

REVIEW

Shale gas in North America and Europe

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Abstract

According to the U.S. Energy Information Administration, shale gas will provide half of the United States' domestic gas by 2035. The United States has already moved from being one of the world's largest importers of gas to being self-sufficient in less than a decade, bringing hundreds of thousands of jobs and attracting back companies that long ago left America in search of cheap manufacturing costs. But the increase in shale gas extraction has also had an environmental cost. There is clear scientific evidence of leaking shale gas wells and induced earthquakes, and in some areas a population increasingly turning against the industry. The technology of horizontal drilling and hydraulic fracturing that was developed in the United States is now being tried outside the United States, including in Europe, Argentina, and China. There are clear reasons why shale gas might be attractive to Europe. It may offer security of energy supply to some countries particularly dependent on Russian gas; it could stimulate growth and jobs; and it could supply a cleaner fuel than coal in power stations. However, prospective shale often underlies areas of high population density in Europe, and moreover, populations that are unfamiliar with onshore gas operations. The main challenge in Europe therefore is not mainly technological but for the industry to achieve a "social license" and for Government and regulations to be manifestly protecting the public and property.

Introduction

Shale is a fine grained, dark colored sedimentary rock that often contains natural gas (methane) as well as other gases. Its origins lie in mud deposited in sea and lake beds. Most of the mud is made up of stable minerals that are the result of advanced weathering of older rocks, but it also contains (often more than 10% by weight) organic matter that comes from plants growing on nearby land areas, as well as algae and plankton that live in the water column [1]. It is this organic material that, through heating and pressure supplied by deep burial under other later sediments, is converted to oil and gas through a complex series of chemical reactions. The temperature required is between 60°C and 120°C, with gas being formed at the high end of this range, and oil at the low end. Thus, shale can

contain oil (known as "shale oil") in certain geological circumstances and gas in others. Shale whose thermal history lies outside the 60–120°C range may not contain any oil or gas [2].

The mineral material that makes up the bulk of shale is very fine and very tightly packed with the result that oil and gas created within the shale cannot readily move within the rock. Unless natural fractures are present, shale will tend to retain its hydrocarbons. This low permeability is the root of the idea of unconventional hydrocarbons, so-called because the oil and gas industry has to resort to new unconventional methods to extract oil and gas. The main advance in the last few decades has been hydraulic fracturing from long horizontal wells that target deep shale layers. Although hydraulic fracturing has been used for decades throughout the world [3], the extent to which the technique is being used now is unprecedented. About

33,000 gas wells are drilled in the United States every year and about 90% of these are fracked [4]. Rarely has a new technology produced such controversy. Cheap energy, energy security, economic growth, and climate amelioration are claims made by shale gas' advocates. Its detractors regard shale gas as a cause of environmental degradation, and also doubt whether its economic benefits are real or long lasting.

An important distinction to bear in mind in any discussion of shale gas is that between resources and reserves. The first concept is the total amount of gas that in geological terms constitutes material of potential value. Reserve, a smaller amount, is the proportion of the resource that is economical to produce, within environmental and social limits. The "recovery factor" connects the two concepts in that it is the percentage of the resources that can become reserves.

Only Canada and the United States have a commercial shale gas business and proven reserves, and so consideration of the effects of shale gas needs to concentrate in those countries.

North America

The main shale areas

The Barnett shale (Fig. 1) was the first shale to be exploited on an industrial scale. It underlies 28,000 square miles in north-central Texas, including the city of Fort Worth. The core producing area is the Newark East gas field covering 500 square miles, with over 2400 producing wells and 2.7 tcf (trillion cubic feet) of proven reserves.

The Marcellus shale is an older shale covering over 75,000 square miles of Ontario, New York, Pennsylvania, Ohio, West Virginia, Maryland, and Virginia with the best shale running in a belt from the northeast in New York, through northeast Pennsylvania into southwest Pennsylvania. The core area – where the formation exceeds 50 feet thick and has the right maturity – covers 50,000 square miles making it the largest potential shale region in North America.

The Eagle Ford shale trends across Texas from the Mexican border up into East Texas, in an area roughly



Figure 1. North American shale gas areas. From the Energy Information Administration (EIA): http://www.eia.gov/oil_gas/rpd/northamer_gas.jpg.

