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THE GREAT, GLOBAL SHALE-GAS DEVELOPMENT RACE

WHERE TO FOCUS COMMERCIAL RESOURCES

By Iván Martén and Eric Oudenot

In the late 1990s, rapid advances in horizontal drilling and hydraulic-fracturing technologies unleashed large-scale commercial production of shale gas in the U.S.[1] By 2005, with the development of the Barnett Basin in Texas and the production bonanza that followed, the shale gas revolution was in full swing. Today, shale gas accounts for nearly 35 percent of total U.S. natural-gas production, compared with only 2 percent ten years ago, and it is on course to reach 45 percent in six to eight years. As a result—and depending on whether the government approves natural-gas exports—the U.S. could go from being one of the world's largest gas importers to one of its largest exporters. Two licenses have been granted so far for liquid-natural-gas export terminals (Sabine Pass, Louisiana, and Freeport, Texas), with at least 15 other applications in the queue.

At the same time, the race has begun to explore and develop shale gas resources elsewhere in the world. The prize—abundant, low-cost natural gas—is likely to be an order of magnitude greater than the resources available in North America. This second revolution in shale gas development will have a significant impact on the global gas industry and ripple effects in many related sectors.

It is also clear that while the technology is mature, there are important challenges—and uncertainties—regarding the geology, economics, regulation, and social acceptability of shale gas development. In order for operators and investors to know whether, where, and when to focus resources, they must systematically assess each region and the specific challenges it poses to resource development.

Key Challenges Affecting Development

Shale gas and shale oil are hydrocarbon molecules trapped in layers of rock (shale), each of which possesses unique attributes; for example, not all shale layers contain exploitable hydrocarbons. Shale gas is referred to as an "unconventional resource" because its geological parameters are different from those of conventional oil and gas reservoirs, with important implications for development.

Conventional and unconventional resources differ from one another in four main ways. (See Exhibit 1.)

- *Source Rocks.* In the development of conventional resources, the hydrocarbons migrate from a source rock to a reservoir rock, where they are trapped. With shale gas, there is no migration: the hydrocarbons remain in the source rock, which is drilled. In many countries, little information has been collected on source rocks, and a limited number of wells have been drilled in these layers.
- *Low Permeability.* Shale gas formations are characterized by very low permeability (the ability of fluids to pass through rock). The permeability of shale layers can be 1,000 to 10,000 times less than that of conventional hydrocarbon reservoirs. Consequently, until recently, extracting unconventional resources was generally a significant challenge.
- *Hydraulic Fracturing.* To be developed, shale gas layers require hydraulic fracturing. Fracking is a reservoir stimulation technique that pumps a mixture of water, chemicals, and sand into a well at high pressure to fracture the shale and release trapped gas and oil. The fractures extend several hundred feet into the shale layers and are kept open by sand fill, thus increasing the permeability of the formation and the production rate of the well. This technique, which continues to evolve, defines the resource. While less than 20 percent of the world's conventional oil and gas wells are fracked, close to 100 percent of shale gas and oil wells will be fracked.
- *Production Profiles.* Shale gas wells have unusual production profiles that force operators to rethink their traditional processes and develop new operating models. Unlike conventional

Exhibit 1 | Differences Between Conventional Gas and Shale Gas

		Conventional gas	Shale gas
Geological factors	Hydrocarbon migration and trapping mechanism	Required: migration from source rock to reservoir rock where the hydrocarbons are trapped	Not required: the hydrocarbons remain in the source rock and do not require a trapping mechanism
	Target zone for drilling	Reservoir rock	Source rock
	Porosity (volume within rock that can contain fluids), %	North Sea fields: 20% to 25%	Low porosity: 4% to 15%
	Permeability (ability of fluids to pass through rock)	Expressed in millidarcy (10^{-3})	Ultralow permeability: expressed in nanodarcy (10^{-9})
Operational and commercial factors	Requires stimulation (hydraulic fracking) to be commercial	Only in some cases: <20% of conventional wells are fracked	Always: ~100% of shale gas wells have to be fracked
	Typical well production profile	Stabilizes at a plateau for a few years and steadily declines thereafter	Peak production in the first 3 months, followed by a sharp decline
	Number of new wells required to maintain production level	Typical well lifetime is several decades, with typical reserves of 50 to 300 Bcf/well[1]	Typical well lifetime is several years, with typical cumulative production of 0.5 Bcf/well[2]
	Ability to plan field development ahead of time	Yes	No: necessary to learn and adjust as drilling proceeds

