HOUSE OF LORDS

SELECT COMMITTEE ON ECONOMIC AFFAIRS

The Economic Impact on UK Energy Policy of Shale Gas and Oil

Oral and Written Evidence

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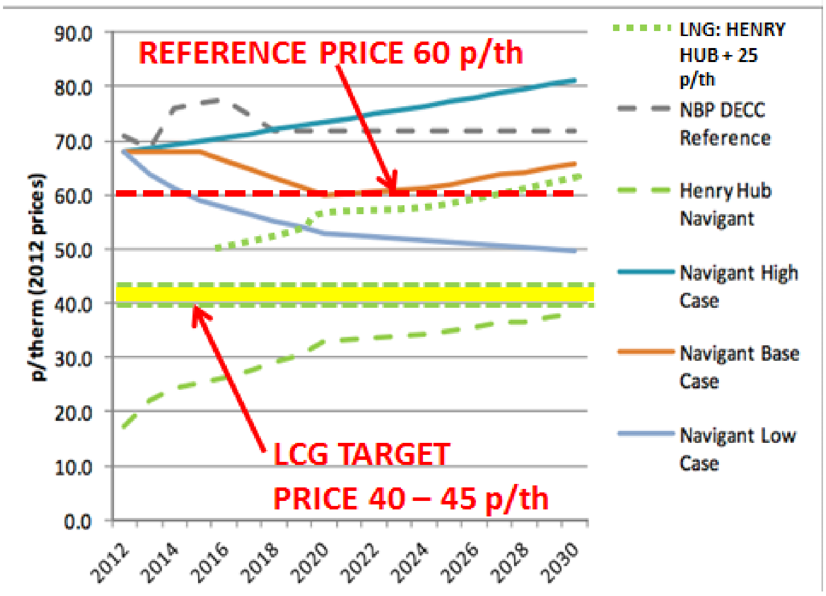
A.R Day—Written evidence

EXECUTIVE SUMMARY

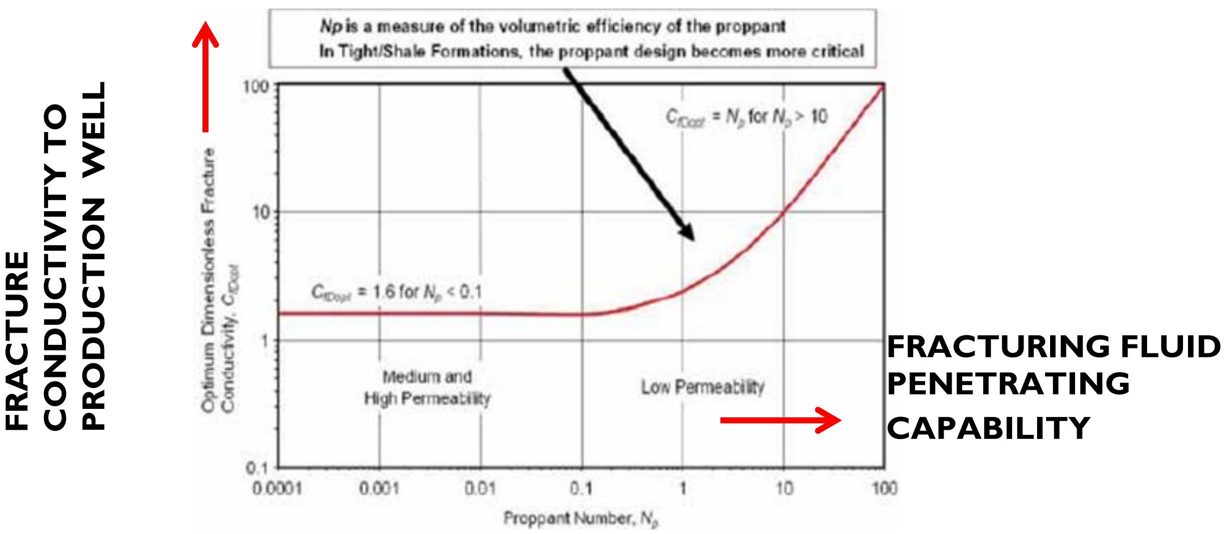
Figure 1: Gas Price Scenarios



1. DECC's central projected UK gas price is 60 p/therm based on convergence with Henry Hub price plus 25 p/therm LNG liquefaction and shipping costs. Shale gas costs reduce by around 50% if the estimated ultimate recovery (EUR) increases from 10% to 30%. Low Carbon Gas can be produced for 40 to 45 p/therm. Taken together, this could partly decarbonise gas supplies at source and reduce the price of storable gas to around 50 p/therm, and the implied price of dispatchable gas fired power generation to around £50/MWh.

2. High pressure carbon negative Low Carbon Gas (LCG) can be produced at 76.75% efficiency for 40 to 45 p/therm, plus 99.6% pure supercritical CO_2 at 40 p/tonne, excluding site specific Transport and Storage costs approximately 25 to 33% per unit energy the T and S costs of CCS on fossil fuel power generation.

3.

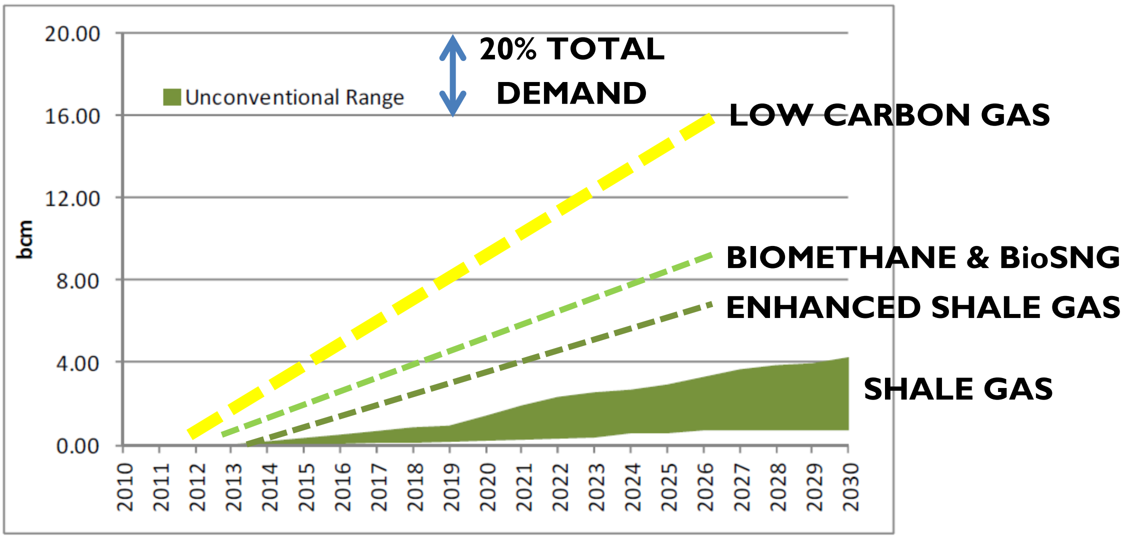


4. The viscosity of supercritical CO_2 is 2 orders of magnitude less than the viscosity of water thus increasing its penetrating power when used for fracking. 5 molecules of CO_2 will selectively desorb 1 molecule of CH_4 from the surface of shale particles. Dissolved CO_2 reduces the viscosity of shale oil. Supercritical CO_2 can be used for oil and gas well re-pressurisation. This can increase estimated ultimate recovery from 10% to around 30%.

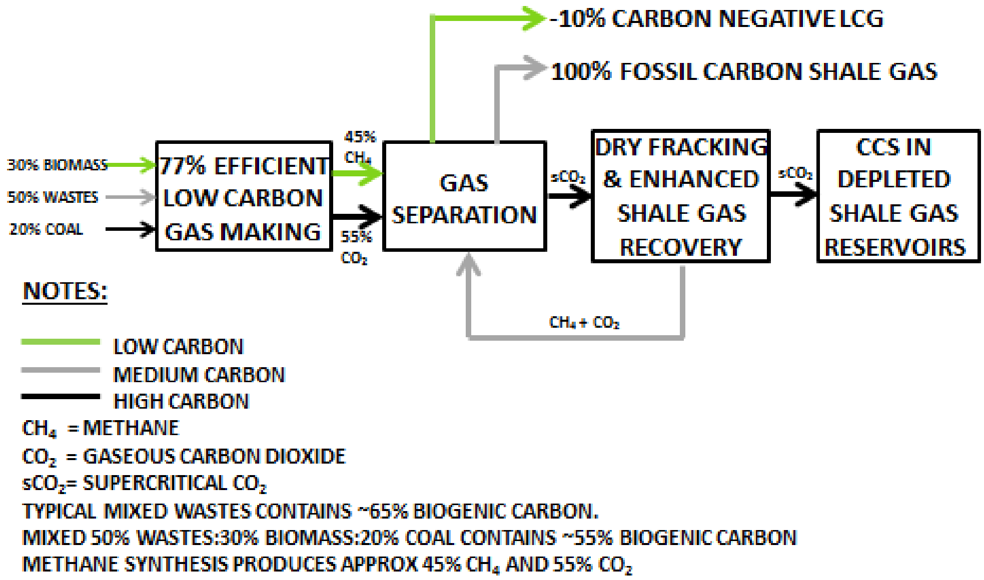
5. Shale gas is likely to contain CO_2 which will require separation prior to shale gas injection into the gas grid. CO_2 separation uses the identical technology as used to produce supercritical CO_2 with LCG.

6. CO_2 separation and supercritical CO_2 can be used for drilling, 'dry' fracking, 'green' completions, enhanced shale oil and gas recovery, well re-pressurisation and CCS. Integrating LCG and shale gas production with CCS in depleted shale gas or oil reservoirs will deliver a low cost onshore low carbon gas industry.

Figure 28: UK forecast unconventional gas production



7. DECC estimates that to decouple UK and EU oil indexed gas prices requires unconventional gas supplying 20% of UK gas demand (or 50% of imports), i.e. 16 to 20 cubm pa. DECC estimates that 1 to 4bn cubm pa of 100% fossil carbon shale gas might be produced in UK by 2030. Enhanced gas recovery could increase this by a factor of 2 to 3, giving a mid-range estimate of (say) 7 bn cubm pa. We estimate that around 28 bn cubm pa of -10% fossil carbon LCG, plus around 65 mtpa of supercritical CO_2, can be produced from 75 mpta of mixed waste, biomass and coal, plus 2 bn cubm pa of 0% fossil carbon biomethane from anaerobic digestion. Taken together, onshore shale gas, LCG and biomethane could supply 50% of total UK gas demand at a net fossil carbon intensity of 10%. Gas currently provides around 40% of UK energy supply. This implies the decoupling of UK gas price from EU oil indexed gas prices, and a reduction in total UK fossil CO_2 emissions of around 20%.



INTEGRATED ONSHORE SHALE AND LOW CARBON GAS CONCEPT

SUBMISSION

7. This is the third of 3 responses to current Parliamentary inquires. I have also recently responded to the House of Commons Select Committee inquiries into CCS and heat. The common thread running through the 3 responses is the role that Low Carbon Gas (LCG) making can play in reducing the cost of delivering UK energy policy, and hence assisting in delivering economic growth. This response also considers the opportunity for low cost supercritical CO_2 produced as a by-product of LCG to assist enhanced shale oil and gas recovery.

8. I provide policy and economic advice to companies currently developing ex-British Gas Synthetic Natural Gas (SNG), ie synthetic methane technology, in China. Substantially identical technology, with only minor changes, can be also used to produce low cost negative emissions Low Carbon Gas (LCG) at large scale from mixed wastes, biomass and coal feedstocks, integrated with: low emissions 'dry' fracking; enhanced shale gas recovery; CCS, and bulk intermittent renewable energy storage using the high pressure gas grid, which is UK's largest and fastest discharge rate energy store. Please see the attached technical appendix.

9. Our objective is to supply low carbon energy at lower cost than incumbent fossil fuels. The organisations engaged in this endeavour are: GL Noble Denton Ltd (formerly Advantica plc, shortly to merge with DNV kema); Timmins CCS Ltd; Johnson Matthey plc, Davy Process Technology; Jacobs Engineering Group Inc; ITM-Power Ltd, and Cambridge University. Substantial decarbonising of UK gas supplies is not supported by HMGovernment.

10. None of these ideas are new, but previous consideration by HMG of waste, biomass and coal co-gasification in 2002/3 was only in the context of power generation, and did not consider CCS. The 2002/3 report was led by UK Coal plc on behalf of DTI, and over-reported the cost of power from waste, biomass and coal co-gasification at 400 MWe scale

by a factor of 1000%. At that time it was assumed that the future of UK energy lay in large scale electrification by a combination of nuclear, renewables and coal with CCS, and that the gas grid would eventually wither away, thus reversing the 1000% expansion of UK gas supplies, largely at the expense of coal and nuclear, between 1960 and 2000. Due to the high 'whole system' cost of electrification and renewables, and the discovery of plentiful new gas supplies, that trend in policy is now reversing.

11. The projected output cost of 60 bar (60 atmospheres pressure) gas grid compliant LCG is around 40 to 45 p/therm for a 1.0 to 1.5 mpta multi-fuel co-gasification plant. LCG production is inherently carbon capture ready, and produces a 150 bar 99.6% pure supercritical CO_2 side stream as a waste by-product at the low cost of around 40 p/tonne supercritical CO_2, excluding site specific transport and storage costs. The transport and storage cost per unit output energy is around 25 to 33% the transport and storage cost of fossil fuel power generation.

12. There is a good deal of current USA Federal and State supported R and D investigating ways of using supercritical CO_2 to reduce the cost and emissions, and enhance the ultimate gas recovery rate, from shale gas 'fracking', with the ultimate objective of using depleted shale gas reservoirs for CCS. This depends critically on the cost of supercritical CO_2. The current market price in USA of supercritical CO_2 for enhanced oil recovery (EOR) is around $15/tonne. EOR is inherently far more profitable than enhanced gas recovery (EGR). For EGR to be profitable, the cost of supercritical CO_2 needs to be substantially reduced. LCG can deliver this objective.

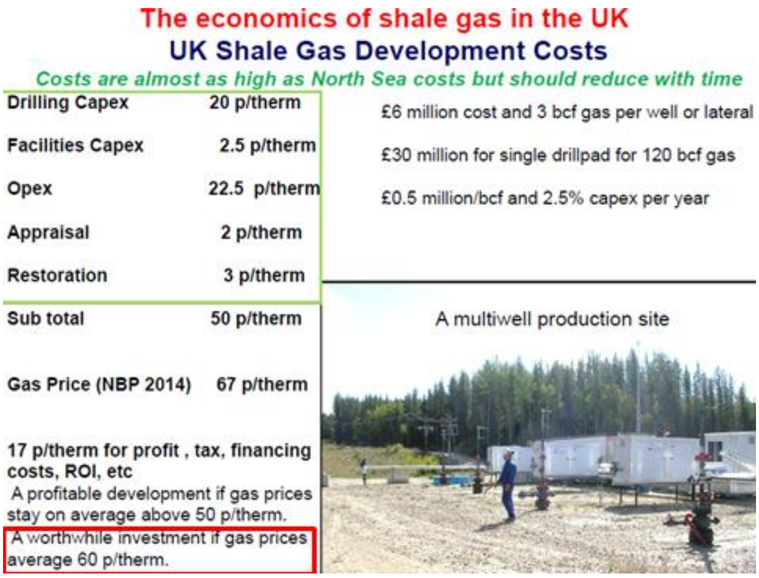
13. The two specific technical advantages of using supercritical CO_2 for shale fracturing and EGR are:

a. Supercritical CO_2 has the characteristics of both a gas and a liquid. Its viscosity is nearly 2 orders of magnitude less than water. It is suitable for driving down-hole well bits, and for hydraulic fracturing. Its lower viscosity increases its 3-dimensional penetrating power, and is suitable for high volume fracturing, which could be suitable for multi-level wells in the deep Bowland Shale. Assuming average 3 kilometer long horizontal well 'laterals', it is possible that between 10 and 15 cubic miles of Bowland Shale could be accessed from a single drilling pad. This would imply a much more concentrated, and less geographically diffuse, pattern of shale gas exploitation in UK than in USA. Supercritical CO_2 would drive multi-level EGR from the bottom up.

b. Methane is a 'sticky' gas which adsorbs onto the surface of organic molecules in coal and shale. CO_2 selectively displaces the organic molecular bonds thus desorbing methane and making it available for recovery at the rate of approximately 5 molecules of CO_2 per molecule of methane. Initial studies on a test well in Kentucky suggest that commencing EGR at around 80% well depletion produces optimum results. When the produced CO_2 to methane ratio becomes excessive, the production well is capped. Supercritical CO_2 injection then continues to provide CCS.

14. If 'dry' fracking and EGR can be made economic in UK, using low cost supercritical CO_2 co-produced with partly renewable LCG with CCS, this will form a virtuous circle where shale gas can be integrated with an onshore UK LCG industry. Retaining a partly decarbonised gas grid at its current size will be far less expensive than current UK energy policy based on decarbonisation via electrification. The method by which this might be

achieved is explained in the attached technical appendix. This is not futurology, and requires only relatively minor modifications to the joint HMG/British Gas Corporation '30 Year Plan' coal to SNG technology successfully developed between 1955 and 1992. The chemical engineering processes named herein: Selexol, HICOM, ADAPT, BGL, etc, are readily available and commercially proven processes. Gas 'sweetening' has been practised by the international gas industry for several decades.



15. Estimates of ultimate recoverable shale gas vary between 10% in UK, and 30% with enhancement in USA. 18% recovery is considered the norm for a good well in USA, without enhancement. If CAPEX is 50% of the total cost of shale gas, and output per well can be increased by a factor of 3, the output cost of shale gas will be reduced by 50%. This is reflected in EIA's estimated 25% to 50% variance in shale gas price depending on EUR.

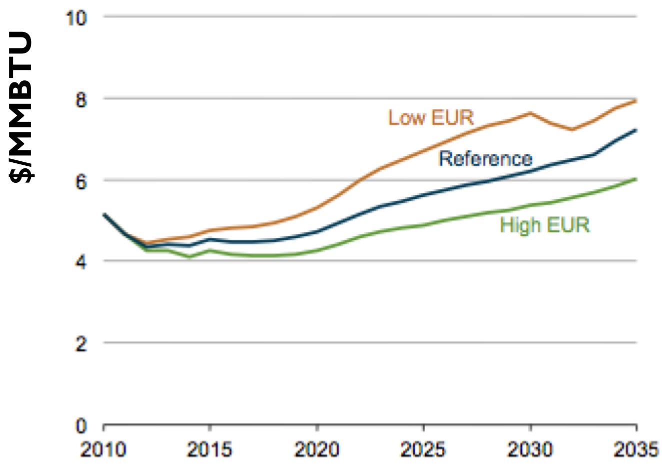
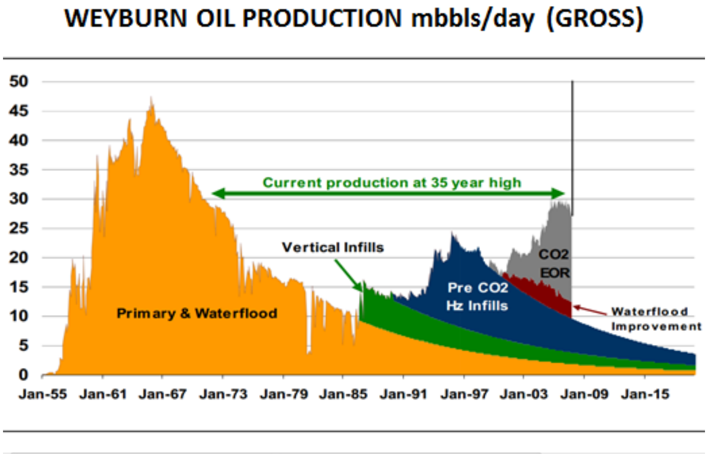
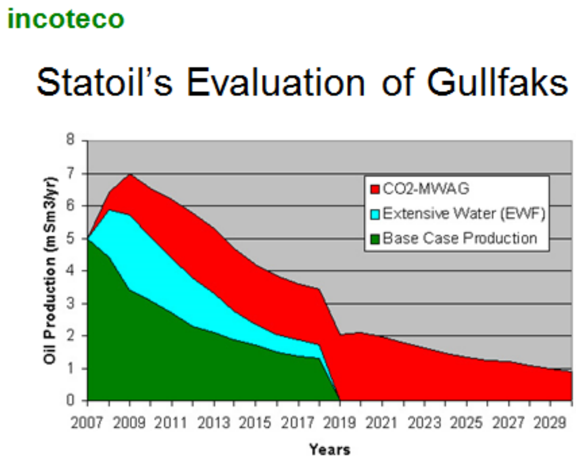


Figure 21: EIA electric power natural gas price predictions.
EUR= Estimated Ultimate Recovery. Source: EIA (2012b)

16. EGR lengthens the productive life of shale gas wells; offsetting the high initial depletion rate; improving cash flow, and reducing financial risk. The diagram below is for supercritical CO_2 enhanced oil recovery (EOR) with secondary water flood. The geophysics of EGR and EOR are significantly different. It is, however, indicative of well life production and

profitability being enhanced by supercritical CO_2. Enhanced shale gas recovery is currently being tested in Kentucky. Initial indications are that commencing EGR at 80% depletion is optimum.





Taking the above facts into account, we can answer the Select Committee's inquiries as follows:

How much scope is there for shale gas and oil – from domestic and overseas sources – to be used in the UK? Over what time frame?

17. There is no theoretical limit to the amount of indigenous and imported shale gas and oil which might be consumed by the UK. Some estimates suggest that by the 2030's gas will overtake coal and oil as the World's principle and cleanest hydrocarbon fuel. Gas will form a major part of UK's energy system until well after 2050.

How will the costs, including those on the environment, of accessing UK's shale oil and gas resources, compare to those of other energy resources?

18. Shale gas and LCG are cheaper per unit energy than any other dispatchable and storable indigenous energy resource. Below ground environmental impacts will be managed in accordance with HMG and EU drilling regulations, etc. Above ground environmental impacts can be minimised by maximising the volume of shale accessed per well pad; using 'dry' fracking techniques, and underground pipelines carrying supercritical CO_2 and mixed methane and gaseous CO_2 to and from gas processing 'hubs'. Atmospheric environmental emissions can be minimised by using 'green' completions; CO_2 separation and reuse;

integration with LCG production, and CCS. None of these measures need be excessively costly; have large land use and; be visually intrusive, or hazardous, provided they are sensitively sited and planned in accordance with normal Planning and environmental criteria.

