CHATHAM HOUSE

briefing paper

The 'Shale Gas Revolution': Developments and Changes

Paul Stevens

Energy, Environment and Resources | August 2012 | EERG BP 2012/04

Summary points

- The 'shale gas revolution' in the United States created an oversupply of liquefied natural gas and downward pressure on gas prices across the globe.
- Disappointing outcomes have reduced the hype about the prospects for shale gas in Europe, and led to the realization that, at least in western Europe, there are serious obstacles to its development.
- There has been considerable debate over the level of technically recoverable shale gas resources together with significant revisions to some estimates of those resources.
- Growing opposition to shale gas is driven by concerns over the environmental impact of hydraulic fracturing and the impact on greenhouse gas emissions.
- In the United States, energy self-sufficiency has increased in importance, making the continuation of the 'shale gas revolution' there more likely.
- There is a growing fear that shale gas may substitute not for coal as many originally hoped, but for renewables.
- Overall, levels of investor uncertainty remain as high as ever, particularly with regard to developments outside the United States.

Introduction

In September 2010, Chatham House published a report by this author entitled *The 'Shale Gas Revolution': Hype and Reality*. The report, after describing the 'shale gas revolution' in the United States, then considered two key questions: could the revolution continue there and could it be replicated elsewhere? The answers to both questions were ambivalent. The resulting uncertainty was beginning to inhibit investment in conventional and unconventional gas. Thus the report argued that in five to ten years' time, given that gas demand would continue to grow, there could be gas shortages because of the long lead times on projects to develop supplies. At the same time, this uncertainty threatened to inhibit investment in renewable energy on the grounds that the prospect of large volumes of cheap gas might appear to provide a cheaper route to a lower carbon economy than high-cost renewables.[1]

Since the report was published, an extremely sharp division has developed between the proponents and opponents of shale gas.[2] As battle lines were being drawn, many analysts, including this author, found themselves in a 'no man's land' between the warring parties, simply uncertain as to the realistic prospects for shale gas. A number of developments have reinforced the uncertainties emphasized in the original report. This briefing paper briefly summarizes the earlier report and provides an update on what has happened since 2010 and how this may have changed the overall picture.

What is the shale gas revolution?

The 'shale gas revolution' refers to a phenomenon that emerged in terms of domestic gas supply in the United States. Shale gas is part of what is described as 'unconventional gas'. The United States Geological Survey describes conventional gas as gas sourced from discrete fields or pools localized in structural stratigraphical traps by the boundary of gas and water. By contrast, unconventional gas is sourced from accumulations with large spatial dimensions and indistinctly defined boundaries existing more or less independently of the water column.[3] To make the distinction simpler, a conventional gas well is drilled and the gas flows in commercial quantities. For unconventional gas, drilling is not enough to generate a commercial flow. Some other artificial stimulus and special recovery processes are required. Two key technologies are especially relevant for shale gas. These are horizontal drilling and hydraulic fracturing (fracking), where water, sand and chemicals are injected into the horizontal borehole of the well at very high pressure to fracture the shale rocks and release the gas. Neither technology is new. Horizontal drilling emerged in the 1930s and the first well was fracked in the United States in 1947.

The impact of the shale gas revolution

Shale gas rose from less than 1% of domestic gas production in the United States in 2000 to over 20% by 2010. The Energy Information Administration projects that it will account for 46% of United States gas supply by 2035. Public attention was first drawn to the issue only in 2007 when the 'US Potential Gas Committee' increased its estimates of unproven US gas reserves by 45%, from 32.7 trillion cubic metres (tcm) to 47.4 tcm to allow for shale gas developments (Kuhn and Umbach, 2011).

Although the ramping up of production is relatively recent – only since 2006 have the numbers begun to be significant – the 'shale gas revolution' was over 20 years in the making. The US government poured huge amounts of R&D money into low-permeability operations, with the results being freely disseminated to operating companies. Crucially, there were many circumstances in the United States that favoured shale gas developments. These, and their implications, are described later in the paper (see also Table 1).

The 2010 Chatham House Report explained how shale gas developments in the United States were having a significant impact on global gas markets, creating an oversupply of liquefied natural gas (LNG) and downward pressure on gas prices. At the time there was a lot

1 Gas is seen as necessary to provide spinning reserve for renewables and is also cheaper than interconnectors and storage.

2 A selection of those in favour includes the Kosciuszko Institute (2011), Ridley (2011), EPRINC (2011a) and Pfeifer (2012); and those opposed include Urbina (2011) and Kennedy (2012).

3 Unconventional gas consists of tight gas, coalbed methane, shale gas and hydrates. In shale gas operations, prospective areas are called 'plays'.

of hype over the prospects for shale gas, especially in western Europe. However, analysis suggested that there were serious barriers to developing its potential. If the hype turned to reality there were prospects for cheap gas but if it did not, then as demand continued to grow eventually supplies would tighten and prices would rise. There was sufficient uncertainty to inhibit investment decisions in gas supply (conventional and unconventional) and also to raise questions about investing in higher-cost energy supplies with (allegedly) zero greenhouse gas (GHG) emissions, such as nuclear and renewables.

The impact of the shale gas revolution has been significant. The increased supply has led to a significant drop in US domestic gas prices. In 2010, prices at Henry Hub[4] were less than $5.00 per million British thermal units (MMBTU) for the second consecutive year despite the fact that in 2010 gas consumption, at 24.1 trillion cubic feet (tcf), was at a 'historic high' (EPRINC, 2011a). In 2011, according to the Energy Information Administration, the average wellhead price was $3.95 per thousand cubic feet and in February 2012 it was $2.46.[5] In general, currently future prospects for gas prices are extremely uncertain (Foss, 2011).

