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Natural Gas Changes the Energy Map

Vast amounts of the clean-burning fossil fuel have been discovered in shale deposits, setting off a gas rush. But how it will affect our energy use is still uncertain.

By David Rotman

The first sign that there's something unusual about the flat black rocks strewn across the shore of Lake Erie comes when Gary Lash smashes two of them together. They break easily and fall into shards that give off the faint odor of hydrocarbons, similar to the smell of kerosene. But for Lash, a geologist and professor at nearby SUNY Fredonia, smashing the rocks is a simple trick designed to catch the attention of a visitor. The black outcroppings that protrude from the nearby bluff onto the narrow beach are what really interest him.

To Lash's expert eyes, the wide band of black shale, which runs roughly parallel to the beach, reveals hundreds of millions of years of geological history. The shale formed more than 350 million years ago when organic muck settled at the bottom of the shallow sea that covered much of what is now the eastern United States; it was once buried more than two kilometers underground but has gradually risen to the surface. Now, the exposed rock shows telltale patterns of breaks and splits. "We've demonstrated that these fractures could only have formed as a result of the generation of hydrocarbons," says Lash.

This formation is the edge of vast deposits of black shale that stretch under tens of millions of acres below western New York, much of western and northern Pennsylvania, and parts of Ohio, West Virginia, Maryland, and Kentucky. The oldest and deepest layer is called the Marcellus shale, and if geologists like Lash are correct, it holds enough natural gas to help change the way the United States uses energy for decades to come.

Experts now believe that the country has far more natural gas at its disposal than anyone thought three or four years ago. The revised estimates are largely due to advanced drilling techniques that make it economically feasible to extract the fuel from shale. And while the Marcellus is the most recently discovered and possibly the largest shale-gas deposit, others are scattered throughout the country. The U.S. consumes about 23 trillion cubic feet (TCF) of natural gas a year, according to the Department of Energy's Energy Information Agency (EIA). The Potential Gas Committee (PGC), an organization headquartered at the Colorado School of Mines, put the country's potential natural-gas resources at 1,836 TCF in a biennial assessment released in June. That's 39 percent higher than its estimate of two years earlier. Add to that the 238 TCF that the EIA has calculated in "proved reserves" (the gas that can be produced given existing economic conditions) and the PGC pegs the future supply at 2,074 TCF. In other words, there is enough natural gas to supply the country for 90 years at current consumption rates. Even if we used natural gas to totally replace coal in generating electricity, domestic supplies would last for 50 years.

Almost all the newfound resources are in shale deposits, which are now estimated to contain 616 TCF of recoverable gas, says John Curtis, a professor of geology and geological engineering at the Colorado School of Mines and director of the Potential Gas Agency, which provides technical assistance to the PGC. Supplies in the Appalachian basin alone are calculated at 227 TCF, with the Marcellus accounting for the bulk of that. And Curtis says he expects that even more shale gas will "be in the mix" in the committee's next assessment.

Indeed, some geologists believe that gas supplies in the Marcellus and other shale deposits might be even more abundant than the PGC estimates. In January 2008, Lash and Terry Engelder, a colleague at Pennsylvania State University, calculated the amount of recoverable gas in the Marcellus deposit at 50 TCF. But initial drilling efforts in the region have gone so well that Engelder now puts the recoverable supply of gas at 489 TCF. If that's correct, it makes the Marcellus the second-largest natural-gas field in the world; only a massive offshore reserve shared by Iran and Qatar is larger.

Natural gas offers advantages over other fossil fuels. It burns cleaner than coal, producing much less carbon dioxide. Since coal-fired power generation is responsible for a third of U.S. carbon dioxide emissions, replacing at least some of that coal with gas could significantly reduce such pollution. And using natural gas to replace gasoline and diesel fuel in vehicles could reduce the country's reliance on foreign oil.

