



CAN FRACKING POWER EUROPE?

Several countries hope to unleash vast natural-gas reserves through fracking, but drilling attempts have been disappointing.

Large petroleum pumps nodded up and down in the background as British Prime Minister David Cameron donned a blue industrial jumpsuit to promote a controversial drilling technique known as hydraulic fracturing, or fracking. In his 2014 visit to a potential drill site in eastern England, Cameron laid out the benefits of tapping Britain's shale formations to release valuable natural gas. "We're going all out for shale," he said. "It will mean more jobs and opportunities for people, and economic security for our country."

Cameron hopes to replicate the surge in natural-gas production that has happened in the United States thanks to fracking — which involves injecting fluids into shale to liberate locked-up hydrocarbon deposits. The fracking revolution helped to revitalize the US economy, and Cameron's Conservative Party seeks to spark a similar gas boom in the United Kingdom. In August last year, his newly

BY MASON INMAN

elected government offered drilling licences for shale deposits and it touted estimates that "investment in shale could reach £33 billion [US\$46 billion] and support 64,000 jobs".

Over the past few years, fracking fever has swept through several European nations, including Denmark, Lithuania, Romania and especially Poland, which has seen more shale exploration than any other nation on the continent. Fracking might help to boost gas production in Europe at a time when it is facing a sharp decline. Older gas fields in the North Sea are running out, as are deposits in Germany, Italy and Romania. The disappointing output has increased Europe's dependence on imported gas, mainly from Russia. European leaders have grown wary of relying on that source, especially after diplomatic relations chilled when Russia invaded Ukraine in 2014.

But Europe's appetite for gas could increase as it tries to cut greenhouse-gas emissions — which will probably require reducing coal consumption (see 'Looming gas crunch?'). The European Commission says that "gas will be critical for the transformation of the energy system".

This means that countries such as the United Kingdom have invested an immense amount of hope in shale gas. But a close examination of the industry suggests that any fracking boom in Europe is a long way off — and some experts say that it may never arrive.

Despite several years of exploratory drilling, there are currently no commercial shale-gas wells in Europe. Tests of the region's shale potential have been limited, and the results so far have been generally disappointing, say geologists and energy experts. It remains highly uncertain how much gas would be recoverable with today's technologies, and even more difficult to forecast how much would be profitable to extract.

BARTEK SADOWSKI/BLOOMBERG/GETTY

Fracking attempts in Poland have not led to commercial wells.

All that leads to big questions about Europe's shale hopes, says Jonathan Stern, a natural-gas expert at the Oxford Institute for Energy Studies in Oxford, UK. "There has been an enormous amount of ridiculous hype about shale gas in Europe."

WAITING FOR A REVOLUTION

A decade ago, the United States was facing a similarly dismal outlook for natural gas. Production from conventional fields was petering out, and geologists did not expect that alternative sources of gas could compensate for the shortfall. But within a few years, the picture suddenly brightened owing to improved drilling and fracking technologies, which tapped previously inaccessible gas reserves and unleashed a boom dubbed the shale revolution. Shale is almost impermeable to oil and gas, so companies must fracture the rock to liberate those hydrocarbons.

The idea that a similar wealth of untapped energy could be lurking in the rocks below Europe is economically appealing. But geologists know relatively little about the potential of shale-rock formations in Europe because there has been less onshore drilling than in the United States. European companies have sometimes drilled through shale to reach other rock formations, but they have rarely taken detailed measurements or collected samples of the shale layers.

So far, Poland's shale formations have attracted the most attention within the region. The nation depends heavily on coal, and what natural gas it does use comes almost exclusively from Russia. In the mid-2000s, the burgeoning US shale boom prompted Poland's government to offer shale exploration licences that went to local companies as well as major international energy firms, including the US companies ExxonMobil and Chevron, and the French firm Total. Poland's foreign minister, Radosław Sikorski, said in 2010 that Poland would become "a second Norway" — referring to Europe's second-largest natural-gas producer, after Russia.

