Natural Gas from Shale: Texas Revolution Goes Global

By Robert W. Gilmer and Emily Kerr

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Natural gas extraction is experiencing what has been called a quiet revolution.

The industry historically viewed natural gas as trapped in reservoirs, where it collects over thousands of years after exiting source rock. Though hard to find, the reservoirs easily give up large amounts of their holdings when penetrated by drilling.

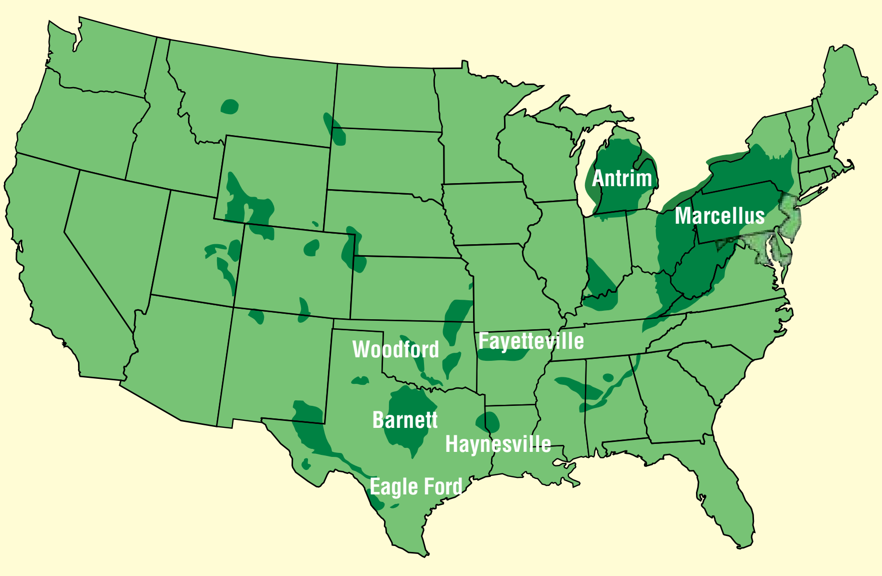
But what if natural gas could be extracted directly from source rock, such as common and easily found shale?

The industry's perspective changed when a few small, independent oil producers from Texas developed a method to economically extract natural gas from shale. Focusing on the source rock, they discovered how to force the more rapid release of natural gas. The feat, representing 10 years of work for George Mitchell and Mitchell Energy, was achieved in the Barnett Shale near Fort Worth.[1] By the late 1990s, their solution was in place, and subsequent technological advances and rising natural gas prices enabled natural gas produced from shale to become profitable.

The innovation involved hydraulic fracturing—injecting a mix of water, sand and chemicals into a well to stimulate production from shale formations. Horizontal drilling, a technique exposing more of the well bore to the source rock, further boosted output and was applied to the Barnett in 2002. Other independent producers took notice. From experimental output levels in 2000, the Barnett produced 380 billion cubic feet of natural gas in 2004 and 1.8 trillion cubic feet by 2009—almost a month's worth of average U.S. natural gas output.[2]

The quiet revolution in Texas has now stepped onto the national and global stage. The technology has moved to other U.S. shale basins (*see map*), notably the Haynesville in East Texas and Louisiana, the Fayetteville in Arkansas, and the Marcellus in New York,

U.S. Shale Plays Boost Natural Gas Supplies



SOURCE: Energy Information Administration.

Pennsylvania, Ohio and West Virginia. The Potential Gas Committee, official arbiter of the U.S. natural gas resource base, recently expanded its estimate of technically recoverable U.S. natural gas by more than one-third—virtually all of the increase due to new shale technology.[3] The newfound supply will likely lower the price outlook and price volatility of natural gas while improving its competitiveness with other energy options.

The technology also spurred investment from the largest producers, such as Exxon Mobil, BP and Shell, which purchased major stakes in the pioneering independents, partly to learn more. A long list of companies from abroad also arrived: Mitsui from Japan, Statoil from Norway, BG Group from Britain, Total from France and Reliance Industries from India. Statoil, for example, hopes to carry the technology to countries such as Hungary, Poland, Austria and China.

