

Overview of Marcellus Shale Development in the Appalachian Basin “Bringing New-Age Technology to an Age-Old Formation”

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I. Introduction¹

Most people still envision oil gushing through the top of the derrick when a successful well is drilled, as captured in the movie “There will be Blood,” with Daniel Day-Lewis as the “oil man.” Still others associate oil discovery with the Beverly Hillbillies, a TV show of the 1960s, where discovery is “hit or miss” and has more to do with luck than technology. Of course, nothing can be further from the truth. For decades, the oil and gas industry has spent billions of dollars researching new technologies to grow and develop the domestic oil and gas industry. Maggie Lee, in *The American Oil and Gas Reporter*, states, “High technology has migrated to almost all phases of exploration and production, and that includes stepping right up to the drilling rig floor. That’s right, the rig floor – the domain of the roughneck and the pipewrench, where the real ‘nitty gritty’ gets done – is becoming more technology-oriented by the day . . . Technology is markedly improving drilling performance and enhancing safety even as it helps trim cost.”²

Environmental and fiscal concerns remain at the forefront of reasons prompting new technologies. Companies want to produce more for less, and as cleanly and efficiently as

¹ Paper originally presented at the EMLF 34th Mineral Law Conference on Wed, Oct 28, 2009. This paper has been updated to reflect developments since that date.

² *The American Oil and Gas Reporter*. Maggie Lee. April 1998, as reported in the article entitled, U.S. Department of Energy (“DOE”) Report entitled, “Environmental Benefits of Advanced Oil and Gas Exploration and Production Technology.” http://fossil.energy.gov/programs/oilgas/publications/environ_benefits/6drill.pdf.

possible. Gifford Briggs, author of an article for the Louisiana Oil and Gas Association, states, “Long gone are the days of oil shooting out of the derrick and spilling on the ground. We are now in an age where more oil is spilled from your outboard motor than is spilled from an offshore platform. Also long gone are the days of inexpensive exploration. Oil and gas reserves are getting more difficult to find and produce. Innovation is necessary to make production financially feasible.”³ That innovation has largely come in developments in the natural gas industry.

II. Background

In 2009, natural gas accounted for just twenty-two percent (22%) of U.S. Energy Consumption.⁴ However, natural gas is being consumed by the U.S. economy at a rate that exceeds domestic production, and the gap is increasing.⁵ Half of the natural gas consumed today is produced from wells drilled within the last 3.5 years.⁶ Underlying the environmental concerns over greenhouse gases and carbon emissions, a clean-burning fuel is becoming more of a priority. “Natural gas is the cleanest of the fossil fuels,” says Christopher Flavin, president of the Worldwatch Institute, a think tank that does environmental research.⁷

³ Louisiana Oil and Gas Association. *Two Technologies That Have Changed the Way We Drill*. Gifford Briggs. <http://loga.la/loganews/?cat=32>. September 28, 2009.

⁴ U.S. Department of Energy - Office of Fossil Energy - National Energy Technology Laboratory. *Modern Shale Gas Development in the United States - A Primer*. p. ES-1. April 2009. http://fossil.energy.gov/programs/oilgas/publications/naturalgas_general/Shale_Gas_Primer_2009.pdf.

⁵ U.S. Energy Information Agency (“EIA”). *Natural Gas Basic Statistics*. September 2008. <http://www.eia.doe.gov/basics/quickgas.html>.

⁶ Independent Petroleum Association of Mountain States (IPAMS). *America’s Independent Natural Gas Producers. Producing Today’s Clean Energy, Ensuring Tomorrow’s Innovation*. September 2008. <http://www.ipams.org/media/docs/Callupdraft10.pdf>.

⁷ As reported in the National Public Radio (“NPR”) report by Peter Overby. *With Little Clout, Natural Gas Lobby Strikes Out*. September 24, 2006. <http://www.npr.org/templates/story/story.php?storyId=113138252&ps=rs>.

