72] IOGAWV. 2009. *History of Natural Gas. Independent Oil and Gas Association of West Virginia, Inc*. http://www.iogawv.com/history.cfm. Accessed November 2009.

[73] GRI. 1997. *Enhancement of the Appalachian Basin Devonian Shale Resource Base in the GRI Hydrocarbon Model*. Prepared by: Gas Research institute; prepared for West Virginia Geological and Economic Survey. December.

[74] WVG&ES. 2009. Personal Communication. West Virginia Geological and Economic Survey. November 5.

[75] Ibid.

[76] NARO-Appalachia. 2009. Personal Communication . National Association of Royalty Owners – Appalachia. November 13.

[77] Wrightstone, G. 2009. *Marcellus Shale – Geologic Controls on Production*. American Association of Petroleum Geologists Annual Convention, Denver CO, June. http://www.searchanddiscovery.net/documents/2009/10206wrightstone/index.htm.

[78] WVGES. 2009. Interactive Mapping Systems website. http://ims.wvgs.wvnet.edu/mar/viewer.htm. Accessed November 2009.

[79] WVG&ES. 2009. Personal Communication. West Virginia Geological and Economic Survey. October 30.

[80] WVG&ES. 2009. Personal Communication. West Virginia Geological and Economic Survey. November 5.

[81] WV OOG. 2009. Personal Communication. West Virginia Office of Oil and Gas. October 30.

[82] WVG&ES. 2009. Personal Communication. West Virginia Geological and Economic Survey. October 30.

[83] IOGAWV. 2009. Personal Communication. Independent Oil and Gas Association of West Virginia, Inc. November 11.

[84] Chernoff, H. 2008. Investing in the Marcellus Shale. March 17. Seeking Alpha $^{\alpha}$ website: http://seekingalpha.com/article/68716-investing-in-the-marcellus-shale. Accessed November 2009.

[85] Engelder, T. 2009. *Marcellus 2008: Report card on the breakout year for gas production in the Appalachian Basin*. Fort Worth Basin Oil & Gas Magazine. August. http://www.geosc.psu.edu/~engelder/references/link155.pdf

[86] ALL Consulting and GWPC. 2009 *Modern Shale Gas Development in the United States: A Primer*. Prepared for the Department of Energy Office of Fossil Energy and National Energy Technology Laboratory, Washington, DC. April.

[87] West Virginia State Budget. Sunshine Review. http://sunshinereview.org/index.php/West_Virginia_state_budget. Accessed November 23, 2009.

[88] Hammond, G. 2009. West Virginia Economic Outlook Update 2009. West Virginia Business & Economic Review. Spring.

[89] West Virginia University, Bureau of Business and Economic Research. 2008. West Virginia Economic Outlook 2009.

[90] Rural Economic Development Data and Intelligence. 2007. Assessing Financial and Economic Impacts: A Guide to Informed Decision-Making; Section 3: Economic Impact Assessment; Direct, Indirect and Induced Impacts. http://www.reddi.gov.on.ca/guide_ecimpactassessment.htm#3.3.1.

[91] BEA. 2007. Glossary. http://www.bea.gov/glossary/glossary.cfm.

[92] Considine, T., R. Watson, R. Entler, and J. Sparks. 2009. *An Emerging Giant: Prospects and Economic Impacts of Developing the Marcellus Shale Natural Gas Play*. The Pennsylvania State University College of Earth & Mineral Sciences, Department of Energy and Mineral Engineering. July 24.

[93] Weinstein, B., and T. Clower. 2009. *Potential Economic and Fiscal Impacts from Natural Gas Production in Broome County, New York*. July.

[94] The Perryman Group. 2007. *Bounty from Below: The Impact of Developing Natural Gas Resources Associated with the Barnett Shale on Business Activity in Fort Worth and the Surrounding 14-County Area.* May.

[95] Loren Scott and Associates. 2009. *The Economic Impact Of The Haynesville Shale On The Louisiana Economy in 2008*. April. http://dnr.louisiana.gov/haynesvilleshale/loren-scott-impact2008.pdf.

[96] University of Arkansas, Sam Walton College of Business. 2008. Projecting *the Economic Impact of the Fayetteville Shale Play for 2008-2012*. March. http://cber.uark.edu/FayettevilleShaleEconomicImpactStudy2008.pdf.

[97] Considine, T., R. Watson, R. Entler, and J. Sparks. 2009. *An Emerging Giant: Prospects and Economic Impacts of Developing the Marcellus Shale Natural Gas Play*. The Pennsylvania State University College of Earth & Mineral Sciences, Department of Energy and Mineral Engineering. July 24.

[98] WVG&ES. 2009. Personal Communication. West Virginia Geological and Economic Survey. November 5.

[99] Considine, T., R. Watson, R. Entler, and J. Sparks. 2009. *An Emerging Giant: Prospects and Economic Impacts of Developing the Marcellus Shale Natural Gas Play*. The Pennsylvania State University College of Earth & Mineral Sciences, Department of Energy and Mineral Engineering. July 24.

[100] EIA. 2009. Energy Information Administration, Forecasts & Analyses webpage, Natural Gas Prices – Yearly Projections to 2030. March. http://www.eia.doe.gov/oiaf/aeo/excel/aeotab_13.xls. Accessed November 2009.