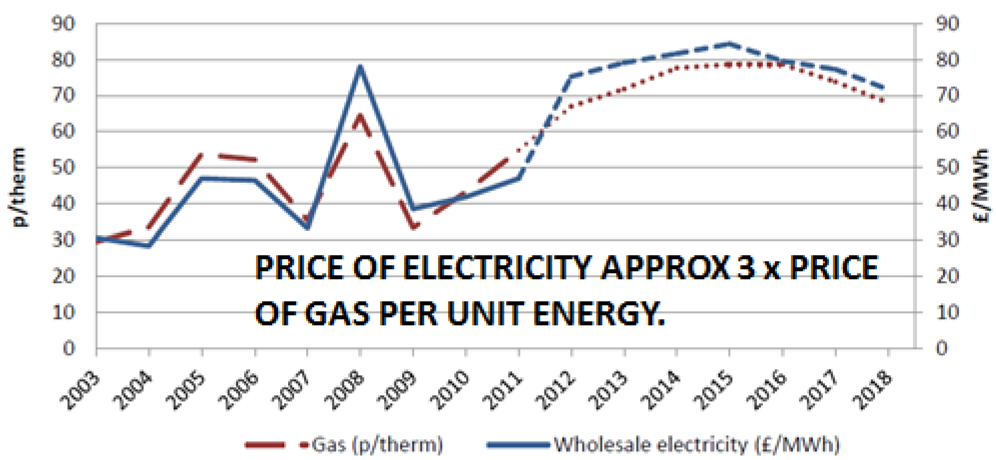
What is the potential impact of shale gas and oil on local economies in areas where development is possible?

19. Conventional economic theory suggests that, subject to proper Planning and environmental controls, and appropriate distribution of wealth, shale gas and oil will have a positive impact on local economies.

What will be the impact of shale gas on the cost of electricity generated at gas-fired power plants, and how will it compare to other forms of generation including nuclear, coal and renewables?

20. 60 p/therm gas price implies £60/MWh power price due to gas normally being the marginal generator in the UK power market. New nuclear, coal with CCS and renewables cannot compete with this price. Existing 'paid down' coal fired power stations will remain cost competitive.

Chart 1: Historic and projected electricity and gas prices



Source: Annual averages. 2010 prices. Historical gas prices: Bloomberg. Historical electricity prices: London Energy Broker's Association. Gas and electricity projections (central): DECC 2011

Will the UK electricity market be easily able to absorb shale gas in future, or will generators be locked into long-term contracts with other energy sources? Are there any other potential barriers to the use of shale gas in electricity generation?

21. Gas is a fungible energy resource. Gas fired power generation is easy to build at low capital cost. Coal and gas fired generation are largely interchangeable depending on the relative input to output cost 'spreads'. The extent to which substitution, or lock-in, occurs depends largely on HMGovernment energy policy.

Which forms of electricity generation is shale gas likely to displace, and by how much?

22. Assuming that renewables remain highly subsidised and shielded from market forces, shale gas is likely to displace new nuclear and new coal fired power generation in UK. Except to the extent that new nuclear and coal are subsidised, or gas is driven out of the market by a combination of policy and the Carbon Floor Price, there will be no economic driver to develop new nuclear or coal in UK, except for over-riding security of supply purposes.

What impact will shale gas and oil have on household energy bills?

23. In an open competitive liberalised energy market increased energy supplies should reduce household energy bills. The UK energy market is a tightly regulated and taxed oligopoly. The extent to which reduced wholesale energy prices reduce household energy bills is in the hands of HMGovernment, OFGEM and National Grid plc.

What effect will the use of shale gas and oil have on carbon emissions compared with other combinations of energy sources?

24. Assuming 33% of total UK power generation is provided by mixed Natural Gas, biomethane and LCG fired conventional power stations, an economically viable low carbon power generating system can be developed meeting the following criteria: 50% renewable energy; 50 gCO_2/kWh 'whole system' emissions intensity, and 50% 'whole system' plant load factor. Please see attached technical appendix.

Will shale gas and oil increase UK energy security?

25. Yes, provided the increase in UK energy security is not undone by the unintended consequences of other energy policies. The economic benefits to the Nation will be reduced if the profits from shale gas and oil are either impounded by HMTreasury, and then not used for wealth creating measures, or are exported by external investors domiciled outside UK. The gas grid is UK's largest and fastest discharge rate energy store, and thus supports energy security. HMG's recent decision not to assist UK gas storage development, compared with massive financial support for renewable power generation, sent the wrong signal to the energy market.

What infrastructure investment will be necessary to cope with the development of shale gas and oil? How far will it help to ensure sufficient UK energy supplies? How will this investment be financed?

26. Please refer to para 18 above for types of infrastructure requirements. Nowhere on the British mainland is very far from the UK gas grid. Shale gas and oil should be profitable investments. Therefore, pipeline investments should not be massively expensive. Traditional gas pipeline investment methods should be adequate, perhaps with some financial assistance from HMG to overcome initial investor risk aversion and to 'prime' the market. Long-term ultimate risk cover for CCS will probably have to be provided by HMG.

What changes to public policies are necessary to maximise the potential of any shale gas development?

27. HMG should abandon electrification as the core of UK energy policy. HMG should develop a single energy policy for both gas and electricity, with equal affordability, security and sustainability criteria applied to both markets. CCS on synthetic gas making is orders of magnitude cheaper than CCS on power generation. Policy should support putting the lowest

cost CO_2 underground first, and the most expensive CO_2 last. Policy should support the development of onshore integrated shale gas, LCG and CCS 'hubs' inter-connected by underground pipelines. The capital cost per MWkm of gas pipelines is around 1/15th the cost of underground power grids.

Will shale gas and oil lead to UK being less dependent on energy from less reliable parts of the World such as the Middle East and Russia?

28. Shale gas and oil will reduce imported energy dependency. UK has not been held to ransom directly by Russia or OPEC. Reduced import dependency will deliver balance of payments, tax revenue, price volatility, supply chain and employment benefits.

What lessons can be learnt from the US experience of shale gas and oil?

29. Enhanced shale gas recovery R and D is ongoing in USA, Poland, Japan and the Middle East. UK should engage with this this knowledge base. UK should develop LCG, 'dry' fracking, 'green' completions, enhanced shale oil and gas recovery (50% of the CO_2 used for EOR stays underground), and low cost CCS in depleted shale gas and oil reservoirs, with gas and CO_2 pipeline infrastructure.

30 September 2013

Bloomberg—Written evidence

Natural gas

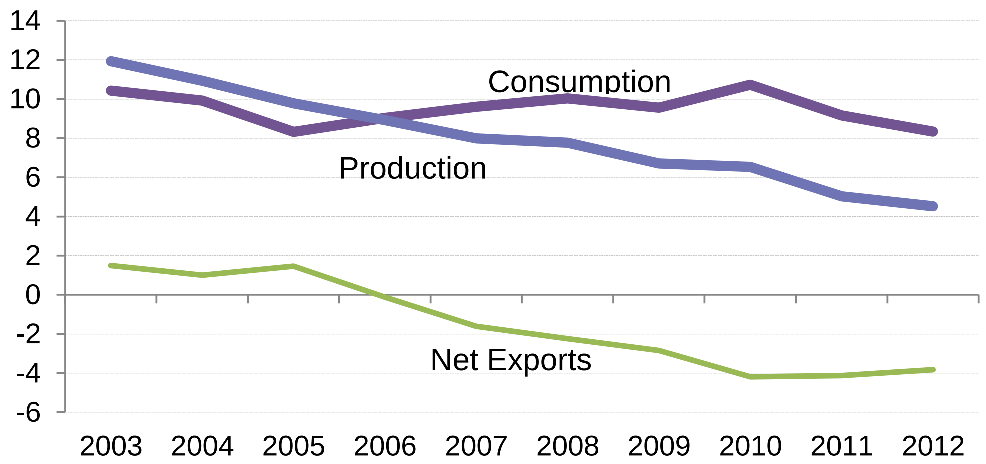
The economic impact on UK energy policy of shale gas and oil

Bloomberg New Energy Finance has been monitoring and researching energy markets for the past 10 years. We have been covering the UK gas market, the North American gas markets and the impact of the shale boom for the past two years. This response to the House of Lords Call for Evidence is given as a summation of our research on the topics pertinent to the questions asked.

1. **How much scope is there for shale gas and oil – from domestic and overseas sources – to be used in the UK? Over what timeframe?**

1. The UK has moved from a position of being a net exporter of natural gas to being an increasingly large net importer since 2006 due to the rapid decline of dry and associated gas production from the UK continental shelf (Figure 1). This has left the UK as a net importer of some 4bcfd (billion cubic feet per day), or 42 billion cubic meters per annum. The deficit would have been even larger had the fall in coal and carbon prices not left UK gas generators running second to coal generators in the generation mix.

Figure 1: UK gas supply and demand (Bcfd)



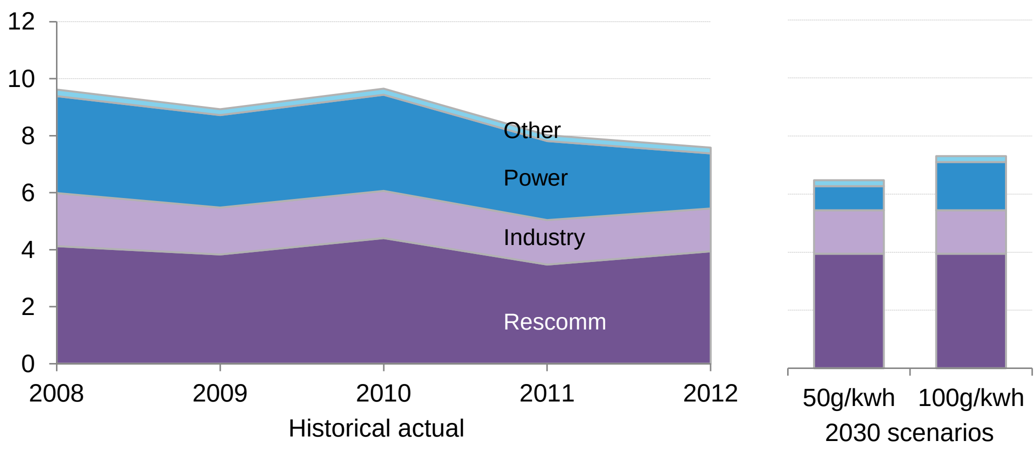
Source: Bloomberg New Energy Finance, National Grid

2. The UK would thus be able to absorb up to 4bcfd of additional gas production without changing the fundamental dynamics of the market and while using current infrastructure. This 4bcfd is the maximum level at which we foresee the UK being able to produce shale gas under our most bullish scenario.

3. The UK has a long-term, legally binding target to reduce emissions at least 80% by 2050 from 1990 levels. The UK Committee on Climate Change has recommended that the carbon intensity of the power sector as a whole should fall to 50gCO2/kWh by 2030 for the UK to stay on course to achieve its long-term emissions reduction goals.

4. A 50gCO2/kWh limit would imply UK power sector gas demand of 7.6–8.8bcm in 2030 (0.83bcfd), assuming power demand in 2030 of 340TWh and the elimination of coal generation by then. This implies that gas consumption for power would need to fall to less than half its value in 2012. Despite this implied demand destruction in the power sector, there should still be ample demand for gas from the residential and industrial sectors to be met by UK shale gas in 2030 (Figure 2).

Figure 2: UK natural gas consumption by sector (bcfd)



Source: Bloomberg New Energy Finance, Dukes. Note: scenarios in 2030 assume residential and industrial demand remain flat from 2012. Assumed power demand in 2030 is BNEF scenario of 335TWh.

2. How will the costs, including those on the environment, of accessing the UK's shale gas and oil deposits compare to those for other sources of energy?

UK shale gas costs

5. Political, environmental and legal concerns will play a significant role in the trajectory of shale gas development in the UK. Ultimately, however, it will be economics that will be the deciding factor: unless the gas is profitable to extract and distribute, the total volume of UK shale gas resources is immaterial.

6. Because of the paucity of data, very little has been published on the cost of shale drilling in the UK or the flow rates which might be expected. We can, however, make educated estimates of these two variables, based on an understanding of comparable figures in the US and anecdotal information from drillers, servicers and geologists.

7. Our analysis focuses on the economics of a single drilling pad (a facility from which several wells can be drilled) and uses our in-house valuation tool to calculate a 'breakeven gas price' – one that covers all out-of-pocket costs and gives an appropriate internal rate of return (IRR) to the driller and their investors. As with all natural resource assets, the main variables affecting unit production costs are upfront costs (known as drilling and completion, or D&C) and production rates (the higher the output, the lower the unit costs will be). In the examples below we present two scenarios reflecting optimistic to pessimistic views on costs and production rates:

- In our favourable case, we assume D&C costs for UK shale gas wells of $8m. An analogous well in the US would cost around $4m to drill and complete, but we have assumed higher D&C costs resulting from the limited availability of drilling service providers. We estimate that it would cost a further $2m to acquire the land, prepare the site and build a one-mile gathering line. We assume six wells being drilled at a single pad site, all of which use the same gathering/processing system. This means that the first well is more expensive than the next. We assume that exploratory works have been completed and that the play is mature – in other words there are no provisions for ancillary costs or unexpected production delays.

- In the pessimistic scenario, we believe D&C costs could be as high as $11m per well. These costs are based on quotes from the oilfield services company Schlumberger on drilling costs in Poland (overall the central European country is likely to have similar costs for onshore shale gas development to the UK). A further $2.5m is spent on land, site preparation and gathering.

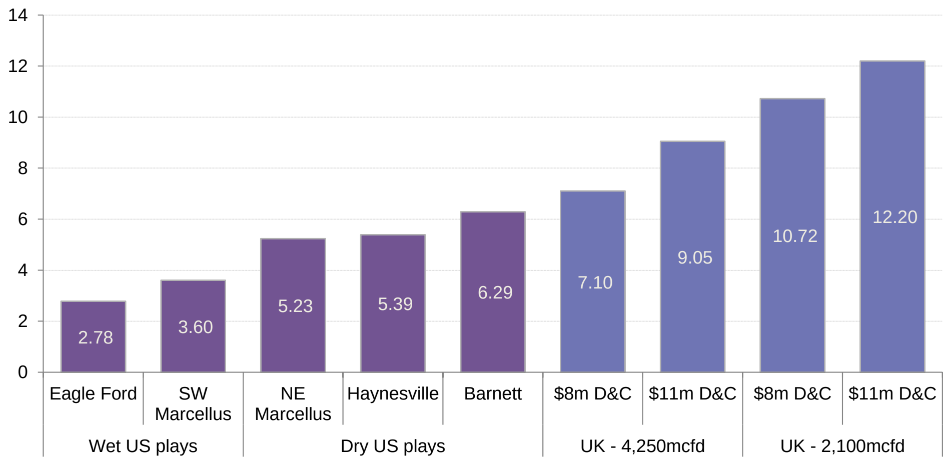
- On the production side, our favourable case assumes a 30-day initial production (IP) rate of 4,250mcfd. This is akin to wells in the US Marcellus and Eagle Ford shales.

- In our less favourable case, we drop the IP rate to 2,100mcfd. This is closer to a well in the Barnett Shale. That said, in this scenario we also drop the number of frack stages from 15 to eight, saving over $1m in D&C costs per well versus where they would otherwise be in this scenario.

8. Certain US plays also benefit from the presence of natural gas liquids (NGLs) in the gas stream. NGLs sell into the oil market and can fetch higher prices than gas, so they provide some economic uplift. But, while the gas composition of UK shale plays is unknown, a sizeable liquids cut would also necessitate the construction of capital-intensive fractionators and parallel pipeline systems for the liquids, potentially outweighing the economic benefits. In any case, the Bowland Shale is thought to be largely dry. We therefore assume that UK shale gas is dry and assign no NGL uplift.

9. Based on the above, UK unit costs for shale gas extraction are likely to be considerably higher than those seen in the US (Figure 3). While dry US plays such as the Marcellus, Haynesville and Barnett have breakeven costs of some $5-6/MMBtu (always assuming a 15% after tax equity IRR), we believe the comparable range for the UK is likely to lie between $7.10 and $12.20/MMBtu. This is close to the $8-11/MMBtu range in which spot UK gas prices have traded over the past two years.

Figure 3: Breakeven gas price for 15% after-tax equity IRR ($/MMBtu)



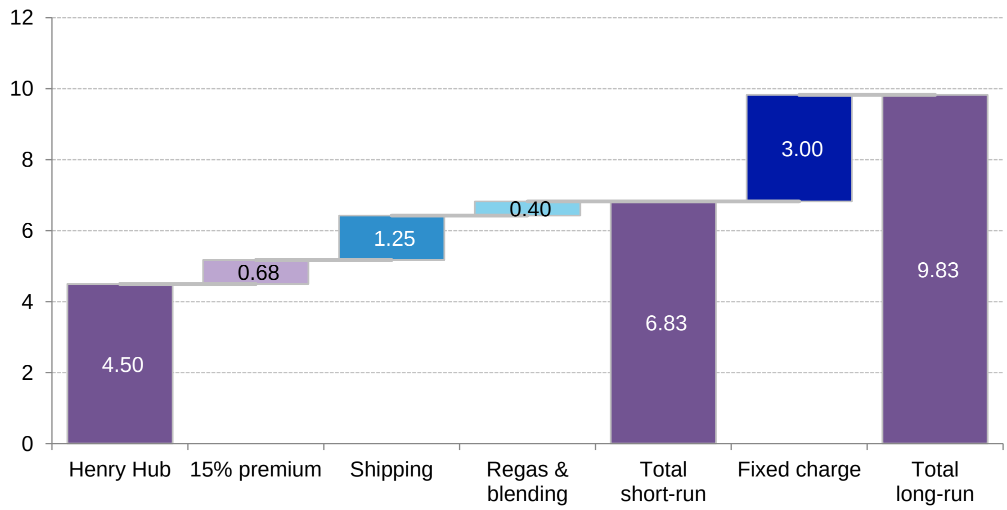
Source: Bloomberg New Energy Finance Note: We invite readers to use our in-house valuation model to reproduce our results for the UK.

Cost of alternative supplies of natural gas

10. The UK has two major alternative sources of supply for Natural gas other than domestic shale. It can either import more from Europe, or import more LNG from the Atlantic basin.

11. The United States will emerge as a significant supplier of LNG into the Atlantic basin over the next five years as the early LNG export projects come to fruition. This source of supply, which will likely amount to 7-8bcfd of capacity or around twice our bullish case for UK shale production, comes with the added advantage of being delivered on highly flexible terms for volume and price, based on the most liquid gas hub in the world at the Henry Hub. Figure 4 shows a typical cost build up in both short-run and long-run terms for US gas delivered to Europe. This range of prices compares favourably with our estimates for the cost of UK shale given in Figure 3.

Figure 4: LNG cost build-up, US Gulf to Europe ($/MMBtu)

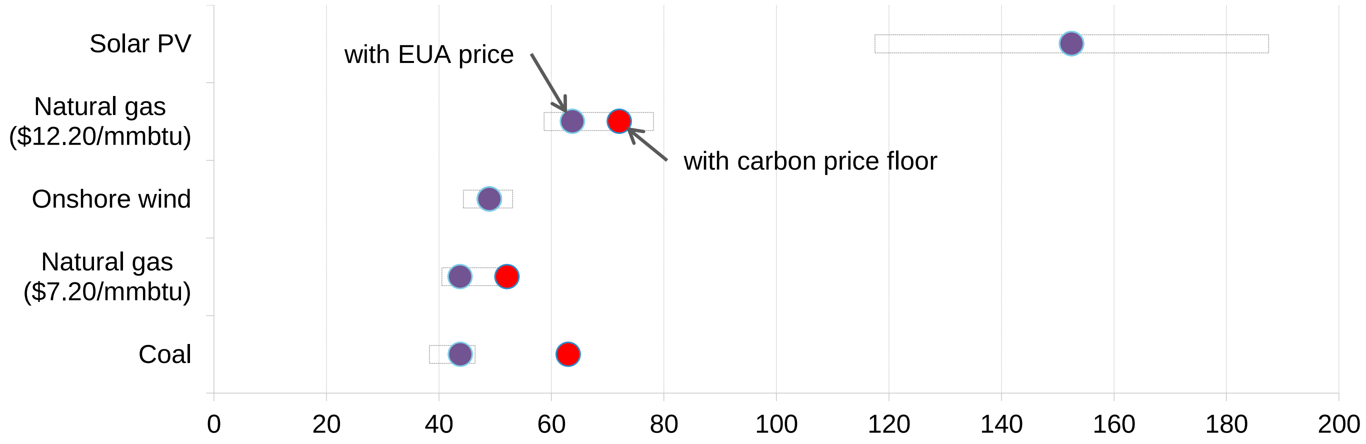


Source: Bloomberg New Energy Finance Note: The fixed charge is the levelised cost of building and financing the liquefaction facility in the US.

Cost of alternative sources of electricity

12. The long run cost of electricity supply is set by a combination of capital costs for the equipment, operating costs to keep the plant running, financing costs and the cost of fuel to run the plant. Bloomberg New Energy Finance track this closely in our levelised Cost of energy research. Figure 5 shows the relative costs of different sources of electricity at current fuel prices prevalent in the UK.

Figure 5: UK levelised cost of energy (GBP/MWH)



Source: Bloomberg New Energy Finance Note: Natural gas is for a new baseload CCGT unit at 54% HHV efficiency and 85% load factor. Coal is for a new baseload super-critical unit at 42% HHV and 85% load factor. Solar PV is utility scale installation at 10% load factor. Onshore wind is a new installation at 28-31% load factor.

13. The current low cost of carbon from the EU ETS scheme, combined with low coal prices gives coal the lowest levelised cost of energy before taking account of the carbon price floor.

14. We include natural gas-fired generation under two scenarios for the cost of gas from shale. In the lower gas cost scenario a new baseload CCGT is GBP5/MWh cheaper than an onshore wind farm in our central case, without the carbon price floor. In our higher cost gas scenario a new baseload CCGT is GBP14/MWh higher than an onshore wind farm.

15. With the carbon price floor, which rises to GBP46/tonne in 2020 and as high as GBP137/tonne in 2030, energy from onshore wind is cheaper than that from natural gas-fired generation in both our high and low cost shale gas scenario.

3. What is the potential impact of shale gas and oil on the local economies in areas where development is possible?

16. Bloomberg New Energy Finance has done detailed research on the jobs impact of renewable energy technologies but has yet to do the same for shale gas.

4. What will be the impact of shale gas on the cost of electricity generated at gas-fired power plants and how will it compare to other forms of generation including coal, nuclear and renewable?

17. Shale gas will only have an impact on the cost of electricity generated at gas-fired power plants in the UK if it changes the price of natural gas in the UK. The price of natural gas in the UK is set at the National Balancing Point (NBP) by the cost of supplying the marginal therm of natural gas. To impact this price, UK shale would need to displace more expensive sources of gas, notably LNG. Further for the UK to see a repeat of the US level of production and price impact, price separation would need to occur between the UK and continental Europe. This effectively requires that the UK become self-sufficient in gas and be able to export sufficient gas to cause export bottlenecks in the gas pipeline network.

18. Technically recoverable shale gas resources in the UK have not yet been estimated with any precision and figures vary hugely. For example, Cuadrilla Resources, which is actively exploring the Bowland Shale, has suggested a figure of 200Tcf, with 10% recoverable, while a preliminary report from the British Geological Survey gave a more conservative estimate of 4.7Tcf of recoverable resources in the same basin. Ultimately, however, no matter how large the resource, in order to have a substantial effect on UK gas prices, the rate of growth of production must be high enough to displace imports.

19. To establish a production rate that would substantially affect UK prices, we examine the gas balance and market structure. As noted in our answer to question 1, annual gas production has fallen by 60% over the past 10 years, turning the UK into a net importer since 2005-06 (Figure 1). Because it has the highest share of spot gas sales (vs. long-term contracts) of any country in Europe, the marginal Btu of gas sets the price. UK producers respond to this by ramping up gas production in the winter months.

20. Therefore, we assume that production must rise to the point where imports are more or less completely displaced in order to lead to a sizeable drop in prices.

