

The Significance of Shale Gas Development

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Abstract

Natural gas production from shale formations is growing exponentially in the United States. This paper introduces the five major shale formations in the United States and the technologies used to produce them. The Barnett, Haynesville, Fayetteville, Woodford, and Marcellus combined hold an estimated 978 trillion cubic feet of total gas reserves. These findings along with recent technological advances in horizontal drilling and completion methods have transformed the natural gas exploration and production industry in the U.S. and have fundamentally changed the U.S. energy picture. Specifically this paper states that the United States through the utilization of natural gas from shale can reduce its carbon emissions and can become more energy self sufficient. Finally, the Harding & Shelton Group states in this paper that the opportunity to locate and produce shale gas in China is very similar to that which has taken place in the United States.

Introduction

The best chance we have in this world, perhaps the only chance, of simultaneously addressing the challenges of energy supply and demand and climate change is to accelerate the development and utilization of new technologies for energy production and to deploy these technologies on a large scale. Harding & Shelton Group (HSG) believes the United States will significantly reduce its dependence on coal and oil by using cleaner natural gas produced from shale. The net result will be that the United States will achieve a higher level of energy self sufficiency and significantly reduce green house gases that are being produced by our oil and coal based energy sources. With the exploration and production of shale gas in the United States we have a unique opportunity to revolutionize energy consumption.

Future growth of shale gas will be predicated by the ability of the U.S. market to deal with the current oversupply of natural gas. It is the Harding & Shelton Group's opinion that the current oversupply and future abundance of natural gas will be greatly utilized in electricity generation. Thus, the United States will become less dependent on coal for electricity generation. By using natural gas to create electricity, the United States can solve its problem of oversupply and limit future CO₂ emissions. Currently, 50% of electricity in the U.S. is generated from coal and only 22% from natural gas. Current U.S. natural gas production is approximately 60 Bcf a day.

Both Chinese and U.S. geological experts predict that China has similar quantities of shale gas reserves as found in the United States. Given the astonishing results of recent shale gas development in the U.S., and the distinctive opportunities awaiting China, we believe shale gas can be developed in abundance and that China can have a thriving natural gas industry. This paper will briefly discuss the Barnett Shale and four other shale plays

in the United States, new technologies being employed, and the significance of future shale gas production in China.

United States Shale Gas Development

Shale gas development is a growing source of natural gas production in the United States. Unlike conventional gas plays, shale gas plays are expansive, lower risk, yield predictable yet marginal results and extend across the continental U.S. The Barnett Shale of the Fort Worth Basin is the most successful play to date both in natural gas production and in its innovation of newer techniques of horizontal drilling and completion practices. These practices have become a model for the development of other shale plays.

The distribution of shale formations in the continental United States with estimated reserves is shown in (Figure 1). The Barnett Shale has set the standard for shale gas development. Since 2004 production has grown from 1 Bcf a day to over 4 Bcf a day (see Figure 2). The Fayetteville, Haynesville, Woodford, and Marcellus are expected to show similar or possibly greater production and reserve growth as exhibited in the Barnett.

Gas production from shale has grown from less than 70 Bcf per year in the late 1970s to over 7.5 Bcf a day in 2008. The majority of growth has been achieved through the exploration and development of the five shale plays shown in table 1, of which an estimated 5 Bcf a day comes from the Barnett Shale.