Natural gas emits approximately half the carbon dioxide (CO₂) of coal, and approximately 30% less than fuel oil.⁸ Because of that, it is generally considered to be central to energy plans focused on the reduction of greenhouse gas emissions.⁹ Robert Hefner, in his book entitled, *The Grand Energy Transition*, states “Natural gas is the fuel that can change everything for our nation.” He goes on to explain that an increase in natural gas usage would not only reduce our dependence on foreign oil, but would also dramatically lower greenhouse gas emissions.¹⁰ The problem up to this point has been a perceived lack of natural gas resources, or at least the ability to effectively access those resources to make natural gas a truly viable option as a “transition fuel.” Scott Kell, President of the Ground Water Protection Council, states, “Natural gas, particularly shale gas, is an abundant U.S. energy resource that will be vital to meeting future energy demand and to enabling the nation to transition to greater reliance on renewable energy sources.”¹¹

Geologists have always known that shale rock holds substantial amounts of natural gas, but as previously stated, it was considered unreachable. Recent technological advances have proven otherwise, and a June 2006 report of The Potential Gas Committee (loosely affiliated with the Colorado School of Mines) states that “natural gas reserves in the United States are actually 35 percent higher than believed just two years ago, and some geologists say even that estimate is too

⁸ EIA. 1999. *Natural Gas 1998 - Issues and Trends*. <http://www.eia.doe.gov/>

⁹ American Clean Skies Foundation. *Natural Gas Myth vs. Fact*. September 2008. www.cleanskies.org.

¹⁰ *The Grand Energy Transition*. Robert Hefner. September 8, 2009.

¹¹ U.S. Department of Energy - Office of Fossil Energy - National Energy Technology Laboratory. *Modern Shale Gas Development in the United States - A Primer*. Foreword. April 2009. http://fossil.energy.gov/programs/oilgas/publications/naturalgas_general/Shale_Gas_Primer_2009.pdf.

conservative.”¹² Analysts have estimated that by 2011, most new reserves growth (50% to 60% or approximately 3 bcf/day) will come from unconventional shale gas reservoirs.¹³

One of the most talked about natural gas plays, which spans six states in the Northeastern United States and was believed to hold as much as 500 trillion cubic feet of natural gas (the equivalent of about 80 billion barrels of oil)¹⁴, is the shale formation in the Marcellus basin (commonly known as “Marcellus Shale”). In fact, according to the EIA, the technically recoverable unproved shale gas resource is 827 trillion cubic feet, which is 480 trillion cubic feet larger than in the Annual Energy Outlook 2010 (AEO2010) Reference case, reflecting additional information that has become available with more drilling activity in new and existing shale plays.¹⁵

The Marcellus Shale covers an area of 95,000 square miles at an average thickness of 50 feet to 200 feet. It also extends into what is known as the Chattanooga Shale. A fairly small gas shale play, still in its infancy, the Chattanooga Shale is located in Eastern Tennessee, Northern Alabama, Southern Kentucky, and Northeast Georgia. It is located below the Floyd Shale, which extends 2,500-6,500 feet below the earth’s surface. Companies Such as Atlas Energy, Inc. (“ATLS”), CNX Gas Company, LLC, a subsidiary of CONSOL Energy Inc. (“CNX”), and GeoMet, Inc. (“GMET”) are actively pursuing this shale deposit and purchasing mineral rights.

¹² As reported in the NPR report by Tom Gjelten. *Rediscovering Natural Gas by Hitting Rock Bottom*. September 2006. <http://www.npr.org/templates/story/story.php?storyId=113043935>.

¹³ U.S. Department of Energy - Office of Fossil Energy - National Energy Technology Laboratory. *Modern Shale Gas Development in the United States - A Primer*. p. ES-1. http://fossil.energy.gov/programs/oilgas/publications/naturalgas_general/Shale_Gas_Primer_2009.pdf. April 2009.

¹⁴ Id.