21. Using a target production rate of 4.0-4.5Bcfd (total UK natural production in 2011 was 5Bcfd, against total consumption of 9Bcfd) and our more optimistic assumptions on flow rates, some 3,000 wells would need to be drilled over a 5-6-year ramp-up period. At the height of activity, around 50 rigs would be drilling one well per 20 days each, or around 900 wells per year. After this initial high level of activity, drilling would slow over the subsequent 10 years to the rate required in order to maintain production. We estimate that approximately a further 7,000 wells would be drilled over this 10-year plateau period, given likely rates of production decline but given also the fact that producers would re-frack their best-performing wells in order to coax out more production without having to drill anew (Figure 6).

22. Assuming that each well drains an area of 90 acres, based on comparable figures in the US, this equates to 870,000 acres drained. For one of the larger US shale plays, these would be eminently achievable targets. However, given that the entire county of Lancashire – home to the highly prospective Bowland Shale – is 761,000 acres in size, drilling 10,000 wells would hardly be realistic. On the other hand, the Bowland is thought to be substantially thicker than its US counterparts, potentially allowing different horizontals to be targeted in sequence. This would reduce the need to expand laterally and allow drillers to drill more wells from the same pad. (A useful analogue is the Williston Basin in the US, where drillers target both the Bakken and deeper Three Forks formations from the same pad.)

Figure 6: UK shale production, high production

Production (MMcfd) Rigs running

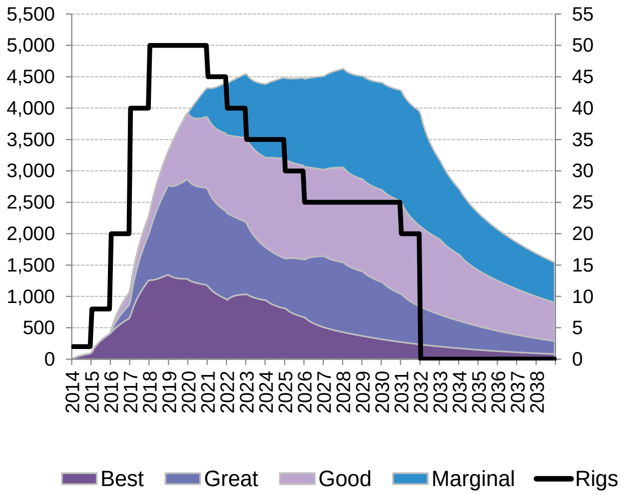
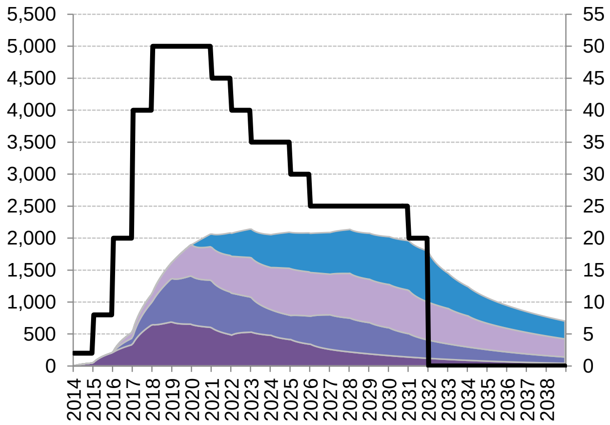


Figure 7: UK shale production, low production

Production (MMcfd) Rigs running



Source: Bloomberg New Energy Finance

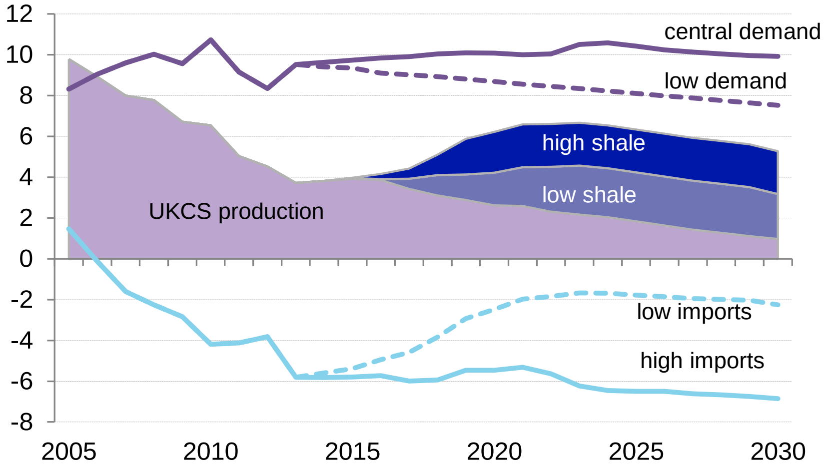
23. Nevertheless, as in all things oil and gas, size does matter. The top 10 operators in the Marcellus Shale hold just under 7m acres, and the core area is thought to underlie more than 15m acres. The commercial area of the Barnett Shale is closer to 2-3m acres.

24. Moreover, were UK shale wells to flow at lower rates (more like the Barnett), those same 10,000 or so wells on 870,000 acres would only amount to peak production of just 2.0-2.1Bcfd. This could offset production declines from legacy assets, but not much more (Figure 7).

25. In summary, while it is not unimaginable that hundreds of drilling sites holding thousands of wells could be set up in the UK, it would require favourable geology, public acceptance and the establishment of a services industry and onshore gathering and midstream infrastructure. None of these can be done quickly.

26. Our conclusion is that even under the most favourable case for shale gas production, with production reaching 4.5bcfd in the mid-2020s, and low demand driven by a power sector emissions target of 50gCO2/kWh, the UK will not be self-sufficient in gas (Figure 8). The reliance on continued imports will ensure that UK gas prices remain tied to European and world markets and so the direct impact of shale on the cost of electricity in the UK will be limited.

Figure 8: UK gas production, demand and imports through 2030 (bcfd)



Source: Bloomberg New Energy Finance, Dukes, DECC, UK Oil and Gas

5. Will the UK electricity market be easily able to incorporate shale gas in future or will generators be locked into long-term contracts with other energy sources? Are there any other potential barriers to the use of shale gas in electricity generation?

27. Purchases of natural gas for electricity generation are done as part of company hedging activities to lock in profits for future years. These activities typically begin around four years ahead of the delivery year and the proportion of generation hedged out increases steadily, reaching 50% two years from delivery, and with almost all generation hedged the month before delivery.

28. The profile of hedging indicates that UK gas generators will be more than able to respond to a change in the source of gas from UK offshore and European imports to shale gas over the time-frame over which shale gas is likely to be developed.

6. Which forms of electricity generation is shale gas likely to displace and by how much?

29. As discussed in question 4 above, shale gas will only displace other forms of generation, relative to a base case for gas generation, if it has a meaningful effect on the price of gas in the UK. We do not believe it will and so do not see electricity generated from shale gas displacing other technologies.

30. Our view on this would change should the government believe the advent of shale gas allows for a higher proportion of gas generation in the mix – allowing it to move away from the use of CfDs for nuclear generation. This would make construction of new nuclear generation in the UK effectively impossible and increase our share of gas in the mix at the expense of nuclear.

31. The build-out of renewables, being almost entirely driven by decarbonisation policy, and supported by the ROC and CfD schemes, would not be directly affected by shale gas if UK gas prices remain unaffected.

7. What impact will shale gas and oil have on household energy bills?

32. We refer to the previous discussion on the impact of shale gas on UK wholesale gas prices. Consumer bills will be affected to the extent that wholesale gas prices will be affected – albeit with a damped and delayed effect. For this reason our view is that shale gas will not have a noticeable impact on UK household energy bills.

8. What effect will the use of shale gas and oil have on carbon emissions compared to other combinations of energy sources?

33. We refer to the previous discussion on the impact of shale gas on the UK generation mix. Gas can affect the UK power generation mix either by delivering low-total-cost generation that undercuts renewable generation on a long-run basis, so making it impossible to build and thus increasing carbon dioxide emissions, or by undercutting coal-fired generation on a short-run cost basis and therefore reducing carbon dioxide emissions.

34. However, in the UK the development of renewable energy generation is an entirely policy-driven undertaking supported by significant out-of-market payments through the ROC scheme and, in future, the CfD scheme. These schemes give price and/or volume certainty for renewable generation and so prevent gas prices having a significant impact on future renewable build. Similarly, in the UK, coal-fired generation is subject to a high and rising carbon price floor. Should this tax continue on its current trajectory, coal-fired capacity will be largely phased out by the early 2020s as it is unable to justify the investments needed to meet the emission requirements set in the Industrial Emissions Directive and will be unable to run economically.

35. For these reasons shale gas is unlikely to have a significant impact on UK carbon dioxide emissions either positively or negatively.

9. Will shale gas and oil increase UK energy security?

36. Bloomberg New Energy Finance does not have a view on this question.

10. What infrastructure investment will be necessary to cope with the development of shale gas and oil? How far will it help to ensure sufficient UK energy supplies? How will this investment be financed?

37. Bloomberg New Energy Finance has not specifically investigated the investment requirements needed in exploration and production, pipeline gathering systems, gas processing and other infrastructure to support UK shale development, and so does not have a view on this question.

11. What changes to public policies are necessary to maximise the potential of any shale gas development?

38. A key enabler of the US shale gas boom has been that landowners are strongly incentivised to lease their land for development. This is due to the fact that they own the mineral resources under their feet and so are able to extract significant lease payments for the privilege of drilling and extracting the oil and gas.

39. In the UK however, the resources belong to the state. This, it is often argued, is an impediment to exploitation of underground assets as there is no immediate commercial arrangement that can be struck between the developer and land owner. State approvals are required, which can take time, and the landowner may have no economic incentive to welcome drilling.

40. The opposite is true in the US, which allows landowners to collect royalties on all the petroleum extracted from their plot. This better aligns the incentives of drillers and landowners and encourages development. Drillers need not pay upfront for the use of the land, which may turn out to be worthless if production is uneconomical. Rather, a relatively small upfront sum is agreed, but the landowner is entitled to a portion (generally 12-20%) of production proceeds (usually the payment is made in cash, rather than in kind). Therefore, if the well is productive, both the landowner and driller profit. If it is not, the driller does not need to take a write-down.

41. For the UK to embrace drilling to the same extent as the US, approvals from the state will be required. In theory the state could act in a similar way to private landowners in the US, with more balanced risk-return arrangements, though the wheels of the UK state generally turn more slowly than those in the US private sector. More importantly, landowners and local communities will have to be compensated for damage and nuisance if they are not to use the means at their disposal to delay or block fracking operations.

12. Will shale gas and oil lead the UK to be less dependent on energy from less reliable regions of the world such as the Middle East and Russia?

42. UK shale gas will, all other things equal, allow for the displacement of alternative sources of gas supply, and will increase to a small extent the supply diversity of global gas. As gas security of supply is an international issue, given the interconnectedness of UK markets with those of the rest of Europe and the world, this diversity will benefit all consuming nations.

43. However, even under our most bullish case of 4.5bcfd of production in the 2020s, UK shale production will still constitute less than one third of Russia-to-Europe gas flows and under 1% of total global gas production. The UK will remain dependent on imports to some extent (Figure 8) and so will not be able to avoid taking an interest in global security of supply.

13. What lessons can be learnt from the US experience of shale gas and oil?

44. The US experience has shown just how low the cost of extracting gas from shale can be under favourable conditions. We believe however that this is unlikely to be repeated in the UK for the following four key reasons.

Geology

45. The British Geological Survey assessment of the UK's shale gas resources[1] suggests that the Bowland Shale is by far the largest and most attractive onshore UK shale basin, and the mineralogy is thought to be suitable for gas extraction. Total organic content is satisfactorily high and the rock is brittle, which allows for good fracture propagation.

46. Useful data are, however, still sparse because earlier wells generally stopped before penetrating the Bowland Shale (conventional oil and gas drilling targets the reservoir rock that overlies the shale source rock) or simply did not core the Bowland Shale layers. This data is needed to assess permeability, porosity and overpressure – key variables in determining production rates.

47. The composition of the gas is also unknown, although much of the shale is thought to be firmly in the dry gas window in terms of thermal maturity. Lastly, the Bowland Shale is quite thick – it is conceivable that multiple depths of the rock could be targeted for extraction. (The Williston Basin in the US is an example of a 'stacked play' – wells drilled from the same pad site target both the Bakken and the deeper Three Forks formations.) This may be important, given the relatively small horizontal extent of the Bowland.

48. Geologists suspect that the UK also has large offshore shale gas resources. Moreover, the UK offshore industry is one of the best developed in the world – the North Sea has been under constant development for more than 50 years. However, offshore shale drilling is currently (and, perhaps, inherently) uneconomical because shale developments rely on continuous drilling to make up for rapid decline curves, but day rates for drill-ships, semisubmersibles and jack-ups are much higher than for onshore rigs.

Land rights

49. Another key difference between the US and the UK – and one that is unlikely to change – is that landowners in the European country do not own the resources beneath their feet. The resources belong to the state. This, it is often argued, is an impediment to exploitation of underground assets as there is no immediate commercial arrangement that can be struck between the developer and land owner. State approvals are required, which can take time, and the landowner may have no economic incentive to welcome drilling.

50. The opposite is true in the US, which allows landowners to collect royalties on all the petroleum extracted from their plot. This better aligns the incentives of drillers and landowners and encourages development.

51. For the UK to embrace drilling to the same extent as the US, approvals from the state will be required. In theory the state could act in a similar way to private landowners in the US, with more balanced risk-return arrangements, though the wheels of the UK state generally turn more slowly than those in the US private sector. More importantly, landowners and local communities will have to be compensated for damage and nuisance if they are not to use the means at their disposal to delay or block fracking operations.

Lack of drilling services market

52. There are currently around 1,700 land rigs operating in the US, compared with around 80 in all of Europe, according to oilfield services company Baker Hughes. Over 10,000 onshore oil and gas wells are drilled in the US each year, meaning that the market for onshore drilling

1 The assessment applies to Pennine Basin shale gas resources, which are thought to be the most prospective.

services is, by a large margin, the largest and most competitive in the world. Drilling service companies undertake various tasks, from early-stage exploration and formation evaluation to development-stage drilling and fracking, as well as later-stage well work-overs and various support functions. While the companies do not produce petroleum, they are essential to the market.

53. The UK does have a very well-developed offshore services market, but it has almost no experience in onshore work. In addition to the lack of experience, there is a lack of equipment – the vast majority of high-horsepower rigs and pressure pumping systems needed to frack are located in North America.

Lack of midstream infrastructure

54. Once a well is brought to production, the gas must find a path to market. While the UK has a robust transmission and distribution system, it lacks the 'gathering' pipelines that take raw gas from the wellhead and bring it to a central processing facility. These gathering lines are relatively small and easy to build, but land easements must be obtained and the pipelines buried. Once again, the UK's system of land ownership and planning, as well as its population density, is likely to make the process of laying gathering lines more time-consuming and costly that in the US.

55. Gas must be processed before it makes its way into the mainline transmission system. This processing removes various inert or toxic gases (such as nitrogen, carbon dioxide and hydrogen sulphide) and also separates out heavier hydrocarbons, leaving a stream of predominantly methane. Currently, the UK's processing capacity is located at receiving terminals on the coast. If onshore production is to contribute to the UK's energy mix, cryogenic processing plants must be built, and – if the raw gas stream contains a substantial portion of heavier hydrocarbons – expensive fractionators and a parallel system of pipelines will have to be constructed to transport these products.

30 September 2013

Centre for Climate Change Economics and Policy (CCCEP) and Grantham Research Institute on Climate Change and the Environment—Written evidence

The Centre for Climate Change Economics and Policy (CCCEP) was established in 2008 to advance public and private action on climate change through rigorous, innovative research. The Centre is hosted jointly by the University of Leeds and the London School of Economics and Political Science. It is funded by the UK Economic and Social Research Council and Munich Re. More information about the Centre for Climate Change Economics and Policy can be found at: http://www.cccep.ac.uk

The Grantham Research Institute on Climate Change and the Environment was established in 2008 at the London School of Economics and Political Science. The Institute brings together international expertise on economics, as well as finance, geography, the environment, international development and political economy to establish a world-leading centre for policy-relevant research, teaching and training in climate change and the environment. It is funded by the Grantham Foundation for the Protection of the Environment, which also funds the Grantham Institute for Climate Change at Imperial College London. More information about the Grantham Research Institute can be found at: http://www.lse.ac.uk/grantham/

This policy paper is intended to inform decision-makers in the public, private and third sectors. It has been reviewed by at least two internal referees before publication. The views expressed in this paper represent those of the author(s) and do not necessarily represent those of the host institutions or funders.

Centre for Climate Change Economics and Policy (CCCEP) and Grantham Research Institute on Climate Change and the Environment—Written evidence

Introduction
The Grantham Research Institute on Climate Change and the Environment (http://www.lse.ac.uk/grantham) and the Centre for Climate Change Economics and Policy (http://www.cccep.ac.uk) welcome the opportunity to respond to this call for evidence by the House of Lords Select Committee on Economic Affairs for its inquiry on 'The economic impact on UK energy policy of shale gas and oil'.

This response is based on 'A UK 'dash' for *smart* gas', by Samuela Bassi, James Rydge, Sam Fankhauser and Bob Ward from the Grantham Research Institute on Climate Change and the Environment and the Centre for Climate Change Economics and Policy at the London School of Economics and Political Science, and Cheng Seong Khor and Neil Hirst from the Grantham Institute for Climate Change at Imperial College London. (http://www3.imperial.ac.uk/climatechange).

Response to select questions

Q1. How much scope is there for shale gas and oil - from domestic and overseas sources - to be used in the UK? Over what timeframe?

1.1 The Government's Gas Generation Strategy states that between 19 and 37 gas-fired power stations will be built before 2030, suggesting that there is scope for shale gas to be used in the UK for power generation (DECC, 2012a). It should be noted, however, that new gas generation capacity at the upper end of this range would result in a carbon intensity of 100g-200g CO_2/kWh by 2030 for the power sector. This is far above the 50g CO_2/kWh level recommended by the Committee on Climate Change (CCC, 2010). Investments in new gas-fired power stations will have to be carefully calibrated with domestic reduction objectives for greenhouse gas emissions, in order to avoid breaching the carbon budgets. Beyond 2030, the scope for gas, including shale gas, to be used in the UK, will depend on the rate at which carbon capture and storage technology can be commercially deployed.

1.2 The future price of natural gas will also be a key factor. The price will partly depend on how much of the shale gas resources available (or 'in place') in the UK and Europe can be commercially exploited (i.e. become 'proven reserves'). It will also depend on whether the United States and China (which are currently estimated to have the largest shale gas resources) are able to trade natural gas on international markets. Both are uncertain.

Shale gas in the UK
1.3 In the UK, the latest figures from the Department of Energy and Climate Change and British Geological Survey (DECC, 2013) suggest that the Bowland-Hodder Unit alone in northern England may have between 23.3 and 64.6 trillion cubic metres of shale gas in place, with a central estimate of 37.6 trillion. This compares with an estimate by the United States Energy Information Administration (EIA, 2013) that the volume of UK shale gas in place is 17.64 trillion cubic metres.

1.4 These numbers are large, but the volume of gas that is technically recoverable and can be demonstrated to be economically and legally producible under existing economic and operating conditions (known as the 'proven reserve') is likely to be much smaller than these resource estimates. The United States Energy Information Administration estimates that the UK has which 0.74 trillion cubic metres of "risked, technically recoverable shale resources", which is approximately 4 per cent of the in place estimate. Applying this to the estimates by the Department of Energy and Climate Change and the British Geological Survey would suggest that the 'proven reserve' of shale gas in the Bowland-Hodder Unit would be 0.9 to 2.6 trillion cubic metres. The British Geological Survey and the Department of Energy and Climate Change have not published an estimate of proven reserves.

1.5 The key point is that UK shale gas resources could increase the UK's energy security and create new jobs. But the information that is currently available does not indicate that UK proven reserves of shale gas will be sufficient to stop the UK being dependent on imports of natural gas.

Shale gas in Europe
1.6 The UK currently imports approximately half of the natural gas it consumes from Europe and the Middle East (National Grid, 2012), so the extent to which shale gas resources in other European countries can be commercially exploited, as well as international prices for oil and liquid natural gas, will have a bearing on the future price of natural gas in the UK.

1.7 A number of European countries are known to have reserves of shale gas, particularly France and Poland. However, the European Commission's Joint Research Centre (JRC, 2012) points out that predictions that shale gas will have a significant impact on the European Union are based on optimistic assumptions about production costs and reserves. So the impact that shale gas resources will have on the price of natural gas is unclear.

1.8 A shale gas 'boom', like that occurring in the United States, is very unlikely to be replicated in the UK and rest of Europe. The amount of technically recoverable gas in the United States is significantly higher and there are big differences in the population density, geology and regulatory framework.

Reserves of shale gas in the United States and China and the impact on international markets
1.9 The natural gas industry is dominated by regionally segmented market structures, rather than globally integrated markets as there are for oil. This is due to high transportation and storage costs. As a result there is no global wholesale price and gas prices vary widely between regions.
1.10 It is very difficult to predict the price impact that future imports of natural from the United States and China (the countries with the largest reserves of shale gas) could have on the prices in the UK and Europe. There are signs that the market could become more integrated. For instance, Centrica this year signed a 20-year deal with United States energy company Cheniere Energy to purchase 2.5 billion cubic feet (70 million cubic metres) of natural gas a year (Financial Times, 2013) from 2015.

1.11 Nevertheless, the uncertainty is great and the evidence so far has not been sufficiently conclusive to allow a robust prediction that the price of natural gas will fall in the UK and Europe in the coming decades. The International Energy Agency (2011), for instance, assumes that natural gas prices will continue to rise worldwide up until 2035.

Q5. Will the UK electricity market be easily able to incorporate shale gas in future or will generators be locked into long-term contracts with other energy sources? Are there any other potential barriers to the use of shale gas in electricity generation?

5.1 The amount of natural gas (shale or otherwise) that the UK can use for electricity generation is constrained by the requirement set out in the Climate Change Act to reduce annual greenhouse gas emissions by at least 80 per cent below 1990 levels by 2050 (HM Government, 2008). To meet this target the UK power sector will need to be largely decarbonised by 2030 (CCC, 2010). This will require substantial investments in low-carbon power generation technologies. Natural gas could be used to balance out intermittent supply from renewable sources, such as wind. It is also likely to remain a significant source of fuel for heating, but its role will be gradually reduced as improvements in energy efficiency and the roll-out of low-carbon heat (like heat pumps) take over.

5.2 The opportunity to use natural gas for power generation will be greatly increased if carbon capture and storage technology can be developed and deployed commercially by 2030. However, more needs to be done by the European Union and UK to support the research and development on carbon capture and storage technology to make this a realistic expectation.

5.3 Beside environmental and technological constraints, a further barrier to the use of shale gas in electricity generation is the potential lack of a conducive investment environment. Notably, conflicting messages from the Government are creating uncertainty about the direction of future policy which could disincentivise investment. For example, the inconsistencies between the Gas Generation Strategy and UK decarbonisation ambition, combined with uncertainty about the outcome of the review of the fourth carbon budget in 2014, could be perceived by the private sector as a significant policy risk and could discourage investment in both gas-fired power plants and low-carbon energy sources.

