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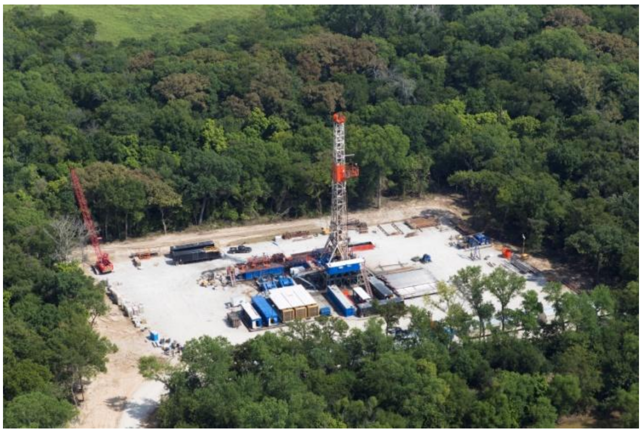
Unconventional Gas



Unconventional sources of gas have recently gained much attention due to the significant contribution they are making to US gas production. This POSTnote examines the potential for unconventional gas exploitation in the UK, the regulatory regimes covering such activity, and the issues surrounding the extraction and use of the gas.

Overview

- UK reserves of unconventional gas, principally shale gas and coalbed methane (CBM), may add an additional 50% to the UK's potentially recoverable gas resources.
- There is significant uncertainty, however, over the prospects for both gas sources. Several companies in the UK are looking to exploit them but there is currently no full-scale production.
- Gas may reduce greenhouse gas emissions by displacing coal, but there are concerns that the gas might instead supplement coal and lead to an overall increase in emissions.
- Several groups are also concerned about the local environmental impact of shale gas extraction, though the industry disputes most of their claims.
- Large-scale production of either shale gas or CBM is unlikely in the next five years.

Background

The principal component of natural gas and the main constituent of both conventional and unconventional gas is methane. The term *unconventional* refers to the source rather than the nature of the gas itself (Box 1). In the last decade, the USA has experienced a significant increase in unconventional gas production as a result of developments in extraction technology. One form of unconventional gas – shale gas – rose from only 2% of US production in 2000 to 14% in 2009, and is forecast to continue rising to more than 30% by 2020.[1] An additional 8% of US production in 2009 was supplied by a second unconventional gas source, coalbed methane (CBM). The growth in shale gas has led many countries around the world to look at exploiting their own unconventional gas resources.

Natural gas forms a key part of the UK's energy supply. A total of 86.5 billion cubic metres (bcm) of gas was consumed in 2009,[2] generating almost half the UK's electricity and fuelling the majority of residential heating. After domestic production peaked in 2000, a growing fraction of the UK's gas has been imported, raising concerns about security of supply. In 2009, imports comprised 32% of the UK's gas supply.[2]

There is also much discussion about the possibility of gas contributing to an even greater share of electricity generation to help the UK meet its greenhouse gas emission-reduction targets, as gas produces half the emissions of coal.[2]

This situation has led to significant interest in the UK's own unconventional gas resources. In particular, the Commons Energy and Climate Change Select Committee has started an inquiry into shale gas in the UK, due to report in mid-2011. In the UK, shale gas and CBM are likely to be the most important of all unconventional gas sources.

Shale Gas

Shale gas is extracted directly from shale (a sedimentary rock). This has a low permeability and so does not release gas easily. To overcome this, the rock is generally fractured ("stimulated") to yield commercial volumes of gas. In the UK, there are several layers of shale that have potential for exploitation. The largest resources are estimated to be in the Upper Bowland Shale of the Pennine Basin (underlying Lancashire and Yorkshire), with further resources in the Wessex and Weald Basins (underlying Sussex, Hampshire and Dorset).