In addition, the global surplus of LNG capacity[6] created by the shale gas revolution has led to lower prices in what has become something of a buyer's market.[7] Certainly in Europe this has threatened to weaken the traditional (contractual) links between gas and oil prices. The growth of shale gas has also affected LNG and pipeline gas imports to the United States. Only five years ago, the expectation was that domestic US gas production would fall, leading to a sharp rise in gas imports. This led to considerable investment in LNG re-gas capacity. By 2009 this had reached 4.5 tcf, of which 75% had been built since 2005. This meant that a number of investors were very badly burnt. In similar vein, in 2011 some 90% of this capacity was idle and US imports of piped gas were at their lowest level since 1999 (EPRINC, 2011a).

Since 2010, environmental concerns have created strong opposition to fracking. This has led to several moratoria, and a great many environmental impact assessments (EIAs) were started. The debate has also become polarized and increasingly vicious.[8] Meanwhile US domestic gas prices continued their fall. However, continuing technological improvements meant that shale gas production costs also continued to fall. There was a growing realization that the technologies used to create the shale gas revolution could also be very effectively applied to increasing the production of hydrocarbon liquids. Energy self-sufficiency has increased in importance in the United States, not least because of growing concern over security of oil supplies in a world of higher prices, and also because of political uncertainties driven by the Arab uprisings. This makes it more likely that the shale gas revolution will continue in the United States, given that its technology is also assisting US domestic liquid fuels production.

Among observers of the 'shale gas revolution' there has been a growing realization that, at least in western Europe, there were serious obstacles to the development of shale gas. Disappointing outcomes reduced the hype. There have been considerable debates over the level of technically recoverable shale gas resources together with significant revisions to some estimates of those resources.

A popular backlash has built up among electricity consumers (especially in recession-hit Europe) against the apparently high costs of securing low carbon energy sources in the form of renewables and nuclear power. Since Fukushima, the latter option has moved down the agenda, leaving gas as the only obvious alternative in the short term. There is a real fear among many analysts that shale gas may substitute not for coal but for renewables.

4 Henry Hub is the main trading hub for natural gas in the US.

5 Between 2004 and 2009 the average price was $6.68.

6 Some of this 'excess capacity' has been absorbed as a result of the increased gas demand for power generation after the events in Fukushima in March 2011.

7 Of the 71 million tons of LNG capacity that came on-stream globally between 2009 and 2011, 26% was originally destined for the North American import market (Jensen, 2012).

8 An extreme example of the vitriol is provided by one critic who wrote: '… investigative journalism by the *New York Times* has brought the paper under attack by the natural gas industry. That campaign of *intimidation and obfuscation* has been orchestrated by top shelf players like Exxon and Chesapeake aligned with the *industry's worst bottom feeders*. This coalition has launched an impressive propaganda effort carried by *slick PR firms*, industry funded front groups and a *predictable cabal of right wing industry toadies* from cable TV and talk radio' (Kennedy, 2011, emphasis mine).

Overall, the levels of uncertainty identified in the 2010 Chatham House report, especially regarding shale gas developments outside the United States, have not diminished, and levels of investor confidence remain as low as ever.

Why the shale gas revolution matters

The shale gas revolution raises three key questions for the future. The first two are the same as before: can it continue in the United States, and is it possible to replicate the experience in other parts of the world? The third follows from the continuing uncertainty in response to the first two questions: what are the implications for investment in gas supplies generally, and more specifically investment in renewables?

The questions are important. All the signs indicate that in the future gas demand will grow, gaining an ever greater share in the global primary energy mix. The IEA's recent reports *Are We Entering a Golden Age of Gas?* and *Golden Rules for A Golden Age of Gas* suggest gas use could grow by more than 50% by 2035 (IEA, 2011; IEA, 2012).[9] This simply reflects the fact that the many constraints on the gas industry which had limited its share in the primary energy mix outside the Soviet Union began to disappear after 1990 (Stevens, 2010).[10] In addition, since the Fukushima disaster in March 2011, the immediate alternative of nuclear power generation looks increasingly unlikely. In the short run, the only viable option to fill this gap is the use of gas in combined cycle gas turbines (CCGT).[11]

There is a real danger that investor uncertainty will inhibit investment in future gas supplies. If the shale gas revolution can be continued and replicated this does not matter. Shale gas can provide abundant supplies of cheap natural gas. However, if it disappoints then, as the 2010 report notes, in five to ten years gas markets could face significant shortages as a result of the very long lead times on upstream gas projects.

There are also related concerns regarding renewables. There is general agreement that the world needs to reduce GHG emissions if climate change is not to become catastrophic. How this is to be done is clearly controversial. However, many see the increasing use of gas as a 'transition' fuel to a lower carbon economy (Helm, 2012), rather than building expensive renewables facilities. Thus the anticipation of cheap natural gas could inhibit investment in renewables. But again, if the revolution fails to deliver a lot of cheap gas, by the time this is realized it could well be too late to revert to a solution to climate change based upon renewables.[12]

Prospects in the United States

Two factors could threaten continuing and expanding shale gas production in the United States. The first is the current low domestic gas price, which means that the economics of all gas operations are looking very weak; a fact reflected in the collapse in the rig count, which measures the number of rigs being used for drilling gas wells. In May 2012 this was down over 30% on an annual basis. However, history suggests such low prices will not continue. Reduced drilling tightens supplies, pushing prices higher, but that is assuming gas demand does not collapse in the context of a double dip recession. Also it would appear that many of the smaller shale gas operators hedged their prices on paper markets and therefore are receiving prices well above current spot prices. Furthermore, the liquids content from shale gas operations have increasingly made the project economics look very much more favourable in view of the current levels of oil prices.