7. What impact will shale gas and oil have on household energy bills?

7.1 As noted above, large uncertainties remain about the amount of shale gas that could be technically and commercially extracted in the UK. Current estimates (e.g. EIA, 2011; Cuadrilla, 2011; DECC, 2012) suggest that shale gas may not be able to render the UK energy-independent and free from the need to import natural gas. Prices on the UK market are therefore likely to remain largely driven by wholesale prices charged by foreign suppliers. So, if the UK does successfully exploit its shale gas reserves, it will not automatically result in lower household fuel bills.

7.2 The Department of Energy and Climate Change has published two reports which come to different conclusions about the impact of shale gas on household bills. In its Fossil Fuel Projects (DECC, 2013b) report published in July 2013, the 'central scenario' indicates that gas prices are expected to settle at 73.8 pence per hundred cubic feet of gas (therm) in the 2020s, compared to 63.6 pence per therm now (see table 1).

Table 1

7.3 A second report, commissioned by DECC from consultancy Navigant (Rathbone & Bass,

DECC 2013 Gas Price Projections

All Prices are in 2013 pence per therm			
	Low	Central	High
2012	61.4	61.4	61.4
2013	54.1	63.6	73.2
2014	51.7	66.7	88.2
2015	49.3	69.7	90.6
2016	46.9	70.6	93.0
2017	44.6	72.2	95.4
2018	42.2	73.8	97.9
2019	42.2	73.8	100.5
2020	42.2	73.8	103.2
2021	42.2	73.8	105.4
2022	42.2	73.8	105.4
2023	42.2	73.8	105.4
2024	42.2	73.8	105.4
2025	42.2	73.8	105.4
2026	42.2	73.8	105.4
2027	42.2	73.8	105.4
2028	42.2	73.8	105.4
2029	42.2	73.8	105.4
2030	42.2	73.8	105.4

2012), indicates in its 'medium' scenario that gas prices will decrease slightly between 2015 and 2030 to 65.7 pence per therm (see Table 2 below) - 20 per cent lower than suggested by the Fossil Fuel Projects (DECC, 2013b). For its 'low' scenario, the Navigant report predicts that gas prices will fall to 49.7 pence per therm.

Table 2

UK Gas Price Scenarios (in 2012 pence/therm)	Low	Medium	High
2015	59.0	67.8	69.9
2020	52.8	59.8	73.4
2025	51.3	62.0	77.2
2030	49.7	65.7	81.1

7.4 Forecasting gas prices that are lower than today requires some notable assumptions. The 'medium' scenario in the Navigant report envisages that shale gas production in the United States and China will continue to grow and that increasing natural gas exports, particularly from the United States, will bring the price down slightly on the UK/European market. The 'low' scenario makes the same assumption but also assumes significant investment in shale gas production in the UK and Europe. It also assumes a falling oil price. It should be noted that organisations such as the International Energy Agency (2011) predict that European gas prices will continue to increase through to 2035.

7.5 It is worth noting that, despite the drop in wholesale gas prices in the United States as a result of its shale gas 'boom', monitoring by the United States Energy Information Administration (2013) suggests that there has been relatively little impact on the average price of electricity for households, which increased by about 3.6 per cent in cash terms between 2008 and 2012. However, the effect on gas bills for residential consumers has been marked: the average residential retail price of gas decreased by about 48.6 per cent in cash terms between 2008 and 2012.

Q8. What effect will the use of shale gas and oil have on carbon emissions compared to other combinations of energy sources?

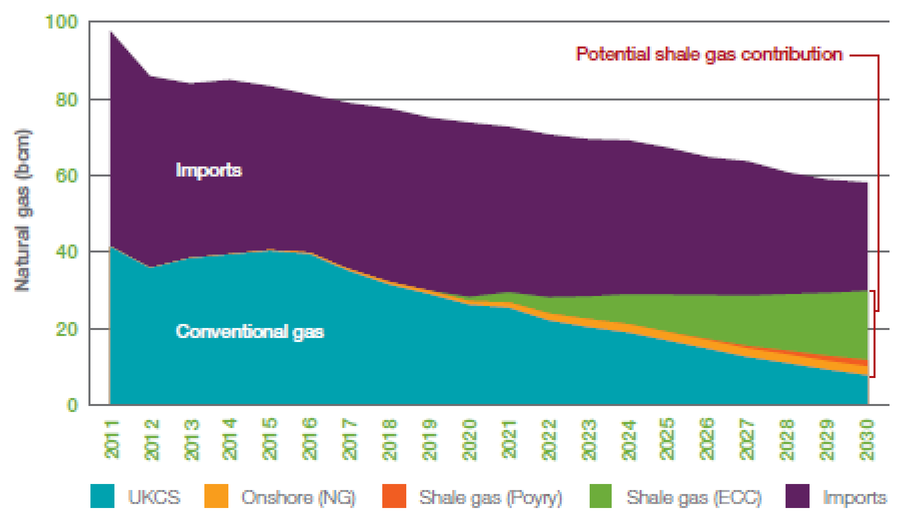
8.1 Shifting from coal to natural gas (including shale gas) for electricity generation can help the UK power sector to decarbonise in the next two decades to 2030, as long as gas-fired power plants do not displace other low-carbon sources.

8.2 Beyond 2030, deeper emissions reductions will mean that natural gas should play a supporting role in the development of a low-carbon power sector, by providing essential backup for intermittent supply from renewables. It could play a bigger role if gas-fired power stations are fitted with carbon capture and storage technology.

Q9. Will shale gas and oil increase UK energy security?

9.1 If it can be extracted cost-effectively, shale gas has the potential to make the UK's energy supplies more secure. However, it is unlikely to make the UK self-sufficient and the UK will continue to be a net-importer of natural gas. Figure 8 below provides more information on the potential contribute shale could make to UK supply.

Figure 8. Future UK gas supply and demand



Source: Calculations based on National Grid (2012), Pöyry (2011) and ECC (2012).

(Bassi *et al.*, 2013)

References

Bassi, S., Rydge, J., Khor, C.S., Fankhauser, S., Hirst, N., & Ward, B., 2013. *A UK 'dash' for smart gas.* London: Grantham Research Institute on Climate Change and the Environment, Centre for Climate Change Economics and Policy (CCCEP) and Grantham Research Institute on Climate Change and the Environment—Written evidence

Grantham Institute for Climate Change, Centre for Economics and Policy. [pdf] Available at: http://www.lse.ac.uk/GranthamInstitute/publications/Policy/docs/PB-uk-dash-for-smart-gas.pdf

British Geological Survey & Department of Energy and Climate Change (DECC), 2013. *The Carboniferous Bowland Shale gas study: geology and resource estimation.* [pdf] London: DECC. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/226874/BGS_DECC_BowlandShaleGasReport_MAIN_REPORT.pdf

Committee on Climate Change (CCC), 2010. *The fourth carbon budget – reducing emissions through the 2020s*. [pdf] London: CCC. Available at: http://www.theccc.org.uk/publication/the-fourth-carbon-budget-reducing-emissions-through-the-2020s-2/

Cuadrilla, 2011. Jobs and Investment. [online] Available at: http://www.cuadrillaresources.com/benefits/jobs-and-investment/

Department of Energy and Climate Change (DECC), 2012a. *Gas Generation Strategy*. [pdf] London: DECC. Available at: https://www.gov.uk/government/publications/gas-generation-strategy

Department of Energy and Climate Change (DECC), 2012b. DECC fossil fuel price projections. [pdf] London: DECC. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/65698/6658-decc-fossil-fuel-price-projections.pdf

Energy Information Administration (EIA), 2011. *World Shale Gas Resources: An Initial Assessment of 14 Regions Outside the United States.* [pdf] Washington DC: EIA. Available at: ftp://ftp.eia.doe.gov/natgas/shalegasreport.pdf

Energy Information Administration (EIA), 2012. *Annual energy review 2011*. [pdf] Washington D.C: EIA. Available at: http://www.eia.gov/totalenergy/data/annual/pdf/aer.pdf

Energy Information Administration (EIA), 2013. *Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States.* [online] Available at: http://www.eia.gov/analysis/studies/worldshalegas/

Her Majesty's Government, 2008. *Climate Change Act 2008*. [online] London: HMSO. Available at: http://www.legislation.gov.uk/ukpga/2008/27/contents

International Energy Agency (IEA), 2011. *World energy outlook 2011, special report: are we entering a golden age of gas?* [pdf] Paris: OECD/IEA. Available at: http://www.worldenergyoutlook.org/media/weowebsite/2011/WEO2011_GoldenAgeofGasReport.pdf

Joint Research Centre (JRC), 2012. *Unconventional gas: potential energy market impacts in the European Union. JRC Scientific and Policy Reports*. [pdf] Luxembourg: Publications Office of the European Union. Available at: http://ec.europa.eu/dgs/jrc/downloads/jrc_report_2012_09_unconventional_gas.pdf

National Grid, 2012. *UK future energy scenarios*. [pdf] London: National Grid. Available at: http://www.nationalgrid.com/NR/rdonlyres/C7B6B544-3E76-4773-AE79-9124DDBE5CBB/56766/UKFutureEnergyScenarios2012.pdf

Rathbone, P., & Bass, R., 2012. *Unconventional gas: the potential impact on UK gas prices, prepared for the Department for Energy and Climate Change.* London: Navigant Consulting (Europe) Ltd. [pdf] Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/223492/navigant_consulting_report.pdf

30 September 2013

Centrica—Written evidence

Executive Summary

- The discovery of shale gas deposits in the UK presents an opportunity to explore a new source of gas to help meet growing UK gas demand.
- At this stage the size and commerciality of shale gas in the UK has not been fully determined - further exploration and appraisal activity is required to provide greater clarity.
- Centrica is the UK's largest energy supplier with substantial technical and project development expertise and has acquired a 25% stake in Cuadrilla's Bowland Basin exploration license (PEDL 165).
- We believe that the extraction of shale gas could deliver significant benefit to the UK and can be carried out safely with sensitivity to local communities and the local environment.
- But, we believe that the Government and Industry need to work together to maximise this opportunity and have provided key recommendations in this submission.

1. Centrica Energy and Shale Gas

1.1. Centrica plc is a FTSE top 30 integrated energy company and the UK's largest energy supplier. Centrica companies are active at each stage of the energy lifecycle: from sourcing and generating energy at Centrica Energy through to processing and storing it at Centrica Storage. The downstream business, British Gas, provides energy and energy services to half the homes in Britain and over 1 million businesses.

1.2. In terms of sourcing energy, Centrica's focus is the development of a balanced and diverse portfolio to help support a balanced and secure UK energy mix. We believe gas will play a key role in securing this mix, particularly in meeting energy demand in the short and medium term.

1.3. This year we expect to invest around £1bn to secure supplies for the UK. We are one of the fastest growing entrants on the Norwegian continental shelf; we continue to maximise resources on the UK Continental Shelf and are a growing natural gas producer on the Western Canadian Sedimentary Basin. We have also entered into recent LNG contracts with QatarGas (2011) and Cheniere (2013) to secure gas supplies for the UK.

1.4. To date UK domestic gas supplies have been offshore, but shale gas represents a new source of gas and as the UK's largest energy supplier we believe it is right to fully assess this new opportunity.

1.5. In June 2013 Centrica plc acquired a 25% interest in the Bowland exploration licence (PEDL165) in Lancashire from Cuadrilla Resources Ltd (Cuadrilla) and AJ Lucas.

1.6. Cuadrilla is the operator of the Bowland exploration, but as a joint venture partner Centrica will work closely with them to bring our strong track record in safe and transparent project development to this exploration programme.

1.7. We will utilise our significant technical expertise in gas exploration and production, including offshore hydraulic fracturing, to assess the opportunity for UK shale gas and support its development.

2. The impact of shale gas on the UK energy market and economy

2.1. Initial data from a British Geological Survey study of Northern England suggests that there could be 1,300 trillion cubic feet (TCF) of shale gas in that sector[2] and Cuadrilla Resources have estimated that there is 200 TCF in the Bowland Basin.[3] This presents a sizeable opportunity to secure new gas resources for the UK.

2.2. At present it is difficult to determine the exact impact shale gas could play on UK energy as although there is a sizeable resource present, more information is required around the recoverability and commerciality of shale gas. Exploration and appraisal wells are needed to determine key factors such as the flow rates of shale gas.

2.3. Centrica is working hard with Cuadrilla, the operator, in Bowland to gain this additional information and the UK Government – particularly through DECC, DCLG the Office for Unconventional Gas and Oil, the Environment Agency and HSE – need to work with industry to ensure that the development of exploration and appraisal wells is able to take place in a timely and efficient manner.

2.4. The Office for Unconventional Gas and Oil has an important role to play in presenting the facts about shale to local communities and highlighting the UK's commitment to developing shale gas, as long as it is carried out safely and sensitively.

2.5. In terms of the impact of shale gas on UK energy prices, we note the report by Navigant that stated: "Our three scenarios give a wide range of potential gas prices by 2030, between 50p and 80p / therm at 2012 prices… In the second half of the period under review, the main factor determining the gas price in our view will be the extent to which US LNG exports and unconventional gas production are able to disrupt the current oil price indexed European gas markets."[4]

2.6. But, we also recognise the comments of the Secretary of State for Energy, Rt Hon Ed Davey MP, when he said: "UK shale gas is unlikely to move global prices significantly". He emphasised that "shale does have the potential to contribute significantly to the UK's energy security, to attract inward investment, to boost growth and jobs in certain areas, and to make a notable contribution to the Exchequer."[5]

2.7. The House of Commons energy select committee inquiry also determined in April that it was "too early to say" whether domestic production of shale gas could result in cheaper gas prices in the UK. It said it was "unlikely" that the US shale revolution could be replicated in the UK, citing differences in "geology, public attitudes, regulations and technological uncertainties".[6]

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[2] British Geological Survey, *The Carboniferous Bowland Shale gas study: geology and resource estimation*, 2013: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/226874/BGS_DECC_BowlandShaleGasReport_MAIN_REPORT.pdf. Accessed August 2013.

[3] Cuadrilla Resources Website: http://www.cuadrillaresources.com/what-we-do/about-natural-gas/. Accessed August 2013.

[4] Navigant, *Unconventional Gas and the Potential Impact on UK Gas Prices*, July 2013: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/223492/navigant_consulting_report.p. Accessed September 2013.

[5] The Rt Hon Ed Davey MP, Secretary of State for Energy and Climate Change, Office of Unconventional Oil and Gas Introductory Event, 11 March 2013. Found at: https://www.gov.uk/government/speeches/office-of-unconventional-oil-and-gas-introductory-event. Accessed August 2013.

[6] House of Commons Energy and Climate Change Committee, *7th Report: Impact of Shale Gas on Energy Markets*, 26th April 2013: http://www.publications.parliament.uk/pa/cm201213/cmselect/cmenergy/785/78502.htm. Accessed August 2013.

2.8. We believe that the development of natural gas from shale could have an important role to play in securing vital gas supplies for the UK as 80% of households are reliant upon gas for heating.[7]

2.9. The extraction of shale gas could also help reduce our reliance on gas imports and support substantial investment and employment. It is estimated that natural gas from shale could reduce the amount of gas the UK has to import in 2030 from 76% to 37%; nationwide investment could reach £3.7bn a year and 74,000 jobs could be supported across the industry and its supply chain.[8]

2.10. We also do not consider that investment in UK shale gas will displace investment in low-carbon generation. Investment in renewables in the US has increased by more than 400% during the last 7 years, at the same time that shale gas has grown dramatically.[9] Centrica has recently marked 10 years of investment in renewables with the opening of the Lincs Offshore Wind Farm in August and we believe that shale gas can play an important role in a balanced UK energy mix.

3. The impact of shale gas on the UK environment

3.1. Hydraulic fracturing of oil and gas reservoirs has been performed since 1949, with 2.5 million fracturing jobs having been performed worldwide, and 60% of all oil and gas wells now using fracturing techniques.[10] The technique is not new to the UK either, where 2,000 wells have been drilled onshore in the UK and 200 of these have been hydraulically fractured.[11]

3.2. The UK government has looked very closely at the impacts of onshore fracturing – including seismicity, impact on water supplies, air pollution and local impact – and is confident that it can be done in a safe and sensitive manner. There are very strict environmental regulations in place to cover all aspects of onshore fracturing and the Department for Energy and Climate Change, Environment Agency, Health and Safety Executive and Office for Unconventional Gas and Oil are working closely together to ensure the industry meets rigorous standards.

3.3. Centrica is committed to rigorous operational standards and although Cuadrilla is the operator, we have published a set of global operating principles, which will be applied to the Bowland project as well as to any future onshore natural gas exploration Centrica is involved in around the world. These principles cover all of the areas highlighted by operations to date in the US and are based on advice from industry experts, including the British Geological Survey, Royal Academy of Engineers, International Energy Agency, and the Centre for Sustainable Shale Development (CSSD) – a coalition of US shale companies and environmental groups.

3.4. The Department for Energy and Climate Change recently published *About shale gas and hydraulic fracturing*,[12] which assesses and provides further details around the key

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7 DECC, *The Future of Heating: A strategic framework for low carbon heat in the UK,* March 2012: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48574/4805-future-heating-strategic-framework.pdf. Accessed September 2013.

8 Institute of Directors, *Infrastructure for Business: Getting Shale Gas Working*, May 2013: http://www.iod.com/influencing/policy-papers/infrastructure/infrastructure-for-business-getting-shale-gas-working. Accessed August 2013.

9 *Ibid*.

10 NSI Technologies, 'Hydraulic Fracturing', 2010: http://www.spe.org/jpt/print/archives/2010/12/10Hydraulic.pdf. Accessed August 2013.

11 Institute of Directors, *Infrastructure for Business: Getting Shale Gas Working*. May 2013.

12 Department for Energy and Climate Change, *About Shale Gas and Hydraulic Fracturing*, July 2013: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/225826/About_Shale_gas_and_hydraulic_fracking.pdf. Accessed August 2013.

issues associated with this process. Also, DECC's Chief Scientific Adviser, Professor David Mackay, also recently reported that "With the right safeguards in place, the net effect on UK GHG emissions from shale gas production in the UK will be relatively small." The report indicated that shale gas rated favourably to other sources of gas in terms of emissions.[13]

3.5. We recognise that there needs to be more information about shale gas and hydraulic fracturing and we call on the Office for Unconventional Gas and Oil to work with DECC, the Environment Agency and HSE to provide information and answer the questions being asked across the country about this industry.

4. Community impact, engagement and benefits

4.1. We firmly believe that the most successful projects are developed through proactive engagement with communities and honest dialogue to address key issues. Centrica has worked on a number of large-scale onshore and offshore projects that required sensitive engagement with local communities and we will work in partnership with local communities and contribute towards sustainable, long-term benefits for the local area and economy through the development of jobs, skills and other initiatives that support local issues.

4.2. The UK Onshore Operators Group's (UKOOG), of which Cuadrilla is a member, will also play an important role in community outreach. They have developed a community engagement charter for their members, which has openness and transparency at its core and provides a robust framework for operators working alongside local communities in the extraction of natural gas from shale. This charter can be found on UKOOG's website.[14]

4.3. It is right that if hydraulic fracturing takes place in the Bowland Basin local communities should receive benefits for hosting these projects. Cuadrilla has already said that, should the project move to the production phase, a community fund would be established to ensure local community benefits from its operations. The UK Onshore Operators' Group (UKOOG) proposed benefits for local communities of £100,000 per well site at exploration/appraisal stage where hydraulic fracturing takes place and a share of proceeds at production stage of 1% of revenues, allocated approximately 2/3rd to the local community and 1/3rd at the county level.[15]

4.4. We do believe, however, that local community benefits must be accompanied by an efficient planning process and should be designed to deliver genuine, sustainable, benefits to the local community.

5. Next Steps and Recommendations

5.1. Shale gas presents an exciting opportunity for the UK, but more information is required to determine the extent of this opportunity for the UK and the key priority is to develop exploration and appraisal wells that can provide further information and data on shale gas. To ensure this takes place we recommend that:

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[13] Professor David Mackay, *Potential Greenhouse Gas Emissions Associated with Shale Gas Extraction and Use*, September 2013: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/237330/MacKay_Stone_shale_study_report_09092013.pdf. Accessed September 2013.

[14] UK Onshore Operators' Group (UKOOG), *Community Engagement Charter*, June 2013: http://www.ukoog.org.uk/elements/pdfs/communityengagementcharterversion6.pdf. Accessed August 2013.

[15] UK Onshore Operators' Group (UKOOG), *Community Engagement Charter*, June 2013: http://www.ukoog.org.uk/elements/pdfs/communityengagementcharterversion6.pdf. Accessed August 2013.

5.1.1. The Government work with industry to engage with local communities to provide the facts about shale gas; answer the questions that local people will have and build trust. OUGO should spearhead this work and support industry in the early shale sites where public acceptance will be more cautious.

5.1.2. Government and Industry need to work with academics and the EA, OUGO, and DECC to present the scientific evidence on shale gas, which could help to assure the local community about the safety of shale exploration. This includes specific enquiries and focuses on key concerns for people, such as water.

5.1.3. Government and Industry need to work to further map the jobs and skills that could be developed alongside shale gas in local communities.

5.1.4. Government should implement a simple and supportive shale gas pad allowance, following HMT's recent consultation on the tax regime for shale gas.

5.1.5. Government needs to support an efficient and effective planning regime for shale gas, to ensure projects are able to take place. DCLG recommendations over the summer were an important step towards this, but the development of secondary legislation in the autumn will also be critical.

30 September 2013

Chemical Industries Association (CIA)—Written evidence

1. The Chemical Industries Association (CIA) is the trade association and employers federation for chemical and pharmaceutical businesses located throughout the UK. The chemical and pharmaceutical industry contributes £20 billion per year to the UK economy, provides direct and indirect employment for over half a million people and is the UKs number one manufacturing exporter. The chemical and pharmaceutical industry is energy intensive and is the largest industrial sub-sector by energy consumption (at 47TWh) in 2012.

2. As a major energy user, the UK chemical industry supports the development of 2 unconventional gas (including shale gas) while protecting the environment and ensuring that the public are both safeguarded and receive associated benefits. This is because indigenous sources of unconventional gas offer a secure and potentially competitive source of feedstock (raw material) as well as energy at a time when supplies from the North Sea are in decline. Development of unconventional gas will improve the business case for investment in UK chemical capacity. The therefore CIA welcomes recent Government initiatives to encourage the development of these resources in the UK

1. How much scope is there for shale gas and oil - from domestic and overseas sources - to be used in the UK? Over what timeframe?

3. The UK may prove to have significant shale gas reserves. If commercially viable, shale gas development could bring benefits - economic, energy security and environmental - to the UK, as it has in the U.S. We believe that shale gas could find a ready market for several decades, and that its use will be limited by its availability rather than demand. As an energy source, it is the same as the gas from the North Sea and elsewhere circulating in the UK gas grid. Shale derived methane could complement declining North Sea output and imported gas, and replace coal in power generation.

4. From a chemical industry perspective, the principal components of shale gas, ethane and methane, are both chemical feedstocks as well as a source of energy (in the case of methane). As supplies of ethane from the North Sea gradually run down, we need to source alternative supplies for the large chemical plants (ethylene crackers) which use it. Methane can be used both for manufacture of ammonia and nitrogen fertiliser. There is potential for cost effective supplies indigenously sourced of shale gas to not only sustain current operations but also to improve the business case for investment in UK chemical capacity. However, prerequisites for growth also include competitive and secure supplies of energy and a level playing field on climate policy related costs. In this respect, the level to which energy intensive businesses will be exempted from the impact of low carbon incentives on power costs (expected to be as high as 70% by 2020) is currently uncertain.