Texas Leads Production

Texas leads the nation in natural gas production, and its position is unlikely to be eclipsed any time soon. The state accounted for more than 70 percent of U.S. shale output in 2008.[4] Shale gas makes up 20 percent of the U.S. supply, up from 1 percent in 2000. Some believe it could exceed 50 percent by 2030.[5] States such as Pennsylvania and New York have become viable energy producers because of their shale resources and proximity to major northeastern markets.

The Barnett Shale in Texas is the nation's largest natural-gas-producing area—though the state has other important shale plays, such as Eagle Ford in South Texas and Haynesville, which are rapidly developing into major fields and bringing billions of dollars of household earnings and tens of thousands of new jobs through direct expenditures on drilling and related multipliers.

Unconventional Reserves Climb

Natural gas occurs over time and can become locked in structural traps or in the earth's strata, where sealed rock creates a reservoir for hydrocarbons (*Figure 1*). This conventional natural gas flows easily to the surface once drilling penetrates the pocket.

Unconventional resources, such as tight sands, coal-bed methane and gas shales, are more difficult to exploit. Natural gas in tight sands is trapped in sandstone and limestone, which have low permeability. Production often depends on using natural fissures in the rock. Coal-bed methane can be exploited specifically for this natural gas because coal is a weak, already highly fractured rock. Additional stimulation by hydraulic fracturing creates a rapid flow of gas from the coal that can be captured. Shale is a soft, impermeable rock that is easily

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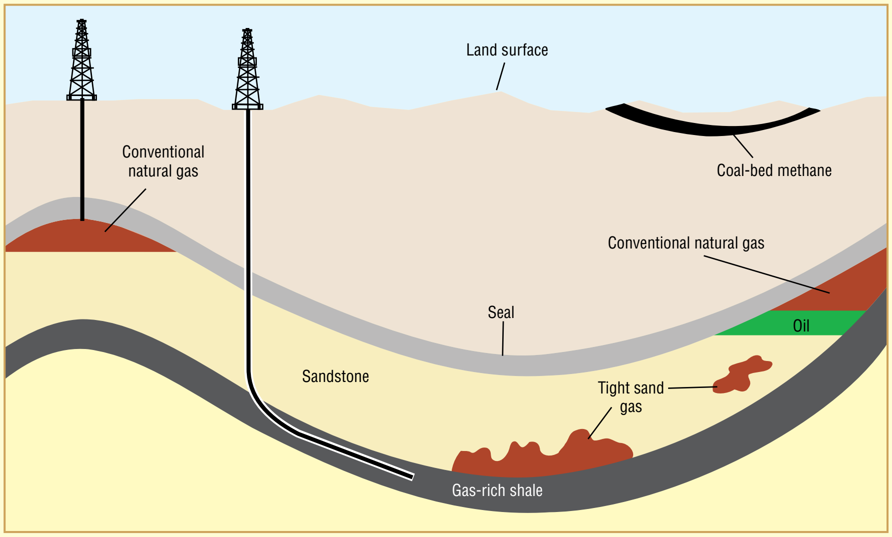
Figure 1
Natural Gas Now Extracted from Earth's Deeper Layers



SOURCE: Energy Information Administration.

U.S. shale gas reserves rose from almost zero in 2000 to 32.8 trillion cubic feet (Tcf) in 2008, and Texas contributed 21.6 Tcf, virtually all from the Barnett.

broken, but freeing the natural gas from it is more difficult. The use of hydraulic fracturing combined with horizontal drilling has reduced extraction costs, greatly enhancing natural gas recovery.

U.S. proven reserves—or the supply of natural gas that can be produced at current prices—increased 38 percent from 2000 to 2008, with more than half of that addition coming from unconventional resources. U.S. shale gas reserves rose from almost zero in 2000 to 32.8 trillion cubic feet (Tcf) in 2008, and Texas contributed 21.6 Tcf, virtually all from the Barnett. Outside the state, shale reserves were concentrated in Oklahoma (Woodford), Arkansas (Fayetteville) and Michigan (Antrim).