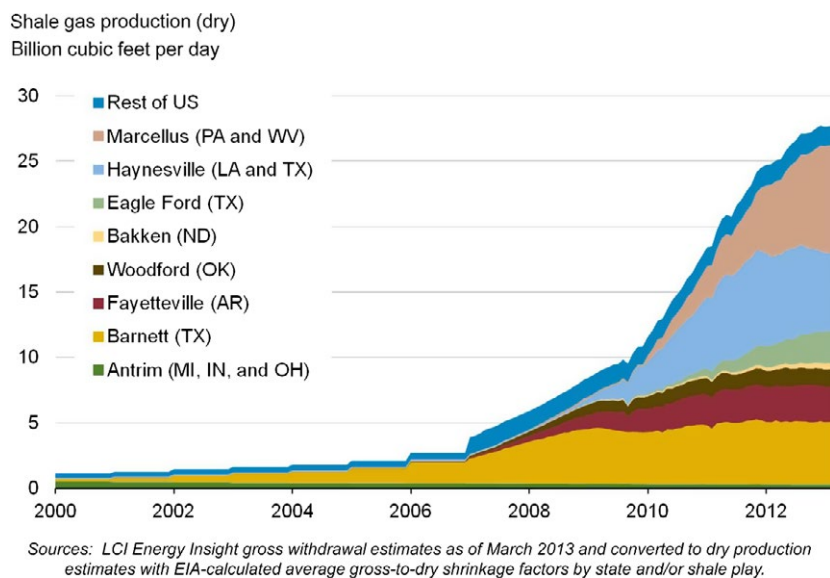


Figure 2. The relative importance of different U.S. shale layers. From Newell 2011, presentation to the OECD, Paris.

50 miles wide and 400 miles long. Here, the shale has an average thickness of 250 feet. The Haynesville shale underlies an area of about 9000 square miles of east Texas and west Louisiana averaging about 200–300 feet thick in the main productive area. The shale is very deep in the area occurring 10,500–13,000 feet below the surface, and produces mainly gas. This makes it quite expensive to drill. The Haynesville shale was one of the fastest growing shale gas businesses in the United States until about 2012 when gas prices fell and it became more difficult to operate profitably because of the depth. Many companies shifted to more profitable shales where they could get oil as well as gas, for example, the Eagle Ford shale.

The Fayetteville shale is roughly the same age as the Barnett shale and underlies much of northern Arkansas and adjacent states. It produces natural gas in the central portion of the Arkoma basin in Van Buren and Cleburn counties where the shale is at a few hundred to 7000 feet below the surface.

In Canada, two shales are important: the Muskwa (Horn River) shale and the Montney shale. The Muskwa shale was first described in outcrop on the banks of the Horn River, a tributary of the Mackenzie River, in the Northwest Territories. In eastern British Columbia, it ranges in depth from 6300 to 10,200 feet, averaging 8000 feet for the prospective area. The Montney shale in northwestern Alberta covers an area of ~1900 square miles at a depth ranging from 3000 to 9000 feet, averaging 6000 feet for the prospective area.

Commercial development of North American shale began in north east Texas in the Barnett shale where the increase in wells drilled is particularly evident between 1997 and 2009 (see [3]). The success in the Barnett shale lead quickly

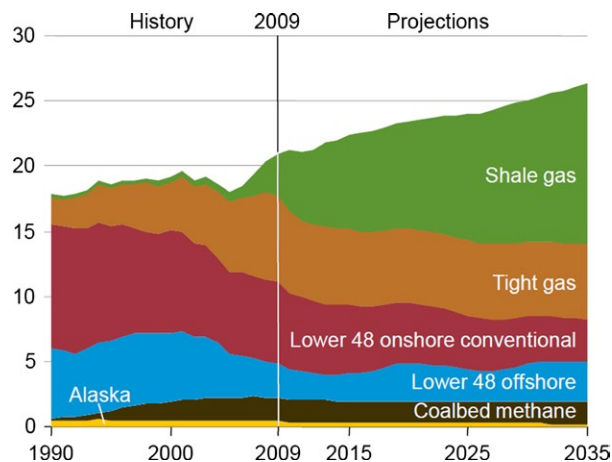


Figure 3. U.S. natural gas production, 1990–2035 (trillion cubic feet per year). From the EIA's 2011 Annual Energy Outlook.

to the development of the Woodford, Fayetteville, Haynesville, Marcellus, and Eagle Ford shales, and also shale in Canada. The relative importance of the different U.S. shale layers in terms of production is shown in Figure 2.