Sources: Royal Dutch Shell; U.S. Energy Information Administration.
Note: The dashed line denotes the main differences between conventional and shale gas.
[1]In 2011, total reserves (already produced and yet to be produced) associated with the 300 wells at the Groningen gas field in the Netherlands were 100 Tcf.
[2]From 1997 through 2010, 15,000 shale gas wells were drilled in the Barnett Basin, resulting in a cumulative production volume of 7,200 Bcf.

wells, where production peaks after three to six months and then stabilizes at a plateau rate that can be maintained for up to 10 or 15 years, production of shale gas peaks during the first week, followed by a rapid decline. Thus, maintaining a high production level for a shale gas field involves continuous drilling (known as "factory drilling").

The need for operating models geared to efficient large-scale drilling explains why it was smaller, independent oil-and-gas companies that spearheaded early shale-gas development in North America, and why these companies continue to operate more efficiently than the major oil-and-gas companies, which tend to be handicapped by slower decision making and more rigid organizations—resulting in higher operating costs. Eight years after the start of the shale gas revolution, the vast majority of the companies operating profitable dry-gas plays (development opportunities in which hydrocarbons mainly take the form of gas rather than liquid) are still independents.

But the majors are now adapting the business models of their independent counterparts, whose advantage in developing unconventional plays is likely to diminish. Since 2006, the majors and the national oil companies have spent more than $120 billion on acquisitions of independent shale-gas producers.

A key challenge for operators and investors is determining where to explore for shale gas basins and what "good" shale is. There are six key exploration parameters:

- Formation depth
- Total organic content
- Net thickness of the shale layer
- Thermal maturity
- Formation overpressure
- Silica and clay contents

Once exploration has started, there are seven core parameters for assessing the commercial potential of a shale gas basin:

- Well costs
- Initial production
- Liquid and natural-gas-liquid content
- Estimated ultimate recovery
- Environmental requirements
- Local commodity prices and taxation regime
- Access to infrastructure

The Global Race Has Begun

Until recently, shale gas development was almost entirely a North American phenomenon. According to the latest U.S. Energy Information Administration (EIA) shale-gas study, the U.S. and Canada hold 16 percent of the technically recoverable shale-gas reserves.[2] However, BCG research shows that at the end of 2012, about 110,000 shale-gas wells had been drilled in the U.S. and Canada, compared with fewer than 200 wells in the rest of the world. At that point, North American shale production (oil and gas) stood at about 6.2 million barrels of oil equivalent per day, accounting for 99.9 percent of global shale production.

Although it is clear that large shale resources exist in locations outside of North America, the question is the amount that is recoverable. EIA's 2013 study, which is the new reference in the industry, estimates the technically recoverable shale-gas resources around the globe at about 7,299 trillion cubic feet (Tcf), of which approximately 1,150 Tcf are in North America. The extent of uncertainty is becoming clear as national institutes of geology release their estimates. For example, while the EIA study estimates Poland's technically recoverable shale-gas resources at 148 Tcf, in 2012, the Polish Geological Institute estimated the country's resources at only 12 to 27 Tcf.

In BCG's view, it is too early in the exploration stage to provide a high-quality estimate of resources outside of North America. More wells need to be drilled, more data need to be analyzed, and more time is needed to understand the source rocks and build detailed reservoir models.

The EIA study proved that large shale resources exist outside of North America and, in particular, in countries that are currently importing gas or have very limited conventional gas reserves. We believe that a second shale-gas revolution will occur in the next four to six years that will have a significant impact on global prices of gas and liquid natural gas, on gas trade flows, and—in some regions—on the price of oil. It is therefore critical that industry players assess the potential impact of shale gas development on their existing operations and determine how best to seize the opportunity that it presents.

