Shale gas and tight oil:
Framing the opportunities and risks

Discussions about broader access to unconventional natural gas and oil should account for a wide range of potential benefits and risks.

Tommy Inglesby, Rob Jenks, Scott Nyquist, Dickon Pinner

Much media and government attention has focused on disruptive innovation in the zero-emission renewables area of the power-generation landscape. But "old energy" has created some disruptive innovations of its own. With the scale-up of two technologies, horizontal drilling and hydraulic fracturing, producers in the United States have demonstrated the viability of extracting more than 50 years' worth of domestic natural-gas and oil resources—but in so doing, have raised important debates on the trade-offs between the potential economic and environmental implications of the new technologies. This article does not set out a view on where these debates should come out. That is the legitimate focus for policy makers in each country where shale-gas and tight-oil resources are located. Instead, it is intended to frame discussions on the potential benefits and risks associated with these new technologies.

In the United States, where shale-gas and tight-oil production have so far been adopted more than elsewhere, these new technologies have shown the potential for significant impact on the energy landscape, and indeed much change has already occurred. The share of natural gas in electric power generation has already increased significantly, for example, and there is great potential for increased use of

low-cost natural gas in transportation and industry. Such developments could enable increases in US economic output and employment—particularly if they facilitate reductions in consumer and corporate energy bills, increases in domestic energy production and reductions in oil imports, and reductions in air pollution and greenhouse-gas emissions (which could happen if natural gas displaces other fossil fuels).

However, the potential benefits need to be considered alongside potential risks. Natural gas is still a hydrocarbon that emits greenhouse gases, although in lower amounts than those of current coal technologies. In addition, methane leakage can worsen the carbon footprint of natural gas. The process of setting up and conducting hydraulic-fracturing operations required to free gas and oil from low-permeability rock creates environmental risks, including water contamination, local air pollution, and land degradation—some of which may be serious and some of which have yet to be fully understood.

Low-cost gas, held by some to represent a low-carbon bridge to a zero-emissions future, is resisted by others who believe it will slow near-term deployment of renewables, and—longer term—create "lock in" of natural-gas usage following large-scale deployment of the supporting natural-gas infrastructure.

Moreover, this is not just a US story. Much attention, and a great deal of money, is focused on the United States because shale-gas and tight-oil resources are more extensively characterized and commercially mature there, but many countries are watching the United States to see how it develops and oversees the use of horizontal drilling and hydraulic fracturing. Countries with significant "unconventional" resources include Abu Dhabi, Algeria, Argentina, Australia, Canada, China, Colombia, Germany, India, Indonesia, Mexico, Oman, Poland, Russia, Saudi Arabia, Ukraine, and the United Kingdom.

The complexity of the trade-offs involved with these disruptive technologies is reflected in the differing policy responses of governments around the world. Some have taken the position that based on our current knowledge, the risks of conducting hydraulic fracturing are too great, and they have banned the process pending further study. Others have proceeded with its development to a greater or lesser degree.

This article does not seek to set out "the right answer" or to suggest which policy decisions governments should take. Instead, it aims to frame discussion, analysis, and debate on the implications, uncertainties, and trade-offs of accessing shale-gas and tight-oil reserves. We describe the origin and evolution of these disruptive technologies and how they could change the ways that energy is used. We then describe the potential economic benefits that could be realized over the next 20 years and the potential environmental risks that must be understood and considered in decision making.

Emergence of new technologies

Producers have long known shale as "source rock"—rock from which oil and natural gas slowly migrated into traditional reservoirs over millions of years. Lacking the means economically to unlock the massive amounts of hydrocarbon locked in the source rock, producers devoted their attention to the conventional reservoirs. It was not until the mid-1990s that technological innovation allowed producers to access resources directly and economically from source rock.

Producers in the Barnett Basin in the Dallas area began to combine a number of reasonably mature drilling and completion technologies and test them on shale rock. Once the industry discovered how to combine two technologies—hydraulic fracturing and horizontal drilling—the extensive gas resources trapped in shale deposits became accessible. Today, the technology is being expanded to unlock both gas and oil resources in a range of low-permeability rock types in new and mature basins around the country.

In 2005, natural-gas prices were above $13 per million British thermal unit (MMBtu), and the United States was expected to be importing more than 20 percent of its gas and generating over 50 percent of its electricity from coal by 2020.[1] At various points in early 2012, gas prices fell below $2 per MMBtu. At the time of this writing, proposals are in place for the United States to export gas, and the share of coal in power generation has fallen from 50 percent in 2008 to less than 40 percent, while gas generation has increased from 20 percent to almost 30 percent.[2] Meanwhile, producers are working to unlock additional gas and oil resources, and service companies are developing new "super fracking" technologies that some industry experts believe could improve recovery rates by up to 70 percent.