Economic effects of shale gas

The Energy Information Administration's 2011 Annual Energy Outlook [5] showed the recent history of shale gas and a projection to 2035 (Fig. 3), predicting that shale gas would make up almost half of U.S. natural gas production by 2035. The EIA Annual Energy Outlook of 2014 [6] indicated that the abundance of cheap shale gas is affecting the way that electricity is generated in the United States,

and the balance of imports and exports of natural gas. Electricity generated by coal will remain the same or will slightly decline while gas-fired electricity generation will markedly increase. The EIA Annual Energy Outlook of 2014 also forecast that exports of U.S. natural gas might grow, both by pipelines to Mexico and Canada, but also as liquefied natural gas (LNG). The United States has already moved from being one of the world's largest importers of gas to being self-sufficient in less than a decade [3].

Shale gas has contributed to American energy security. American conventional natural gas production peaked in the early 2000s, and the widely discussed solution to the shortfall was to import LNG from conventional natural gas fields in the Middle East, Australia, and Russia. In 2006, there were four operating onshore LNG import terminals in the United States and more were expected to be built [3]. Since that time shale gas production has reduced U.S. natural gas imports to a level not seen since 1994. The EIA Annual Energy Outlook of 2012 [7] suggests that the United States will become a net exporter of gas in the form of LNG in 2016. More than 2 billion cubic feet per year may be being exported by 2019 [7].

The EIA Annual Energy Outlook of 2014 [6] predicts a jump in U.S. manufacturing powered by cheaper fuel in the form of shale gas. The main industries affected will be energy intensive bulk chemicals and primary metals, both of which provide products used by the mining and other downstream industries such as fabricated metals and machinery. The bulk chemicals industry is also a major user of natural gas and, increasingly, hydrocarbon gas liquids which are often produced with gas from shale. One of these is ethane which is used to make ethylene which in turn has many industrial products including PVC, polystyrene, latex, detergent, and vinyl. The Dow Chemical Company announced in 2012 that it would build a \$1.7 billion ethylene and propylene production facility in Texas using ethane from local shale.

The low price of U.S. fuel now means that manufacturing costs are decreasing and companies that once left the United States to find cheaper production abroad are "reshoring" or returning production to the United States, which could result in 1 million more manufacturing jobs as companies build new factories [8]. Shale gas created 600,000 jobs in the United States as a whole up to 2010 and is predicted to provide 1 million jobs by 2025 [9] and 1.6 million by 2035 [10]. In Pennsylvania alone, the home of the huge Marcellus shale, the shale gas business is predicted to bring \$18 billion extra business, nearly \$2 billion local tax and 200,000 jobs by 2020 [11]. The U.S. Bureau of Labor Statistics [12] observed that between 2007 and 2012 employment in Pennsylvania's oil and natural gas industry (mainly shale gas) increased by 15,114 (259.3%), also that while the state's average annual pay

increased by \$5158 (11.9%), to \$48,397 in 2012, wages in Pennsylvania's oil and natural gas industry rose by \$22,104 (36.3%), to \$82,974 in 2012. For the United Kingdom recently, Ernst and Young [13] predicted 64,500 jobs at peak for a U.K. shale gas industry of 4000 wells.

One result of the substitution of gas for coal in electricity generation is that for the years 2006–2011, CO₂ from fossil fuel consumption declined by 430 million tons (or 7.7%) in the United States [14]; although U.S. energy-related CO₂ emissions increased from 5267 million tons in 2012 to 5396 million tons in 2013 [6].

Environment

Concerns over degradation of the environment in North America center on three main topics: groundwater contamination by stray methane, uncontrolled emissions of methane to the atmosphere (fugitive emissions), and earthquakes directly or indirectly related to hydraulic fracturing. Perhaps the area that has caused most concern has been the first. At least two peer-reviewed papers representing studies of groundwater in Pennsylvania close to hydraulic fracturing of shale have reported contamination of shallow water wells [15, 16].