The Leaders in the Race for Shale Gas

According to BCG's research, six countries are clearly in the lead in the exploration for shale gas: Argentina, Poland, Ukraine, China, Australia, and South Africa. (See Exhibit 2.) These countries started their exploration efforts at about the same time, but each faces unique challenges that will affect the pace at which production occurs. This is exemplified by the experiences of the top-three leading countries:

- *Argentina.* As demonstrated by a growing number of positive well-test results in the Vaca Muerta formation, Argentina is the only country where the shale layers that have been tested are productive and respond well to hydraulic fracturing. But difficulties in accessing foreign capital and in setting up a sustainable gas-pricing mechanism to reward producers are slowing the pace of development.

- *Poland.* The main challenge here will be to prove that the source rock can be productive and efficiently stimulated through fracturing. However, the results of the first 50-plus wells that have been tested have not met expectations.

- *Ukraine.* Most of the conditions have been met for rapid development, including the existence of conventional gas fields (and therefore the availability of midstream pipelines). However, the political and business environment remains a deterrent for a number of independent oil companies and could slow development.

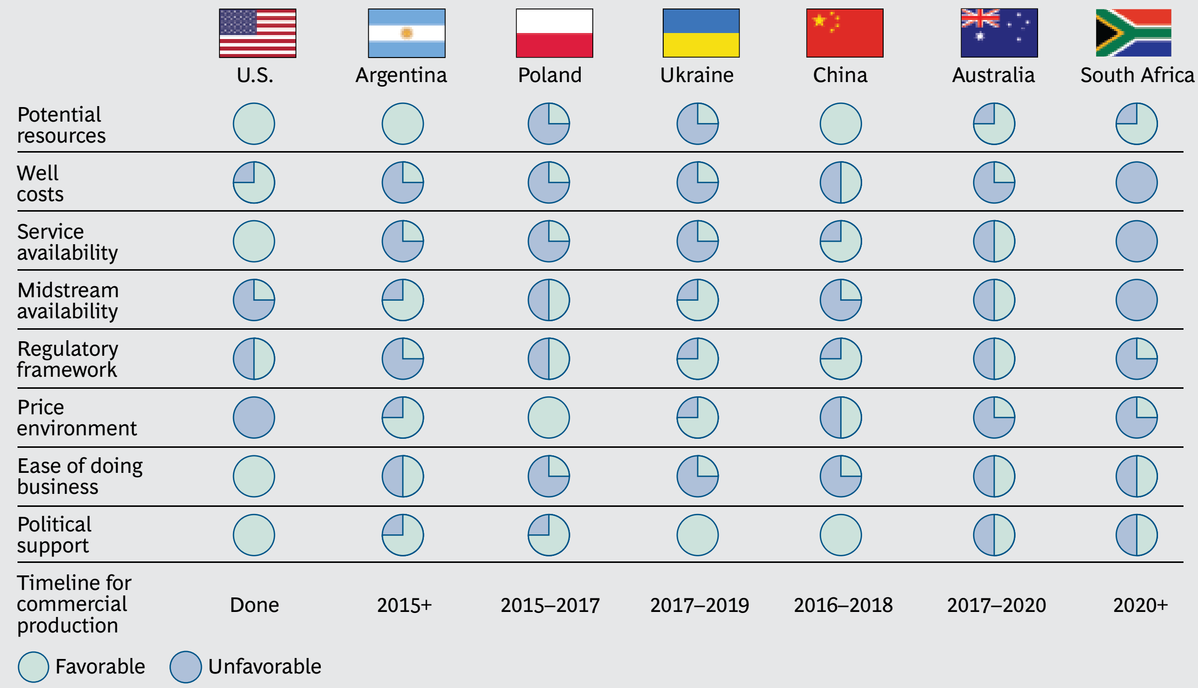
Some traditional oil- and gas-exporting countries, including Saudi Arabia, Russia, Brazil, Colombia, and Algeria, are starting to explore for shale and represent a second group of countries where development could take off. In addition to the uncertainty surrounding the commercial viability of these countries' shale-gas reserves, however, their existing conventional resources could weaken the incentive to develop unconventional resources such as shale.

The Ripple Effect: Other Sectors to Watch

Beyond its direct impact on oil and gas markets, shale gas development outside of North America will have a significant positive economic impact on a number of related sectors. And these businesses represent attractive investment opportunities. There are four core services that are critical to shale gas development. Without any one of them, there can be no production from a given well.