But it's still uncertain how the large supply of natural gas will actually change U.S. energy consumption. Coal is generally cheaper than natural gas, so it remains the fuel of choice for most power producers. Meanwhile, car and truck makers have no economic reason to start producing natural-gas-fueled vehicles, and there's no infrastructure in place to refuel them in any case. In the absence of federal policy changes, the EIA predicts, demand for natural gas will stay relatively flat for the next several decades.

Liberal Washington-based lobbying groups, gas-industry interests, and environmental groups are pushing for policies to favor natural gas in the country's energy mix, citing its environmental and national-security benefits. If those groups can persuade legislators, incentives to increase use of the fuel could be a key part of the federal energy bill being debated in Congress this fall. Previously, policy makers presumed that natural gas was a "declining resource," says Reid Detchon, executive director of the Energy Future Coalition, a Washington-based advocacy organization. But now, he says, it's possible to develop an energy policy based on "as much gas as you need."

"It doesn't matter what the exact number is," says Mark Zoback, a professor of geophysics at Stanford University. "The numbers are all so big it means we have an extremely large domestic resource that is going to play a significant role in the country's energy future." Natural gas is not a complete solution, he cautions. Still, he says, "it's not unreasonable that over the next decade or two we could completely get off coal, using gas as the principal fuel for electricity generation. I don't think natural gas is an alternative to renewables, but I do think it is by far the best fuel to use as we transition away from fossil fuels."

Gas Country

The rush to drill the Marcellus shale for gas is already under way in Pennsylvania. According to a report released this summer by Penn State, drilling in the Marcellus will generate $3.8 billion and create more than 48,000 jobs in 2009. And the business of extracting natural gas from the deposit "is still in its infancy," says Robert Watson, an associate professor emeritus of petroleum and natural-gas engineering and coauthor of the report. "It's a brand-new industry."

Not only does natural gas lie under 60 to 65 percent of the state, Watson says, but many of the most promising drilling areas are adjacent to existing pipelines that can cheaply transport it throughout the Northeast, the world's largest market for the fuel. "Some of the pipelines go right over the heart of the Marcellus shale," he says. "You have a well, and next to it you have a [pipeline] that goes right into New York City." Watson predicts that gas drilling will generate $1 trillion over the hundred-year life of the shale development and create some 120,000 jobs for the state by 2020. "Pennsylvania has the potential to become an OPEC of natural gas," he says. "It's mind-boggling. It will have an impact on Pennsylvania's economy not seen since the collapse of the steel industry."

His seemingly hyperbolic assertion becomes more plausible when you visit southwestern Pennsylvania, an area known for steel production and coal mining. Tough times for steel have left behind abandoned, rusting factories and, until recently, economic hardship. These days, brand-new four-wheel-drive pickups and heavy industrial drilling equipment fill the rural roads. Tucked away among the rolling hills and small farms are dozens of new gas wells. Occasionally, a tall drilling rig peeps over a ridgeline.

One of the companies leading the Pennsylvania gas rush is Range Resources, a Fort Worth-based firm that drilled the first commercial wells in the Marcellus shale in 2004. At one of Range's drilling sites, about 45 minutes south of Pittsburgh, a massive, multimillion-dollar rig rises high above the quiet farmland. The rig will drill half a dozen wells spaced just a few feet apart; once it has finished drilling a well, hydraulic jacks will lift the tons of equipment and "walk" it into position for the next one. Beside the drilling site is a small pond lined with plastic, filling up with the mud and debris that spurt from the well.

Range and other gas producers rely on drilling techniques that have been used for the past decade in the shale-gas fields of northeast Texas. Inside the trailer that serves as a field office, the complexity of the task is evident. On a wall is a chart mapping the drilling plans. The drill bit will head down more than a thousand meters through various types of sediments. Then, over the course of roughly 275 meters, it will gradually turn 90°, so that when it enters the layer of Marcellus shale at around 2,000 meters, it will be traveling horizontally through the gas-rich rock. Drillers can control the location of the bit to within several centimeters. Staying within a six-meter window, the bit will follow the Marcellus layer for up to 1,600 meters. The horizontal approach is crucial, allowing the well to tap into a large area of the shale layer. Eventually, the several wells at the site will spread out underneath the countryside, draining gas from hundreds of acres of shale.