5. Shale oil will be readily absorbed in the global crude oil supply. The quantities being produced in the US are having a significant effect on trade patterns and might have helped to reduce prices were it not for the elevated risk to supplies caused by Middle Eastern instability.

6. While the development of shale gas and oil in the UK has an uncertain timeframe, we note that the UK Onshore Operators Group is predicting that 20-40 exploration wells will be

drilled by the end of 2014. This could align with the chemical industries' new Strategy for delivering chemistry-fuelled growth[16] which calls for further proof of commercial viability by the end of 2014 to enable commercial flows by 2017. Availability of exported US shale gas in quantity in the UK may also offer a nearer term prospect.

2. How will the costs, including those on the environment, of accessing the UK's shale gas and oil deposits compare to those of other sources of energy?

7. These are still early days for determining the costs of extracting UK shale gas in commercial quantities. While comparisons with the US should be made with caution, experience there suggests shale gas can be produced at relatively low cost, and certainly on a competitive basis with gas supplied from other sources such as imported liquefied natural gas (LNG). The British Geological Survey results[17] show the UK's Bowland reserves are 10 times thicker than any US shale reserves. This could help to reduce the cost of extraction.

8. While UK shale gas will not result in a US-style surplus and fall in general gas prices – because the effect will be diluted in the larger European market - it could reduce the risk of UK gas price spikes due to shortages and could also help to reduce prices in UK forward markets.

9. The UK is linked to mainland Europe by several gas pipelines, some of which can transport gas in either direction. Together with other pipeline networks in the North Sea, these offer flexibility in moving gas from Norway and the UK to and from different parts of Europe. The price of gas within this European network is also heavily influenced by contracts which are linked to the oil price. UK gas prices are mainly determined by such contracts and the general supply/demand balance in Europe as a whole.

10. However, at times of high demand, especially in the UK, the price will be set by the cost of marginal supply, usually LNG. In winter, the rest of Europe is also likely experience high demand, and the flow of gas by pipeline to the UK may be restricted, either for reasons of capacity, or because all available gas is needed for local customers in mainland Europe. This may lead to price spikes as UK suppliers are either forced to bid for such LNG cargoes as are available on the global market, and/or offer incentives for some customers to reduce their demand. Greater availability of indigenous UK gas, whether shale, coal-bed methane, or indeed new North Sea supplies, reduces the likelihood of such events.

11. Because US shale gas has displaced coal in US power generation, more US coal has become available on world markets. This has reduced coal prices in Europe, so that for power generation coal is currently the preferred fuel, even with current carbon charges. However, environmental constraints mean that many existing coal fired generators will close and gas fired power is cheaper than new nuclear or wind, even before taking into account the cost of back-up for days when the wind does not blow.

12. Environmentally, we believe the paper by DECC issued on 30 July About shale gas and about shale gas and hydraulic fracturing (fracking)[18] is a fair assessment of the environmental implications and should give confidence that environmental risks are well understood and can be safely controlled. The UK's long term carbon reduction targets will ultimately

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[16] http://www.cia.org.uk/Portals/0/Documents/Growth%20Strategy%20FINAL.PDF
[17] https://www.gov.uk/government/publications/bowland-shale-gas-study
[18] https://www.gov.uk/government/publications/about-shale-gas-and-hydraulic-fracturing-fracking

require the use of gas as a fuel to be combined with carbon capture and storage (CCS) technology and, preferably, usage technology. More support is needed for research into technically and economically viable CCSU options and revenues from shale gas could help to fund this.

3. What is the potential impact of shale gas and oil on the local economies in areas where development is possible?

13. US experience has been that shale extraction has boosted the local economy, creating well paid jobs for local people and the instigation of a $100bn boom in petrochemicals investment[19]. The successful development of shale extraction in the UK will create skilled jobs, directly increase GDP and help to reduce the country's trade deficit. It may bring downward pressure on energy prices, and lead to further gains in output in the rest of the economy

14. Shale gas producers will pay substantial taxes to Treasury on their production income and will also provide benefits to local communities. The IoD estimates[20] that investment in shale gas production could reach £3.7bn a year, supporting 74,000 new jobs. Locally producers will provide communities with financial benefits of £100,000 per well site during exploitation and 1% of production revenues. Shale gas could also help to sustain and grow the UK chemical industry which contributes £20 billion per year to the UK economy and provides direct and indirect employment for over half a million people throughout the economy with key production locations in the north west and north east of England, Humberside, and the east coast of Scotland.

4. What will be the impact of shale gas on the cost of electricity generated at gas-fired power plants and how will it compare to other forms of generation including coal, nuclear and renewable?

15. Coal is currently the cheapest generation fuel with gas acting as a more marginal fuel, setting the power price most of the time. "Old" nuclear has a lower marginal cost, but the "strike price" being discussed for electricity from new nuclear is much higher than the cost from gas fired plant. Wind, certainly the offshore variety, is more expensive still, even before the extra costs of bringing power from remote locations, and providing back-up for its unpredictable and unreliable output are taken into account. Gas usually provides the necessary back-up, because of its rapid response capability. However, investment in new gas fired generation plant is hard to justify because it must always make way for wind power when the latter is available. "Capacity payments" offer an incentive to provide such back-up, and the government is currently deliberating on what precise form they should take in the UK energy market.

5. Will the UK electricity market be easily able to incorporate shale gas in future or will generators be locked into long-term contracts with other energy sources? Are there any other potential barriers to the use of shale gas in electricity generation?

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[19] http://www.businessweek.com/articles/2013-07-25/chemical-companies-rush-to-the-u-dot-s-dot-thanks-to-cheap-natural-gas
[20] http://www.iod.com/influencing/policy-papers/infrastructure/infrastructure-for-business-getting-shale-gas-working

16. We see no problems, contractual or otherwise, with incorporating shale gas into electricity generation. Indeed, the more renewables are installed, the greater will be the need for gas fired capacity as back-up. The only other forms of generation which provide similar dependability are coal, nuclear and hydro, and none of these is likely to see aggregate capacity increased.

6. Which forms of electricity generation is shale gas likely to displace and by how much?

17. We foresee that coal fired power generation will continue to decline. Climate policy could eliminate coal entirely, although there would be security of supply benefits from retaining some operational coal fired capacity. Natural gas (shale or otherwise) is likely to fill the gap. Present nuclear capacity is also scheduled to be retired, and it appears unlikely to be replaced in time by new build. Only coal and gas can provide a reliable alternative, and of these gas is to be preferred because of its lower emissions intensity.

7. What impact will shale gas and oil have on household energy bills?

18. Shale gas could help to reduce household energy bills, although not dramatically. (See comments under Q3 and Q4). If shale gas comes to be seen as an acceptable alternative (at least in the interim) to more expensive renewables, the downward impact on household bills will be much greater. The recent report by Navigant consultants, commissioned by DECC[21], provides an analysis of the likely impact on wholesale gas prices. This effect will be diluted in household gas bills, because the wholesale price of gas is only a part of the total. There may be a further indirect impact on electricity costs, because gas is likely to be the marginal fuel in power generation. Again, however, household energy bills contain many other components such as transmission costs, which have been increased by the need to connect remote wind locations to the grid, and the cost of more general subsidies to renewables operators.

8. What effect will the use of shale gas and oil have on carbon emissions compared to other combinations of energy sources?

19. The recent report by DECC: Potential Greenhouse Gas Emissions Associated with Shale Gas Extraction and Use[22] concludes that, if adequately regulated, the overall carbon footprint of piped shale gas will be comparable to conventional pipeline gas and lower than that for imported liquefied natural gas.

20. Greater use of shale gas instead of coal will clearly reduce emissions, as has been witnessed in recent years in the US. Using more (shale or other) gas to back-up wind would probably have little effect on overall emissions, since gas used relatively inefficiently as a fill-in for fluctuating wind produces much the same aggregate emissions as gas used efficiently on a continuous basis. House of Commons paper #517, "The Economics of Wind Power" submitted to the Commons Energy and Climate Change Select Committee during its 2012-13 session, contains plausible calculations to this effect. The UK's long term carbon reduction targets will ultimately require the use of gas as a fuel to be combined with carbon capture and storage (CCS) technology and, preferably, usage technology. More support is

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[21] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/223492/navigant_consulting_report.pdf

[22] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/237330/MacKay_Stone_shale_study_report_09092013.pdf

needed for research into technically and economically viable CCSU options and revenues from shale gas could help to fund this.

21. Oil is unlikely to be used in power generation, and substituting shale oil for any other crude oil will make no difference to emissions from transport or domestic fuel oil heating. Any additional volume of UK shale oil would be insignificant in setting the global oil price and thereby affecting overall usage and associated emissions.

9. Will shale gas and oil increase UK energy security?

22. Yes, certainly for gas. Although oil is a globally traded commodity with many sources, and gas is also fast approaching that status, from a security of supply perspective it is preferable to have readily available indigenous resources available wherever possible. In the same way that a "just in time" manufacturer prefers to have his key suppliers located close at hand, it is desirable to minimise dependency on major long range supply lines where single failures can have serious consequences: pipelines can fail, and LNG shipments can be diverted to other markets willing to pay a higher price.

23. As highlighted under Q1, from a chemical industry perspective, the principal components of shale gas, ethane and methane, are also chemical feedstocks and will continue to be important in terms of feedstock security. As supplies of feedstock from the North Sea decline, indigenously sourced supplies of shale gas have the potential not only to sustain current operations but also to improve the business case for investment in UK chemical capacity.

10. What infrastructure investment will be necessary to cope with the development of shale gas and oil? How far will it help to ensure sufficient UK energy supplies? How will this investment be financed?

24. Producers should benefit from the ease of delivering shale gas to the gas grid because of likely proximity to part of the existing comprehensive network of main gas pipes. Provision of pipeline connections to the gas grid, and connections for water and power supplies from the equivalent local sources, are the main infrastructure requirements, which we expect would largely be financed by the shale producers.

25. When it comes to ethane, which is a component of shale gas and of value as a feedstock to the chemical sector, there is potential to use the existing ethylene pipeline to ship supplies from the northwest of England to petrochemical plants on the east coast of Scotland and in the north east of England.

11. What changes to public policies are necessary to maximise the potential of any shale gas development?

26. The past 12 months has seen a strong, concerted policy response from the Government regarding the potential for shale gas development in the UK. The Chancellor has proposed a reasonable taxation system which recognises the risks inherent in shale exploration and extraction. And the Office for Unconventional Gas and Oil is addressing the need to streamline permitting and that the government has issued guidance to streamline the planning process. We hope these developments will support the expeditious and fair application of the planning process and operational regulations.

12. Will shale gas and oil lead the UK to be less dependent on energy from less reliable regions of the world such as the Middle East and Russia?

27. The development of shale gas will help further to diversify the UK's options to supply its future natural gas demand. While, as noted above, the UK is already part of a closely interconnected regional European gas market, the presence of a new, indigenous gas should benefit UK gas security.

13. What lessons can be learnt from the US experience of shale gas and oil?

28. The main lesson from the US experience – other than being able to adopt straight away some of the drilling techniques which have been perfected over several decades – is that most of the "scare" stories about hydraulic fracturing have been proved groundless. The sheer scale of US operations now provides reliable evidence that shale gas and oil extraction by the hydraulic fracturing process is a safe procedure.

29. A second lesson is that with a "can do" spirit, enormous economic benefits follow. The shale gas boom has sparked a huge wave in investment in chemical plants using ethane and methane, while the cheapness of US energy – both gas and electricity – is prompting a "reshoring" of much other manufacturing activity. A recent report from IHS[23], a leading provider of market and economic analysis, estimates that already in 2012 the US shale boom had created over 2 million extra jobs, contributed $285 billion to US GDP and generated almost $75 billion in federal and state tax receipts. By 2020 the jobs total is projected to reach over 3 million, the annual GDP contribution to be $468 billion and tax receipts to be $125 billion. Net overseas trade will be boosted by $160bn annually and the disposable income of the average US household will be increased by $2500 a year.

30. Such impressive figures cannot be translated directly to the UK economy, for the various reasons already outlined above, but in the context of the smaller UK economy, the boost to activity could nevertheless be dramatic.

3 October 2013

[23] America's New Energy Future: The Unconventional Oil and Gas Revolution and the US Economy: Volume 3: A Manufacturing Renaissance (September 2013)

Cuadrilla—Written evidence

Introduction

Cuadrilla has attracted much of the media focus on exploration of shale gas in the UK and is proud to be the first-mover in what could prove to be a very economically beneficial industry for the UK. In our view a UK shale gas industry could, if managed correctly, be instrumental in providing highly skilled jobs in areas which badly need them, in building energy security, in supplying tax revenues for the exchequer as North Sea revenues diminish, in meeting demand for energy for electricity, heating and industrial use, and in playing an important role in the UK's future energy mix.

Cuadrilla is a small, specialist, British SME with some of the foremost experts in geology and unconventional oil and gas engineering and drilling in Europe. We are in the vanguard of unconventional oil and gas exploration in Britain and likewise in Holland. Together with our partners Centrica and A.J. Lucas we hold a 1200 KM2 licence in the Bowland basin in Lancashire. Cuadrilla plans to drill, hydraulically fracture and flow test a small number of exploratory wells to show how much of the huge quantity of natural gas in place in the Bowland shale (a resource recently assessed by the British Geological Survey as most likely to be 1,300 trillion cubic feet) is commercially recoverable.

The opportunity in the Bowland Basin

Cuadrilla believes that the successful exploration and development of the Lancashire Bowland Basin - regarded as potentially one of the most significant ever UK gas discoveries - can be done safely, environmentally responsibly and, in conjunction with investment in renewables, provide the best possible pathway to a low carbon energy future for the UK.

It has been stated that the geology of shale in the UK is different from the United States and not conducive to successful and commercially significant shale gas production. In the view of our own expert geologists and other qualified experts who have viewed the available data this is not the case so far as the Bowland basin is concerned. In fact the shale layer in the Bowland is more than a mile thick and Cuadrilla and other expert assessment of the shale samples recovered from exploratory wells demonstrate that it can be successfully hydraulically fractured.

It is also frequently stated that the population density in the UK means that the shale revolution in the United States cannot be reproduced here. In that respect the nature of the Bowland geology is highly significant because the thickness of the shale layer in the Bowland basin (many times greater than typical US shale basins) could allow for gas to be produced from relatively fewer vertical wells with a much larger number of lateral wells radiating below the surface from each vertical. These lateral or horizontal wells would be effectively stacked one above another draining gas from multiple levels within the shale.

The Institute of Directors (IoD) report *Getting shale gas working,* authored by Corin Taylor, Senior Economic Adviser at the IoD, concluded that: "only a small amount of land is needed for shale gas development. One 2-hectare site could potentially support 40 horizontal wells and supply enough gas to power 747,000 homes at peak production. One hundred such sites would take up just two square kilometres of land, and could supply around one third of our UK gas needs at peak".

Obstacles to Development of UK shale gas and oil

Unfortunately development of this potentially very positive economic scenario is hampered by a proliferation of scientifically unproven scare stories. Contrary to the views of a vocal minority there is a clear scientific and academic consensus, underlined here in the UK by the Royal Society and the Royal Academy of Engineering joint report (see joint report July 2012 http://royalsociety.org/policy/projects/shale-gas-extraction/report/), and by other prominent academic experts that unconventional oil and gas exploration and production can be carried out entirely safely in the UK. Concerns that have been raised around water and air contamination and seismicity can all be managed by strong regulation and industry best practice. The Government argues and we agree that the oil and gas regulatory process in the UK is already the strongest in the world.

Although there is clear evidence that public opinion favours continued exploration for shale gas (see Nottingham University – Public Perception of Shale Gas extraction in the UK: Increasing acceptance July 2013) it is also the case that scare stories are not immediately and decisively addressed by the relevant regulatory bodies who should be able to deal with the misinformation immediately and with credibility.

We believe there is a role for Government in ensuring that the views of independent academic experts are made available to the public in areas where exploration will take place. This committee is in a position to make clear how the UK should look at this opportunity, and to help focus policy makers on the job to be done. Our recommendation is that the Committee uses this opportunity to circumvent the extremist narrative, reassure the public that appropriately regulated exploration of this opportunity can and must take place in a timely fashion, and to recommend more work on community benefit structure and delivery.

Scientific Consensus in Support of Safe and Environmentally Sustainable Exploration and Production

Additionally there is a growing scientific consensus that shale gas has a role to play in contributing to reduction of CO_2 in the UK. The report commissioned by the Department of Energy and Climate Change and led by the department's Chief Scientist, Professor David Mackay, with Dr Timothy Stone, published on 9 September (Potential greenhouse gas emissions associated with shale gas extraction and use: A study by Professor David J C MacKay FRS and Dr.Timothy J Stone CBE) is very interesting in this regard. The report concluded that shale gas's overall carbon footprint is comparable to gas extracted from conventional sources (e.g. the North Sea), lower than that of imported Liquefied Natural Gas and significantly (four to five times) lower than coal.

The debate on Britain's energy needs almost invariably defaults to the supply of electricity, the need to decarbonise our electricity generation and the threat of the "lights going out". In the context of this debate it is very important to note that some two thirds of UK gas demand has nothing to do with electricity generation and is in fact used for domestic heating, cooking and industry. Over 90% of UK homes use gas for heating. In the absence of a credible plan to replace this heating demand, then, irrespective of what happens in the electricity supply market, gas is going to have a major role to play in Britain's energy supply for the next thirty years or more. Given the decline in Britain's reserves of gas from the North Sea and increasing dependence on imported gas in the form of LNG from Qatar and pipeline gas from Russia and Norway the debate should really focus on not whether or not the UK will need gas but rather where will that gas be sourced from. UK shale gas offers the potential to significantly reduce reliance on imported gas with attendant benefits to UK balance of payments as well as the opportunity for improved energy security.

This need not be at the cost of a reduction of investment in renewables for as noted gas demand in the UK is likely to remain strong for several decades to come irrespective of the increased percentage share that renewables are forecast to secure in electricity generation.

The Economic opportunity

There is clear evidence that a successful shale gas producing operation could have a major economic impact especially driving jobs and growth in areas such as the North West of England that badly need investment and jobs. The recent IoD report *Getting shale working* (see reference above) found that investment in shale gas could peak at £3.7 billion a year, supporting 74,000 jobs, not just in specialist areas such as geology and engineering but for construction workers, truck drivers and in local retail and service industries. Gas also provides essential feedstock for important industries such as chemical and fertilizer manufacture which are increasingly struggling to compete with the US where prices for feedstock and energy are some 30% lower. The IoD study supported the view that shale gas production in the UK could support jobs in the chemical industry and wider manufacturing, helping British industry to be more competitive.

Overall the IoD identified the potential opportunity in the North West of England for local communities to replicate the 'Aberdeen effect' and develop a local onshore gas and oil exploration and production expertise which could lead the development of these industries elsewhere in the UK and across Europe.

Community engagement is also a very important constituent part of sensible development and Cuadrilla has consistently advocated that local people should benefit from hosting shale exploration and development in their areas. Under the recently announced community benefit scheme local communities would receive, during the exploration phase, £100,000 per hydraulically fractured exploration well site. In addition during any subsequent production phase 1% of revenues from each hydraulically fractured well would be allocated to communities. Local people stand to benefit hugely. Work still needs to be done to detail exactly how this money would be administered, but we hope that this, along with other imaginative collaborative work with communities, will eventually create a public understanding of an inclusive industrial shale revolution providing long-term investment in communities associated with pride in British engineering and innovation.

Conclusion

Cuadrilla is at the forefront of the UK shale exploration process. Since 2008 we have drilled three gas wells in Lancashire, partially fractured and flow tested one, and conducted a 3D seismic survey of 100 km2 of our 1200 km2 Lancashire license area. Our plan in the next two years is to drill, hydraulically fracture and flow test a relatively small number of further horizontal exploration wells in the shale. The data from these wells and in particular from the flow tests will begin to answer the very important question "how much of the huge quantity of natural gas trapped in UK shale can be safely and sensibly produced".

If the UK is to have a meaningful discussion about the economic opportunities, and attract investment to help develop that opportunity (should it wish to do so) it is vital that this exploration plan must be fulfilled in a safe and responsibly, but also in a timely manner.

Response to questions

1. ***How much scope is there for shale gas and oil - from domestic and overseas sources - to be used in the UK? Over what timeframe?***

1.1 We believe that there is huge scope for competitively priced domestic shale gas to substantially reduce our gas import dependency. Total UK gas demand is currently some 3 trillion cubic feet (tcf) per annum. The British Geological survey has estimated that in the North of England alone the Bowland shale contains, most likely, 1,300 tcf of gas. If just 10% of that gas could be recovered that represents over 40 years of domestic supply. By 2030, without shale gas, it is forecast by DECC that the UK will be importing some three quarters of its gas needs. Developing our own shale resources has we believe the potential to halve import dependency by 2030. However the full scope of this potential can only be properly addressed through a near term exploration and appraisal process.

1.2 There has been a lot of speculation, some well-informed, about the size of the resource and how much can be recovered.

1.3 Estimates for how much of gas and oil resources can be recovered have always been dependent on the technical ability, at time of estimate, to both make assessments of the size of the resource and what fraction of that resource can be recovered. While the resource itself remains the same, our ability to comprehend how much is there and what is viable to extract on economic grounds changes, and history tells us very often increases over time. So while a 10% recovery factor might be considered a reasonable estimate today, in 10 years' time that is likely to have increased. Oil and gas fields are never abandoned because they have run out of oil and gas. It becomes a question of the technology and economics of extracting the remaining reserve.

1.4 The technical limitations depend upon subsurface shale characteristics; the well deliverability, operational issues such as the pace of new drilling; and the industry's capacity to field rigs, fracturing equipment and crews. These factors in particular are what distinguish onshore shale gas extraction from the conventional deposits offshore. We will only know accurately how much is potentially available when we have more empirical data.

2. ***How will the costs, including those on the environment, of accessing the UK's shale gas and oil deposits compare to those of other sources of energy?***

2.1 The cost of exploration will to some extent depend on the ability of the planning and permitting authorities to work through a relatively small number of exploration well applications in a timely manner. It will also depend on aspects of the geology only understood in full once exploration is complete.

2.2 Cuadrilla is confident that development of a natural gas resource as huge as the Lancashire Bowland Basin will prove to be commercially viable but it requires support from the office of unconventional oil and gas, the local planning authorities, regulators and communities to make this happen.

2.3 In any production phase costs are likely to be dominated by drilling and hydraulic fracturing. Industry experience is that these costs tend to be much higher at the start of activity in a new basin (such as Lancashire Bowland) and then fall dramatically over the first few years as the industry develops its knowledge of drilling and fracturing in the context of the local geology and with economies of scale as activity levels increase.

2.4 In the US breakeven costs for shale gas production are estimated to be approximately $3per thousand cubic feet (mcf). In the UK current wholesale gas prices average some $12 to $13 per mcf (i.e. over 4 times US levels). Thus whilst it is likely that UK costs will prove significantly higher than the US (particularly in the early stages), the economic potential is clear.