At the same time, technological developments in shale gas operations have been progressing by leaps and bounds, and producers have dramatically increased the productivity and efficiency of their drilling operations while improving well flow management (EPRINC, 2011a). Thus drilling

9 Much later in the 2011 report it points out this would be inconsistent with a global temperature rise of 2°C.

10 These included regulatory restrictions on use of gas in power in the EU and US; the monopolist–monopsonist position of many gas utilities; the lack of currency convertibility inhibiting international oil companies (IOCs) from investment in gas in many developing economies; and finally the increasing number of LNG projects adding significant flexibility to world gas trade.

11 These can be built economically on a small scale and very quickly – two years with an ability to generate within one year. They also have very high conversion efficiencies – at 60–65% compared with 30–35% for standard thermal stations. For further discussion on the impact of Fukushima see Froggatt et al. (2012).

12 It is also important to point out that, at best, natural gas can only provide a transition to a zero carbon economy. Natural gas itself remains a source of greenhouse gas emissions.

time for wells has fallen from over 30 to around 10 days per well, and decline rates[13] and initial production rates have improved over time (EPRINC, 2011a). All these technological improvements mean lower costs. In 2011, the IEA estimated that the majority of shale gas cost between $4 and $6/MMBTU, which compared favourably with most sources of gas elsewhere in the world (IEA, 2011).

Estimates from Cheniere suggest that the breakeven price at Henry Hub (assuming a 15% rate of return) is between –$0.25 and $1.00/ MMBTU for Eagle Ford liquid plays; less than $4.00 for Hayneville and Marcellus and less than $5.00 for Fayetteville and Barnet (Abiteboul, 2012).

There has been growing buy-in from the IOCs which have deep pockets and can weather short-term cashflow problems. For example, in August 2010, Mitsubishi invested around $450 million into Penn West Energy Trust's shale gas operations in Cordova Embayment in British Columbia. Also in 2010, Mitsui bought 25% of Anadarko's Marcellus assets for $1.4 billion and BHP Billiton bought Chesapeake Energy's shale interests in the Fayetteville Play for $4.75 billion.

Nevertheless there has been growing media attention suggesting that the 'recoverable resources' of shale gas and the profitability of the operations are being grossly overstated (Urbina, 2011).[14] This doubting of the estimates of resources has become widespread and reflects constant revisions of estimates in what is in any case a very uncertain area.[15] Specifically, there is a general tendency to reduce estimates of technically recoverable resources. In March 2012, Poland, which had been extremely bullish over shale gas prospects, reduced its estimates of technically recoverable resources from the Energy Information Administration's estimate of 5,300 billion cubic metres (bcm) to 346–768 bcm – a reduction to around one-tenth of the original estimates.[16]

The second threat to shale gas operations in the United States is growing concern about the negative environmental consequences of fracking, expressed in growing opposition from local communities and NGOs. The 2005 Energy Act explicitly excluded fracking from the Environmental Protection Agency's (EPA) Clean Water Act, a clause that has become known as the 'Cheney-Halliburton Loophole'. It was known that fracking involved injecting chemicals, and when companies refused to disclose which chemicals were being used, allegedly for reasons of 'commercial confidentiality', this inevitably fed conspiracy theories.[17] The Loophole also meant that not only were many shale gas operations done without a proper environmental impact assessment, since they had begun with no measurement of the 'baseline', but they could not be properly assessed after the event either.[18] The growing pressure on operators to divulge the chemicals they are using has resulted in many companies now openly declaring them. The 'Fracking Act' is currently wending its way through Congress and if successful will force all operators to divulge all chemicals.[19] In general the evidence suggests that media coverage in the United States is not favourable to

13 In the early days of the 'shale gas revolution', very high decline rates on shale gas wells were a major cause of concern (Stevens, 2010). The rapid decline rates were thought to make shale gas drilling uneconomic. However, the technology has been improving rapidly. Advanced Resources International, Inc. (quoted in EPRINC, 2011a) shows the evolution of new shale well initial production rates and 30-day production rates along with a greater average lateral (horizontal) length of new wells. The result is that 'longer lateral lengths coupled with additional fracking stages and a better feel for shale play sweet spots have combined to shift the shale production curve upwards: shale wells have higher IP rates, less steep decline rates and higher cumulative production' (EPRINC, 2011a. p. 7).

14 The *New York Times* ran a series of articles attacking the 'shale gas revolution'. However, this prompted a series of counterattacks, not least by the newspaper's own Ombudsman Arthur Brisbane. See Boehm (2011a; 2011b).

15 Arthur Berman (quoted in the articles in Urbina, 2011) argues that no one really understands the decline curve of shale gas technology and that the producers are overstating the estimated ultimate recovery factor because they include a lengthy 'runout tail' that will probably not be realized (James Jensen, private communication).

16 See also the section on replication prospects, below, and Ivanenko and Schlesinger (2012) for a discussion of other barriers to shale gas operations in eastern Europe.

17 The history of shale gas operations has been a classic example of how the oil industry consistently and regularly shoots itself in the foot. This author has been involved in numerous 'panels' at conferences on shale gas where representatives of large IOCs have dismissed concerns of fracking with the argument that 'we have been doing this for years and we know what we are doing'. It is almost as though they have never heard of the Macondo spill. A further argument from similar sources is that 'the chemicals are the sort you would find in any kitchen'. This rather ignores the fact that most kitchens carry some very lethal chemicals. Another example of very poor PR is that many presentations used to explain fracking shorten the vertical scale to get the diagram on one slide. As a result, they show the fracking layers very much closer to the water aquifers than they are in reality.

18 An EIA looks at the impact of an operation on the environment. To consider the impact, the pre-existing conditions (i.e. the baseline) need to be registered so that changes from this can be assessed.

19 In April 2011, the House of Representatives Committee on Energy and Commerce disclosed all chemicals used in fracking operations between 2005 and 2009, though excluding 'proprietary information'.

fracking. Thus the Energy Institute (2012) concluded that media coverage in the Barnett, Haynesville and Marcellus shale areas was overwhelmingly negative – about two-thirds of coverage was on the side of the opposition.