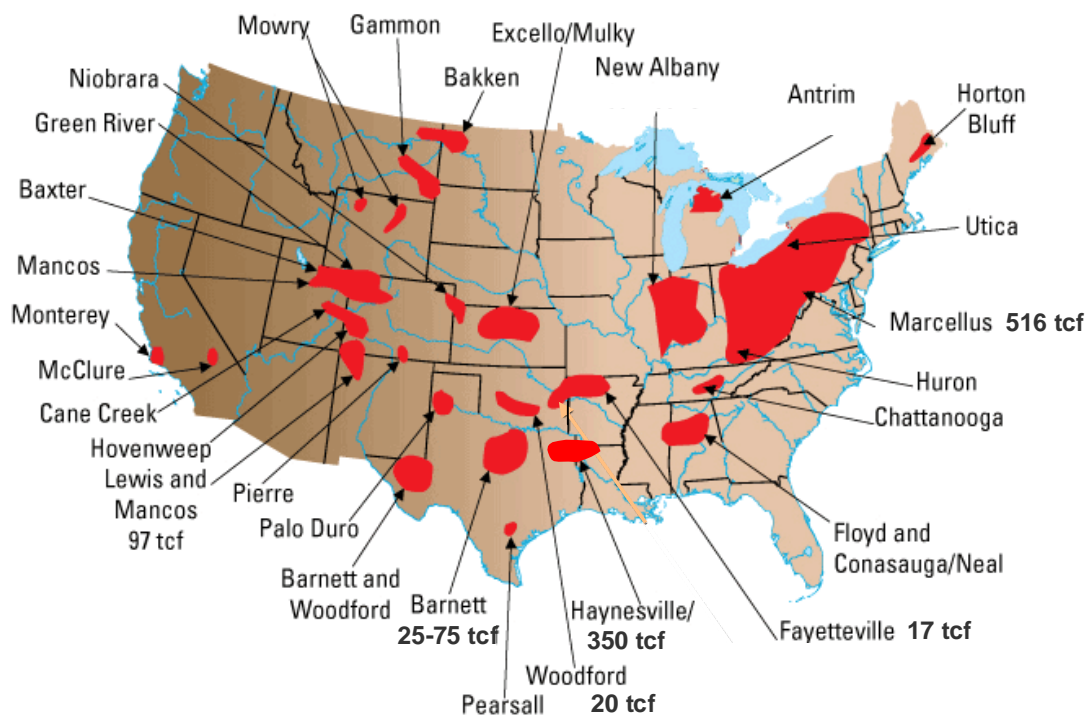


Figure 1: Gas Shale Basins of the United States

Five Major Shale Gas Plays in United States

Barnett

The recent success of the Barnett Shale has caused many operators to use this play as an analog for exploration and development. The history of the play reveals the impact of technology and how the oil and gas industry overcame challenges to unlock the resource potential and improve recovery factors. Figure 2 shows the development history for the Barnett play using annual gas production and producing well count. The play was quietly developed by one operator in the early 1980s through the mid-1990s using vertical well technology. Major horizontal development began in 2004. As of 2008, over 10,000 wells have been drilled, and two thirds of them are horizontal wells.

The Mississippian Barnett Shale in the Fort Worth Basin is the most active natural gas play in the United States (Figure 1). Activity levels in the Barnett Shale have increased dramatically since 2000, from 190 completions to over 1,750 completions in 2008. Production per year has also increased significantly over this same time period, growing from 80 Bcf in 2000 to over 1,500 Bcf in 2008.