Osborn et al. [16] described high concentrations of methane from water wells close to active hydraulic fracturing sites and used the chemical composition of the methane to show that it was thermogenic rather than biogenic, and so likely to have come from shale rather than shallow biological action. The paper was criticized (e.g., Davies [17]) for the rather small amount of supporting data, and for the lack of baseline data on how much methane naturally occurs in water wells in Pennsylvania (see, e.g., [18]). However, Jackson et al. [15] working on the same area in Pennsylvania showed statistically significant evidence from a larger number of data points that water wells within 1 km of hydraulic fracturing wells contained high levels of stray methane. Molofsky et al. [18] and Molofsky et al. [19] showed that the methane – though clearly thermogenic shale gas – probably emanated from shale layers above the hydraulically fractured layer (the Marcellus shale) suggesting that hydraulic fracturing was not the direct cause of stray gas, but that leaking or faulty production wells were [15]. However, large studies of areas undergoing intense hydraulic fracturing elsewhere, such as the Arkansas Fayetteville shale, have found very low concentrations of only biogenic methane in water wells, suggesting that this leakage is a local problem for Pennsylvania [20]. Recent tentative evidence from study of a groundwater supply contamination incident in Pennsylvania showed that additives probably derived from drilling or hydraulic fracturing fluid were present in groundwater [21].

However, concerns over additives used in hydraulic fracturing fluid mainly center on them reaching the environment from spills at the surface or in transport, from illegal dumping of wastewater, or from damage to the liners of wastewater impoundment dams [22]. Most of the hydraulic fracturing fluid is water but the nontoxic sand proppant is also an important addition. On average 0.17% of the volume of the hydraulic fracturing fluid is made up of other additives [23]. These usually include inhibitors to prevent scale on the walls of the well, acid to help initiate fractures, and biocide to kill bacteria that can produce acids that lead to corrosion.

In a recent survey [24], 81 common additives were identified and categorized according to their functions. Of these, 17 chemicals were considered to present potential treatment challenges but most of the additives were considered “nontoxic or of low toxicity” with three “classified as Category 2” oral toxins according to standards in the “Globally Harmonized System of Classification and Labeling of Chemicals” (see [24]). Stringfellow et al. [24] noted that toxicity information was not located for 30 of the additives and recommended that further research and assessment was needed.

Richardson et al. [25] found that just under half of a survey of U.S. states permitting hydraulic fracturing currently require some form of fracturing fluid disclosure but the detail varies across states. Environmental groups (and some in industry) have suggested that states should insist on disclosure whether the federal government asks for it or not. Many companies voluntarily disclose information on the web database FracFocus (<http://fracfocus.org/>).

Howarth et al. [26] studied the methane emissions from the surface installations of several shale gas wells finding high levels of methane release into the atmosphere as a result of two routine processes: flow back and drill out. Flow back is the liquid that returns to the well and then to the surface following hydraulic fracturing. Typically it carries methane. The practice of leaving the flow back water in open tanks at the surface (ready for disposal or reuse) allows methane to escape directly into the atmosphere. After drill out (where plugs in the well that partitioned parts of the well for hydraulic fracturing are removed), methane also escapes from the well to the atmosphere. Howarth et al. [26] published data that showed a very high level of methane leakage of between 3% and 8% of a well's production over its lifetime. Given that methane is a potent greenhouse gas, [26] considered that such levels of emissions cast doubt on the claims that shale gas could be a low carbon fuel, for example, in comparison with coal. Howarth's paper has been contested and recent work [27] suggested that the high figures for emissions quoted in the paper were unrepresentative of

the industry as a whole. Recent work from a larger number of shale gas drilling sites [28] suggests that the leakage rate is about half of 1% of gas production.

Evidence of earthquakes caused directly by hydraulic fracturing is extremely rare in the United States, though in Canada there are well-documented cases [29]. However the associated activity of deep geological disposal of flow back water is increasingly associated with earthquakes. Frohlich [30] showed that flow back disposal wells in the Barnett shale area in northeast Texas were responsible for several small earthquakes and concluded that the wells that were near faults, and particularly faults with stress, were the most likely to trigger earthquakes. The few studies like these suggest that permanent underground disposal of waste water is much more likely to produce earthquakes than hydraulic fracturing mainly because the water injected is permanent rather than temporary and because very large volumes can build up underground.

Europe

The EIA [31] indicated that much of the world's shale gas is probably outside of North America – in Europe, China, Argentina, and Mexico, though there has been very little development in these areas. The way that this resource is seen, and its potential for commercialization, depends largely on the individual circumstances of the country with regard to energy prices, energy supply security, and environmental concerns.