Box 1. Conventional Gas
Fossil fuels (such as gas, oil and coal), are produced by the slow decomposition of organic matter buried underground as a result of increased temperature and pressure. With shale gas and CBM, the gas is directly extracted from the rock that was the source of the gas (shale and coal respectively). This is not the case with conventional gas reservoirs.
Over the course of hundreds of thousands of years gas (and oil) can migrate upwards and sideways out of a source rock (such as shale). In high permeability rocks this migration occurs relatively quickly, while low permeability rocks may effectively prevent migration. A conventional reservoir forms when a layer of high permeability rock (usually sandstone) is capped by an impermeable layer. This upper layer acts as a seal, trapping the oil and/or gas at the highest point and forming a reservoir (Figure 1). If the reservoir contains gas *and* oil the gas is said to be "associated", while a gas-only reservoir is "non-associated".

Tight Gas
Tight gas reservoirs form when gas is trapped in relatively low permeability rocks. It is more challenging to extract but is nevertheless considered conventional by the gas industry and has been part of the UK energy mix for several decades.

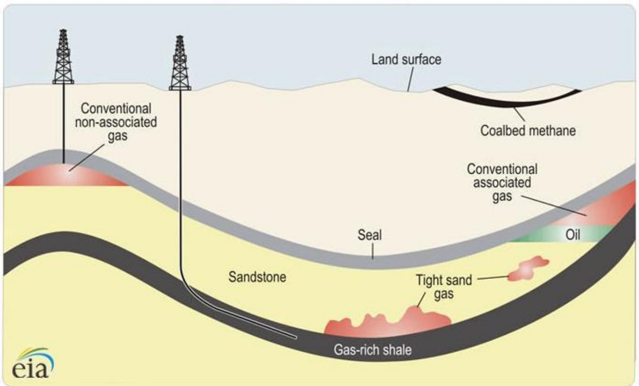


Figure 1. Schematic of the Geology of Gas Sources (EIA, USA)[1]

The potentially recoverable resources (Box 2) of shale gas in the UK are uncertain. In 2010, the British Geological Survey (BGS) estimated the figure to be 74-148 bcm,[3] while a recent study for the US Energy Information Administration puts it at 565 bcm.[1] Both estimates are small compared with the USA's more certain 'proven reserves' (Box 2) of shale gas of 1,720 bcm,[1] and compared with the UK's potentially recoverable conventional resources of 1470 bcm (of which 256 bcm are proven reserves).[2] It is possible that additional shale gas resources will be identified offshore, but as yet there is little interest in this due to higher anticipated costs.

Coalbed Methane

CBM is defined as gas extracted from intact coal seams, in contrast to gas extracted from active or abandoned mines (Box 3). Some coal seams in the UK have relatively low permeability and so fracturing may be required to extract the gas commercially.

In 2010 the BGS mapped the locations of CBM wells in the UK and areas that may be of interest for future development (principally in central Scotland, north Staffordshire, Cheshire, Humberside and south Wales).[4] It was estimated that the UK has total onshore CBM resources of 2,900 bcm. Even with a yield of 10%,[4] the potentially recoverable resources of CBM (at 290 bcm) would be larger than those of shale gas, although, this volume is also small when compared with conventional resources. Together, shale gas and CBM are likely to add no more than 50% to the UK's potentially recoverable resources.

Box 2. Reserves versus Resources
In discussing gas sources, several different terms are used to describe the volume of gas present. These differentiate the various reservoirs according to how cheap it will be to extract the gas, whether it is technically feasible and/or how much information is available for a given reservoir. The terms used here are:

- **Total Resources** (gas-in-place): the total volume of gas estimated to be present for a particular resource
- **Potentially Recoverable Resources**: the estimated volume of gas that may be recovered from the total resource. This does not consider the cost of extracting the resource.
- **Reserves**: the fraction of the potentially recoverable resources that are deemed to be commercially recoverable. This is further sub-divided into proven, potential and possible reserves based on the confidence that reserves will be recoverable. **Proven Reserves** are considered almost certain to be recoverable.

Reserves may thus be discussed with a much greater level of certainty than potentially recoverable resources.