¹⁵ EIA Executive Summary. December 16, 2010. http://www.eia.doe.gov/forecasts/aeo/executive_summary.cfm

The Chattanooga Shale in eastern Tennessee averages 80-200 feet in thickness, and thickens to over 1,000 feet as it moves north into Kentucky.¹⁶

An article entitled, “Marcellus Shale – Appalachian Basin Natural Gas Play”, portrays the “coming of age” of Marcellus Shale, stating, “a few years ago, every geologist involved in Appalachian Basin oil and gas knew about the Devonian black shale called the Marcellus. However, very few of these geologists were excited about the Marcellus Shale as a major source of natural gas. Wells drilled through it produced some gas but rarely in enormous quantity. Few if any in the natural gas industry suspected that the Marcellus might soon be a major contributor to the natural gas supply of the United States - large enough to be spoken of as a ‘super giant’ gas field.”¹⁷ In 2008, when leasing was exploding and payments reached as high as \$2,000/acre¹⁸, people began asking the question “When was the shale discovered?” and “Why has it taken so long to drill it?” The answer to these questions is very simple, but shows just how important technology research and development can be. In truth, the Marcellus Shale formation is 400 million years old, stretching from New York to West Virginia, and is located at a depth between 4,000 and 8,500 feet below the surface, depending on location.¹⁹ Companies, as well as geologists, have known about the shale for many years, but lacked the technology to make it cost-effective to produce the massive natural gas reserves it contains. A typical vertical completion well would be uneconomical and unsuccessful in adequately producing the

¹⁶ Information on Chattanooga Shale found at <http://oilshalegas.com/chattanoogaashale.html>

¹⁷ *Marcellus Shale - Appalachian Basic Natural Gas Play*. www.geology.com.

¹⁸ Id.

¹⁹ U.S. Department of Energy - Office of Fossil Energy - National Energy Technology Laboratory. *Modern Shale Gas Development in the United States - A Primer*. p. 21. April 2009. http://fossil.energy.gov/programs/oilgas/publications/naturalgas_general/Shale_Gas_Primer_2009.pdf.

reserves.²⁰ So, what has changed from the past that now enables us to drill and produce the Marcellus Shale, and other similar natural gas reserves around the United States? The answer is, horizontal drilling and hydraulic fracturing.

III. Horizontal Drilling

Horizontal drilling is considered by many to be the most valuable technology ever introduced to the oil and gas industry. In 2009, it accounted for about 8% of onshore wells drilled in the U.S., and this percentage increases each year.²¹ Two major causes for the increase involve environmental and financial benefits. The environmental benefit of horizontal drilling is reserve areas can be reached with less surface disruption. Wells can be drilled horizontally to reach gas reserves under parks, buildings and other locations without disrupting their surface areas. Also, multiple horizontal wells can be drilled from the same well pad allowing for far greater access from a single well site. Complete development of a 1-square mile section could require 16 vertical wells each located on a separate well pad. Alternatively, six to eight horizontal wells, drilled from only one well pad, could access the same reservoir volume, or even more.²²

The financial benefits are equally impressive. The Department of Energy (“DOE”) has indicated that drilling a horizontal well can increase a well's reserves by 2%, which in a tight market is substantial. The DOE also indicated that the production ratio for horizontal wells is 3.2

²⁰ However, one operator, Atlas Energy Resources, has reported record breaking production from a two-stage frac in several vertical Marcellus Shale wells. Reported in *The Marcellus Shale Today*. December 19, 2008. <http://marcellustoday.blogspot.com>.

²¹ Louisiana Oil and Gas Association. *Two Technologies That Have Changed the Way We Drill*. Gifford Briggs. September 28, 2009 <http://loga.la/loganews/?cat=32>.

²² Parshall, J. 2008. *Barnett Shale Showcases Tight-gas Development*. Journal of Petroleum Technology. September 19, 2008. http://www.aboutoilandgas.org/spe-site/spe/spe/jpt/2008/09/1Cover_Content.pdf.

to 1, while the cost ratio is only 2 to 1.²³ At \$3 million to \$5 million per well, the Marcellus Shale wells are some of the most expensive onshore wells in the country. Companies are drilling horizontal wells that extend as far out as 4,000 feet horizontally, with some companies trying to extend that distance as far as 7,000 feet.