The 2008 reserve estimates illustrate how fast shale's prospects are changing. Two years ago, there were no significant reserves in south Texas, where the Eagle Ford Shale recently blossomed, and there were small reserves in the Haynesville Shale. Extraordinary leasing activity and initial drilling have occurred over the past two years in the Marcellus Shale in the Appalachian region, though 2008 estimates show no reserves in the area. Large additions to the calculation are likely as the numbers are updated.

Calculating Exploration Costs

Whether the cost of recovering natural gas from shale can be justified is a subject of debate. Shale drilling is very different from conventional exploration. It's costlier because of horizontal drilling and additional fracturing, but the high initial expense is offset by an absence of exploration risk. There is no hit-or-miss drilling for a reservoir; shale deposits are well-defined and easily located.

Delivering natural gas to the wellhead usually costs $4 to $8 per thousand cubic feet (Mcf). Engineers have tried to narrow this generally accepted range but have run into complications. One is evolving technology. Most shale production has been in the Barnett, and it is unclear how well tools developed there will travel elsewhere. Another is uncertainty about volumes and the timing of delivery. Shale wells yield very high volumes at first, but production rates fall rapidly during the first year and stabilize in the following years. This initial decline rate varies from 50 percent in the Barnett to 80 percent in the Fayetteville.

Nevertheless, the industry has recently seen large increases in drilling amid depressed natural gas prices. The recession curtailed demand for natural gas from all sources and cut its price. But by July 2009, producers resumed drilling, with new activity mostly involving shale. Last April, 283 additional rigs were searching for gas in the U.S., with 257 of them drilling horizontally, mostly in shale.[6]

What stimulated this shale activity? The average wellhead price of natural gas during this period was $3.98 per Mcf, compared with the $6.02 average that prevailed in the five-year period before the latest recession. A sharp increase in shale-directed drilling at a price below $4 does not necessarily indicate that natural gas can be produced from shale this inexpensively. The price was probably too low to reflect the full cost of production including leasing, drilling and transportation.

Much of this drilling was based on hedges that locked in the higher prices of the previous winter. Further, many producers in the Haynesville and Marcellus recently bought expensive leases that needed to be secured by drilling. This cycle's resiliency is illustrated by the fact that gas production never fell during the recession (*Chart 1*). Despite the sharp decline in overall drilling, producers brought on one high-volume shale well after another, responding to incentives perhaps not well-reflected in the market price.

Environmental Reviews Under Way

Several environmental issues complicate shale gas production, with possible drinking water contamination perhaps the most compelling. There is concern that the fluid used in hydraulic fracturing—typically a mixture of 99 percent water and sand and 1 percent chemicals—is toxic and could seep into underground aquifers or contaminate surface water.

Risks are mitigated by well construction requirements calling for steel piping to be cemented into place with multiple casings to ensure groundwater is protected during all phases of operations. Shale is found far underground (7,000 feet in the Barnett, 10,000 feet in the Haynesville and 4,000 feet in the Marcellus), providing thousands of feet of impermeable rock between freshwater aquifers and the fracturing process. Most drilling fluid is recovered before production begins and, depending on its composition, disposed of via surface discharge, commercial facilities or disposal wells.

States such as Texas, Louisiana and Oklahoma have long been home to oil and natural gas exploration, and hydraulic fracturing has been used since the 1940s. According to the American Petroleum Institute, fracturing has been safely employed in the U.S. more than a million times. However, as the technology spreads beyond the oil patch, states including Pennsylvania and New York have questioned the environmental impact of drilling and natural gas production—in particular, hydraulic fracturing in shale.

The massive oil spill from deepwater drilling in the Gulf of Mexico this year demonstrated how a proven and trusted technology can fail, especially if oversight is insufficiently vigilant. In the case of shale, regulation of drilling and fracturing rests with the states, which have stepped in to review existing rules due to concerns about the large amounts of water required for fracturing, potential groundwater pollution and the disposal of recovered liquids. A typical horizontal well might use 3 million gallons of water, and heavy drilling activity can stress some regions' supplies.