- *Onshore Contract-Drilling Market.* The rapid decline that characterizes shale gas production means that a tremendous number of wells must be drilled. Where a standard large, deep-water oil field would require 40 wells throughout its 20-year life, a shale gas field would require 10 to 15 times more wells to produce the same amount of hydrocarbons over a similar period. Drilling shale gas wells requires a specific type of rig, which has to be powerful (around 1,000 to 1,500

EXHIBIT 2 | Challenges and Potential Timelines for Production of Shale Gas



Sources: BCG analysis.

horsepower), mobile, able to drill on multiwell sites, and, ideally, able to use some of the shale gas produced as its own fuel.

- *Pressure-Pumping Market.* Currently this market is almost entirely dependent on the hydraulic fracturing of shale wells in North America. It grew from $10 billion in 2009 to $35 billion in 2012. The unavailability of fracking crews, including engineers and equipment (such as pumps and trucks), has been a key bottleneck in many basins.

- *Proppant Market.* Sand (silica or resin-coated) or ceramic materials are required for every hydraulic-fracturing job to "prop" the fractures open. Over the last ten years, the U.S. market has grown sixfold, reaching $4 billion in 2012. Today about 2,000 tons of proppant—an amount that would fill about 20 100-ton railcars—are required for each well. Reliable access to sand mines and the ability to deliver the material to well sites are thus essential to the fracking process.

- *Oil Country Tubular Goods Market.* Almost every shale-gas drilling site requires specific types of pipe and tube products (known as "oil country tubular goods," or OCTG) able to withstand the stress induced by long horizontal wells and hydraulic fracturing. Shale gas development will boost the global market for premium "seamless" OCTG, as it has in North America.

A second group of less essential sectors will also be important to the industry's expansion.

- *Fracturing Fluids.* The chemicals used in fracking will be governed by local regulations and will likely vary from region to region. Fracturing fluids account for less than 0.5 percent of the volume pumped during fracking, but their chemical properties are critical to the success of the process. Price swings for some of these nonreplicable elements (which cannot yet be synthesized chemically) can be significant. For example, the price of guar gum increased 600 percent in 2011.

- *Pipelines and Railcars.* The history of shale gas development in North America indicates that significant value can be captured by controlling existing mid-stream pipelines and railways. Railcars are needed to transport OCTG equipment and proppants to well sites, and pipelines are needed to transport crude oil and gas from well sites to refineries.

- *Real Estate and Water Management.* These two sectors could potentially offer high investment returns given their role in shale development, but their attractiveness will depend on local regulations. Water requirements in shale gas development are significant, now reaching approximately 220,000 barrels per well. As to real estate, first movers on promising U.S. acreage for shale gas development have managed to sell some of these properties for around $10,000 per acre, making a five- to tenfold profit on the initial purchase price.

- *Petrochemicals.* This sector could experience a significant expansion, depending on the composition of the shales discovered. In particular, the presence of natural-gas liquids, which are a critical feedstock for the petrochemical industry, will be a key indicator of the magnitude of the opportunity.[3] For example, in the U.S., plans for 14 ethane-cracker facilities have been announced over the past three years, while not a single such plant was built in the previous decade.

Shale gas is a complex resource to develop, and operators have far less experience with it than they do with conventional oil and gas. Not all shales are commercially viable, and in many regions, geological, commercial, and regulatory challenges will prevent the relatively rapid, large-scale development that is occurring in North America.

But vast shale-gas resources are known to exist outside of North America, and development over the next four to six years promises to have a dramatic impact on the global gas and related industries. These are still early days in what is likely to be a long race in a rapidly changing environment. To be successful in focusing their resources, operators and investors must continue to critically assess each region in terms of its changing geological, commercial, and regulatory challenges. Complementing this highly structured and granular view should be the ability to respond rapidly to opportunities as they arise.

Notes

1. Shale gas was first extracted in Fredonia, New York, in the mid-1820s. It was used to fuel streetlights.
2 . U.S. Energy Information Administration, *Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries,* June 2013.
3. “Natural-Gas Liquids: The Implications of the Next Energy Tsunami,” BCG article, October 2012.

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This article is the first in a series of articles from the Energy practice on shale gas development.

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