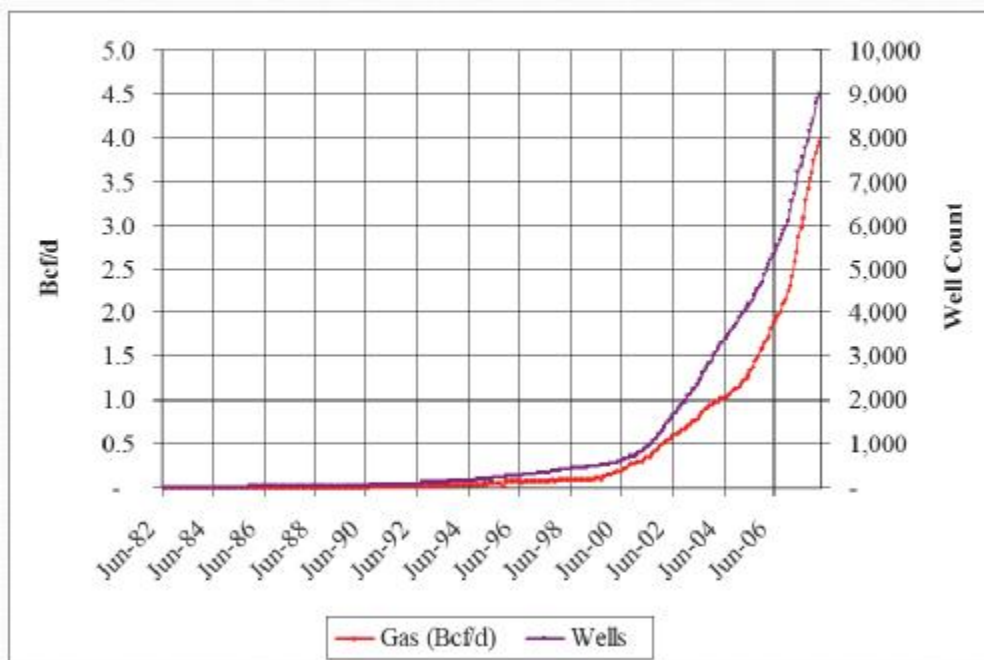


Figure 2: Barnett Shale Production (based on data from PI Dwigths as of August 2008)

Total organic content (TOC) is approximately 4.5% with the total porosity between 4-5%. The Barnett Shale extends across most of the Fort Worth Basin and is located at depths ranging from 6,500 feet to 8,500 feet. The Barnett has a shale thickness from 100 to 600 feet. Estimated reserves per well in the Barnett are 2.2 Bcf. The initial estimated daily production per well is 2.7 Mmcft. Estimated reserves are 75 trillion cubic feet of gas (see Table 1).

The Barnett play will continue to evolve and expand through drilling and application of new technologies to overcome challenges in new and existing

areas of the basin. In doing so, operators are gaining a greater understanding of better approaches and techniques as well as accelerating the learning curve and increasing the chance of better success in new plays.

Haynesville

Development in the Haynesville gas play began in late 2007. Current natural gas production exceeds 500 million cubic feet a day from approximately 100 wells. The Haynesville is an Upper Jurassic formation overlain by the Cotton Valley Group, and lies over the Smackover Formation. The Haynesville shale is located in northwest Louisiana and East Texas, particularly in Caddo, Bossier and DeSoto Parishes, but also to a lesser extent in Red River and Sabine Parishes, and Harrison and Panola Counties (see Figure 1). Deeper than most shale gas plays, the Haynesville is located at depths ranging between 10,500 and 13,500 ft. Shale thickness is estimated at 200-300 feet or more in the better areas. The TOC in the Haynesville play is between 0.5-4.0 % with a total porosity around 8-9%. Estimated reserves per well in the Haynesville are 4.5 Bcf. The initial estimated daily production per well is 6 Mmcf. Estimated reserves are 350 trillion cubic feet of gas (Table 1). The Haynesville is currently believed to be potentially the most prolific producing shale play in the United States.

Woodford

The Devonian Woodford Shale of the Arkoma Basin is also one of the newer plays to emerge with significant drilling activity and production. The focus of the emerging play is in southeastern Oklahoma in Hughes, Pittsburg and Coal Counties (Figure 1). Intensive horizontal development of the Woodford play began in 2004. At the end of 2008 gross daily production had grown to an estimated 900 mcf a day. Gross thickness of the Woodford Shale ranges from 120 to 220 feet. Depth to the Woodford in the active area ranges from 6,000 to 11,000 feet. The total organic content in the Woodford play is between 1.0-14.0 % with a total porosity around 3-9%. Natural fractures and high silica content contribute to the success of the Woodford shale play. Estimated reserves per well in the Woodford are 3 Bcf. The initial estimated daily production per well is 3.5 Mmcf. Estimated reserves are 20 trillion cubic feet of gas (Table 1).

Fayetteville

The Mississippian Fayetteville Shale of the eastern Arkoma Basin is another new play to emerge and already has significant drilling activity and production. The play is being developed in the Arkansas portion of the Arkoma basin (Figure 1). Drilling first began in 2003 and current production is around 1.1 Bcf a day. The play is developing in a depth range of slightly less than 3,000 feet deep to over 7,000 feet. Gross thickness of the productive section ranges from 20 to 200 feet. The total organic content in the Fayetteville play is between 4.0-9.8 % with a total porosity around 2-8%. Estimated reserves per well in the Fayetteville are 2.5 Bcf. The initial estimated daily production per well is 2.5 Mmcf. Estimated reserves are 17 trillion cubic feet of gas (Table 1).