A further environmental issue is that water recovered from fracking operations may contain materials from the surrounding rocks.[20] These can include radioactive materials and heavy metals and need to be treated or properly disposed of to avoid contamination of water supply. This is another example of the need for proper regulation to minimize damage from fracking. However, a number of moratoria have been declared pending the outcome of EIAs.[21] Meanwhile, a number of smaller studies have begun to appear which suggest that problems have been overstated,[22] and that many of the environmental problems come from poor well completion rather than fracking itself. Again, this is something that can be solved by enforcing existing regulations. The signs are that fracking will be given a (largely) clean bill of health in the United States in terms of environmental impact. The conclusions of Moore (2012) appear to confirm other reports, namely that the failures of the shale gas experience in the US have been 'failures of regulation, not of the shale production technologies themselves'.

However, concerns will remain. A recent review of fracking by the University of Texas's Energy Institute (Sample, 2012), while concluding that there was little or no evidence of fracking contaminating aquifers, urged states to do more to prevent accidents. Certainly a large number of recommendations are being put forward for minimizing the negative effects of future shale gas operations (US Department of Energy, 2011). These range from calls for greater transparency, communication and information-gathering to enforcement of existing regulations.

Another environmental concern that has surfaced relates to the role of shale gas and climate change. Given the greater energy required to produce shale gas, it might be expected that CO_2 emissions would be higher than for conventional gas. Also methane is a very powerful GHG and therefore leakages associated with shale gas operations could be serious. In 2011 a study by the Tyndall Centre at Manchester University (Wood et al., 2011) concluded that shale gas operations accounted for around only 0.29–2.9% more CO_2 emissions than conventional gas production; however, it (explicitly) excluded methane leakages. Until recently the only other study covering methane emissions relating to shale gas operations came from Cornell University (Howarth et al., 2011). This concluded that shale gas produced more emissions than coal. However, the study was criticized for several reasons. First, it took a life-cycle of 20 years as well as the 100 years normally taken in such studies. Given that methane's shelf life as a GHG is around 20 years, the shorter life-cycle measurement overstates the climate change impact of shale gas.[23] Secondly, the study assumed very high levels of leakage (Cathles et al., 2012).[24] Finally, it neglected the fact that coal production also generates methane leakages.

Different conclusions are reached in other more recent studies in peer-reviewed journals, such as Hultman et al. (2011), Jiang et al. (2011) and Skone (2011). Skone found a relatively minor GHG difference between conventional and unconventional gas. Jiang et al. concluded that natural gas from the Marcellus shale had generally lower life-cycle GHG emissions than coal for the production of electricity in the absence of any effective carbon capture and storage processes. The difference was 20–50% depending upon plant efficiencies and variability of natural gas emissions.

20 For an analysis of the role of water in fracking operations see Robart (2012).

21 Some are state-level restrictions, such as New York State imposing a moratorium on oil and gas drilling. In Pennsylvania an executive order barred further natural gas developments of state forest lands and the Delaware River Basin Commission imposed a moratorium in the Marcellus area within the basin. Maryland passed the Shale Safe Drilling Acts of 2011, restricting operations in the Marcellus until 2013 and the completion of a two-year drinking-water EIA. Moratoria have also been introduced at much more local levels. For example, Bartonville, a small town on the Barnet Play, introduced a 90-day moratorium on new permits for drilling and fracking. The EPA is currently undertaking a major study, with the initial results expected at the end of 2012 and a full report by mid-2014.

22 For example, MIT 2011 examined 20,000 wells drilled and only identified 43 'incidents'.

23 Howarth et al. argued that taking 20 years was justified if there was the danger of an imminent tipping point in the global climate.

24 However, the level of methane leakages is controversial; see Tollefson (2012). The IEA (2012) produced a figure (p. 40, Figure 1.5) showing that the range of methane leakages was crucial to the global warming potential of gas production. However, it is worth pointing out that 40% of methane leakages arise from natural causes and 38% from livestock and agriculture (IEA, 2012). A healthy cow produces between 100 and 500 litres per day of methane from both ends.

In similar vein, Hultman concluded that for electricity generation the GHG impacts of shale gas were only marginally (11%) higher than those of conventional gas, and remained substantially lower than those of coal.[25] The IEA (2011) concluded that shale gas produced to proper standards resulted in 'slightly higher' well-to-burner tip emissions than conventional gas. In its more recent publication (IEA, 2012) it points out that the GHG emissions impact is crucially dependent on the assumed level of leakage from operations. However, the debate continues (Howarth et al., 2012) and clearly much more research is needed before definitive conclusions can be reached.[26]

A key factor concerning the future of shale gas operations in the United States concerns the issue of import dependence and the long-standing goal of 'energy independence'. President Nixon started this in November 1973 at the time of the first oil shock. It called for energy self-sufficiency for the United States by 1980. This was followed by President Carter's speech in April 1977 describing the 'energy crisis' as the 'moral equivalent of war'. Subsequent presidents have expressed similar sentiments. Energy self-sufficiency remains a politically powerful objective in the United States and is a key priority for the still institutionally powerful neo-conservatives. It has been pushed back onto Washington's agenda by the events associated with the Arab uprisings in 2011 (Stevens, 2012) and the growing tensions over the Iranian nuclear programme. In this context, shale gas represents manna from heaven. Thus Medlock et al. (2011) argued that it would reduce the petro-power of major conventional gas producers in the Middle East, Russia and Venezuela.

Furthermore these arguments are reinforced because technology developed for shale gas is transforming the production of liquids. Thus, as EPRINC (2011b) concludes, there is huge scope for transferring shale gas technology to liquid plays in a number of basins.