2.5 In relation to the environmental cost, we strongly believe that hydraulic fracturing of the Lancashire shale rock, over 6,000 feet below the surface, can be conducted with minimum cost to the surrounding environment. Water management is an important part of this. Despite some media reports to the contrary, there have been no proven cases of hydraulic fracturing fluid contaminating groundwater. Cuadrilla plans to use in Lancashire a fracturing fluid that will be non-hazardous to groundwater and contains few chemical additives any of which will require the prior approval of the Environment Agency and will be publically disclosed. The water that flows back to the surface from the shale rock with the produced gas has also been assessed as non-hazardous by the Environment Agency although it does contain very low levels of naturally occurring radioactivity. Initially this water will be taken for treatment at EA approved waste treatment facilities but over time we would expect to be able to recycle flow back water and re-use it for hydraulic fracturing.

2.6 Well integrity is vital, and much can be done at the design stage to ensure that a well is fit for purpose to prevent water contamination. Cuadrilla's wells are designed to the highest international standards. Each vertical well we drill has several layers of steel casing, the layers of which always extend beyond the depths at which the aquifer is found.

2.7 Our well designs are overseen by an independent well examiner, before being submitted to the HSE. Once the HSE has reviewed the design, and we have received all further planning applications and permissions, we are free to proceed with the construction of the well. We are confident about our well design.

2.8 The potential flaring of natural gas from shale is an area that has also been inaccurately reported on with descriptions of thousands of flares lighting up the countryside. Flaring is carried out in the exploration phase for a limited duration (typically 30 to 90 days), on a small number of exploration wells and with the volume to be flared per well restricted and regulated by both DECC and the Environment Agency. This is because in the exploration phase wells are not connected to the gas grid. During any subsequent production phase when a gas grid connection will have been established at each producing site then there should be no requirement to flare as wells are drilled and produced.

2.9 With regard to methane emissions and carbon footprint, as already noted the report by DECC's Chief Scientist, Professor David McKay, has concluded that the carbon footprint of UK shale gas extraction and use is likely to be comparable to gas extracted from conventional North Sea sources, less than imported LNG and four to five times less than coal.

2.10 In short there will be environmental costs in relation to the industrial process, truck movements etc. These environmental impacts need to be viewed in context and not be exaggerated especially in relation to the possibility of water contamination, emissions or seismicity.

3. ***What is the potential impact of shale gas and oil on the local economies in areas where development is possible?***

3.1 The US evidence is that the economic impact on local communities is profound. Our own contribution to this has been to enable independent study. Of the four studies to date, the most all-encompassing was done by the Institute of Directors. This modelled US data, to show that at peak developing a significant shale discovery such as the Lancashire Bowland formation would create 76,000 direct and induced jobs in the UK. Our suggestion is that the Committee recommend a series of economic workshops so that affected Councils begin to have a better sense of this opportunity.

3.2 It is of course very difficult to accurately predict the long term impact of an industry still in its infancy. What is particularly hard to grasp is the ongoing nature of capex and opex investment. The US will invest more than $40B this year in shale gas and oil production. And next year, and the year after that.

3.3 A productive rig can drill of the order of eight to ten wells per year (a combination of vertical and lateral). In doing so that rig will consume some £100M in capital and operating investment per year, which is of course deployed into the supply chain. Over its lifetime, a single rig could easily turn over £1B in investment.

3.4 The supply chain and skills needed to supply just 20 productive rigs would be very significant. Every single person working on a drill rig has some kind of certification, and many are required to have multiple badges from assessment. This is not an industry of "casual labour". It requires and develops both artisanal and academic skills of the highest value. In this sense it is just like the offshore industry.

3.5 There is also the demand for technology. What will develop if shale is successfully produced in the UK are markets - for rigs, fracturing equipment, seismic kit, casing, cement, and hundreds of other components. We think that this has the potential to become a new regional industry. The important thing is to maximise the percentage of UK content. We see no reason why the industry could not aim for a 65% UK content goal.

3.6 We would welcome a committee recommendation for local authorities to jointly take actions to learn more about what a fully-fledged industry could represent. Further, it may be appropriate to look at an Enterprise Zone strategy for certain regions. Given all the energy businesses in Lancashire, renewables, nuclear and shale, there is no reason why the whole North West could not take the lead in establishing an energy enterprise zone.

4. ***What will be the impact of shale gas on the cost of electricity generated at gas-fired power plants and how will it compare to other forms of generation including coal, nuclear and renewable****?*

4.1 We would emphasise that gas produced from shale is identical to natural gas from other sources, and trades in the same market as all natural gas. Natural gas is a commodity and like all commodities its price is driven primarily by supply, demand and the distance / cost involved in transporting from the sources of supply to the centres of demand. Any increase in UK domestic gas supply close to UK domestic demand will exert a downward pressure on price. In the early years of shale gas that downward pressure may be modest. Over time however as production increases and in particular with other shale gas discoveries and production in the European market a more significant downward pressure on price could emerge.

4.2 The Committee also undoubtedly understands that intermittent renewables (wind and solar) need more network balancing and instant-on generation than persistent renewables (tidal). CCGT generation can play a significant role.

5. ***Will the UK electricity market be easily able to incorporate shale gas in future or will generators be locked into long-term contracts with other energy sources? Are there any other potential barriers to the use of shale gas in electricity generation?***

5.1 We have no comment on this question.

6. ***Which forms of electricity generation is shale gas likely to displace and by how much?***

6.1 Others invited to give evidence will have more expertise in the market dynamics of energy supply.

7. ***What impact will shale gas and oil have on household energy bills?***

7.1 As mentioned, if shale gas can be produced in meaningful quantities it is likely to exert a downward influence on price. Whether that means primarily avoiding price increases or can be translated into price reductions remains to be seen.

8. ***What effect will the use of shale gas and oil have on carbon emissions compared to other combinations of energy sources?***

8.1 The relative carbon output from different sources of energy is well-documented, and other parties will speak more authoritatively on this. The study by Professor David Mackay released this month is insightful on this topic.

8.2 Natural gas, like other fossil fuels, is used for generating electricity, heating, cooking and transport, but when compared to coal, natural gas produces roughly half of the CO_2 when burned, therefore, has a smaller environmental footprint. Developing UK shale gas could help the UK use less coal according to the industry regulator Ofgem.

9. ***Will shale gas and oil increase UK energy security?***

9.1 Speaking only for the Bowland license area, even that resource alone has the potential to make an appreciable difference if it can be developed at scale. Pöyry Consulting, whom the Committee has invited to give testimony, did an analysis using Cuadrilla's exploration data and showed a significant potential impact, up to 21% of UK supply by 2030, equalling the contribution from conventional indigenous production. This has a measurable impact on UK energy security.

9.2 The Institute of Directors report published in May 2013 indicated that 76% of the UK's gas is likely to be imported by 2030, costing £15.6 billion. In the IoD's central scenario, shale gas production could reduce gas imports to 37% in 2030, and the cost of imports could fall to £7.5 billion. This would assist with the UK's balance of payments and support energy security.

10. *What infrastructure investment will be necessary to cope with the development of shale gas and oil? How far will it help to ensure sufficient UK energy supplies? How will this investment be financed?*

10.1 In terms of enabling investment, Lancashire is heavily networked with gas lines already in place. In the sites we have evaluated, the nearest connection point is usually only a few kilometres away. Water lines will have to be run to sites in some cases but again there is an extensive water grid in place and connection points are widespread throughout Lancashire. In this respect the UK is actually far better positioned than the US ever was to develop a shale gas industry.

10.2 The strategic investment involved should be considered in the context of the "gas is an essential transition fuel" message. There needs to be R&D devoted to development of a cost-effective low carbon energy system. This could incorporate the potential use of CCS, but also many other solutions that result in efficiency and demand reduction. This investment could be financed by ring-fencing a portion of tax receipts.

11. *What changes to public policies are necessary to maximise the potential of any shale gas development?*

11.1 Cuadrilla supports and seeks to reinforce the regulatory framework in the UK, although we are impatient with the pace of implementation, and as we have said, distressed by the inability of the regulators to get across a necessary message of environmental safety.

11.2 Cuadrilla is confident that shale gas exploration and subsequent development can be conducted safely and environmentally responsibly through robust regulation and this is supported by the scientific consensus amongst recognised and qualified expert opinion. It is crucial for the commercial future of the industry, however, that we are able to conduct our relatively modest exploration in a timely manner to provide the additional technical data essential for the scoping and assessment of potential development at scale.

12. *Will shale gas and oil lead the UK to be less dependent on energy from less reliable regions of the world such as the Middle East and Russia?*

12.1 Significant domestic shale gas production would evidently significantly reduce the need for imports from which ever source.

13. *What lessons can be learnt from the US experience of shale gas and oil?*

13.1 There are two lessons from the industry's experience in the States. One is that effective regulation is a collaborative and continuously developing process, not a fixed prescription. Contrary to popular view, American regulation in this sector is extremely experienced, intensive, and confident. American regulation has evolved in collaboration with industry, communities and environmental stakeholders. This multi-stakeholder approach has proved effective in dealing with issues as they arise. Regulatory agencies have done much to assuage public anxiety because their process has been inclusive and timely.

13.2 The second lesson is about technology and innovation. The shale gas industry is composed of people and companies who try new solutions. A cycle of continuous innovation makes its way into the industry. Collaborative regulators are able to see improvements, and build them into regulation process. Doing something new and different provided it is safe and environmentally responsible is not frowned upon.

13.3 There is of course a third observation from the States. This industry has the potential to re-energise a moribund economy, and provide a sense of self-determination and progress. We believe this is applicable here, although we understand that the pace and scale of development will be necessarily different.

30 September 2013

Durham Energy Institute, Durham University—Written evidence

1.0 Durham Energy Institute, Durham University

1.1 Durham Energy Institute (DEI) covers the spectrum of energy research but the areas in which we excel are those which lie at the boundaries between the traditional technical disciplines and the social sciences and humanities. In terms of this call for evidence we have world-leading experts in the geoscience of shale gas and also in power engineering.

1.2 ReFINE (Researching Fracking in Europe) is a pan-European research consortium led by DEI. The researcher group to date are Durham, Keele, Newcastle and Heriot Watt universities. The advisor-stakeholder group includes the European Commission's Joint Research Centre, the UK's Environment Agency and the UK's Department of Energy and Climate Change. Supporting organizations are the Geological Society of Bulgaria and The Geological Society, London. Funders are NERC, Chevron, Shell and Total.

2.0 Poten

3.0 tial Scale of Shale Gas in the UK

2.1 The UK is at a very early stage in shale gas exploitation – known as the exploration phase. During this phase drilling activity is limited to a small number of exploration wells. After which there will be a better understanding of whether the gas can be produced at economic rates and quantities. It is possible that results will be disappointing. If the results are promising then there would be a significant increase in the number of wells drilled to develop and produce the resource.

2.2 Analysis on the gas resources estimated by the BGS (BGS, 2013) for Northern England indicate that the potential is significant and that the UK may have sufficient shale gas to meet UK demand for many years to come.

2.3 The number of wells that could be drilled to exploit shale gas in the UK depends on a number of factors including social acceptance and economics.

2.4 Using data from producing shale gas wells from 5 shale provinces in the USA, the ultimately recovery (EUR) from a shale well varies from between 1.4 BCF (Billion Cubic Feet) to 5.9 BCF. We estimate that on average a conventional gas well in the Southern North Sea (UK) produces between 8 and 33 times more gas in its lifetime. Therefore as a rule of thumb a shale gas well produces a fraction of the gas that a conventional gas well produces.

2.5 If one assumes that development takes place mainly unhindered by factors such as social acceptance, then one can use this range in EURs of 1.4-5.9 BCF as a guide to the number of wells that would be required for every 1 TCF (trillion cubic feet) of total production in the UK. We estimate that every 1 TCF of production would need between 169 and 714 wells. This statistic hides the fact that much of the production comes from the first couple of years of life of the shale gas well. There is normally a rapid decline in production after that. In 2012 the UK imported about 1.8 TCF of gas.

4.0 Lessons learnt from USA shale gas and oil

3.1 At least two million hydrocarbon wells have been drilled in the USA.

3.2 Just 2,152 hydrocarbon wells that have been drilled onshore in the UK already since 1902, targeting conventional reservoirs. By way of comparison there are 250,000 abandoned mine shafts in the UK the locations of which are unknown. We estimate that 1138 of the 2152 wells in the UK are what the American's would term 'orphaned' – they have no clear ownership because the company that drilled the well no longer exists.

3.3 If shale gas takes off in the UK unhindered by economics or acceptability then the UK could drill more wells than we have in our last 111 years. It is very likely to be the biggest increase in drilling activity onshore since the 1940s.

3.4 Several wells (e.g. based on the USA around 12) could be drilled from a well pad.

3.5 There is no easy way to find out how many of the existing onshore UK wells are leaking.

3.6 Our research indicates that many wells in the UK cannot be effectively monitored as they been buried by subsequent land use, such as farming and housing developments.

3.7 There are examples of best practice on well monitoring in Pennsylvania where an online database on well infringements exists as well as some sort of investment which provides insurance for well repairs after the company has left or gone out of business.

4.0 Role in the Energy Mix

4.1 Gas plays, and is likely to play, a very considerable role in the UK energy mix. While gas's share of generation fell from 40% in 2011 to 28% in 2012 (DUKES, 2013), it was due to coal being relatively cheaper than gas as the result of shale gas replacing coal for electricity generation in the USA and therefore USA dumping cheap coal on world markets. However this trend may be reversed in future as the ratio between gas and coal changes.

4.2 Cheap coal means that more coal has been burned in the UK (increase from 30% in 2011 to 39% in 2012) with the resulting detrimental effect on CO2 emissions (burning coal releases approximately twice as much CO2 than burning gas per unit of electricity produced). However the EC regulations (Large Combustion Plant Directive) limit the number of hours a coal plant can operate unless it has equipment limiting emissions of sulphur dioxide, nitrogen oxides and dust. Due to availability of cheap coal such plant have been closing earlier than expected, with only 1GW currently operating (out of the original 9GW of coal plant without emission-limiting equipment in 2008), half of which should close by 2014/15. On the other hand UK regulations prevent building new coal plants that are not ready to accept Carbon Capture and Sequestration (CCS) equipment. All this means that the role of coal is likely to be limited in the future UK supply mix.

4.3 Shale gas is a fossil fuel, therefore burning it add greenhouse gases to the atmosphere, but it is cleaner than coal – as stated earlier burning coal releases approximately twice as much CO2 than burning gas per unit of electricity produced. If cheap shale gas becomes available in the future, it is likely to replace coal with a relatively positive environmental effect. The extent to which cheap shale gas could displace wind generation depends on the appropriate subsidy/tax regime reflecting impact of gas and wind on the environment. Such displacement is unlikely to happen if the current generous subsidy regime for wind continues in the future when shale gas becomes available.

4.4 It is not widely appreciated that gas plays a significant role in supporting wind generation. Wind intermittency (i.e. relatively rapid changes of generation when wind speed changes) requires a back-up from other sources of generation. The main source of such balancing is gas generation due to a relatively fast speed with which gas plants can change their output. Coal plants, and especially nuclear plants, are quite inflexible. This means that significant amounts of wind generation will require a significant support from gas generation.

4.5 A balancing service for intermittency of wind (point 4.4 above) could also be provided by energy storage, customer response or via interconnection with other countries thus limiting the importance of gas. However energy storage is still, and likely to remain, prohibitively expensive, interconnectors have limited capacity and it is not clear at all at the moment to what extent one will be able to rely on the customer response balancing intermittency of wind. Hence the role of gas in supporting wind, while perhaps diminishing in the future, is likely to remain quite significant.

4.6 Regarding security of supply, Ofgem expects (Electricity Capacity Assessment Report 2013) that generation capacity margins "will decrease to potentially historically low levels in the middle of the decade and that the risk of electricity customer disconnections will appreciably increase, albeit from near-zero levels". However it is unlikely that UK's shale gas will help in filling the generation gap due to a significant time lag (at least 5-10 years) before the UK's shale gas becomes available (due to the time required for exploration and supply chain development). Hence it is expected that shale gas is unlikely to play a significant role in the security of supply in the short- to medium-term.

4.7 In summary, the availability of cheap and abundant shale gas would support expansion of wind generation while reducing CO2 emissions by replacing coal, improving security of supply in the long-term and reducing energy bills. The evidence from USA is that shale gas has reduced dramatically gas prices thus reducing energy costs (http://www.eia.gov/dnav/ng/hist/n9190us3m.htm). The extent to which cheap shale gas could displace wind generation depends on the appropriate subsidy/tax regime reflecting impact of gas and wind on the environment.

References:

Baihly, J., Altman, R., Malpani, R., Luo F., 2010, Shale gas production decline trend comparison over time and basins, SPE 13555.

DUKES, Digest of UK Energy Statistics 2013, DECC

Electricity Capacity Assessment Report 2013, Ofgem 2013.

27 September 2013

Électricité de France (EDF) Energy—Written evidence

Key Points

- EDF Energy is committed to delivering affordable, secure, and low carbon supplies based on a diverse energy mix. As part of this, we believe that unabated gas fired generation, including that from shale gas, will play an important role in the transition towards a decarbonised power sector in the 2030s by providing the firm backup generation required for balancing the electricity system.

- However, further investment in any unabated gas generation plant, beyond the minimum that is required to bridge the gap to the transition to low carbon technologies, would introduce significant challenges in meeting the UK's legally-binding climate change objectives. Such investment substantially increases the risk that the UK's long term emissions reduction targets will not be met, or at least be met in a cost-effective manner. This is either because the carbon emissions from these new assets will be 'locked in' or, alternatively, because it increases the risk of stranded assets.

- We support the steps that the Government has taken so far to develop shale gas in the UK, and its ambition to ensure that any debate is supported by evidence-based information. The environmental risks from drilling and hydraulic fracturing must continue to be managed effectively. This will require the Government to establish a strong regulatory regime with the aim of reducing risk to as low a level as reasonably practicable to assuage public concerns over the environmental and safety aspects of shale gas operations.

- Based on the currently available evidence, we agree with the conclusion of the House of Commons Energy and Climate Change Select Committee from its May 2011 report that shale gas is unlikely to be a "game changer" for the UK, and that we are unlikely to replicate the production experience of the USA.

- European shale gas production costs are likely to be higher than those in the USA. Reasons include differences in regulatory, fiscal, labour and environmental regimes, as well as land and resource access issues pertaining to geology and population density.

- Although the volume of gas available worldwide may be increasing, once the cost of LNG transportation (and re-gasification) to Europe is taken into account, this may only curb the extent of price rises in the longer-term rather than drive prices down from current levels. In addition, it is likely that LNG cargoes diverted from the USA will be used to meet growing demand in Asia rather than go to Europe.

- We welcome the Secretary of State for Energy and Climate Change's recent announcement that "we must not and will not allow shale gas production to compromise our focus on boosting renewables, nuclear and other low carbon technologies"[24]. Shale

[24] 'Davey: UK shale gas development will not be at expense of climate change targets', DECC Press Release, 9 September 2013, http://tinyurl.com/nvrcsr4

gas should be considered as a complement, and not an alternative, to low carbon technologies such as renewables and nuclear.

- It is imperative that the Government maintains its continued momentum on Electricity Market Reform (EMR). The Government's proposals will provide the investment framework that is crucial for the low carbon investment that the country needs to deliver its energy policy objectives, and will keep costs down for consumers.

About EDF Energy

EDF Energy is one of the UK's largest energy companies with activities throughout the energy chain. We provide 50% of the UK's low carbon generation. Our interests include nuclear, coal and gas-fired electricity generation, renewables, and energy supply to end users. We have over five million electricity and gas customer accounts in the UK, including both residential and business users.

EDF Energy's response to your questions

1. How much scope is there for shale gas and oil - from domestic and overseas sources - to be used in the UK? Over what timeframe?

1. The UK has historically been self-sufficient in gas as UK Continental Shelf (UKCS) production has been able to meet all of the UK's annual heating and gas-to-power demand. However, over the past decade domestic production has declined with imports making up the shortfall. This has come from a diverse range of sources including Norway, Continental Europe and globally sourced liquefied natural gas (LNG). In 2011, imports exceeded production for the first time and comprised 53% of the UK's gas supply[25]. This trend is likely to continue with the UK forecast to import at close to 70% of its gas consumption by 2025[26].

2. Shale gas is similar in chemical composition to conventional gas and so in this respect there is nothing inherently unique about it. We believe that it should therefore be considered as an additional source of gas rather than a new fuel per se as is often portrayed. The impact of shale gas and oil on the UK will largely depend on how much can be produced and what the production costs will be.

3. In terms of potential shale resource and production volumes, the most recent estimates indicate shale gas volumes in place in the UK to be substantial, ranging from 18 trillion cubic metres (tcm)[27] to 38 tcm[28]. However, estimates of technically recoverable resources are much lower, ranging from 150 billion cubic metres (bcm)[29] to 740 bcm[30.] This represents 2-9 years of UK gas demand in 2012[31]. It is important to treat these figures with caution because as the Government acknowledges "little

[25] 'Potential Greenhouse Gas Emissions Associated with Shale Gas Extraction and Use', D. MacKay & T. Stone, 2013
[26] 'The Myths and Realities of Shale Gas Exploration', E. Davey speech, 9 September, http://tinyurl.com/pdoaeoa
[27] 'Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States', US Energy Information Administration, 2013
[28] 'The Carboniferous Bowland Shale gas study: geology and resource estimation', British Geological Survey, 2013
[29] 'The Unconventional Hydrocarbon Resources of Britain's Onshore Basins - Shale Gas', British Geological Survey, 2010
[30] 'Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States', US Energy Information Administration, 2013
[31] UK Future Energy Scenarios', National Grid, 2013 states 2012 UK gas demand was 77.3 bcm

drilling or testing has taken place [and so] it is not at this stage possible to make meaningful estimates of how much shale gas may be practically and commercially recoverable"[32].

4. Estimates of UK shale oil resources are more limited due to the absence of detailed geotechnical data[33]. The US Energy Information Agency estimated the UK possessed 54 billion barrels[34] of shale oil resource in place, of which technically recoverable resource amounts to 690 million barrels[35].

5. In Europe, estimates for the volume of shale gas are also significant with potential volumes up to 139 tcm[36] and technically recoverable resources ranging 17[37] to 25 tcm[38]. Within Europe the most attractive potential markets are Russia, Poland, France and Ukraine. However, we note that to date Polish shale gas exploration has been less successful than anticipated[39]. Russia, which already possesses large resources of conventional gas, and France, which currently has a hydraulic fracturing moratorium in place, will likely be slower to develop their shale resources in the short to mid-term. European shale gas is expected to be imported to the UK through existing or new continental interconnectors.

6. As the most mature market in the world, the US is the only country with proven reserves of shale gas amounting to 2.7 tcm in 2011[40]. Unproven resources are estimated to be 15.4 tcm leading to total technically recoverable resources of 18.0 tcm[41]. However, the true size of potentially extractable shale gas resources remains uncertain and is still being discovered. Today shale gas accounts for around 35% of total US natural gas production[42] with the US going from being one of the world's largest gas importers to one of the largest exporters. Due to the relatively isolated nature of the US gas market, shale gas will be shipped globally after being converted to LNG (the UK has existing LNG annual import capacity of c.50 bcm). The US has minimal existing LNG export capacity but several large projects are under construction and expected to be operational by the second half of the decade. Two LNG export licences[43] have been granted to date with a further 13 applications being assessed[44].