The excitement was bolstered in 2011 by an assessment from Advanced Resources International (ARI), a consultancy in Washington DC that was commissioned by the US Department of Energy to study shale-gas resources worldwide. That study estimated the quantity of shale rock and other parameters such as the total organic content of the rock, which is the source of oil and gas. ARI also estimated parameters to represent the risk that some shale zones, or plays, might not prove promising or that only a portion of them might be amenable to drilling. Given these assumptions, ARI calculated that Poland's shale-gas plays hold about 5,295 billion cubic metres (bcm) of technically recoverable gas, the most shale gas of any nation in Europe. If all of that gas could be extracted, it

would be equivalent to 325 years of Poland's current gas consumption¹.

While companies began drilling dozens of test wells in Poland, the Polish Geological Institute (PGI) in Warsaw made its own estimate in March 2012. Taking the considerable uncertainty over the data into account, the PGI calculated that Poland has 346–768 bcm of recoverable shale gas onshore — about one-tenth of ARI's figure².

Then in July 2012, the US Geological Survey (USGS) released another study of Poland's shale-gas resources. The agency assumed that

"IT IS TOO SOON TO DISMISS POLAND'S EXTENSIVE SHALE POTENTIAL."

individual wells would yield about half as much gas as the PGI assumed and that the area that is likely to contain recoverable gas is only about one-third of the size. So the USGS wound up with an estimate even smaller than the other two, with a mean result of just 38 bcm of recoverable gas, and a huge range of uncertainty, from 0 to 116 bcm. The mean was about one-tenth that of the PGI's estimate, and about one-hundredth of ARI's³.

"One report — huge potential. A year later — nothing," says PGI geologist Hubert Kiersnowski. "The scale of uncertainty is so big."

Meanwhile, results started coming in from test wells. Of the 72 wells drilled by the end of 2015, 25 were successfully fracked to release gas. However, these wells yielded only about one-third to one-tenth of the flow that would be required to turn a profit, says petroleum geologist Paweł Poprawa of AGH University of Science and Technology in Krakow, Poland, and formerly of the PGI. None of the wells has become a commercial producer.

At the peak of interest in early 2013, companies held shale-drilling licences covering about one-third of Poland. But throughout 2013 and 2014, the major international energy firms gave up their shale-exploration licences and left the country, often citing disappointing results. The last to leave was Texas-based ConocoPhillips in June 2015 — now Poland's shale drilling is almost at a standstill.

One major hurdle to development is that Poland's shale is expensive to drill because it is

buried around 3–5 kilometres down, compared with around 1–2 kilometres for most successful US plays. Some of Poland's shale also has a high clay content, which makes the rock harder to fracture. And exploratory holes into one of Poland's most promising shale formations — in the north, near the Baltic Sea — showed that it held a geological barrier that would limit how much gas could be tapped by individual wells, says Poprawa. The drilling results suggest that ARI "overestimated the acreage, the thickness, and the quality of the shale", he says.

The PGI says that its previous lower estimates are reinforced by its latest, as-yet-unpublished assessment, which draws on recent shale-drilling tests. PGI spokesperson Andrzej Rudnicki calls ARI's much higher estimates "enthusiastic, but geologically unrealistic".

"The results in Poland to date indeed have been disappointing," concedes geologist Scott Stevens of ARI. He says that the main reason for the unproductive wells was "extremely high" stresses in the rock, which makes fracking less effective. "There was no way that the exploration companies could know that in advance," he notes. Nonetheless, he argues, "It is too soon to dismiss Poland's extensive shale potential." Given the limited available data, he does not see a reason to revise ARI's estimate.

Even the PGI's lower estimates suggest that there is still a substantial amount of gas trapped in Poland's shale. However, it is uncertain whether any of that gas will be profitable to extract. "I am still hopeful," Poprawa says. "But the initial hopes were not realistic."

DASH FOR GAS

Although companies raced to grab concessions in Poland, activity in the United Kingdom has been subdued. In 2011, Cuadrilla Resources fracked the United Kingdom's first shale well near Blackpool in northern England, but this triggered two small earthquakes, which led the government to place a year-long moratorium on further fracking. After the moratorium lifted, companies slowly began vying to tap UK shale.