One source has estimated that liquids from shale plays (crude and natural gas liquids) will rise from 2 million b/d in 2011 to over 7 million b/d by 2020, giving a payback period of 1.5–2.5 years at $100 per barrel (Abiteboul, 2012). It is inconceivable that Washington would do anything to prevent a reduction in dependence upon imported oil.[27]

For all these reasons, the contribution of shale to gas supplies in the US will continue to grow. One source has suggested that after 2030 it will account for 50% of domestic gas consumption (Medlock et al., 2011). This virtually matches the Energy Information Administration's forecast that by 2035, shale gas will account for 49% of domestic production (EIA, 2012). The shale gas revolution has also given rise to speculation that the United States could become an exporter of LNG[28] (Abiteboul, 2012; Jensen, 2012; Ebinger et al., 2012). By 2012, eight projects were being considered with a total capacity of 15.5 billion cubic feet per day (bcfd). One project – Sabine Pass at 2.2 bcfd – has already been approved by the Department of Energy (Abiteboul, 2012). However, whether Washington would be happy to see large-scale LNG exports is another matter. They would significantly diminish the prospects of a security of supply advantage and almost certainly lead to higher domestic gas prices. Thus while there are a large number of potential projects it is likely that regulatory requirements will limit the number that are finally approved (Jensen, 2012). However, this debate is only just beginning (Ratner et al., 2011; Ebinger et al., 2012). In February 2012, Representative Ed Markey introduced two natural gas export bills to Congress which would ban any LNG exports from the United States.

Prospects outside the United States

There appear to be very large amounts of technically recoverable resources of shale gas located throughout the world; in 2007, the US National Petroleum Council estimated the global figure to be 16,112 tcf, compared with

25 One of the issues concerns whether the shale gas is used for electricity generation or heat. Most of the existing studies focus on GHG emissions in the context of electricity generation.

26 Howarth et al. (2012) provide a table comparing the emissions cited in a number of studies.

27 The in-joke among oil analysts in 2011 was that North Dakota would become the next member of OPEC. By the end of 2011, it was producing more oil than Ecuador.

28 The prospects of greater shale gas supplies have also revived the United States' prospects of getting back into petrochemicals in a big way.

proven conventional gas reserves of 6,609 tcf. In 2011, the US Energy Information Administration estimated the shale gas resources for 32 countries at 6,622 tcf, compared with conventional gas reserve estimates for those countries of 1,274 tcf. While such estimates need to be treated with great caution[29] (and scepticism[30]), shale gas undoubtedly has considerable production potential. However, it is worth pointing out that revisions of resource estimates tend to be lower than before, suggesting greater conservatism in the estimation process (World Energy Council, 2011).

The question is how far the conditions that created the shale gas revolution in the United States can be replicated elsewhere, allowing the resources to be converted into actual production. Table 1 presents a comparison between the United States and western Europe.

The differences listed in Table 1 suggest that while shale gas will eventually play an increased role in European energy, little of significance is likely within a five- to ten-year time-frame.[31] There are growing pressures in Europe from NGOs to restrict shale gas operations.[32] In the UK, the BBC website reported (29 May 2012) there was strong opposition from environmental groups even to the words 'Golden Age of Gas' in the title of the IEA's recent report (IEA, 2011), on the grounds that increasing gas use by more than 50% would risk temperature rises that would be catastrophic. France and Bulgaria have already banned shale gas operations. The UK has so far resisted pressure. The House of Commons Select Committee on Energy and Climate Change (House of Commons, 2011) has given fracking a clean bill of health and the Department of Energy and Climate Change has rejected calls (from the Tyndall Centre) for a two-year moratorium. In Germany, where there is very strong local opposition to shale gas operations, ExxonMobil voluntarily agreed to a moratorium on its operations pending an EIA. Within the EU generally, there is considerable concern that there are many serious loopholes in the regulatory environment, and a major report produced in 2011 for the European Parliament concluded that because of risks to the environment and human health what was needed was a new directive at European level to provide comprehensive regulation covering all issues in the context of shale operations (European Parliament, 2011). Much hinges on the quality of the operations. The IEA, in its *Golden Rules for a Golden Age of Gas*, correctly points out that 'full transparency, measuring and monitoring of environmental impacts and engagement with local communities are critical to addressing public concerns' (IEA, 2012, p. 10).

However, it is possible that the gathering environmental concern regarding shale gas operations and their political fallout may seriously inhibit the development of shale gas in Europe. Unfortunately it appears to be an area where popular ignorance overrules science (Energy Institute, 2012). The most recent study concluded that the 'health, safety and environmental risks associated with hydraulic fracturing … as a means to extract shale gas can be managed effectively in the UK as long as operational best practices are implemented and enforced through regulation' (Royal Society and Royal Academy of Engineering, 2012, p. 4).[33] However, if the public has become convinced that shale gas operations are 'bad' then no amount of scientific study or knowledge will counter this. The IEA (2012) has a Low Unconventional Case, where it assumes that – primarily because of a lack of public acceptance – unconventional gas production in aggregate rises only slightly above current levels by 2035.

29 In the words of one study, 'Whilst estimates of unconventional gas resources in the United States remain very uncertain, this is eclipsed by the much greater uncertainty surrounding unconventional gas resources in the rest of the world' (McGlade et al., 2011, p. 1). This report provides an excellent survey of estimates of unconventional gas resources.

30 Cuadrilla, a company operating in the UK, has claimed that the technically recoverable shale gas resources in North West England amount to 210 tcf. UK proven gas reserves are 9 tcf. This 210 tcf estimate was based upon only two-and-a-half wells being drilled. Also Cuadrilla is not listed on any stock exchange and can therefore claim whatever it likes with impunity.

31 To provide just one example of slower development, of the 127 test wells promised in all the exploration licences in Poland, by mid-2011 only seven had actually been drilled (Overbeek, 2011).

32 These received a major PR boost when it was established that Cuadrilla's fracking of wells caused (albeit very) minor earthquakes in Blackpool.