7. In terms of production costs, the literature we have reviewed indicates that European shale gas production costs are likely to be higher than those in the US, with predictions between 50[45] and 100 per cent higher[46]. Reasons include differences

[32] 'About shale gas and hydraulic fracturing (fracking)', DECC, 30 July 2013
[33] Stated in 'The Carboniferous Bowland Shale gas study: geology and resource estimation', British Geological Survey, 2013
[34] 'Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States', US Energy Information Administration, 2013
[35] *Ibid.*
[36] *Ibid.*
[37] 'Breaking with Convention', IHS CERA, 2010
[38] 'Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States', US Energy Information Administration, 2013
[39] *Ibid.*
[40] 'Assumptions to the Annual Energy Outlook 2013', US Energy Information Administration, 2013
[41] *Ibid.*
[42] 'The Great, Global Shale-Gas Development Race', Boston Consulting Group, 2013
[43] *Ibid.*
[44] According to Office of Energy Projects, US Federal Energy Regulatory Commission, 2013
[45] 'The Impact of Unconventional Gas on Europe', Pöyry, 2010
[46] 'Unconventional Gas, The Potential Impact on UK Gas Prices', Navigant Consulting, 2012

in regulatory, fiscal, labour and environmental regimes, supply chain maturity and detailed knowledge of the underlying geology. Public support, and ultimately social acceptability, may also prove a significant hurdle to replicating US production costs.

8. It is also important to highlight that the low gas price in the US (c.25 p/therm versus c.65 p/therm in the UK) is due to current overproduction and oversupply, and partly driven by the fact that shale gas is being extracted as a by-product from shale oil production which can attract a greater margin due to the higher price of oil. The current price is perceived by several market analysts to be below break-even and unsustainable for dry (i.e. non-oil associated) shale production and this has likely contributed to over $10bn of asset impairments in 2012. The US price is expected to rise as shale gas becomes available for export and the oversupply condition is re-balanced.

9. In the future, imported LNG will continue to play a role in offsetting the decline of UK indigenous production. Some of this volume could include exports of US LNG derived from shale. LNG conversion processes (liquefaction and regasification) and shipping contribute to significant transportation cost of delivering US gas to the UK market. The mark-up of transportation to Europe has been indicated to be up to 100% of the US wholesale gas price[47]. These costs mean US gas prices are not so different from UK prices once transportation is taken into account. This gap could narrow further as US gas prices rise as a result of rebalancing of the US market away from its current oversupplied condition, considering, of course, some uncertainty over the future range of gas prices. We would also highlight that demand from Asia will also play a role in determining whether US LNG can have a major impact on the European market since currently Asia sets the global premium price for LNG.

2. What is the potential impact of shale gas and oil on the local economies in areas where development is possible?

10. As is common with investment in other forms of large-scale energy infrastructure, shale gas and oil has the potential to create jobs and drive growth for communities that host such projects. For example, it has been estimated a multi-well shale gas pad could create a peak of around 400 direct, indirect and induced jobs during the initial construction and drilling stage and around 50 total jobs per year during the remainder of the pad's operational life[48]. However, due to the infancy of the industry in the UK, these estimates are likely to be revised as the shale gas industry gains further exploration and drilling experience.

11. As a counter to the benefit of creating jobs and supporting related industries, shale gas development is likely to have some adverse impact on local communities. It has been estimated a typical 10 well shale gas pad would require up to 8,000 truck movements[49] over its operating life, of which the majority would occur during the early drilling and construction phase. Access road and export pipelines may require construction depending on existing infrastructure at well sites. These, and other activities, could prove disruptive and so it is important that the industry fulfils its

[47] 'Unconventional Gas, The Potential Impact on UK Gas Prices', Navigant Consulting, 2012
[48] 'Infrastructure for Business, Getting Shale Gas Working', Institute of Directors, 2013
[49] *Ibid.*

commitment to early engagement with local communities to identify and mitigate local concerns in a proactive way.

12. EDF Energy supports the principle of local communities receiving direct benefits for hosting vital energy projects, and with these being distributed across the Local Authority according to the geography of the impacts from the development.

13. We note that the United Kingdom Onshore Operators Group (UKOOG), the representative body for UK onshore oil and gas companies, has published a 'Community Engagement Charter'[50]. As part of this, the industry has committed to provide community benefits at the exploration/appraisal stage of £100,000 per well site where hydraulic fracturing takes place. In addition, it will provide 1% of revenues at the production stage (split approximately 2:1 between the local community and county level).

3. What will be the impact of shale gas on the cost of electricity generated at gas-fired power plants and how will it compare to other forms of generation including coal, nuclear and renewable?

14. Shale gas is no different to the gas currently used in Combined Cycle Gas Turbine (CCGT) plant. The operating characteristics of such plant are defined by low fixed costs and high variable costs, the major contribution to which are operational costs associated with fuel and carbon.

15. The Government regularly publishes fossil fuel price projections and estimates prices rising from the current level of around 65p/therm to around 74p/therm by 2020 in its central scenario[51]. The current consensus indicates shale gas is unlikely to have a significantly impact on UK gas prices, even if significant production volumes can be achieved[52]. This means that the introduction of native or imported shale gas will have a limited impact on gas prices and the cost of generation of gas-fired plant. Please see our response to Question 5 for further detail on the issue of impact on energy costs.

16. Electricity produced from CCGT is around half as carbon intensive as electricity produced from coal-fired plant. Therefore an increasing carbon price will improve the economics of gas-fired generation relative to coal.

17. DECC publishes estimates of electricity generation costs for new build renewable and non-renewable technologies on an annual basis. Due to the interaction of a number of dynamic factors (including wholesale fuel costs, carbon costs, technology maturity, cost of financing) levelised lifecycle generation costs for different technologies can evolve significantly over time. Chart 1 illustrates DECC's most recent forecast for the evolution of the cost of generation for selected power plant technologies.

18. The cost of generation from existing power plant will vary significantly depending on plant efficiencies, operating regime, site specific factors amongst other parameters.

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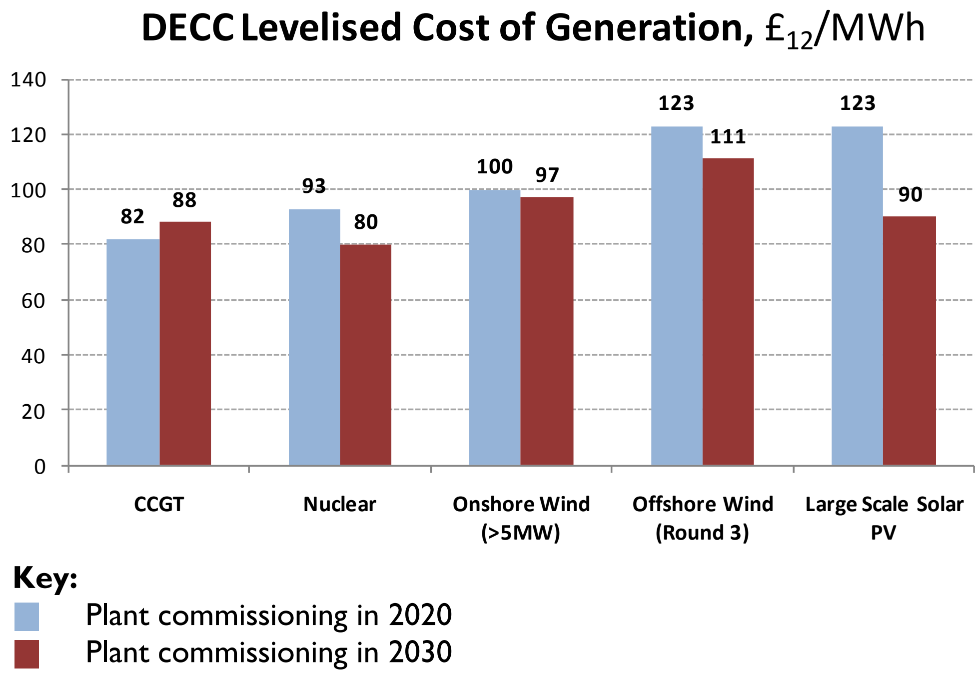
[50] http://www.ukoog.org.uk/elements/pdfs/communityengagementcharterversion6.pdf
[51] 'Fossil Fuel Price Projections', DECC, 2013
[52] 'Pöyry Point of View: Shaping the Next Future, How will Lancashire Shale Gas Impact the GB Energy Market?', Pöyry, 2012

Chart 1: DECC estimates for the levelised cost of generation by technology for power plant commissioning in 2020 and 2030[53]



4. **Will the UK electricity market be easily able to incorporate shale gas in future or will generators be locked into long-term contracts with other energy sources? Are there any other potential barriers to the use of shale gas in electricity generation?**

19. EDF Energy does not anticipate there being any major barriers with respect to the future incorporation of shale gas in the electricity market. We currently purchase our gas on a three year or less horizon, and it is our understanding that only a small proportion of UK gas demand is covered by long-term gas contracts. We therefore believe that there is not a material risk that long-term gas contracts with 'take or pay' clauses would prevent generators from using shale gas.

20. It should be noted that the UK's current gas quality standards are based on the quality of gas sourced from the UKCS[54]. Shale gas will only be allowed in the National Transmission System (NTS) if it meets the required gas specifications. It is possible that shale gas may require processing to reach this specification. For example, nitrogen injection (to reduce gas quality) or propane injection (to increase gas quality) could be needed, and this will therefore incur additional processing costs compared to existing indigenous sources of gas.

5. **What impact will shale gas and oil have on household energy bills?**

21. The impact of shale gas on the wholesale gas market price will largely depend on the volume of gas which can be produced at a competitive price compared to alternative sources. In the short term, due to the lack of onshore drilling supply chain

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[53] Table 6, central scenario from 'Electricity Generation Costs 2013', DECC, 2013
[54] Ofgem, https://www.ofgem.gov.uk/gas/wholesale-market/gas-quality

experience, European well costs will be considerably higher. However, these initial costs could be expected to reduce as European demand increases the availability of onshore drilling equipment and experienced operators.

22. Recent studies have highlighted the limited likelihood of shale gas contributing to significant reductions in consumer gas and electricity bills. Pöyry estimates that Lancashire shale gas could reduce UK gas prices by 2-4% based on an optimistic production of 12-20 bcm per year[55] from 2020 to 2030. However, our analysis calculates this would only correspond to a 2% reduction on a typical consumer's gas bill, and 1% reduction on a typical consumer's electricity bill. These reductions are not significant compared to the uncertainties surrounding future commodity prices.

6. What effect will the use of shale gas and oil have on carbon emissions compared to other combinations of energy sources?

23. Gas-fired generation (whether fuelled by conventional or shale gas) will play an important role in the transition towards a decarbonised power sector in the 2030s by providing the firm backup generation required for balancing the electricity system.

24. However, further investment in any unabated gas generation plant (whether fuelled by conventional or shale gas), beyond the minimum required to bridge the gap to the transition to low carbon technologies, would introduce significant challenges in meeting the UK's legally binding climate change objectives (as set out in the Climate Change Act 2008). While gas-fired generation has lower carbon dioxide emissions than old coal-fired generation, without carbon capture and storage (CCS) technology it is still a significant source of carbon emissions in its own right.

25. Such additional investment in unabated gas generation plant substantially increases the risk that the UK's long-term emissions reduction targets will not be met, or at least not be met in a cost efficient manner. This is either because the carbon emissions from these new assets will be 'locked in' for the duration of their operational life or, alternatively, because it increases the risk of stranded assets.

26. We welcome the Secretary of State for Energy and Climate Change's recent announcement that "we must not and will not allow shale gas production to compromise our focus on boosting renewables, nuclear and other low carbon technologies"[56]. Shale gas should be considered as a complement, and not an alternative, to low carbon technologies such as renewables and nuclear

27. It is imperative that the Government maintains its continued momentum on Electricity Market Reform (EMR). Reform of the existing electricity market arrangements is necessary to ensure the market is capable of delivering the reliable diverse energy mix required to deliver the UK's energy policy objectives. The Government's proposals will provide the investment framework that is crucial for the low carbon investment that the country needs, and will keep costs down for consumers.

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55 'Pöyry Point of View: Shaping the Next Future, How will Lancashire Shale Gas Impact the GB Energy Market?', Pöyry, 2012

56 'Davey: UK shale gas development will not be at expense of climate change targets', DECC Press Release, 9 September 2013, http://tinyurl.com/nvrcsr4

28. There is general agreement within both industry and the Government that power sector decarbonisation by 2030, or soon thereafter, is necessary to meet the UK's statutory requirement of an 80% reduction in greenhouse gas emissions by 2050. This is because low carbon electricity generation is likely to be a key driver in the decarbonisation of the residential heat and surface transport sectors. We would highlight that a number of analyses, including the Government's 2050 Pathways Analysis, show that new nuclear will be a vital component of any pathway compatible with the 2050 objective. This is because it is the most internationally competitive and lowest cost option for firm low carbon electricity supplies (as illustrated in Chart 1 above) and can make a significant contribution to providing safe, secure and affordable low carbon energy in the UK.

29. As recognised by the House of Commons Energy and Climate Change Select Committee[57], we note that there continues to be a divergence in opinion with regard to the lifecycle greenhouse gas footprint of shale gas (including direct and indirect emissions of both carbon dioxide and methane), and the issue of leakage during extraction will need to be studied further. Recent estimates for the greenhouse gas emissions intensity for shale gas, when used for electricity generation, are likely to be in the range 423-535gCO_2e/kWh[58]. This range is higher than that of conventional gas but lower than LNG life-cycle emissions.

30. The potential emergence of significant volumes of shale gas reinforces the need to establish a credible and enduring carbon price signal so that investors can make informed investment decisions. Currently the EU Emissions Trading System (ETS) price is unable to provide sufficient long-term signals to ensure relevant investments in low carbon generation. The introduction of the carbon price floor in the UK should help restore the long-term price signal that the EU ETS was expected to achieve. However, it does not remove the need to continue to expedite reform of the EU ETS at the European level.

7. What changes to public policies are necessary to maximise the potential of any shale gas development?

31. EDF Energy supports the steps that the Government has taken so far to develop shale gas in the UK and its ambition to ensure that any debate is supported by evidence-based information. We welcome the establishment of the Office of Unconventional Gas and Oil (OUGO) and in particular its role in working with regulators and industry to ensure that the regulatory regime is clear, robust and protects the local environment. It is imperative that the environmental risks from drilling and hydraulic fracturing continue to be effectively managed. This will require the Government to establish a strong regulatory regime with the aim of reducing risk to as low a level as reasonably practicable to assuage public concerns over the environmental and safety aspects of shale gas operations.

32. It is important that the concerns of the public are adequately addressed through open and transparent communication between policy makers, operators and the

[57] 'Shale Gas, Fifth Report of Session 2010-12, Volume II', House of Commons Energy and Climate Change Committee, 2011
[58] 'Potential Greenhouse Gas Emissions Associated with Shale Gas Extraction and Use', D. MacKay & T. Stone, 2013

general public. This is necessary as part of the ongoing initiatives to inform the public of the need for the transition to new safe, secure and affordable low-carbon energy infrastructure. This will help promote greater transparency and build trust between the different stakeholders involved.

33. Engaging communities during the development of proposals helps to improve people's understanding of the infrastructure, its impacts and any mitigation measures required, as well as fostering a sense of trust. Building constructive relationships with neighbours and key stakeholders throughout the planning process also helps to ensure constructive relationships later during operation and beyond.

34. We believe that both local and central Government have a number of responsibilities in relation to the public understanding of risk, not only just in relation to shale gas, but energy projects in general. This includes consulting on and defining national policy; ensuring that the public has access to clear and reliable information; and providing resources for world class research and for authoritative independent agencies.

35. We welcome the Government's commitment to work with the relevant regulators, including the Environment Agency in England and the Health and Safety Executive, to monitor and control the environmental and health and safety aspects of shale gas operations as appropriate. It is important that these agencies work together in a co-ordinated and consistent manner to help foster public trust.

36. We support the Government's decision to accept the recommendations of the Royal Society and the Royal Academy of Engineering, as set out in their review of hydraulic fracturing[59]. In particular, we note that they recommend that "monitoring should be carried out before, during and after shale gas operations to inform risk assessments"[60]. Adopting the recommendations will help improve the credibility of the steps being taken to develop shale gas. We also believe that the regular publication and promotion of information (e.g. Q&As), that addresses key areas of public concern such as safety, air pollution, seismicity and water use and contamination, will also be useful in helping to increase public acceptance.

8. What lessons can be learnt from the US experience of shale gas and oil?

37. The commercialisation of shale gas extraction in the US took place slowly over 30 years. This included significant Government sponsorship through R&D programmes, suitable fiscal policies and market deregulation which introduced pricing signals incentivising shale development. Today operators have access to better technology and shale gas know-how than US pioneers but innovation will be required to adapt to areas where geology, access to required resources and local regulation is significantly different from the US.

38. Technological innovation has been the key driver of increasing shale gas production and commercialisation. Improvements such as 3D micro-seismic mapping, horizontal drilling, multi-stage fracturing and reduction in requirement for proppant (sand or

[59] Royal Society and the Royal Academy of Engineering, Shale gas extraction in the UK: a review of hydraulic fracturing, June 2013.
[60] *Ibid.*, p4

ceramic materials which help to keep fractures open) and fracturing fluid volumes have all contributed to a significant reduction in the costs of production.

39. However, it is likely exploration and production in the UK will face new, country-specific challenges. These will only be able to be overcome if the UK's shale development potential can be confirmed through further exploration and geological mapping. If sufficient commercial incentives are in place, including gas price signals and a suitable fiscal framework, companies will be able to commit to research and development to overcome anticipated technical challenges.

40. Independent operators were the first to develop shale gas plays in the US but the increasing capital costs of "factory drilling", amounting to around $32 billion capital expenditure in 2012[61], has lead to significant consolidation of the US industry. It is likely that the UK will follow a similar path of independents being first to develop resources with larger oil and gas companies, who have more attractive short-term investment opportunities in conventional oil and gas, entering the market once shale gas play resources are confirmed and investment becomes de-risked.

41. For the UK, a particular challenge will be overcoming environmental and local community opposition. This is in contrast to the US where generally, due to sparser population density, landowners possessing mineral rights, a history of large scale onshore oil and gas production and the creation of strong employment opportunities in the industry, social and environmental acceptance has been more easily achieved. We believe that the UK has a world class regulatory regime for high-risk energy production industries which can be adapted to suit the specific risks of shale gas extraction. However, overcoming public opposition will require both industry and the Government addressing concerns in a transparent way and ensuring host communities are compensated in a reasonable and fair manner.

30 September 2013

[61] 'Infrastructure for Business, Getting Shale Gas Working', Institute of Directors, 2013

E.ON—Written evidence

Summary of key points

- E.ON is one of the largest suppliers of gas and electricity in the UK. We own and operate various fossil and renewable power stations and a gas storage facility in the UK. We also have an Exploration and Production business with a regional focus in gas and oil production in the North Sea, Russia and Algeria.
- E.ON is not involved in any unconventional gas production activities in Europe or elsewhere.
- We do not expect shale gas to have a significant impact on gas prices in the short to medium term, so would caution against assumptions that shale gas will dramatically reduce energy bills. However, provided the regulatory regime is sufficiently robust, we do believe that opportunities can be explored in a sustainable way.
- We do not believe significant quantities of shale gas will be produced and marketed within Europe in the next decade at least.
- The UK is part of a well connected, liquid and established European gas market; any cost benefit following a discovery of cheaper gas in the UK (whether shale or not) would therefore be smeared across the wider European and global gas markets. This means that, taken with our expectations of the scale of shale gas exploitation in the UK, any impact of domestic shale gas would be limited.
- We recognise that neither the UK nor Europe is likely to be able to produce shale gas on a scale which leaves them self-sufficient. This means that the UK and Europe are likely to continue to need to import gas from outside Europe and so wholesale prices will reach the levels where this occurs regardless of domestic shale gas production.
- Our understanding is that environmental concerns associated with shale gas extraction need not be any greater than those from other forms of gas (or mineral) extraction and that, whilst extraction techniques may be different, the risks associated with shale gas extraction can be managed without causing undue harm to the environment.

We have focused our response on questions where we feel most able to comment.

How much scope is there for shale gas and oil - from domestic and overseas sources - to be used in the UK? Over what timeframe?

1. Gas is likely to play a role in our energy market for some time to come. In its latest report (Next Steps on Electricity Market Reform[62]) the Committee on Climate Change sets out a number of scenarios for a future low carbon electricity generation mix in 2030. In the most ambitious of these, which achieve a CO_2 intensity of 50g CO_2/kWh, the CCC still expects around 40-45TWh of electricity to be generated from gas in 2030

[62] http://www.theccc.org.uk/publication/next-steps-on-electricity-market-reform-23-may-2013/

(down from 86.3TWh in 2012). Generation mix scenarios that reflect a higher cost of low carbon generation, but are still consistent with the UK's climate change goals (achieving 100g CO_2/kWh), see up to 125TWh of electricity generated from gas in 2030. It is likely that the demand for gas for heating will reduce over this period as UK consumers replace gas fired boilers with electric heat pumps (indeed, the CCC's analysis assumes an increase in demand for electricity for precisely this purpose).

2. It is clear, therefore, that there is a continued role for gas, from whatever source, as part of a low carbon energy system. However, as we outline below, the extent to which shale gas is used in the UK is likely to be limited, at least in the short to medium term, by the economic benefits it brings.

What will be the impact of shale gas on the cost of electricity generated at gas-fired power plants and how will it compare to other forms of generation including coal, nuclear and renewable?

3. The UK gas market is well connected to the wider European gas markets and has the capability to import gas from outside of Europe. Any cost benefit following a discovery of cheaper gas in the UK (whether shale or not) would therefore be smeared across the wider European and global gas markets, reflecting the prevailing price in those markets. Therefore we do not expect to see a significant change in the cost of power generation as a result of the quantities of economically viable shale gas we expect to be recovered in the UK.

4. Based on the experience of North Sea Oil and Gas and how that market has evolved since the 1960s, we do not expect significant quantities of shale gas to be produced within Europe in the next decade. If significant quantities were subsequently produced, their impact on price is unclear due to the uncertainty associated with the cost of extraction and the price of other sources of gas. We would therefore caution against assumptions that discovery and extraction of shale gas will reduce energy prices in the foreseeable future.

5. Changes in wider global energy markets and national and international regulatory frameworks are more likely to impact the cost of generation in the UK going forward. For example, the extensive use of shale gas in the US has actually reduced the cost of coal in the UK (and the rest of the world) due to the reduced demand for coal in the US as it is replaced by gas. This meant that in 2012 coal-fired generation produced 39% of the UK's electricity, up from 29% in 2011[63], increasing UK CO_2 emissions as a result.

6. Any increase in the accessible (importable) supply of gas globally is likely to put downward pressure on gas prices and therefore reduce the cost of gas-fired power generation from what it would otherwise have been. However, with a rising European carbon price, which is a fundamental and necessary element of the EU's climate change package, gas could remain an expensive form of generation in the long term when compared to low carbon generation, even if gas prices were to fall in real terms.

7. When comparing the cost of gas generation to other forms of generation it is important to consider the scope for cost reductions based on the maturity of each technology. Gas, coal and nuclear generation technologies are relatively mature; therefore fixed or capital costs of these technologies are unlikely to reduce significantly in future.