Potential benefits

Shale gas and tight oil therefore represent disruptive technologies. They raise potential benefits and risks, all of which must be understood and considered in order for key stakeholders in the public and private sectors to make informed decisions.

Looking at potential benefits through a US lens, cheap gas could bring lower energy bills for consumers and businesses, increased competitiveness for US industry, greater domestic energy production, and increased employment and GDP. In addition, there could be reduced greenhouse-gas emissions in the power sector through the displacement of a considerable amount of coal-fired power generation, as well as increased energy security in the form of reduced oil imports for transportation. There are also likely to be significant opportunities beyond the United States.

Economic impact in the United States. At today's prices, greater adoption of natural gas would significantly reduce consumer and wholesale energy costs. In the residential segment, according to the US Energy Information Administration, lower-cost natural gas has cut annual energy costs for US households by an average of almost $800 per household, or 25 percent, since 2005.[3] Looking forward, consumers and commercial and industrial customers could gain further significant savings on their energy bills.

There could also be benefits to the US economy as a whole. Lower energy costs would make US industries more competitive and lead to higher output; reduced price volatility and the associated reduction in uncertainty could increase investment; and increased domestic energy production could lead to higher economic output and employment.

Greenhouse-gas emissions. CO_2 combustion emissions per unit of energy are lower for natural gas than for other fossil fuels, particularly coal. Efficient combined-cycle natural-gas power plants

produce less than half as much CO_2 per kilowatt hour as do typical coal-fired power plants, significantly less nitrogen oxides, and just 1 percent as much sulfur oxides.[4] Natural-gas-fueled vehicles could also produce fewer CO_2 emissions per mile than gasoline-fueled vehicles, and industrial facilities powered by natural-gas combustion could emit less carbon dioxide than plants powered by combustion of coal or petroleum products. (As discussed later in this article, assessments of the net impact of horizontal-drilling and hydraulic-fracturing technologies on greenhouse-gas emissions must also reflect an understanding of the ways in which the realization of shale-gas resources could increase emissions.)

Energy security. Natural gas has the potential to displace petroleum in the transport and industrial sectors. In addition, there has been a significant increase in US onshore tight-oil drilling. Producers are deploying horizontal drilling and hydraulic fracturing in various oil formations in the United States, with great early promise. For example, in the Bakken formation in North Dakota, oil production rose from fewer than 30,000 barrels per day (bbl/d) in 2008 to 469,000 bbl/d by the end of 2011.[5] By replacing some oil use with natural-gas use and satisfying some demand for oil by drilling for tight oil, the United States could significantly reduce its net liquid-fuel imports, bringing the country closer to energy independence.

Global opportunities. Significant opportunities exist to develop horizontal-drilling and hydraulic-fracturing technologies for use globally. The International Energy Agency estimates that global recoverable reserves of unconventional gas are nearly triple those in the combined United States and Canada, and that unconventional gas is present in virtually every country.[6]

Global investors around the world have invested more than $40 billion since 2008 in emerging unconventional gas and oil plays in the United States in order to gain the operational know-how required to develop shale plays in their own regions. However, it may be more challenging to develop unconventional resources in regions outside North America due to various factors, including geology, lack of pipeline infrastructure, regulatory and tax structure, and less developed upstream services industries.

As an example, the emergence of a shale-gas and tight-oil industry has been slow in Europe, where some governments have put moratoria on developing hydraulic fracturing until producers can guarantee greater levels of environmental safety.

In China, shale and tight-oil resources have the potential to unlock a gas resource base that is, by some estimates, 50 percent larger than that in North America.[7] Chinese companies have made substantial investments in North American operations. They are reviewing opportunities to take direct investments in the service sector as well. Were China and other countries to deploy horizontal-drilling and hydraulic-fracturing technologies at scale within their borders, they could change the economics of oil and gas globally, potentially affecting the competitiveness of different regions just as efforts in the United States are affecting global competitiveness today.

Potential risks

The potential benefits of shale-gas and tight-oil development, discussed above, should be considered in the context of the potential environmental risks these technologies could pose if they are scaled up. This will be particularly challenging given that the producer landscape is highly fragmented in the United States (where there are more than 2,000 onshore gas and oil producers), and drilling activity is highly dispersed (nearly 10,000 horizontal wells were drilled in the lower 48 states of the United States in 2011).[8]

The potential environmental risks include the effect on air quality and greenhouse-gas emissions and the impact on land and water. These challenges are complicated by the proximity of some shale-gas and tight-oil reserves to urban communities in states such as Texas, Pennsylvania, New York, and Ohio.

Air quality. Much of the equipment used in the drilling process for gas and oil wells is diesel-fired and emits NOx, SOx, and particulates that contribute to air pollution.