Prospects

In the UK, there is a notable lack of information about the prospects for shale gas resources, so an extensive exploration phase is needed before production can begin. This contrasts with the situation in the USA prior to the 'shale boom' there, where a large volume of data was available from earlier conventional oil and gas exploration. Companies seeking to exploit shale gas could thus move quickly to the production stage once effective production techniques had been developed. It is also thought that UK shales will be harder to exploit than the major US basins because:

- UK basins are smaller and more fragmented
- UK source rock tends to contain less gas at lower pressure
- fracturing (see below) may be more challenging due to higher clay contents in the rock

Currently only one company, Cuadrilla Resources, is actively exploring shale gas in the UK.

For CBM, exploration is aided by the significant volume of information available on the location of coal seams in the UK and their gas contents. Substantial exploration is nevertheless required to determine the commercial prospects. At the time of writing, several companies (including Composite Energy, IGas Energy, Greenpark Energy and Centrica Energy) are exploring CBM potential in the UK.

Unconventional gas development in the UK is at an early stage. For CBM, several companies are at the pilot production stage but large-scale production in the UK is unlikely before 2016, while large-scale production for shale gas is even more distant. Shale gas in the UK is not yet at the pilot production stage, while even in Poland, one of the most advanced nations in Europe with regards to shale gas exploration, large-scale production is not expected before 2017. Additionally, development of unconventional gas sources in Europe may be constrained by a lack of equipment and the absence of a mature exploration service sector, though this point is disputed. In the mid-to-long term, development will be strongly dependent on the success of initial ventures. Should US-style expansion rates occur, it has been predicted that production from UK shales would peak in 2035.[5]

Box 3. Other Unconventional Fossil Fuel Sources

Coal or Abandoned-Mine Methane (CMM or AMM)

CMM/AMM is gas that accumulates in coal mines (either active or abandoned). As these seams have already been extensively opened up there is no need to stimulate gas production and the drilling required is minimal. The number of CMM/AMM sites in the UK is expanding, but this technology occupies a niche market and at forecast peak production will yield a maximum of 0.05 bcm/year.

Coal Gasification

Coal can be converted to a high-energy gas mixture "syngas" (composed of hydrogen, carbon monoxide and carbon dioxide), through coal gasification. This gas mixture can subsequently be combusted in a gas turbine or used as a feedstock in the chemical industries. Historically, coal was converted to syngas in industrial plants, but,several companies are now looking to perform this process *in situ* underground. The potential resources available in the UK via underground gasification are unquantified, but may be large.

Methane Hydrate

Methane hydrate, a type of ice containing up to 15% methane, forms spontaneously at low temperatures and high pressures where both gas and water are present. It is widespread in both the deep ocean (400m or more below sea level), where gas is being released into the water, and in the boreal permafrost (at depths of 200-600m). Due to the depth at which hydrates form, exploitation of this resource is technically challenging. Nevertheless, several countries are currently exploring their resources and Japan is expecting to start production in 2015. In addition, sizeable pockets of concentrated gas may be present under large hydrate deposits. Estimates place the global resources of methane hydrate at around 10,000,000 bcm (principally in the deep ocean). The UK is not anticipated to have significant resources as it has a shallow continental shelf, but further exploration is needed to confirm this.

Regulation and Legal Issues

A variety of legislation in the UK covers the individual activities associated with unconventional gas developments but does not address their use specifically for such a purpose. Regulators consider the legislation satisfactory but some groups (such as The Co-operative) have raised concerns over its adequacy for shale gas exploitation.

Regulation in the UK tends to be prescriptive in terms of objectives (derived largely from EU Directives) but operates on an 'industry best practice' and case by case basis. Companies must demonstrate how they will meet environmental and health and safety standards. Compliance is monitored by the Health and Safety Executive, the Environment Agency (EA) or the Scottish Environment Protection Agency, and by independent inspections. Both the industry and regulators believe that the regime in the UK is one of the best in the world, but some have questioned how well "best practice" can be defined. There is also concern about whether the UK has the skills base and capacity to deal with the increased burden that would be placed on regulators by a substantial increase in unconventional gas exploitation.