European shale areas

The most prospective areas in Europe include the eastern Baltic, north-eastern Ukraine, western Ukraine, the Balkans, central Poland, northern Germany, parts of southern Norway and Sweden, Netherlands, northern France, and northern England. European countries with the most advanced shale gas development, in terms of exploration, drilling, and licenses are Poland and the United Kingdom.

Poland

Poland appears to have a substantial shale gas resource [31]. The Polish Geological Institute [32] estimated shale gas resources in the range 346–768 billion cubic meters.

Poland also has gas supply security concerns, and as a member state of the European Union is part of ambitious plans to reduce Europe-wide greenhouse gas emissions through the EU Emissions Trading Scheme (ETS). Almost 70% of Poland's natural gas is imported (mainly from Russia) and almost 90% of its electricity is generated using local Polish coal [33]. There is therefore a

clear policy need for Poland to not only switch away from coal to generate electricity, but also to lower dependency on Russian supplies. Shale gas is therefore being considered very seriously by the Government of Poland and much of the country is licensed for gas exploration. The concession areas of exploration cover 37,000 square kilometers, which constitutes 11% of the country’s territory and extend as a wide belt from Pomerania (northeastern Poland), through Mazowsze and Podlasie (central Poland), to Lubelszczyna (southeastern Poland) [33]. By the end of 2012, companies had drilled 33 exploration wells and fracked 11 of those, but results from drilling and testing appear to have been mixed.

The United Kingdom

The United Kingdom has three main prospective areas, the north of England to the east and west of the Pennine Hills, the central lowlands of Scotland, and the Weald in south-eastern England. The largest resource is within the Bowland–Hodder shale unit (containing 1300 tcf) in the north of England; the central lowlands contain 80.3 tcf of gas, and 6.0 billion barrels of oil; and the Weald contains 4.4 billion barrels of oil [2, 34, 35].

Western European countries tend to have more diverse sources of energy supply than those in eastern Europe. The United Kingdom sources are coal, gas, and nuclear. British gas power stations use Norwegian gas and Qatari LNG. Since the peak of production from the North Sea, Britain has become a net gas importer and as British North Sea oil and gas continue to decline, dependency on imports will increase. Although British oil imports come mainly from Norway, other sources are in less stable countries and there is a concern that world events like the “Arab spring” that began in 2010, might affect Britain’s ability to source its energy. Thus, security of supply is a significant issue.

The United Kingdom has also committed to greenhouse gas reductions of 80% by 2050. Much of this reduction could be supplied by nuclear, but the cost of nuclear new build and decommissioning power stations – and the public dislike of them – has made their development more and more difficult. Another of the United Kingdom’s plans to reduce emissions while still using fossil fuels in power stations – carbon capture and storage – has been slow to start. The technology, which has only been proven on a small scale, is expensive and difficult to commercialize without a high price for carbon emissions per ton through the ETS [36]. For all these reasons the United Kingdom