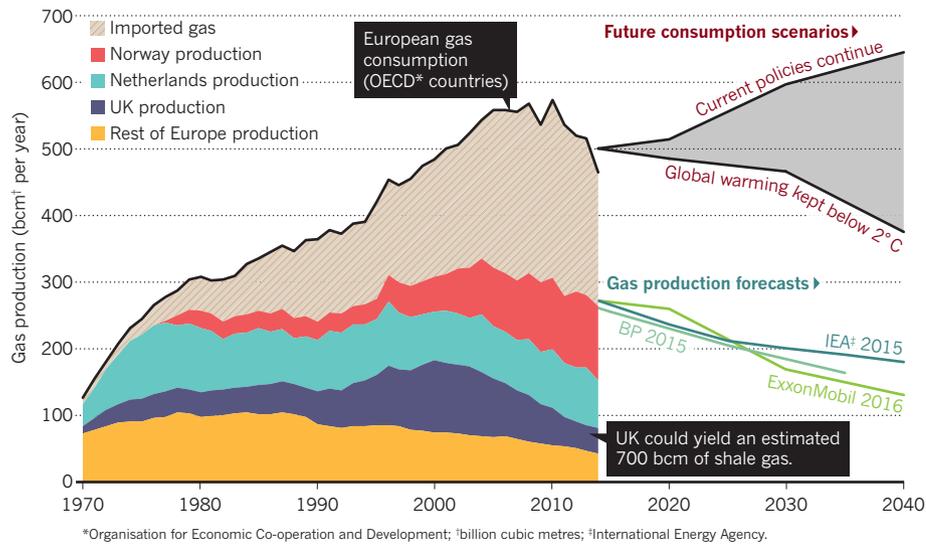
According to a 2013 assessment by ARI, UK shale holds 17,600 bcm of gas. Only 728 bcm of this is judged to be technically recoverable: if that could be profitably extracted, it would satisfy the United Kingdom's gas needs for about a decade⁴.

The British Geological Survey (BGS) has assessed the shale-gas resources in the United Kingdom's three major plays by constructing a 3D model of the subsurface using drilling records and seismic surveys, which has allowed it to roughly estimate the volume of shale rock. But geologist Ian Andrews of the BGS insists that this estimate is just a first pass based on the seismic information available, "which is sparse, and fairly poor".

By testing old rock cores stored by the government, the BGS was also able to measure some of the properties of UK shale, such as the total organic carbon (TOC) content. Successful shale plays in the United States typically

LOOMING GAS CRUNCH?

Domestic production of natural gas has fallen in Europe (except Russia) and forecasts predict further declines. That could force nations to increase their imports, depending on consumption trends. Fracking could unlock additional supplies, but drilling results so far have not been promising.



have TOC values greater than 2%. Although TOC measurements for the United Kingdom are scant, the available data suggest that there are large volumes of rock above the 2% threshold. But data are lacking for other key parameters, such as the rock porosity, which adds greatly to the uncertainty of these projections.

The BGS estimated that the three shale plays it has assessed so far hold around 39,900 bcm of gas, with an uncertainty range of 24,700–68,400 bcm (refs 5,6). This is more than the ARI estimate, but that study only considered the most promising rock. The BGS did not attempt to estimate how much of that gas would be technically recoverable. “How much we can get out of the ground, I don’t think anybody knows yet, because the drilling hasn’t happened to test it,” says Andrews.

Although the BGS’s studies used US shale plays as analogues for crucial parameters, the two nations have different geological histories. The United States has large deposits of shale that are not too thick and have been folded little over time. The shale in the United Kingdom is more complicated, says petroleum geoscientist Andrew Aplin of the University of Durham, UK. “It’s been screwed around with more”, creating more folds and faults.

That greater complexity could pose challenges. One risk is that pumping fluid into rock can trigger earthquakes if the wells are near faults or large natural fractures. “It’s better to stay away from them, especially when they’re located near densely populated areas,” says natural-gas expert Rene Peters of the Netherlands Organisation for Applied Scientific Research (TNO) in the Hague. But there has been relatively little high-resolution seismic imaging in Europe, he says, so “not all these fractures are known”. Small faults can pose another challenge. If the fracking fluid leaks into a fault, the pressure on the rock is reduced

and the fracking is less effective. Given the geological hurdles and the United Kingdom’s dense population, it may prove difficult to find many promising, acceptable places to drill.