Licences to exploit gas are provided by the Crown (through the Department of Energy and Climate Change and the Coal Authority), as mineral rights are owned by the Crown rather than the landowner. Companies must then obtain planning permission from the local authority and obtain HSE and EA approval before drilling can begin. The Supreme Court recently ruled that a drilling company could acquire, compulsorily, rights from a landowner to drill horizontally underneath his land (*Star Energy v Bocardo*[6]). However, the industry is uncertain how this will work in the future, particularly if many landowners need to be consulted.

Extraction Issues

Site Development

In the USA, shale wells were initially drilled on individual sites. This changed with the relatively recent development of horizontal drilling, which enables the industry to use multi-well "pads" (of 8-10 wells) to extract gas from a large subterranean area (over 100 ha) from a small surface site (1-2 ha). This leads to a substantially smaller production site area in the long-term, though in the short-term the industry has acknowledged that the more intensive development associated with multi-well pads will temporarily increase local noise and light pollution and significantly increase road traffic. Reduction of noise and light pollution is possible and often required for planning consent in the UK. Companies have also stated that they will engage with local communities to mitigate the impact of their work.

Hydraulic Fracturing

The aim of hydraulic fracturing is to improve the gas flow and yield by creating a latticework of fractures in the shale or coal adjacent to bore hole. This is achieved by pumping a mixture of water, sand, and chemicals into the well at very high pressure, with the sand being used to 'prop open' the fractures once formed. Typically the fractures will extend 100 m away from the well, though longer fractures may be formed if required.

For shale wells, the total volume of water required to fracture a well is usually 9-90 million litres (equivalent to the yearly UK water use of 170 to 1700 people). Cuadrilla will use a fracturing fluid composed of 99.75% water and sand, and 0.25% chemicals. In the USA, chemical contents of approximately 2% are common,[5] with the exact composition varying between companies. In the UK, companies are required to disclose the chemicals to the regulators; Cuadrilla has further opted to disclose its list publicly. The chemicals it uses are hydrochloric acid (to clean the well), polyacrylamide (a friction reducer) and a biocide (to prevent bacterial growth). The amount of fracturing fluid that remains underground varies[5] but is significant (Cuadrilla estimates that 75% will remain in its wells) and this has caused some concern about groundwater pollution (see below). The hydraulic fracturing of CBM wells can usually be achieved using less water and fewer chemicals.

Surface Pollution

Concerns have arisen in the USA about the disposal of the excess fracturing fluid and residual fluids (which may include small amounts of heavy metals and naturally occurring radioactive materials) produced by the well. In particular, complaints have been made about the temporary storage of these fluids in open pits, which could lead to local environmental damage should the pits overflow (e.g. following heavy rain). In the UK, Cuadrilla stores the fluids in tanks before transferring them to a disposal plant to avoid this risk. Significant volumes of water are also produced by CBM wells; this are collected and, if necessary, treated before disposal in a way deemed suitable by the regulators.

Groundwater Pollution

Some anecdotal evidence from the USA and a 2008 report for Garfield County, Colorado, USA indicates the possibility of contamination of groundwater with gas and/or fracturing fluid.[7] Drilling companies have acknowledged that, as a result of a poor design or construction (Box 4), a small number of failures of the well cement has led to groundwater pollution. They contend, however, that the fracturing itself is not a problem, noting that since 1947 hydraulic fracturing has been used over 1 million times worldwide (including in the UK, though not in combination with horizontal drilling), with no proven instances of contamination. This conclusion was also reached in a 2004 report by the US Environmental Protection Agency (EPA).. However, baseline studies to monitor water pollution were not typically performed in the USA during the expansion of shale production and, amid claims by landowners of gas contaminating water supplies and increasing public concern, the EPA has commissioned a second, larger, investigation due to report in 2012.[8] The New York State Legislature also issued a moratorium on shale gas development in 2010 (later vetoed by the Governor). In the UK, WWF and The Co-operative have called for a similar moratorium until after the EPA report is completed, stating that any instance of contamination resulting from hydraulic fracturing would be very difficult to clean up.