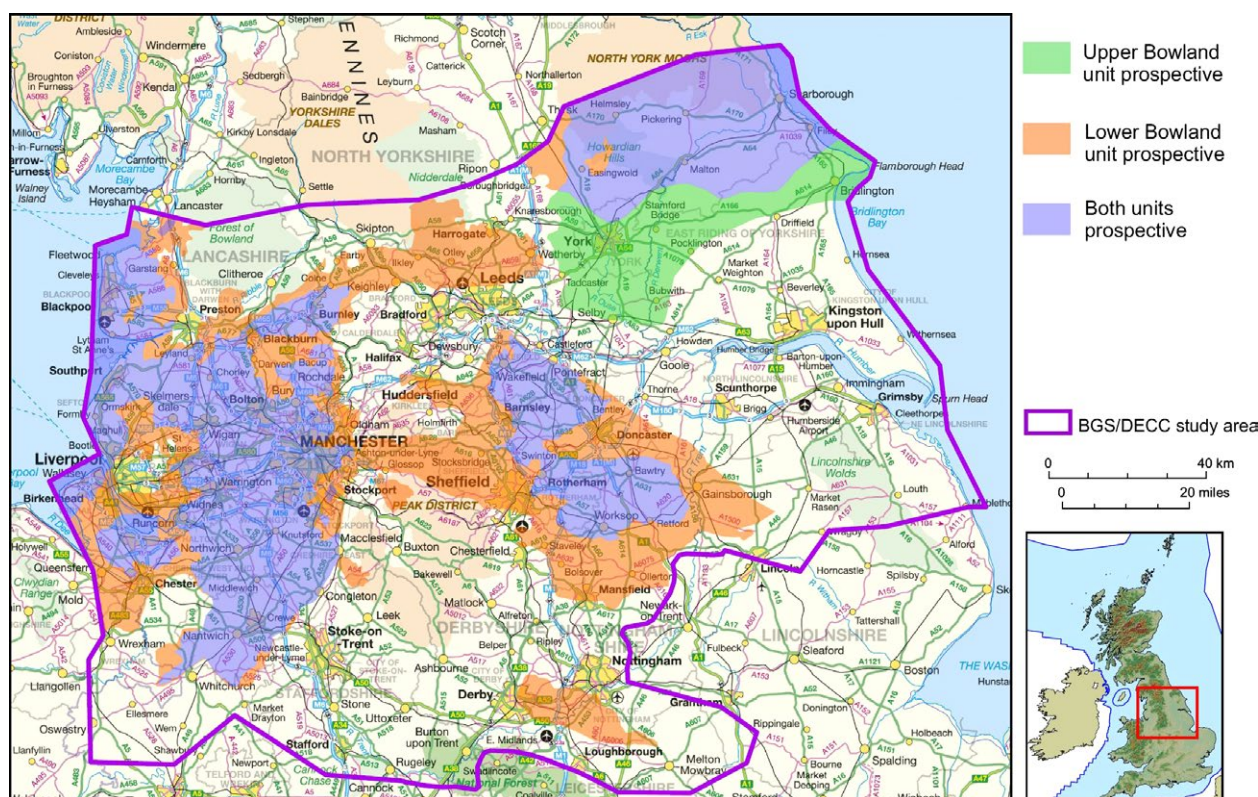


Figure 4. The two main prospective layers of shale in the North of England and their distribution with respect to population and infrastructure. From Andrews [2].

government has shown interest in the development of shale gas and is offering support, including tax incentives. As of early 2014, a percentage of revenues from production will be available to local people and local councils will receive an increase in the rates from operations.

Environmental concerns in Europe

The most detailed estimate for shale gas thus far in Europe has been that carried out in the north of the United Kingdom to assess the size of the resource in the Bowland–Hodder shale layer [2]. Among the findings of the report were a substantial resource of 1300 tcf, very thick shale layers underlying parts of the north of England either side of the Pennine hills – and crucially a concentration of prospective shale under areas with relatively high population density (Fig. 4; [2]). The cities of Manchester, Liverpool, Blackpool, Leeds, York, and Sheffield are all underlain by prospective shale as are high-value agricultural land and National Parks. The coincidence of populated areas and shale is not entirely a matter of chance since the Bowland–Hodder shale layer is related to the Coal Measures that geologically overlie it. These coal deposits fueled the 19th Century industrial revolution that encouraged human settlement.

This coincidence highlights the central problem in Europe – that shale gas resources often underlie dense populations and populations that are also unused to oil and gas drilling, unlike in the United States and Canada. This is the main reason for the overall lack of support such that there are moratoria on drilling in several countries (e.g., France, Netherlands, Czech Republic, and Bulgaria); and in many others, even with substantial resources, there is very slow progress in drilling.

In the United Kingdom there have also been some very public problems in early drilling, for example, the first attempts at hydraulic fracturing of the Bowland–Hodder shale layer near Blackpool in the northwest resulted in a number of small earthquakes, including two above 1.0 on the ML scale [37]. Following these in May 2011, hydraulic fracturing was suspended by the U.K. Government and an intensive study of hydraulic fracturing in the area was commissioned by the U.K. Department of Energy and Climate Change (DECC) and carried out by an independent panel of experts in seismology, induced seismicity, and hydraulic fracturing. Among the recommendations were that: (1) hydraulic fracturing should invariably include a smaller preinjection and monitoring stage before the main injection; (2) hydraulic fracture growth and direction should be monitored during operations; (3) future hydraulic fracturing operations in Lancashire should be subject to an effective monitoring system that can provide automatic locations and

magnitudes of any seismic events in near real time. Perhaps most important, the report recommended that operations should be halted and remedial action instituted, if seismic events of magnitude 0.5 ML or above are detected. This has become known as the traffic light system [37].