FAR FROM PROFITABILITY

The United Kingdom’s appetite for gas is expected to grow sharply. In November, the government set out the goal of phasing out coal-fired power plants by 2025, unless they have carbon capture and storage systems. The government expects nuclear, wind and solar power to play a part in filling the void left by coal — but natural gas would be the linchpin because it produces less carbon dioxide and other pollution than does coal, and existing infrastructure can be used to produce electricity from gas. “We’ll only proceed if we’re confident that the shift to new gas can be achieved within these timescales,” UK energy secretary Amber Rudd said in a speech announcing the policy shift. “We currently import around half of our gas needs, but by 2030 that could be as high as 75%. That’s why we’re encouraging investment in our shale-gas exploration so we can add new sources of home-grown supply.”

Other European nations are also counting on natural gas to help them to cut their coal use and meet their commitments under the United Nations climate treaty signed in Paris in December. But shale gas may not provide the answer. At the June 2015 World Gas Conference in Paris, industry speakers were pessimistic that Europe would see a fracking boom like that in the United States. Philippe Charlez, manager of unconventional resources development at Total, said that given the current costs for shale wells, “we are very, very far in Europe from profitability”.

Many assessments in the past two years — including those by the International Energy Agency and oil giants BP and ExxonMobil

— agree that Europe is unlikely to produce much shale gas, and that conventional gas production will continue to decline^{7–9}. And if gas imports cannot make up the difference, says Stern, “Europe is going to have even more difficulty reducing carbon emissions”.

The most recent signs are not good for shale across the continent. Besides retreating from Poland, major petroleum companies have pulled out of nascent shale drilling efforts in Romania, Lithuania and Denmark, usually citing disappointing yields. Various members of the European Union from Bulgaria to France have instituted moratoria or bans on fracking, as have Scotland, Wales and Northern Ireland, all citing environmental concerns.

England is home to some of the few remaining attempts to tap shale gas in Europe. A handful of companies have applied for permission to drill, which could finally reveal whether the United Kingdom’s shale deposits will be a jackpot or a dud. But environmentalists have put up a strong fight, and permissions have been slow to emerge.

Cuadrilla requested approval in January 2015 to drill beneath the undulating fields of Lancashire, but the county council rejected the request in June over concerns about traffic, noise and the visual impact of drilling. That decision and the broader difficulties that confront fracking in Europe leave the future of natural gas there in limbo. To figure out whether any play has potential, companies must drill as many as 50 to 100 wells. But the public opposition and the poor drilling results so far mean that companies are not eager to sink that kind of effort into fracking in Europe right now, says Stern. “I can’t see any country, including the UK, where that will happen anytime soon.” ■

Mason Inman is a reporter in Oakland, California. Travel for this article was supported by the European Geosciences Union’s Science Journalism Fellowship.

1. US Energy Information Administration. *World Shale Gas Resources* (EIA, 2011); available at <http://go.nature.com/yq9cbo>
2. Polish Geological Institute. *Assessment of Shale Gas and Shale Oil Resources of the Lower Paleozoic Baltic–Podlasie–Lublin Basin in Poland — First Report* (PGI, 2012); available at <http://go.nature.com/buxvqp>
3. US Geological Survey. *Potential for Technically Recoverable Unconventional Gas and Oil Resources in the Polish-Ukrainian Foredeep, Poland, 2012* (USGS, 2012).
4. US Energy Information Administration. *Technically Recoverable Shale Oil and Shale Gas Resources* (EIA, 2013); available at <http://go.nature.com/lkhhmx>
5. British Geological Survey. *The Carboniferous Bowland Shale Gas Study: Geology and Resource Estimation* (BGI, 2013); available at <http://go.nature.com/tdavyi>
6. British Geological Survey. *The Carboniferous Shales of the Midland Valley of Scotland: Geology and Resource Estimation* (BGI, 2014); available at <http://go.nature.com/dbdytt>
7. International Energy Agency. *World Energy Outlook 2015* (IEA, 2015).
8. *BP Energy Outlook 2035* (BP, 2015); available at <http://go.nature.com/s1zomr>
9. *The Outlook for Energy: A View to 2040* (ExxonMobil, 2016); available at <http://go.nature.com/fkpiif>