Marcellus

The Marcellus Shale is part of a large suite of rocks known as the Devonian shales, and stretches NE-SW about 600 mi across several Appalachian states, including New York, Pennsylvania and West Virginia. The naturally fractured, dry gas-producing Marcellus covers an area of about 95,000 square mi, and ranges in thickness from 50 to 200 ft. Like the Fayetteville, the Marcellus thins from east to west, with 200-ft sections in northeastern Pennsylvania and 50-ft sections in northern West Virginia, Ohio, Pennsylvania and western New York. The formation depth ranges from 4,000 to 8,500 ft. The TOC in the Marcellus play is between 3.0-12.0 % with a total porosity around 10%. Estimated reserves per well in the Marcellus are 2 Bcf. The initial estimated daily production per well is 2.5 Mmcf. Estimated reserves are 516 trillion cubic feet of gas (Table 1). The estimated reserves are higher in the Marcellus than any other play due in part to its large geographical area.

Table 1 presents a comparison of the characteristics of the five shale gas plays in the U.S including: estimated reserves play size, production volumes, and depth to production zone.

Gas Shale Basin	Barnett	Marcellus	Fayetteville	Haynesville	Woodford
Estimated Basin Area, square miles	5,000	95,000	9,000	9,000	11,000
Depth, feet (ft)	6,500-8,500	4,000-8,500	3,000-7,000	10,500-13,500	6,000-11,000
Net Thickness, feet (ft)	100-600	50-200	20-200	200-300	120-220
Total Organic Carbon %	4.5	3.0-12.0	4.0-9.8	0.5-4.0	1.0-14.0
Total Porosity %	4-5	10	2-8	8-9	3-9
Gas-In-Place, Tcf	250	2,500	52	1050	66
Reserves, Tcf	75	516	17	350	20
Estimated Initial Gas Production, mcf/day/well	2,700	2,500	2,500	6,000	3,500
Estimated Average Reserves per well, Bcf	2.2	2.0	2.5	4.5	3.0

Table 1: Characteristics of five shale gas plays in the U.S (Adapted from Authur et al, 2008).

Implications

Natural gas production from shale formations is growing exponentially in the United States, increasing from less than a billion cubic feet a day in 1998, to

over 7.5 billion cubic feet a day in 2008. In addition to the shale basins we discussed there are approximately 17 other shale basins located onshore in more than 20 states in the U.S. including Texas, Oklahoma, Arkansas, Louisiana, West Virginia, Wyoming, Colorado, New Mexico, West Virginia, Pennsylvania, New York and Michigan (see Figure 1).

Recent technological advances in horizontal drilling and completion technologies have transformed the natural gas industry, particularly as it pertains to shale. Operators are working on efficiencies and improved well economics such as drilling longer lateral sections, more horizontal lateral sections per well, and increasing the number of frac stages per lateral. These findings indicate significant potential for the expanded use of domestically produced natural gas especially for electric power generation.

We believe the development of shale gas resources in the United States has fundamentally changed its energy picture. Furthermore, natural gas has provided the U.S with an opportunity to significantly reduce its dependence on foreign sources of energy. Moreover the U.S through the utilization of natural gas can further reduce its carbon emissions.

Future shale gas exploration and development activity is more possible now than ever before. Not to mention, emerging shale-gas plays around the world will be developed with a shorter learning curve than the previous development cycles of plays in the United States like the Barnett shale.

In order to show the potential benefit of an active shale gas play in China, we created a hypothetical model using accepted reserve and production parameters from the Haynesville shale play in the U.S. For this model we have assumed the following parameters: 1) initial production per well 6 Mmcf per day, 2) maximum rig utilization of 700 rigs, 3) number of wells completed per rig per year equals 8, 4) initial production decline rate in the first year 65%, 5) ultimate reserves per well equals 4.5 Bcf, and 6) production life for each well equals 15 years. In this model all drilling ceases after 15 years. The graph below (Figure 3) reveals this model's production forecast. In the tenth year the hypothetical model reaches a production level of 50 Bcf a day ultimately reaching 58 Bcf a day in the fifteenth year before decline in the seventeenth year. Figure 3 shows approximately 78,000 completions over 15 years. Total gas production over project life equals 350 Tcf.