[101] Considine, T., R. Watson, R. Entler, and J. Sparks. 2009. *An Emerging Giant: Prospects and Economic Impacts of Developing the Marcellus Shale Natural Gas Play*. The Pennsylvania State University College of Earth & Mineral Sciences, Department of Energy and Mineral Engineering. July 24.

[102] Engelder, T. 2009. *Marcellus 2008: Report card on the breakout year for gas production in the Appalachian Basin*. Fort Worth Basin Oil & Gas Magazine. August. http://www.geosc.psu.edu/~engelder/references/link155.pdf.

[103] Ibid.

[104] EIA. 2009. Energy Information Administration, Forecasts & Analyses webpage, Natural Gas Prices – Yearly Projections to 2030. March. http://www.eia.doe.gov/oiaf/aeo/excel/aeotab_13.xls. Accessed November 2009.

[105] NARO-Appalachia. 2009 Personal Communication. National Association of Royalty Owners – Appalachia. November 13.

[106] Weinstein, B., and T. Clower. 2009. *Potential Economic and Fiscal Impacts From Natural Gas Production In Broome County, New York.* July.

[107] Engelder, T. 2008. *Unconventional natural gas reservoir could boost U.S. supply*. Penn State Live. January 17. http://live.psu.edu/story/28116. Accessed November 3, 2009.

[108] MIG. 2009. IMPLAN. Minnesota IMPLAN Group, Inc.

[109] Bureau of Economic Analysis, U.S. Department of Commerce. State Annual Personal Income. http://www.bea.gov/regional/spi/default.cfm?selTable=summary.

[110] BEA. 2009. Table 2.1, Personal Income and Its Disposition. http://www.bea.gov/national/nipaweb/TableView.asp?SelectedTable=58&ViewSeries=NO&Java=no&Request3Place=N&3Place=N&FromView=YES&Freq=Year&FirstYear=2002&LastYear=2008&3Place=N&Update=Update&JavaBox=no#Mid.

[111] Considine, T., R. Watson, R. Entler, and J. Sparks. 2009. *An Emerging Giant: Prospects and Economic Impacts of Developing the Marcellus Shale Natural Gas Play*. The Pennsylvania State University College of Earth & Mineral Sciences, Department of Energy and Mineral Engineering. July 24.

[112] BEA. 2009. Table 2.3.5, Personal Consumption Expenditures by Major Type of Product. http://www.bea.gov/national/nipaweb/TableView.asp?SelectedTable=65&ViewSeries=NO&Java=no&Request3Place=N&3Place=N&FromView=YES&Freq=Year&FirstYear=2004&LastYear=2008&3Place=N&Update=Update&JavaBox=no#Mid.

[113] Weinstein, B., and T. Clower. 2009. *Potential Economic and Fiscal Impacts From Natural Gas Production In Broome County, New York.* July.

[114] Engelder, T. 2008. *Unconventional natural gas reservoir could boost U.S. supply*. Penn State Live. January 17. http://live.psu.edu/story/28116. Accessed November 3, 2009.

[115] Considine, T., R. Watson, R. Entler, and J. Sparks. 2009. *An Emerging Giant: Prospects and Economic Impacts of Developing the Marcellus Shale Natural Gas Play*. The Pennsylvania State University College of Earth & Mineral Sciences, Department of Energy and Mineral Engineering. July 24.

[116] Loren Scott and Associates. 2009. *The Economic Impact Of The Haynesville Shale On The Louisiana Economy In 2008*. April. http://dnr.louisiana.gov/haynesvilleshale/loren-scott-impact2008.pdf.

[117] Baumann, R.H., D.E. Dismukes, D.V. Mesyanzhinov, and A.G. Pulsipher. 2002. *Analysis of the Economic Impact Associated with Oil and Gas Activities on State Leases*. Louisiana State University Center for Energy Studies, Baton Rouge, La. 11 pgs.

[118] Walker, D., and N. Sonora. 2005. *The Economic Impacts of the Natural Gas Industry in La Plata County, 2003-2004.* School of Business Administration, Fort Lewis College, Durango, CO. 18 pgs.

[119] Considine, T., R. Watson, R. Entler, and J. Sparks. 2009. *An Emerging Giant: Prospects and Economic Impacts of Developing the Marcellus Shale Natural Gas Play*. The Pennsylvania State University College of Earth & Mineral Sciences, Department of Energy and Mineral Engineering. July 24.

[120] U.S. Census Bureau. West Virginia Quick Facts. http://quickfacts.census.gov/qfd/states/54000.html.

[121] Real, P. 2009. *Economic & Practical Impacts of the West Virginia Oil & Natural Gas Industry*. Natural Gas Forum. August 12.

[122] BEA. 2007. Glossary. http://www.bea.gov/glossary/glossary.cfm.

[123] Tudor, Pickering, Holt, and Co. 2009. Inside the Marcellus Play. July. (slide 25).

[124] Considine, T., R. Watson, R. Entler, and J. Sparks. 2009. *An Emerging Giant: Prospects and Economic Impacts of Developing the Marcellus Shale Natural Gas Play*. The Pennsylvania State University College of Earth & Mineral Sciences, Department of Energy and Mineral Engineering. July 24.

[125] WVDO. 2009. West Virginia's Natural Gas and Oil. West Virginia Development Office website: http://www.wvdo.org/business/ng_oil.html. Accessed November 2009.