33 However, the report also stated that 'Neither risks associated with the subsequent use of shale gas nor climate risks have been analysed' (p. 5). Thus there is likely to be continued opposition from those driven by concerns about climate change, who regard shale gas as simply extending the life of fossil fuels as a source of energy and therefore supporting a carbon-based economic system.

Table 1: Factors creating the 'shale gas revolution' in the United States as compared with Europe

Conditions in the United States which generated the 'shale gas revolution'	Conditions in Europe which could inhibit replication
Geology	
1. Large shallow, material plays, implying large technically recoverable resources.	1. Shale plays are smaller, deeper, less material and with a high clay content, making fracking more difficult.
2. Plenty of drill core data available to allow explorers to find the 'sweet spots' on the plays.	2. Very limited core data, much of which has been 'lost'.
Regulation	
1. 2005 Energy Act explicitly excludes hydraulic fracturing from the Environmental Protection Agency's Clean Water Act – the so-called 'Cheney-Halliburton Loophole'.	1. Very strict regulations regarding environmental issues and water. For example, both Poland and the UK Environment Agency require full disclosure of fracking fluids. Also 'Groundwater protection and waste treatment are stronger [than the US] in the UK' (Moore, 2012, p. 10). However, unconventional hydrocarbons are not even mentioned in the petroleum regulations. Regulatory uncertainties are slowing down shale gas development in many countries (World Energy Council, 2011).
2. The 1980 Energy Act gave tax credits amounting to 50 cents per million BTUs. It also introduced the Intangible Drilling Cost Expensing Rule, which covered (typically) more than 70% of the well development costs, crucial for small firms with a limited cash flow.	2. Only Hungary has some small tax credits for unconventional operations. Otherwise there are no financial dispensations for unconventional gas.
3. Property rights in the United States make the shale gas the property of the landowner, creating a financial incentive for private owners to allow the disruptions associated with shale operations. Also, the population is used to proximity to oil and gas operations.	3. Property rights reside with the state and landowners receive no compensation or reward. This is in a context where shale gas operations are extremely disruptive. It has been likened to 'the circus coming to town'. Onshore oil and gas operations are not common in Europe. However, shale gas operations can create significant levels of employment, which may enhance their attractiveness to local communities.
4. Pipeline access is based upon 'common carriage' so gas producers have some access to existing pipelines, transforming the economics of shale gas production.	4. Pipeline access is based upon 'third part access' which means if the pipeline is full any gas suppliers must build their own pipeline to access markets.
5. The US is a 'commodity supply gas market', i.e. a lot of buyers and sellers and good price transparency. Gas is easy to sell.	5. Europe is a 'project supply market' with few buyers and sellers and poor price transparency. Transaction costs to buy and sell gas are high.
Industry	
1. The industry was dominated by small, entrepreneurial companies, the so-called 'momma and poppa' companies.	1. While there are some small operators, the industry traditionally was dominated by large players. This could have interesting consequences. For example, in Poland, where shale gas is seen as the key to 'liberation' from dependence on Russian gas imports (65%), the IOCs dominate and it is possible that much of the shale gas produced could be exported via the Russian-controlled pipeline network (Overbeek, 2011).
2. The majority of the work was done by a dynamic, highly competitive service industry. At the height of operations in the Barnet Play in 2008, 199 rigs were operating	2. The service industry is an American-dominated oligopoly. In July 2010 there were only 34 lands rigs in all of western Europe. It has been suggested that drilling a shale gas well in Poland costs three times as much as in the United States, reflecting the lack of service industry competition (Pfeifer, 2012). Another estimate suggests drilling a shale well in Europe costs $6.5–14 million compared to $4 million on the Marcellus (Deutsche Bank, 2011).
3. The system is used to license large areas for exploration with fairly vague work programme commitments, which is what is needed when dealing with shale plays.	3. Licensing acreage traditionally covers relatively small areas with strict work programmes.
Research	
1. In 1982 the US government began extensive funding of R&D by the Gas Technology Institute into 'low permeability hydrocarbon bearing formations'. The results were widely disseminated to the industry.	1. According to the CEO of ExxonMobil, the technology does not translate well into European geology (Carroll, 2012). The EU Commission shows no willingness to invest in basic R&D for shale gas, arguing that it should be left to the market.

There is likely to be a further complication that has not yet surfaced. A key characteristic of shale gas is that no two operations are the same. Thus shale plays differ and even wells on the same play differ. Even if shale gas operations are given a clean bill of environmental health in play A, there can be no certainty that these results can be extrapolated to play B. This is likely to become an increasingly commonly heard argument against shale gas even given positive results from EIAs.

In general, it is fair to say that in the last couple of years in Europe, much greater reality has entered views on the future of shale gas. Disappointing results in Hungary and increasingly in Poland are forcing many previous missionaries for shale gas to reconsider their positions.

As for other geographic areas, the prospects appear better. This is simply because many of the obstacles in Europe arise from opposition within local communities. In other parts of the world this is less of a problem. For example, China, which has very large resources of shale gas, is pushing ahead strongly to develop its potential in a context where the Americans have agreed to allow it to use their technology.[34] In March 2012, China's National Energy Administration (NEA) announced the first five-year plan for the shale gas sector, with output targets of 6.5 bcm in 2015 and 60–100 bcm in 2020.[35] However, timing is again a key uncertainty, and a recent study concluded that it was doubtful whether more than 10 bcm/year could be produced within the next decade (Gao, 2012). The constraints cited included technological capacity, water usage and land access. Current gas price restrictions in China are also likely to raise questions over the economics of shale gas projects.

Argentina is another country where hopes are high. Its shale resources are thought by some to be the third largest in the world and a boom is beginning around Neuquén in Patagonia (Pfeifer, 2012). In November 2011, Repsol announced it was to invest $20 billion to develop an extensive shale oil and gas play discovered at Loma La Lata.