Greenhouse-gas emissions. Combustion of natural gas and oil results in emissions of carbon dioxide, the main greenhouse gas. Increased use of these fossil fuels will therefore increase greenhouse-gas emissions. Even though the combustion of natural gas emits lower amounts of CO_2 than other fossil fuels, increased production and distribution of natural gas can result in increased methane-gas emissions ("fugitive emissions"). Because methane is a much more potent greenhouse gas than CO_2 (more than 25 times stronger on a 100-year time scale),[9] even a small amount of fugitive emissions could negate the combustion benefit of natural gas. The life-cycle emissions of natural-gas production, distribution, and consumption, especially with increased shale-gas production, are a continued source of uncertainty that needs to be better understood.

Low-cost gas also has the potential to displace zero-carbon renewables, increase demand for energy overall, and catalyze the return to the United States of energy-intensive industries. Taking these effects into account, we estimate the net impact as ranging from a slight reduction to a slight increase in overall US greenhouse-gas emissions, depending on the level of fugitive methane emissions.

Land use. As drilling activity moves from fairly remote areas into more densely populated ones, the land-use impact of concentrated drilling operations—which can, in some areas, reach one well for every 40 acres—is more strongly felt. This is particularly so during the initial drilling process, when a typical shale-gas or tight-oil well may require over a month of continuous operation, with hundreds of truck trips to and from a site.

Water availability, contamination of aquifers, and treatment and disposal. Hydraulic fracturing at a single oil or gas well involves injecting up to five million gallons of water into low-permeability rock at high pressure. Today, 30 to 70 percent of that water remains within the natural fractures of the rock.[10] A great deal, however, returns to the surface with the gas, where it must be treated or otherwise disposed of.

At present, only a portion of such water is effectively recycled for reuse. As a result, water sourcing is a growing challenge for the industry. Some regions, such as the Marcellus Basin, offer ready access to surface water. However, water is less plentiful around the Barnett, Eagle Ford, and Haynesville Basins in North Texas, South Texas, East Texas, and Louisiana.

Another contentious issue is the potential contamination of local drinking-water aquifers. In December 2011, a preliminary US Environmental Protection Agency (EPA) report linked hydraulic fracturing to groundwater contamination.[11] However, it should be noted that the EPA has said that its findings need to be reviewed, and that the conclusions drawn were specific to the location.

Water treatment and disposal are also potentially serious issues. Currently, the majority of water is disposed of in deep wells or treatment facilities, although treatment for reuse is increasing now that seismologists have linked deep-well injection to earthquakes in some regions.[12] But treatment has not always been adequate: there are cases in which operators have not sufficiently treated or disposed of "flowback" water.

Given the many water-related challenges, we are already seeing a proliferation of new water technologies, such as the use of propane to replace water as the fracking fluid. This area is likely to be the focus of considerably more technological innovation in the future.

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Technological development presents what is possibly the biggest energy disruption in decades—with significant economic benefits and geopolitical consequences. But technological development also comes with potentially significant risks, which must be considered alongside these benefits. Decisions about how to realize shale-gas and tight-oil resources will need to be informed by an ever-increasing understanding of the implications and trade-offs involved. ○

[1] US Energy Information Administration, *Annual energy outlook*, 2005.
[2] US Energy Information Administration (www.eia.gov).
[3] US Energy Information Administration, *Annual energy review 2010*, October 2011 (www.eia.gov/totalenergy).
[4] US Energy Information Administration (www.eia.gov).
[5] North Dakota Industrial Commission, Department of Mineral Resources, Oil and Gas Division, February 19, 2012.
[6] International Energy Agency, *Golden rules for a golden age of gas: World energy outlook special report on unconventional gas*, May 29, 2012 (www.worldenergyoutlook.org).
[7] Energy Information Administration, "World shale gas resources: An initial assessment of 14 regions outside the US," April 5, 2011, and *Annual energy outlook: Early release overview*, 2012 (www.eia.gov).
[8] HPDI.
[9] Intergovernmental Panel on Climate Change, *Fourth assessment report*, Chapter 2, Table 2.14, 2007, p. 212 (www.ipcc.ch).
[10] US Department of Energy, Office of Fossil Energy and the National Energy Technology Laboratory, *Modern shale gas development in the United States: A primer*, April 2009.
[11] US Environmental Protection Agency, *Investigation of ground water contamination near Pavillion, Wyoming (draft report)*, December 2011 (www.epa.gov).
[12] The Oklahoma Geological Survey has suggested a link between shale-gas wastewater injection and a series of earthquakes of magnitude 3.7 to 5.6 in the Oklahoma area in November 2011. To date, earthquakes associated with shale operations have been tied to deep-injection wells, in which "flowback" water is repeatedly injected under pressure into deep caverns near old faults. Hydraulic fracturing itself at the well site has not been linked to earthquake activity.

Tommy Inglesby is a principal in McKinsey's Houston office, where **Scott Nyquist** is a director. **Rob Jenks** is a consultant in the Seattle office, and **Dickon Pinner** is a principal in the San Francisco office.