Horizontal drilling is exploiting the Marcellus Shale and other shale plays around the country. It seems that every year a new shale gas play comes onto the scene, but they are not the only beneficiaries of horizontal drilling – it also plays a big role in offshore exploration. Deepwater wells in the Gulf of Mexico will employ horizontal drilling to gain access to large fields from one platform, greatly reducing production costs.²⁴ It is easy to see why many consider this to be such an important technological advancement.

IV. Hydraulic Fracturing

Hydraulic fracturing, or “fracking” is used in oil and natural gas production. After a well is drilled into reservoir rock that contains oil, natural gas, and water, every effort is made to maximize the production of oil and gas. In hydraulic fracturing, a fluid (usually water containing specialty high-viscosity fluid additives) is injected under high pressure. The pressure exceeds the rock strength, and the fluid opens or enlarges fractures in the rock. These larger, man-made fractures start at the injection well and extend as much as several hundred feet into the reservoir rock. After the formation is fractured, a “propping agent” or “proppant” (usually sand carried by the high-viscosity additives) is pumped into the fractures to keep them from closing when the

²³ 1995 Report of the U.S. Department of Energy, as quoted by DOE, Office of Fossil Fuel. *Environmental Benefits of Advanced Oil and Gas Exploration and Production Technology*.
http://fossil.energy.gov/programs/oilgas/publications/environ_benefits/6drill.pdf.

²⁴ Id.

pumping pressure is released.²⁵ Hydraulic fracturing allows the oil or natural gas to move more freely from the rock pores to a production well so that it can be brought to the surface.

While the process from well to well may be very similar, the fluids and proppant will vary from company to company, and even well to well. The most important part of determining fluid and proppant to be used is the type of formation that will be fracked – i.e., a tighter higher pressure sand formation will need stronger proppant to maintain the cracks. Each company also has their own recipe they believe provides the best results. While the companies are required to maintain a list of the chemicals used in their water mixture, the particular blend is proprietary.

One of the challenges with hydraulic fracturing, especially in the Marcellus Shale and other shale gas plays, is the amount of water required to frac the well. Marcellus Shale wells are typically fracked for about 3,000 feet, though this is increasing. A Marcellus Shale well frac uses about 3,000,000 gallons of water, of which only a small portion returns to the surface.²⁶

The other challenge is that some feel that when the fluids are injected under pressure they have a chance of contaminating the drinking water supply. This has become a volatile issue in several states, including Pennsylvania, New York and West Virginia. There seems to be a trend of assuming that any environmental effects on the water supply are caused by fracking, when, in fact, there is no evidence to suggest a connection. A series of articles appeared in West Virginia's *The State Journal* addressing these assumptions because of the issue of Total Dissolved Solids, or TDS, found in the water supply of the Monongahela River in West Virginia.

²⁵ U.S. Environmental Protection Agency. http://www.epa.gov/ogwdw000/uic/wells_hydrofrac.html. Accessed October 2009.

²⁶ U.S. Department of Energy - Office of Fossil Energy - National Energy Technology Laboratory. *Modern Shale Gas Development in the United States - A Primer*. p. 64. April 2009. http://fossil.energy.gov/programs/oilgas/publications/naturalgas_general/Shale_Gas_Primer_2009.pdf.