Conclusions

Several conclusions can be drawn from the above analysis. Environmentally based opposition to shale gas operations is growing apace,[36] especially in Europe, and the debate is becoming increasingly polarized and even vicious. This debate is also coinciding with much greater scepticism regarding the levels of technically recoverable shale gas resources. Newer estimates tend, almost without exception, to be lower than previously claimed. At the same time there is growing realization in Europe that there are serious obstacles to replicating the experience in the United States. Much of the earlier hype has dissolved and the dates for significant impact are being extended.

In terms of gas markets the shale gas revolution is already having an impact. It has created an oversupply of LNG and a general downward pressure on gas prices. However, the current uncertainties regarding the future raised in the original Chatham House Report in 2010 remain unresolved. How far technically recoverable resources of shale gas will translate into actual production continues to create serious investor uncertainty. If the hype turns into reality, then world energy markets can look forward to floating on clouds of cheap gas, certainly up to 2030, if not beyond. However, if the hype remains hype then current investor uncertainty will limit future gas supplies. Assuming gas demand continues to increase, the effect in the next five to ten years would be much higher gas prices.

A further consequence of the prospects for cheap gas has already been mentioned. Concern is growing among energy consumers in many countries that the cost of renewables to try to mitigate climate change is too high and likely to rise even higher. The argument is being heard (Helm, 2012) that gas provides an obvious transition fuel to a lower carbon economy, especially if the shale gas revolution increases supply and keeps prices low. However, if this argument begins to gain traction, then gas could well end up substituting not for (cheap) coal but for (relatively expensive) renewables. In terms of climate change concerns, this is seriously bad news.

34 However, it appears that shale plays in China may not be suited to the technology developed for the United States (Carroll, 2012).

35 In 2010, China's gas consumption totalled 109 bcm (BP, 2011).

36 It has been suggested to the author than the environmentalists in the United States are beginning to lose this particular battle. The current administration appears to favour shale gas and a new Republican administration would be even more favourably inclined.

References

Abiteboul, J. (2012), ‘What is the Time Line for LNG Exports from the USA?’, presentation to the Flame Conference in Amsterdam, 18 April.

Boehm, K. (2011a), ‘NY Times Asked to Investigate Shale Gas “Bubble” Series’, National Legal and Policy Center (http://nlpc.org), 7 July.

Boehm, K. (2011b), ‘NY Times Ombudsman Critical of Shale Gas “Bubble” Series’, National Legal and Policy Center (http://nlpc.org), 18 July.

BP (2011), *Statistical Review of World Energy 2011* (London: BP).

Carroll, J. (2012), ‘Fracking failing to crack China, Europe shale, Exxon says’, Bloomberg, 8 March.

Cathles, L. M., Brown, L., Taam, M. and Hunter, A. (2012), ‘A Commentary on “The Greenhouse Gas Footprint of Natural Gas in Shale Formations” by R.W. Howarth, R. Santoro, and Anthony Ingraffea’, *Climatic Change* 113.

Deutsche Bank (2011), *European Gas: A First Look at European Shale Gas Prospects*, Deutsche Bank, Commodities Special Report, 20 October.

Ebinger, C., Massy, K. and Avasarala, G. (2012), ‘Liquid Markets: Assessing the Case for US Exports of Liquefied Natural Gas’, Policy Brief 12-01, Brookings Institution, Washington, DC, May.

EIA (2012), *2012 Annual Energy Outlook*, Energy Information Administration, Washington, DC.

Energy Institute (2012), *Fact-based Regulation for Environmental Protection in Shale Gas Development. A Report for the Energy Institute*, The University of Texas at Austin, http://www.energy.utexas.edu/images/ei_shale_gas_regulation120215.pdf.

EPRINC (2011a), ‘Natural Gas Industry Fakes the Moon Landing’, EPRINC Briefing Memorandum, Washington, DC, 1 July.

EPRINC (2011b), ‘The Bakken Boom: An Introduction to North Dakota’s Shale Oil’, EPRINC Briefing Memorandum, Washington, DC, 7 July.

European Parliament (2011), ‘The Impact of Shale Gas and Shale Oil Extraction on the Environment and Public Health’, Report from Policy Department A: Economic and Scientific Policy, Directorate General for Internal Policies.

Foss, M. M. (2011), ‘The Outlook for US Gas Prices in 2020: Henry Hub at $3 or $10?’, NG 58, Oxford Institute for Energy Studies, December.

Froggatt, A., Mitchell, C. and Manaqi, S. (2012), *Reset or Restart? The Impact of Fukushima on the Japanese and German Energy Sectors*, Chatham House Briefing Paper, July.

Gao, F. (2012), ‘Will There Be a Shale Gas Revolution in China by 2012?’, NG 61, Oxford Institute for Energy Studies, April.

Helm, D. (2012), ‘EU Energy Policy and the Role of Gas in Decarbonisation’, presentation to the Flame Conference in Amsterdam, 17 April, http://www.dieterhelm.co.uk/sites/default/files/FLAME%20D%20Helm.pdf.

House of Commons (2011), Shale Gas. Energy and Climate Change Committee. Fifth Report of Session 2010–12, London.

Howarth, R. W., Santoro, R. and Ingraffea, A. (2011), ‘Methane and the Greenhouse-gas Footprint of Natural Gas from Shale Formations’, *Climate Change Letters* 106: 679–90.

Howarth, R. W., Santoro, R. and Ingraffea, A. (2012), ‘Venting and Leaking from Shale Gas Development: Response to Cathes et al.’, *Climatic Change* 113.

Hultman, N., Rebois, D., Scholten, M. and Ramig, C. (2011), ‘The Greenhouse Impact of Unconventional Gas for Electricity Generation’, *Environmental Research Letters* 6.

IEA (2011), *Are We Entering a Golden Age of Gas?*, Special Report, International Energy Administration, OECD, Paris.