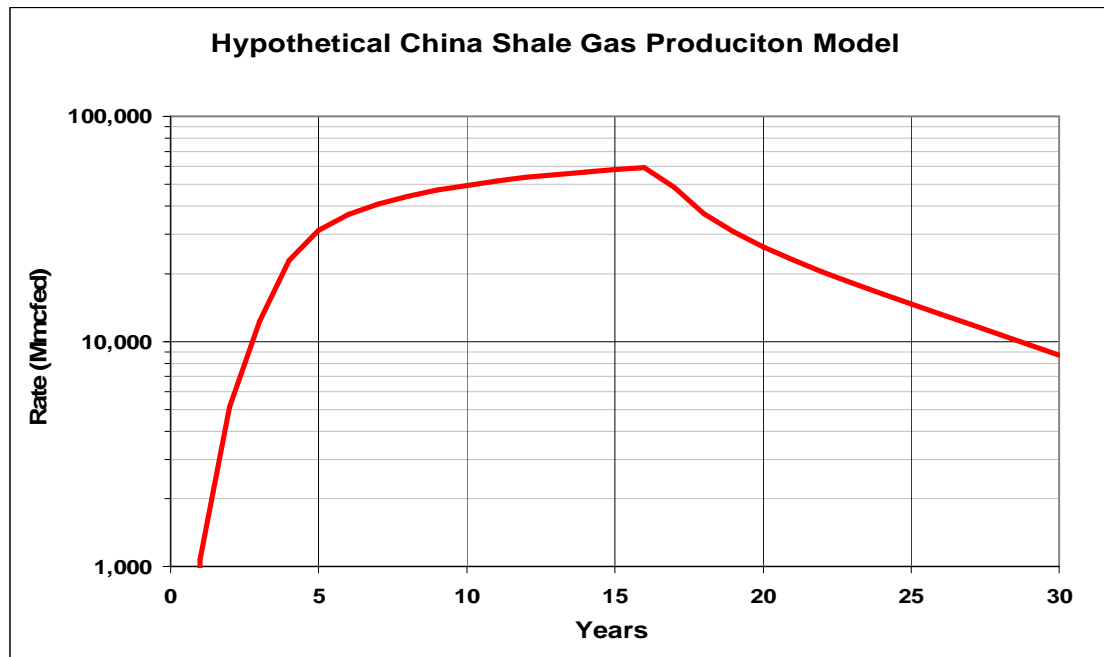


Figure 3: Production Forecast for a hypothetical Shale gas play in China

Conclusion

In conclusion, the Harding & Shelton Group believes the opportunity to produce shale gas in China is very similar to what has taken place in the United States. If so the impact shale gas could have on energy supply and demand and the reduction of CO₂ emissions in China could be immense. For example, consider that in 2008 China produced 2.7793 trillion kilowatt hours of electricity from coal fired plants (National Development and the Reform Commission, 2008). Calculations show that 1000 cubic feet of natural gas equals 1 mmbtu and 1 kWh of electricity equals 3413 Btu as well as controlling for the 55 % energy efficiency that combined cycle natural gas power plants provide. We can project that if China could produce 58 Bcf per day of natural gas, a feasible number considering China's shale gas potential, it could replace the energy output of all the existing coal fired power plants used to produce electricity. The significance of shale gas development has been realized in the United States, what happens in China is yet to be determined.

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About the Principal Author

Before Harding & Shelton Group, John Shelton held management, engineering, and geological positions related to exploration and production at Texas

International Petroleum, Continental Resources, and Harding & Shelton Inc. His areas of responsibility covered activities in Alaska, Canada, the Rocky Mountains, Oklahoma, Texas and the Louisiana Gulf Coast. Over the last 25 years, Mr. Shelton has served as President at Harding & Shelton Inc. Harding & Shelton, Inc has explored, drilled and produced wells all over Oklahoma, and has subsidiaries in workover rigs, pipelines, and real estate. John earned a BS in Petroleum Engineering in 1972 and an MS in Petroleum Engineering in 1973 both from the University of Oklahoma. He currently lives in Oklahoma City, Oklahoma.