The trickiest part of the operation comes after the drilling is done and the large rig is removed. A small armada of specialized equipment, including dozens of tanker trucks filled with water, will move in to perform a procedure called hydraulic fracture stimulation, or hydrofracturing, which is designed to get the gas flowing efficiently into the well. Although the Marcellus shale is soaked with gas, the rock holds the hydrocarbon tightly trapped. To allow it to escape, engineers will force millions of gallons of water down the well and into the shale formation at high pressure. If all goes well, the natural gas will rush out of the shale and into the pipe after the water is pumped back out.

That the process works is a tribute to the wonders of geology and the ingenuity of the drilling engineers. Like the black shale on the shores of Lake Erie, the Marcellus shale is riddled with tiny natural fractures created million of years ago as the newly formed hydrocarbon gases expanded. The high-pressure water, which is mixed with fine sand and chemical additives, works to enlarge those cracks. The results: gas-permeable zones of damaged rock a hundred or more meters across, radiating out from the well pipe.

Geologists like Gary Lash and Terry Engelder have long known that the black shale in the Appalachian basin contains large amounts of natural gas. In fact, the nation's first natural-gas well was drilled in Fredonia, NY, in 1825, a few miles from Lake Erie;

wooden pipes were built to transport the fuel so that it could light houses in the town. But the geologists have been surprised to discover that so much gas can be recovered economically. After Range released its initial drilling results in 2007, Engelder recalls, he was asked during a conference call with investors in New York just how much natural gas the Marcellus shale contained. It wasn't a calculation he had ever bothered to do. Engelder remembers pausing and then answering, "I'm not sure, but by the end of the day I will be dead certain." He did some calculations based on the size of the formation and the likely gas content of the rock; then he called Lash and asked him to do his own. The next day, Lash called back with his numbers. They had come to the same conclusion, says Engelder: "Holy cow, there's a lot of gas."

Building Bridges

The arguments in favor of using more natural gas and less coal and petroleum are, at least at first glance, straightforward. Coal-fired plants generate about 50 percent of the electricity used in the United States, but they produce 82 percent of the power industry's carbon dioxide emissions. Burning natural gas produces roughly half as much carbon dioxide as coal. What's more, plenty of existing gas-fired power plants already have excess capacity, since they are generally used as backup to coal plants at times of peak electricity demand.

It's also easy, from a technological perspective, to substitute natural gas for gasoline or diesel fuel in cars and trucks. Unfortunately, this wouldn't reduce greenhouse-gas emissions nearly as much as replacing coal in power production. A natural-gas car emits about 25 percent less carbon dioxide than a gasoline-powered vehicle, but since transportation accounts for only about a third of U.S. greenhouse-gas emissions, even switching over all the country's vehicles to natural gas would reduce overall emissions by just 8 percent. Still, using natural gas in a portion of the nation's fleet vehicles, such as buses and taxis, would be relatively simple and could help reduce dependence on imported petroleum.

In mid-August, the Energy Future Coalition and the Center for American Progress, an influential Washington group with close ties to the Obama administration, released a paper called "Natural Gas: A Bridge Fuel for the 21st Century." The timing of the report was triggered by the recent shale-gas findings and the desire to make natural gas a part of the discussion as Congress debates an energy bill. Proposed provisions in that bill, such as a cap-and-trade program that would effectively put a price on carbon dioxide emissions, could create a strong and growing market for this fuel. Once the carbon price reaches $20 to $30 a ton, says the Energy Future Coalition's Detchon, "it would be economically advantageous for utilities to switch to gas from coal." Detchon also favors a "low-carbon" mandate, which would require utilities to use natural gas for a certain percentage of their electricity production, and incentives for power producers to close down their oldest and dirtiest coal-fired plants.