In the United Kingdom hydraulic fracturing and shale gas did not come to mass public attention, however, until protests started at a drilling site in Balcombe in the south-east of England in July 2013. Ironically the well was being drilled for a conventional accumulation of hydrocarbons (not shale) but nevertheless the site captured media attention. A large number of protesters tried to stop the drilling. This and a heavy police presence made operations very difficult so the company involved eventually suspended drilling in August 2013.

An advantage of the concerned public reaction has been a more cautious approach to shale gas development (both in terms of environment and regulation) than in North America. In the United Kingdom and Poland studies of geological conditions before hydraulic fracturing (known as baselines) have been initiated. The purpose of these is to establish if changes have occurred that could be unequivocally attributed to hydraulic fracturing.

The most important of these baselines is the British Geological Survey (BGS) Groundwater Baseline Survey which looks at the natural amounts of methane in British groundwater in areas most likely to be developed for shale gas (Fig. 5). BGS has also calculated the underground vertical separation between aquifers that carry potable water and prospective shale gas layers in a series of aquifer-shale separation maps intended for the guidance of planners, policy makers and shale gas exploration companies.

As was seen at Balcombe in the United Kingdom, even with a well-developed regulatory and licensing system for oil and gas and with exploration licenses and planning permissions in place, protests by local people can make operations difficult, or impossible. Sociologists and economists refer to general acceptance on the part of the public that a new technology can and should proceed, as *social license*. This has proved difficult to obtain for shale gas companies operating in some parts of Europe.

The nature of the extraction technique of hydraulic fracturing and the fact that it operates deep underground in an environment that for many people is unfamiliar may mean that more effort may have to be made in educating and informing the affected public. In modern democracies, the trend is toward ever increasing information and data availability often through the internet. Many people want to know precisely about the activities that might go on under their land or houses. This trend is often at odds, however, with the culture of oil and gas companies which will tend not to provide information about operations – often because they do not think it is