Given the likelihood of widely expanded fracturing as shale development proceeds, the federal government has entered the picture, with the Environmental Protection Agency recently announcing a two-year study of hydraulic fracturing.

Additional vigilance and protection of groundwater could change the economics of producing natural gas from shale. More stringent development rules, if imposed, would increase costs and might halt production.

The industry has taken note, and concerns are sufficiently elevated that some recent mergers and acquisitions have been contingent on regulatory acceptance of hydraulic fracturing.

Shale Gas Outlook

The Texas experiment in the Barnett Shale proved the technical feasibility of shale gas development and brought costs within bounds that promise to give shale gas an important role in global energy supplies for decades to come.

Shale gas cost estimates vary widely, partly because of limited experience in a few basins and partly because the technology is evolving. Prices of competing energy sources at levels seen today will likely stimulate continued rapid development of natural gas from shale. However, additional regulations to protect or conserve groundwater could halt or slow development in some states or regions and reduce the projected contribution of shale gas to national energy supplies.

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Notes

[1] "The Father of the Barnett Natural Gas Field: George Mitchell," by Marc Airhart, Geology.com, www.Geology.com/research/Barnett-shale-father.shtml.

[2] Texas Railroad Commission, http://www.rrc.state.tx.us/data/fielddata/barnettshale.pdf

[3] "Potential Supply of Natural Gas in the United States," Potential Gas Committee, Dec. 31, 2008. No time frame or market price is associated with these resource estimates; only technical feasibility of production is inferred.

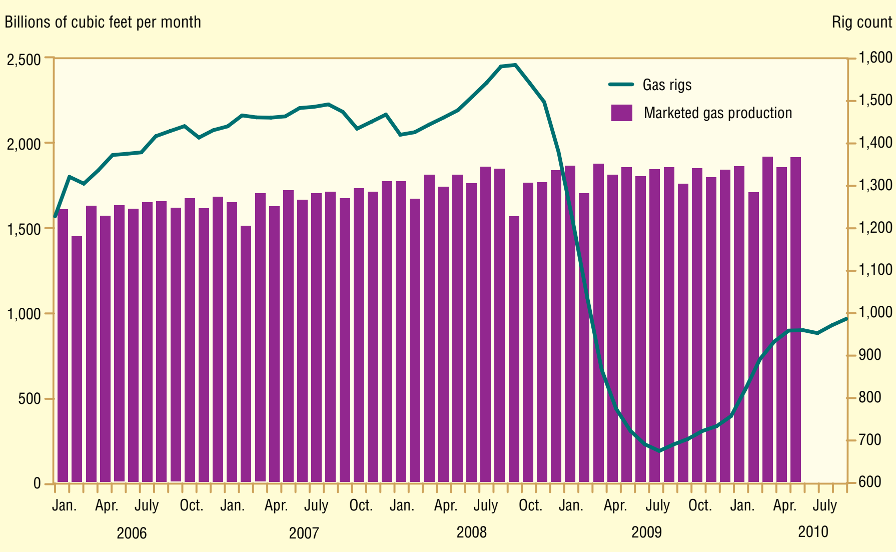
[4] Energy Information Administration, Office of Oil and Gas, www.eia.gov/dnav/ng/ng_enr_shalegas_s1_a.htm

[5] "Fueling North America's Energy Future: Executive Summary," IHS Cambridge Energy Research Associates, February 2010.

[6] The split between oil- and gas-directed horizontal drilling activity is available periodically on the Baker Hughes website. The latest full month available is April 2010. (See "Total number of horizontal rigs, split by oil and gas," http://blogs.bakerhughes.com/rigcount/2010/06/11/total-number-of-horizontal-rigs-split-by-oil-vs-gas.) New gas-directed drilling after July 2009 was concentrated in the Haynesville and Marcellus basins.

Chart 1

Shale Activity Lifts Gas Production During Downturn



SOURCES: Energy Information Administration; Baker Hughes.