Such policy changes are critical to encouraging further drilling in shale-gas deposits, says Jeff Ventura, the COO of Range. Prices for natural gas peaked at $13 per thousand cubic feet (MCF) last year, but oversupply and lackluster demand depressed them to around $3 per MCF this summer, the lowest level since December 2001. As a result, drilling slowed down, almost reaching a standstill in many regions of the country (though drilling in the Marcellus has actually increased). A "reasonable price" of around $6 to $8 per MCF, Ventura says, would enable drilling companies to more fully exploit shale gas. Getting back to that price will require not only an economic recovery but also policies that increase demand by influencing power generators to shift to natural gas. "That is something that could happen immediately," he says. "More power generation from natural gas would have an immediate impact."

Drilling for shale gas could also provide a less obvious environmental benefit, if research begun by the Stanford geophysicist Zoback is successful. Fossil-fuel power plants, whether they use coal or natural gas, will eventually need to capture and sequester their carbon dioxide emissions. That means finding a safe, economical way to store carbon dioxide so that it cannot leak out. Zoback believes that shale deposits might provide one solution.

Zoback is testing the feasibility of a process that could trap carbon dioxide in depleted natural-gas wells--and wring additional productivity from them at the same time. It is thought that at least some of the methane in the shale is adsorbed to the sediments: the gas molecules form a thin film that adheres to the surface of the organic material and clay in the deposits. Preliminary tests have shown, however, that carbon dioxide binds to these materials more strongly than methane does. Carbon dioxide pumped into wells that have grown less productive, Zoback believes, could displace the adsorbed methane, which would then flow out of the shale and into the well. If it works, the process would free extra natural gas in these wells while confining the carbon dioxide securely underground.

Zoback says it will be years before he knows whether the process works. "Of course, there is a long way from concept to implementation. And there are a hundred and one questions that need to be answered," he says. But, he suggests, the recent slowdown in gas drilling provides an opportunity to test the idea before the pace of drilling picks up again, as he expects it to in 2011 or 2012. Zoback notes that pipelines are now used to deliver carbon dioxide to oil-drilling sites to enhance production; a similar infrastructure, he says, could be built around shale-gas wells. And, he says, building some of that infrastructure while developing shale-gas drilling will make carbon storage much more practical.

Dream World

Still, not all experts think it's wise to rapidly expand the market for natural gas. Simply put, they worry that the country could become addicted to yet another fossil fuel--one that could turn out, over the long term, to be far less abundant and more expensive than many now predict.

The experience of Great Britain in the late 1980s provides a sobering example. The country was adjacent to an enormous, underdeveloped resource of natural gas in the North Sea. At the time, the Conservative government headed by Prime Minister Margaret Thatcher was fighting with the coal miners, and natural gas looked like an economically and politically attractive fuel. So government and industry pushed forward with what became known as the "dash for gas," allowing the use of that fuel in power plants for the first time. The country's coal industry all but disappeared, and nuclear power was largely neglected. "The whole country moved very rapidly toward building new gas-fired power stations," recalls Tony Meggs, who was then an executive at BP responsible for a building an export pipeline for the fuel. "We started exploiting the underdeveloped gas fields, and it was great. We were very happy."

But in retrospect, says Meggs, now a visiting engineer at MIT and codirector of the school's forthcoming report on natural gas, the rapid expansion of the market in Great Britain turned out to be "bad policy." These days, he says, the U.K. imports substantial amounts of the natural gas it depends on for much of its electricity generation; by 2020 it will be forced to import 70 percent, most of it from continental Europe. "So we went from a position of great supplies and security, with everyone saying there's a lot a gas, to a position that from an energy-security perspective is very unattractive," Meggs says. "It is very important that the U.S. doesn't go the same route, expanding markets and using resources inappropriately and then ultimately becoming import-dependent."