Box 4. Well Design and Construction

Both conventional and unconventional gas wells use the same design and construction methodology, with variation between wells arising as a result of local geology rather than the source of the gas. Shale gas wells are generally deeper than CBM wells and thus are inherently more complex. CBM wells are usually 300-1,200 m deep, whereas Cuadrilla has drilled down to 2,700 m for shale gas. Drilling shale wells typically occurs in a number of stages; Cuadrilla will use four. During the drilling of each stage, metal casing is inserted into the well and this is then cemented in place to the desired depth. Each stage is narrower than the preceding one and extends from the surface to the (new) bottom of the well. With Cuadrilla's wells, the final (innermost) casing extends all the way from the surface down to the target formation, with three layers of casing between the inside of the well and any groundwater source.

Methane Emissions

In the final stage of well completion, a volume of gas is typically released from the well into the atmosphere to test its recoverability before production begins. Cuadrilla plans to burn (flare) this gas onsite rather than emit it directly, because the carbon dioxide (CO_2) produced by combustion is a much weaker greenhouse gas than the methane gas itself. Methane is also released as "fugitive" emissions during the drilling and production of both unconventional and conventional wells, and as part of the processing, transportation and storage of the gas. Such emissions were previously considered small relative to the overall emissions of natural gas, which include those from its combustion for electricity or heat generation. However, the EPA recently increased its estimates of fugitive emissions from US unconventional gas wells. [9] Howarth *et al.*[10] recently used these data and estimate that fugitive emissions from US unconventional gas are "at least 30% more than and perhaps more than twice as great as those from conventional gas". Actual emissions data are expected to be published by the EPA in mid-2012.

Meeting Emissions Targets

On the basis that the use of gas has a smaller greenhouse effect than coal (a view challenged by Howarth *et al.*[10]), natural gas has been proposed as a "bridging-fuel" to displace coal in the transition to a low carbon economy. In the longer term, the use of carbon capture and storage (CCS)[11] could further reduce emissions from both fuels. An abundance of gas caused by the exploitation of unconventional sources could reduce its cost and that of gas-based electricity. Shale gas production has already reduced the price of gas relative to oil in the US and it is expected that US gas imports will decline in the coming decades.[1] This is likely to have a knock-on effect on long-term global gas prices.[12]

Some groups are concerned that additional gas production may supplement rather than displace the use of coal, especially in countries with increasing energy demand. Even in the USA, which has a relatively stable demand, forecasts anticipate little or no decline in coal usage up to 2035.[1] There is also concern that increasing gas-based electricity generation, fuelled by abundant unconventional gas, would discourage investment in low-carbon technologies, making them less financially viable both in the UK and around the world. This would require an increased use of CCS – currently an unproven technology at industrial scales – to meet emissions targets. If the world's shale gas reserves are consumed without CCS, the Tyndall Centre has calculated that atmospheric CO_2 concentrations would rise significantly (by up to 11 parts per million).[5]

Endnotes

1 Energy Information Administration, USA (www.eia.doe.gov)
2 DECC *Digest of UK Energy Statistics* and website (www.decc.gov.uk)
3 DECC, 2010, *The Unconventional Hydrocarbon Resources of Britain's Onshore Basins – Shale Gas*
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5 The Tyndall Centre, 2011, *Shale Gas: a Provisional Assessment of Climate Change and Environmental Impacts,* and New York State, 2009, *Draft Supplemental Generic Environmental Impact Statement on the Oil, Gas ...*
6 http://www.supremecourt.gov.uk/docs/UKSC_2009_0032_ps.pdf
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POST is an office of both Houses of Parliament, charged with providing independent and balanced analysis of policy issues that have a basis in science and technology. POST is grateful to Dr Benjamin O'Driscoll for researching this briefing, to the Royal Society of Chemistry for funding his parliamentary fellowship, and to all contributors and reviewers. For further information please contact the co-author, Dr Stephen Allen, on allens@parliament.uk.