IEA (2012), *Golden Rules for a Golden Age of Gas*, Special Report on Unconventional Gas, International Energy Administration, OECD, Paris.

Ivanenko, V. and Schlesinger, B. (2012), ‘Political Economy of Shale Gas Industry in Eastern Europe’, IAEE Energy Forum, First Quarter 2012.

Jensen, J. (2012), ‘LNG Exports from North America: How Competitive Are They Likely to Be?’, Presentation to the Paris Energy Club, 4 May.

Jiang, M., Griffin, W. M., Hendrickson, C., Jaramillo, P., Van Briesen, J. and Venkatesh, A. (2011), ‘Life Cycle Greenhouse Gas Emissions of Marcellus Shale Gas’, *Environmental Research Letters* 6.

Kennedy, J. F. (2011), ‘The Fracking Industry’s War on the *New York Times* – and the Truth’, http://www.huffingtonpost.com/robert-f-kennedy-jr/fracking-natural-gas-new-york-times-_b_1022337.html.

Kosciuszko Institute (2011), ‘Unconventional Gas – a Chance for Poland and Europe? Analysis and Recommendations’, Kosciuszko Institute, Krakow.

Kuhn, M. and Umbach, F. (2011), ‘Strategic Perspectives of Unconventional Gas: A Game Changer with Implications for the EU’s Energy Security’, EUCERS Strategy Paper, King’s College London.

McGlade, C., Speirs, J. and Sorrell, S. (2011), ‘A Review of Regional and Global Estimates of Unconventional Gas Resources. A Report to the Energy Security Unit of the Joint Research Centre of the European Commission’, 15 December.

Medlock, K. B., Jaffe, A. M. and Hartley, P. R. (2011), ‘Shale Gas and U.S. National Security’, Baker Institute, Rice University, Houston, TX, July.

MIT (2011), *The Future of Natural Gas*, MIT, June, available at http://web.mit.edu/mitei/research/studies/documents/natural-gas-2011/NaturalGas_Report.pdf.

Moore, S. (2012), *Gas Works? Shale Gas and Its Policy Implications*, Policy Exchange Report, London.

Overbeek, E. (2011), 'Shale Gas Doesn't Make Poland the New Norway Yet', *European Energy Review*, 14 June.

Pfeifer, S. (2012), 'Finds that form a bedrock of hope', *Financial Times*, 22 April.

Ratner, M., Parforak, P. W. and Luther, L. (2011), *U.S. Natural Gas Exports: New Opportunities, Uncertain Outcomes*, CRS Report for Congress 7-5700, Congressional Research Service, Washington, DC, 4 November.

Ridley, M. (2011), *The Shale Gas Shock*, GWPF Report 2, Global Warming Policy Foundation, London.

Robart, J. (2012), 'Water Management Economics in the Development and Production of Shale Resources', IAEE Energy Forum, First Quarter 2012.

Royal Society and Royal Academy of Engineering (2012), 'Shale Gas Extraction in the UK: A Review of Hydraulic Fracturing', Royal Society and the Royal Academy of Engineering, London, June, available at http://royalsociety.org/policy/projects/shale-gas-extraction and raeng.org.uk/shale.

Sample, I. (2012), 'Scientists call for stricter rules of shale gas "fracking"', *Guardian*, 17 February.

Skone, T. (2011), *Life Cycle Greenhouse Gas Analysis of Natural Gas Extraction and Delivery in the United States*, National Energy Technology Laboratory, US Department of Energy, Pittsburgh, PA.

Stevens, P. (2010), *The 'Shale Gas Revolution': Hype and Reality*, Chatham House Report, September.

Stevens, P. (2012), *The Arab Uprisings and the International Oil Markets*, Chatham House Briefing Paper, February.

Tollefson, J. (2012), 'Air Sampling Reveals High Emissions from Gas Field', *Nature*, Vol. 482, 9 February.

Urbina, I. (2011), 'Insiders sound an alarm amid a natural gas rush', *New York Times*, 24 June. (There were two further articles on 25 and 26 June.)

US Department of Energy (2011). 'Shale Gas Production Sub-Committee – Second Ninety Day Report', US Department of Energy, Washington, DC, 18 November.

Wood, R., Gilbert, P., Sharmina, M., Anderson, K., Footitt, A., Glynn, S. and Nicholls, F. (2011), 'Shale Gas: A Provisional Assessment of Climate Change and Environmental Impacts', Tyndall Centre Technical Reports.

World Energy Council (2011), 'Survey of Energy Resources: Shale Gas – What's New?', World Energy Council, London.

Chatham House has been the home of the Royal Institute of International Affairs for ninety years. Our mission is to be a world-leading source of independent analysis, informed debate and influential ideas on how to build a prosperous and secure world for all.

Professor Paul Stevens is Senior Research Fellow for Energy at Chatham House and Emeritus Professor at Dundee University. He was educated as an economist and as a specialist on the Middle East at Cambridge and at SOAS, London. He taught at the American University of Beirut in Lebanon (1973–79); the University of Surrey (1979–93); and as Professor of Petroleum Policy and Economics at CEPMLP, University of Dundee (1993–2008). He is also Consulting Professor at University College London (Australia). He won the 2009 OPEC Award in recognition of his outstanding work in the field of oil and energy research for his services to petroleum research.

The author would like to thank the following for comments on an earlier draft: at Chatham House, Antony Froggatt, Bernice Lee and Gemma Green; at Clingendael, Coby van der Linde and Lucia van Geuns; and Jim Jensen from Jensen Associates. Also thanks are due to Margaret May and Nick Bouchet for editing skills. Obviously all errors are the responsibility of the author.

Chatham House
10 St James's Square
London SW1Y 4LE
www.chathamhouse.org

Registered charity no: 208223

Cover image © Getty Images/Spencer Platt
Designed and typeset by Soapbox, www.soapbox.co.uk