While Meggs calls the shale-gas supply in the United States a "great blessing," he cautions that it is still unclear how large a resource it will be, because drilling for it "is a relatively young phenomenon." Any energy policy must take those uncertainties into account, he says. MIT's natural-gas study, for example, will focus on "not just how much is there but how much it costs to get it out of the ground, how long it will last, and what is the range [of uncertainties], both in terms of cost and in terms of ultimate recoverability."

The worry, of course, is that much less gas than experts have estimated will turn out to be recoverable from shale at an acceptable environmental and economic cost. Jay Apt, executive director of the Carnegie Mellon Electricity Industry Center in Pittsburgh, is blunt: "We're in an early stage of a shale boom. Every practitioner in a boom thinks it will last forever and is surprised, in five or seven years, that it isn't going to last forever." Apt predicts "an inevitable downgrading of the number of cubic feet that these deposits can supply." After all, he says, "there is a difference between what Mother Nature gave you and what the town will allow you to extract." The gas producers' extensive land and water use is already creating a backlash in Pennsylvania, he says. And the danger of rapidly converting more electricity plants to natural gas is that once shale-gas supplies "top off," power producers will be reliant on imports and vulnerable to volatility in their prices.

Some energy experts say that even if supplies of natural gas remain abundant, it's unclear to what extent power producers will switch to the fuel, and how long it will take if they do. Many gas advocates display a "practical naïveté" about the conversion of coal-fired power production, says David Victor, director of the International Law and Regulation Laboratory at the University of California, San Diego. "If you look at the quantity of gas needed to replace all the coal plants in the United States, you're talking about increasing gas consumption by something like 50 percent," he says. "It's a huge number." Such a large increase in production will require extensive shale drilling, some of it in heavily populated locations. And, he says, "we don't know what [the shale-gas drilling] looks like on a truly massive scale." Many of those advocating a large-scale shift to natural gas are "living in a dream world," Victor says. "They haven't worked out the practical details."

Generating electricity with more natural gas and less coal could clearly decrease carbon dioxide pollution. Says Victor, "If shale gas plays out at very large volumes and at low cost, then it will be a cost-effective way of making substantial reductions in emissions." But, he says, those reductions won't be enough to meet the long-term goal of cutting the nation's overall carbon dioxide emissions 80 percent by 2050, as President Obama and a number of other political leaders have advocated. The switch to natural gas, he says, "buys you a little time" before other changes can be made, such as introducing more wind, nuclear, hydroelectric, solar, and other zero-carbon power sources. "The concern is that natural gas is a bridge to nowhere," Victor says. "And it could be a very costly bridge to an outcome that doesn't readily get you to the 80 percent reductions."

From a technology perspective, natural gas and renewable sources, such as wind and solar, could complement each other. Natural-gas-fired turbines could be used to generate electricity when the wind isn't blowing or the sun isn't shining. But the economic and political relationship between natural gas and renewables is more complicated. If federal and state policies continue to mandate that power producers use more renewables, the electricity industry is likely to concentrate its new capacity on those technologies while keeping its low-cost coal-fired power plants. Policy will drive the use of renewables, and economics will drive the use of coal. Natural-gas plants will be squeezed out.

Then again, a focus on natural gas as a way to trim carbon dioxide emissions could divert attention--and money--from the need for zero-carbon technologies. "I am a big fan of clean natural gas, but there is a very big danger of getting everybody revved up about gas and losing sight of the fundamental technological transformation that is needed," says Victor.

The availability of vast natural-gas resources in the Marcellus shale and similar sediments around the United States has changed energy calculations in a fundamental way. The discovery of this large and seemingly economical new source of fossil fuel has surprised even geologists who have spent their careers studying the shale. Little wonder, then, that policy makers and politicians are just beginning to try to figure out what the discoveries mean.

It's not clear how--or even whether--those responsible for energy policy will take advantage of the opportunity. At best, the newly identified supplies of gas will buy time, providing a chance to reduce greenhouse gases while more innovative technologies are developed and deployed. At worst, the country will burn through large volumes of this fuel only to find that we haven't reduced carbon dioxide emissions very much--and that we've put off investing in research to create cleaner technologies.

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