One article discussed the lack of seasonal precipitation as a precursor to higher TDS levels²⁷, while yet another article discounted the assumption that oil and gas development, particularly of the Marcellus Shale, has any impact on TDS levels.²⁸ Over the past 50 years more than 1,000,000 wells have been drilled using this technique, and not one verifiable case of contamination has been reported.²⁹ In 2005 the U.S. Congress passed the Energy Security Act, which explicitly stated that hydraulic fracturing was to remain exempt from the Safe Drinking Water Act. Environmental groups are now trying to change that rule. If successful, it could increase drilling costs approximately \$100,000 per well and therefore, reduce the number of wells drilled.³⁰ In an effort to prevent looming regulation, one company, Schlumberger Ltd., the world's largest oilfield-services provider, is pressing suppliers for permission to disclose the chemicals used in a drilling process.³¹ They don't want to see the fracking process slowed by regulations after spurring an increase in U.S. natural gas production. Many operators are in agreement that disclosure is in their best interests. For a typical well drilled in the Marcellus Shale, "about 99.5% of the fluid used to fracture rocks is made up of sand and water," says Vello Kruuskraa, a board member for Houston-based gas producer Southwestern Energy Co. and president of energy consulting firm Advanced Resources International Inc., in Arlington, Virginia. "I think the industry and the forward thinkers realize that, 'let's just put it out there,

²⁷ The State Journal. *Dissolved Solids Could Rise Again With Low Fall Precipitation*. Pam Kasey. September 2009.

²⁸ The State Journal. *Oil, Gas Industry Isn't Adding to Total Dissolved Solids Problem*. Armando Benincasa. September 2009.

²⁹ Louisiana Oil and Gas Association. *Two Technologies That Have Changed the Way We Drill*. Gifford Briggs. <http://loga.la/loganews/?cat=32>. September 28, 2009.

³⁰ id.

³¹ Bloomberg. *Schlumberger Presses for Shale-Gas Openness as Regulation Looms*. David Wethe. September 2009.

we're better off,'" Kuuskraa said.³² Regulation could significantly slow production from shale formations, which drove a 5.9% gain in U.S. production in 2008.³³ Still today, articles arguing for production (leads to creation of jobs³⁴, expansion of domestic supply) and against production (environmental concerns³⁵) run rampant.

V. Production Update - Pennsylvania

Three counties in Northeast and Northcentral Pennsylvania accounted for more than a third of the natural gas produced from the Marcellus Shale in the state during the second half of 2010, according to new production data posted online by the Department of Environmental Protection this week. Bradford, Tioga and Susquehanna counties produced more than 100 billion cubic feet of that gas, and all of the 10 best-performing Marcellus wells during the six-month period were in Susquehanna County.

Although the current reporting period from July through December 2010 is only half as long as the previous 12-month reporting period released by the state, Pennsylvania's Marcellus Shale wells produced twice as much gas: 256 billion cubic feet, or enough to heat more than 2.5 million homes for a year. At least 1,147 Marcellus wells were producing gas during the six-month period.³⁶

³² Id.

³³ Id.

³⁴ Marcellus Shale Coalition, Issue Alert: *By The Numbers: The Mighty Marcellus, A Powerful Job Creation Engine*; April 1, 2011.

³⁵ Wall Street Journal. *The Road to a Clean Energy Future?* Mark Brownstein, chief counsel of the Environmental Defense Fund's Energy Program. April 2, 2011.

³⁶ thetimes-tribune.com. *New production data shows shale's promise and growth*. Laura Legere. February 19, 2011.

VI. Conclusion

Only through the combination of both horizontal drilling and hydraulic fracturing is the Marcellus Shale now being produced. We have always known about the potential, but we couldn't extract the gas in a cost-effective manner. The potential that the U.S. has with its vast shale resources is endless. In order to really understand how important these innovations are, consider this: in the 1980's it was assumed that the U.S. had about 9 years worth of natural gas supply remaining – years of growth and expansion later, it is estimated that we have 109 years of natural gas supply remaining, and that number grows with each shale discovery.³⁷ Keith Kohl, Editor of *Energy & Capital*, writes, “When it comes to our natural gas, it's all about electrical power generation and industrial demand. Those two areas make up nearly 60% of our total consumption. And we're fully expecting that demand to grow, too. The EIA has made that part clear. Industrial demand is expected to increase to 9.4 trillion cubic feet in 2020. That's a 42% jump compared to the 6.6 trillion cubic feet the sector used in 2010.”³⁸

³⁷ Id.

³⁸ Energy & Capital. *Ending the Hydraulic Fracturing War: The Last War We'll Fight on American Soil*. Keith Kohl. March 18, 2011.