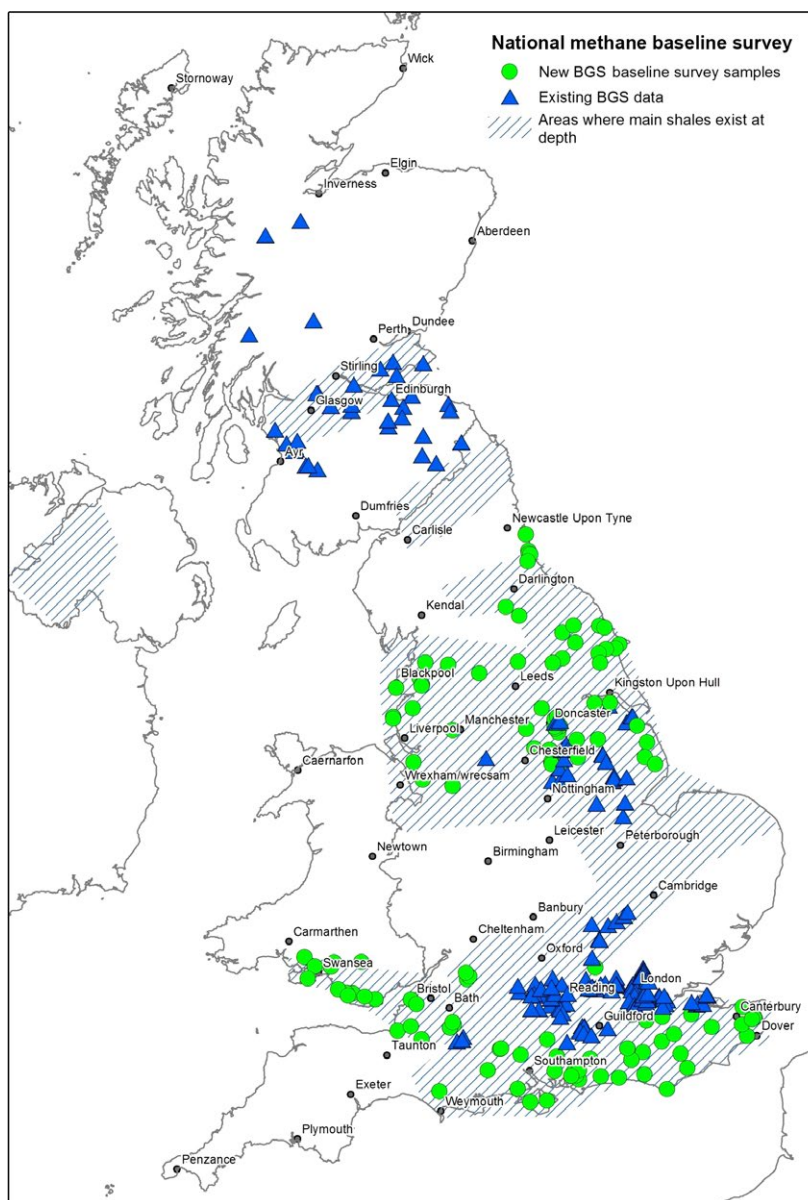


Figure 5. A survey of methane in groundwater for Britain will establish what the natural methane levels are before any shale gas extraction. British Geological Survey © NERC 2014. Contains Ordnance Survey data © Crown Copyright and database rights 2014.

necessary, or because there are matters of commercial advantage at stake. For example, a company may not want to reveal the precise contents of its hydraulic fracturing fluid because it believes that this fluid gives the company a particular commercial advantage over other companies. In the United States, the so-called “Halliburton loophole” has excused companies from disclosing all the materials that they use in their hydraulic fracturing fluids. However this is changing as companies realize that a crucial part of obtaining a social license is to be fully open in the activities and materials involved in hydraulic fracturing.

It may be however that to get social license for unfamiliar extraction techniques or any subsurface usage (e.g., deep geological radioactive disposal) may require a more radical approach. Recently it has been proposed that full disclosure of materials and activities should be accompanied by monitoring and measurement of a wide range of environmental variables, for example groundwater quality and air quality – and that the data so derived should be made open and available in real time for anyone to see [38]. The kind of monitoring involved could include seismic and groundwater monitoring, down hole sensors,

and other down hole techniques such as electrical resistivity tomography, as well as remote sensing. In the United States and Canada, dedicated websites already provide this in-depth information to allow the public to peruse local energy extraction activities and their effects on the environment.

A good example is the Alberta Government's Oil Sands Information Portal. Oil sands have only recently been considered to be part of the world's oil reserves, as higher oil prices and new technology enable profitable extraction and processing. The oil sands of Athabasca are among the most controversial in the world in relation to the environmental effects of their exploitation. Environmentalists' concerns relate to CO₂ emissions of the process by which they extracted, other non-CO₂ air pollutant emissions, the use of water in processing, the effect of exploitation on ground and surface water, and the long-term effects on landscape, wildlife and ecology. The oil sands are also a huge resource of oil, but many Albertans and other Canadians are uneasy about the effects of mining on the environment. The Oil Sands Information Portal provides environmental information on the web, as far as possible in real time, to show the effects (if any) of the processes of extraction on the environment including information on the mines and tailings ponds, and air and water quality. Another example dealing with shale gas and the environment (albeit on a smaller scale) includes Colorado Water Watch (CWW), a real-time groundwater monitoring pilot program for shale gas sites.

Conclusions

The technology of shale gas is well developed and has made a huge impact in the United States and is making an impact in Canada. Whether shale gas extraction makes an impact elsewhere in the world depends largely on the applicability of technology developed in U.S. shale layers to shale layers outside the United States, and perhaps more importantly on the public attitude to shale gas.

The technology developed in the Barnett shale was quickly adapted for widely different shales in the United States. This was helped by a generally entrepreneurial oil and gas culture, by subsurface ownership rules favorable to rapid development, and by a buoyant gas market – at least in the early years of shale gas. The variety of shale types that have been successfully exploited already within the United States is probably comparable to the amount of variety that drilling companies will encounter elsewhere in the world and so it is not unreasonable to imagine that U.S. techniques will quickly adapt to new conditions.

However, as noted before, many prospective areas in Europe, for example, are densely populated and so shale gas extraction will require very high levels of environmental assurance to gain a social license. This is probably a more

intractable problem than that of technology and may need radical solutions, for example, increasing levels of transparency in operations, including full public disclosure of data relating to extraction.

The cost of gaining a social license will likely be high in Europe, and seen against the falling prices of oil and gas, may make commercial investment less attractive and more challenging for industry both in Europe and the United States

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Conflict of Interest

None declared.

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