[63] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/225045/statistics_press_notice_2013.pdf

Renewable technologies such as wind (particularly off-shore) or solar are relatively immature and so there is greater scope for cost reductions as these technologies become increasingly industrialised. The rate and scale of these costs reductions will be crucial in any cost comparison with gas generation.

8. Cheaper gas prices would favour gas generation over coal generation, particularly when combined with a rising carbon price (as coal generation produces around twice as much CO_2/kWh than gas). However, given the UK's carbon price floor policy, European environmental regulations such as the Industrial Emissions Directive, the potential for a new global climate deal in 2015 and further strengthening of the EU's Emissions Trading System, it is in any event unclear how much coal generation will remain on the system in the UK by the time shale gas could be entering the global market in significant quantities.

Will the UK electricity market be easily able to incorporate shale gas in future or will generators be locked into long-term contracts with other energy sources? Are there any other potential barriers to the use of shale gas in electricity generation?

9. As described above, the UK's gas market is part of an established, liquid and well connected European gas market. The UK market uses a virtual trading location known as the National Balancing Point (NBP) where gas is exchanged between buyers and sellers. To the extent that shale gas has an impact on price, we would expect this to be reflected in NBP prices. Many gas contracts are indexed to NBP and therefore even long term contracts should reflect any impact of shale gas.

10. From a physical perspective, shale gas would need to be treated to ensure it met the relevant quality standards before introducing it to the gas network or for use in power stations, although this would be true of any other source of gas.

11. Should shale gas offer economic benefits in future, we expect the UK electricity market to be able to incorporate it relatively easily.

Which forms of electricity generation is shale gas likely to displace and by how much?

12. As described above, we do not expect domestic (UK) shale gas to have a significant impact on the cost of gas in the immediate future. Therefore, we do not expect domestic shale gas to significantly alter the generation mix in the UK. Similarly, domestic shale gas is not expected to significantly reduce the cost of gas fired heat when compared to electrical heat.

13. Assuming the UK and EU remain committed to their climate change goals, and given our expectation that the price of gas will be largely unaffected, shale gas is highly unlikely to replace low carbon forms of generation.

14. To the extent that it has any impact on price, shale gas could displace coal generation; although, as noted above, it is likely that coal generation would have already been severely reduced by carbon prices and environmental regulations by the time this happens. There may however be a greater impact in terms of replacement of coal generation in other countries where coal is otherwise expected to be a greater part of the future generation mix going forward (e.g. China, India).

What impact will shale gas and oil have on household energy bills?

15. We do not expect significant quantities of shale gas to be produced and marketed within Europe for the next decade. The UK market is also well connected to the European and wider global gas markets, and so we would caution against assumptions that shale gas will reduce energy bills in the near future. We do not expect a significant impact on the wholesale price of gas in the UK as a result of domestic shale gas in the short or medium term.

16. Discovery and extraction of shale gas would further diversify the UK's sources of energy and therefore could provide security of supply benefits in the longer term, reducing reliance on other sources of gas. However, we note that, as the UK is already part of a well connected and liquid gas market, it is already relatively insulated from supply side shocks.

17. Assuming the UK and EU remain committed to action on climate change, it is likely that, by the time shale gas and oil have any impact on household energy prices (whether for electricity, heat or transport), cheaper, lower carbon sources of energy will be available. This is due to the likely reduction in cost of low carbon energy as technology matures and the impact of higher carbon prices on fossil fuels (especially in the UK through the carbon price floor).

What effect will the use of shale gas and oil have on carbon emissions compared to other combinations of energy sources?

18. Carbon emissions from shale gas and oil can be considered in two parts:
    - Emissions when burning the fuel; and
    - Emissions when extracting/transporting/processing the fuel.

19. Emissions when burning the fuel are no different to any other form of gas or oil (although precise emissions will depend on the quality of the fuel which may vary depending on its source).

20. A material reduction in the cost of gas generation relative to coal generation could reduce UK carbon emissions by displacing coal in the power sector. However, as we note above, we do not expect any impact from UK shale within the next decade, at which point coal power generation is likely to be very limited anyway as a result of high carbon prices and European environmental regulations.

21. We are not best placed to comment on emissions from extracting/transporting or processing shale gas or oil. However, we would note that transport emissions would be lower when using domestic sources of gas or oil rather than LNG/oil imports.

Will shale gas and oil increase UK energy security?

22. New domestic sources of gas or oil will undoubtedly improve UK energy security by diversifying our energy sources further. However, we do not expect shale gas to be produced at such a scale to make the UK (or Europe) self-sufficient in gas. Therefore the UK will continue to rely on imports of gas from the wider global market.

23. The UK is already part of a well connected European gas market and has access to global LNG supplies, so we consider the risks to gas security to be relatively low today.

Last year for example, we saw an unusually prolonged and cold winter, leading to an inevitable tightening of the gas market. The market responded as expected by providing the right price signals to gas shippers and the gas flowed.

What changes to public policies are necessary to maximise the potential of any shale gas development?

24. As described above, whilst we believe the potential for shale gas should be explored in the UK, we would caution against premature assumptions that shale gas will result in lower energy bills for customers. Any change to public policy should reflect this uncertainty along with the importance of reducing CO_2 emissions in the UK in order to meet our legally binding climate change targets.

25. The fundamental geology in the UK cannot be changed, therefore if Government wishes to promote and encourage shale gas development it can only do so by affecting 'above ground' factors. The key above ground challenges to shale gas development appear to be financial (giving companies the incentive to explore given the uncertainty involved), regulatory and public perception. To overcome these challenges, it is important that any fiscal regime (such as the proposal published in July 2013) is accompanied by consistent, coherent and robust regulatory regimes that are appropriate for the risks posed by shale gas extraction along with strategies for public engagement at both local and national levels.

26. We note that recent developments have polarised the debate into extremes, with some parties claiming shale gas will significantly reduce energy bills whilst others are stating that the environmental costs are too great.

27. We take a more balanced view: we are sceptical that shale gas will significantly affect gas prices in the UK but believe that provided the regulatory regime is sufficiently robust, opportunities can be explored in a sustainable way.

Will shale gas and oil lead the UK to be less dependent on energy from less reliable regions of the world such as the Middle East and Russia?

28. See answer to Q9 above. Discovery and extraction of UK shale gas and oil will increase energy security by diversifying supply although we believe the UK gas market is already well insulated from specific supply issues from certain regions.

29. Imported gas is likely to remain a key part of the UK's energy mix in future so imports from regions such as the Middle East and Russia, where a considerable amount of global gas reserves are located, are still likely.

What lessons can be learnt from the US experience of shale gas and oil?

30. Whilst E.ON has not explored shale gas opportunities to date, we would caution against using the US as an example of what can be achieved with shale gas. Differences in geology, licensing regimes and environmental regulation mean that lessons from the US experience have limited relevance in the UK and elsewhere in Europe.

31. The US is also currently a more isolated market without significant export capacity relative to the amount of domestic gas now available. This means changes in domestic reserves have a greater impact on price. As described above, the UK has benefitted

from a liquid and well connected European market which brings more stable prices and increased energy security. This does mean that the price impacts of shale gas will be less extreme than those witnessed in the US thus far.

30 September 2013

Friends of the Earth England, Wales and Northern Ireland, Greenpeace UK and World Wildlife Fund (WWF-UK)—Written evidence

Summary

- This joint response from WWF-UK, Greenpeace UK and Friends of the Earth England, Wales and Northern Ireland focuses on UK shale gas.

- While there might be some sizeable reserves of shale gas in the UK, evidence suggests that it is highly unlikely that these reserves could be available fast enough, cheaply enough and in enough volume to offset the price-setting role of imported gas in the UK. Given the very distinct circumstances applicable in the UK compared to the US and the fact that the UK is an integral part of the European gas market, it is highly unlikely that a UK shale gas boom could significantly reduce the price of gas in the UK, let alone offset the UK's increased dependency on gas imports (see questions 1, 2 and 4).

- Even in the event of substantial exploratory drilling going ahead, it will not be possible for a number of years to know the size, if any, of the UK's economically extractable shale gas reserve. However, highly optimistic claims on the future potential of shale gas create the risk of incentivising the construction of an excessive reliance on new gas infrastructure in the UK. This would cement even further the UK's dependence on imports of gas, would increase its vulnerability to the international gas price and would result in the UK being locked into a gas heavy system that is incompatible with its goal of reducing its emissions of greenhouse gases by at least 80% by 2050 in the Climate Change Act 2008.

- Thus, it is important on economic, energy security and environmental grounds that the prospect of future gas extraction in the UK does not lead to policies encouraging an increase in gas usage in the power or other sectors. It would be similar to an argument that enhanced extraction of North Sea oil should affect policy on consumption of petrol and diesel (see question 9).

- The UK is not faced with a false choice between burning lots of coal – as it is currently doing given the low prices of both coal and carbon - or burning lots of shale gas instead to meet its energy needs. As clearly demonstrated in recent evidence from the Committee on Climate Change[64] and major institutions such as the International Energy Agency[65], the World Bank[66] and the United Nations Environment Programme[67], the answer to the long-term decarbonisation, affordability and energy security challenges faced by countries like the UK is to make an early and decisive move towards an efficient

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[64] *Next Steps on Electricity Market Reform*, the Committee on Climate Change, 23 May 2012: **http://www.theccc.org.uk/publication/next-steps-on-electricity-market-reform-23-may-2013**
[65] *World Energy Outlook 2012'*, the International Energy Agency, November 2012: **http://iea.org/publications/freepublications/publication/English.pdf**
[66] *Turn Down the Heat: Why a Warmer 4°C World Must Be Avoided',* the World Bank, November 2012: **http://climatechange.worldbank.org/sites/default/files/Turn_Down_the_heat_Why_a_4_degree_centrigrade_warmer_world_must_be_avoided.pdf**
[67] *'The Emissions Gap Report 2012'*, United Nations Environment Programme, November 2012: **http://www.unep.org/publications/ebooks/emissionsgap2012/**

and low-carbon energy system. This would significantly reduce the UK's demand for gas (and other fossil fuels) in the next twenty years (see questions 8 and 9).

- A recent report from Cambridge Econometrics showed, for example, that compared to a dash for gas generation, policies enabling a continued deployment of offshore wind farms in the UK to 2030 would increase UK GDP by £20bn/ year by 2030, create 70,000 more jobs by then, reduce gas imports by some £8bn/ year and produce emissions in the power sector that would be three times lower, with only minimum impact on UK electricity prices. Importantly, these conclusions remain valid under a wide range of assumptions on the future price of gas and the economic benefits remain the same with or without UK shale gas exploration[68].

- To put the UK on such a path, UK energy policy should be strengthened through the adoption of a commitment to decarbonise the UK's power sector in the Energy Bill currently going through the House of Lords and by the Government's clear endorsement of the Fourth Carbon Budget recommendations from the Committee on Climate Change during the review expected in spring 2014.

- Further, the recent *Redrawing the Climate and Energy Map* report from the International Energy Agency suggests that meeting the internationally agreed limit of 2 degrees centigrade of warming would mean that just under half of all 'currently proven gas reserves' (i.e. discovered volumes having a 90% probability that they can be extracted profitably) must go unexploited by 2050[69]. The IEA, Ernst and Young[70] and Bloomberg[71] have forecast that UK/EU shale gas production will be relatively expensive (by comparison to conventional extraction and US shale gas). This means that encouraging a "new shale gas revolution" in the UK could either contribute towards the world burning more gas than is compatible with tackling dangerous levels of climate change or result in there being simply no market for UK shale gas. Thus, there is a significant risk that UK shale gas extraction could lead to stranded assets (see questions 6, 8 and 9).

[68] *A study into the Economics of Gas and Offshore Wind*, Cambridge Econometrics, November 2012: **http://www.wwf.org.uk/wwf_articles.cfm?unewsid=6342**

[69] *Redrawing the Climate and Energy Map*, International Energy Agency, June 2013, page 98-99 & figure 3.5: **http://www.worldenergyoutlook.org/media/weowebsite/2013/energyclimatemap/RedrawingEnergyClimateMap.pdf**;

[70] **http://www.shalegas-europe.eu/en/docs/E&Y_Shale-gas-in-Europe_revolution-or-evolution.pdf**

[71] *"Is UK Shale Gas all it's fracked up to be?"*, Bloomberg New Energy Finance, 7 February 2013.

Introduction

1. This submission is made on behalf of WWF-UK, Greenpeace UK and Friends of the Earth England, Wales and Northern Ireland. In line with the latest scientific findings of the Intergovernmental Panel on Climate Change[72], our organisations are strongly committed to helping prevent the worst environmental, societal and economic impacts of climate change and in particular preventing global average temperatures from rising above 2°C compared to pre-industrial levels.

2. We believe that an increased deployment of renewable energy technologies[73] coupled with a greater focus on improving energy efficiency and increasing the UK's interconnection with European grids and other demand management/response techniques are the most viable options to deliver a successful and cost-effective decarbonisation of the UK's and the EU's power sector by 2030, with gas playing a limited role as a transitional and system balancing fuel.

3. This is supported by a substantial body of analysis showing that renewable energy, energy efficiency and greater regional interconnection can form the bedrock of the decarbonisation of the EU and the UK's power sectors. This includes Poyry's work for the Committee on Climate Change's *Renewable Energy Review*[74], research from DECC, the Crown Estate and industry supporting the UK's *Offshore Valuation Report*[75], research from Imperial College and Kema supporting the European Climate Foundation's *Roadmap 2050* report[76], research from Garrad Hassan underlying WWF-UK's *Positive Energy* report[77] and recent cross-industry research supporting Carbon Connect's *Power from Renewables* report[78].

4. We are strongly of the view that rapidly decarbonising the UK's energy system makes economic as well as environmental sense. A recent report from Cambridge Econometrics showed for example that compared to another dash for gas generation, policies enabling a continued deployment of offshore wind farms in the UK over the next 20 years would increase UK GDP by £20bn/ year by 2030, create 70,000 more jobs by then, reduce gas imports by some £8bn/ year and produce emissions in the power sector that would be 3 times lower, with only minimum impact on UK electricity prices. Importantly, these conclusions remain valid under a wide range of assumptions on the future price of gas and the economic benefits remain the same with or without UK shale gas exploration[79].

Question 1: How much scope is there for shale gas and oil – from domestic and overseas sources – to be used in the UK? Over what timeframe?

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72 *Fifth Assessment Report - Summary for Policy Makers*, Intergovernmental Panel on Climate Change, 27 September 2013: **http://www.climatechange2013.org/images/uploads/WGIAR5-SPM_Approved27Sep2013.pdf**

73 We would urge the Committee to review the conclusions of the Crown Estate Offshore Wind Cost Reduction project, released on 13 June 2012 **http://www.thecrownestate.co.uk/media/305094/Offshore%20wind%20cost%20reduction%20pathways%20study.pdf**

74 *Renewable Energy Review*, Committee on Climate Change, May 2011: **http://www.theccc.org.uk/reports/renewable-energy-review**

75 *The Offshore Valuation Report*, DECC / Crown Estate / Industry, July 2010: **www.offshorevaluation.org**

76 *Roadmap 2050*, European Climate Foundation, September 2010: **http://www.roadmap2050.eu/**. See also the *Power Perspectives 2030* report, November 2011**: http://www.roadmap2050.eu/project/power-perspective-2030**

77 *Positive Energy: How renewable electricity could transform the UK by 2030,* WWF-UK, October 2011: **www.wwf.org.uk/positiveenergy**. The underlying technical analysis carried out by Garrad Hassan is also available on the same page.

78 *Power From Renewables*, Carbon Connect, September 2013**: http://www.policyconnect.org.uk/cc/research/report-future-electricity-series-part-2-power-renewables**

79 *A study into the Economics of Gas and Offshore Wind*, Cambridge Econometrics, November 2012: **http://www.wwf.org.uk/wwf_articles.cfm?unewsid=6342**

5. The question of how much shale gas can be made available for the UK market depends on the following critical questions: (i) how much shale gas is there in the UK; (ii) what is the realistic flow of production for UK shale gas; (iii) how much gas can be used going forwards in the UK given its legally binding commitments in other areas such as those under the Climate Change Act 2008; (iv) how much gas will be used globally if international action to tackle climate change reaches agreed ambition; and (v) over what timeframe?

(i) How much shale gas is there in the UK?

6. The recent British Geological Survey (BGS) report estimated that the Bowland shale in Lancashire and Yorkshire may contain 1300 trillion cubic feet (tcf) of gas. The BGS stressed that this is a highly uncertain estimate and also included high and low estimates at 2281 tcf and 822 tcf respectively. It stressed that these numbers are not indicators of the volume of gas likely to be extracted, which will depend on economic, technological and environmental factors. The estimate often used for the percentage of gas which can actually be recovered is 10%, although actual recovery figures appear to be more like 6.5%[80]. If 10% of the 1300tcf of gas were extracted, then this would be equivalent to about 41 years of UK current gas consumption. However a study by the US Environmental Information Agency[81] (EIA) concluded that once risks are factored in only around 4% of the UK's resource was likely to be technically recoverable.

7. The Bowland shale has an upper and lower layer. There is some evidence that the upper layer resembles some North American shales such as the Barnett. The lower layer, in which the majority of the gas can be found (1065tcf of the 1300tcf estimated to be present), is less well understood and estimates of gas in place in the lower layer have a far higher degree of uncertainty[82].

(ii) What is the realistic flow of production for UK shale gas?

8. While the BGS has recently revised upwards its estimate of shale gas reserves in the UK, evidence suggests that it is unlikely that the UK will witness similar rates of production and downward impacts of gas prices (see response to question 2) than those observed in the United States.

9. Analysis provided in a recent report from Bloomberg New Energy Finance found for instance that *"UK shale gas will not be available fast enough, cheaply enough or in enough volume to take over the price-setting role from imported gas"*[83]. This is in part due to a set of circumstances that are very different to those in the United States, in terms of geology, property rights (with UK landowners not having the right to mineral resources under their land), the lack of midstream infrastructure (such as gathering pipes transporting raw gas to processing facilities) and the lack of an onshore drilling services market.

10. Based on analysis comparing production flow rates from comparable shale gas basins in the United States, the report concluded that *"UK shale gas production would need to rise to 4.0-4.5Bcfd to offset declines from the UK continental shelf and eliminate the need for imports. Even if test fracking demonstrates high flow rates, this would require around 50 rigs drilling almost 1,000 wells in the English countryside each year at the peak of activity."* Given the higher

80 **http://www.foeeurope.org/sites/default/files/publications/foee_unconventional_unfounded_may2013_1.pdf**
81 **http://www.eia.gov/analysis/studies/worldshalegas/**
82 **https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/209021/BGS_DECC_BowlandShaleGasReport_MAIN_REPORT.pdf**
83 Bloomberg New Energy Finance, 7 February 2013, "Is UK Shale Gas all it's fracked up to be?"

population density in the UK and the wave of recent protests at shale gas exploration sites, shale gas developments of that scale seem unlikely to happen.

(iii) How much gas is compatible with the UK's other legally binding obligations?

11. The UK has a legally binding obligation under the Climate Change Act to reduce greenhouse gas emissions by at least 80% on 1990 levels by 2050. The Committee on Climate Change provides advice on how to achieve this goal including recommendations on interim milestones, one of which is that the UK power sector should be largely decarbonised by 2030. The level of decarbonisation which the Committee has recommended is 50gCO2/kWh by this date. Whilst this leaves some space for unabated gas-fired generation in the electricity mix, any use of unabated gas in the power sector would have to be limited by 2030 to providing flexibility as opposed to baseload power. A statement from the CCC's David Kennedy made this very clear: *"the role for unabated gas fired power generation should be limited to balancing the system in 2030, by which time the share of unabated gas generation in the total should be no more than 10%, compared to 40% today"*[84].

12. The picture is the same with respect to heat, where gas provided 80% of the UK's heating needs in 2011. The Government's own Carbon Plan published in 2011 and advice from the Committee on Climate Change on the carbon budgets clearly state that emissions from buildings need to be reduced to almost zero by 2050, while industry must reduce their emissions by up to 70% over the same period. Much of this reduction will come from replacing fossil fuels, including gas, with low carbon heat supplies alongside the decarbonisation of the power sector. By 2030, 34% of heat demand from domestic properties and 74% from non-residential buildings will need to be met by low carbon heat[85] via the electrification of heat and the deployment of district heating schemes. Industry will also rely heavily on the decarbonisation of the power sector, as it replaces gas as the largest supplier of industrial energy demand by 2030[86].

13. Planning a major expansion of unconstrained gas infrastructure (such as through the construction of a large fleet of new gas power stations envisaged in some scenarios contained in the Government's Gas Strategy and EMR Delivery Plan) fuelled by hopes of high rates of domestic shale gas production would therefore be incompatible with the UK's legally binding obligations under the Climate Change Act (see question 9 for more details). If one assumes that the UK Government takes these obligations seriously, the market for shale gas is therefore limited going forwards and a dash for gas-dependent infrastructure could therefore lead to a risk of stranded assets.

(iv) How much gas will be used globally if international action to tackle climate change reaches agreed ambition?

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[84] Committee on Climate Change, Letter from David Kennedy, 24 May 2012, **http://www.theccc.org.uk/news/latest-news/1186-unabated-gas-fired-generation-24-may-2012**

[85] Committee on Climate Change, The Fourth Carbon Budget, December 2010, **http://archive.theccc.org.uk/aws2/4th%20Budget/CCC-4th-Budget-Book_interactive_singles.pdf**

[86] DECC, 2012, The future of heating, **https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48574/4805-future-heating-strategic-framework.pdf**

14. Assuming the world takes action to tackle climate change, this means UK shale gas will come on stream just as the **IEA predicts**[87] that the world's already proven supplies of gas will begin to push down prices (over 60% of proven supplies go unused by 2035). Indeed, the IEA predicts that gas use for the power sector will have peaked world-wide before 2030.

15. The IEA has published **new EU gas price forecasts**[88] assuming global action to tackle climate change. These suggest wholesale gas prices may be below the UK cost of shale gas extraction as forecast by Ernst and Young, leaving shale gas assets in the UK either stranded or in need of financial support (the IEA predicts prices of 63p/therm by 2035 below the top end of EY's range at 78p/therm).

16. **Navigant, in its report for DECC**[89], which does not assume a 2 degrees pathway, forecast gas prices remaining at their current levels through to 2030, or rising if global unconventional gas extraction fails to deliver. In either scenario, shale gas extraction in the UK may struggle economically.

17. As the IEA warns, *"countries vulnerability to this risk [of stranded assets] may be greater if their asset base is more heavily weighted towards [fields] that are not yet developed and towards those that have the highest marginal production cost"*. UK shale fits both of those criteria.

18. In short, allowing unchecked shale gas exploration could leave the UK economy over-dependent on fossil fuel extraction and over-exposed to the economic impacts on the fossil fuel industry of global action to tackle climate change. The situation in Poland, where an industry has already moved into reverse simply because Polish gas is not economic at current prices is a warning of the economic risk of UK shale.

(v) Over what timeframe?

19. There are considerable uncertainties over the speed of development of any shale gas industry in the UK. A report by Poyry for Cuadrilla[90] indicated a scenario where gas starts to flow significantly in early/mid 2020s, peaks in 2030 and declines thereafter. This indicates that shale gas offers no short-term fix to any perceived energy security problem. Indeed, it rather suggests that UK shale gas production would be peaking just as the UK would have made significant improvement in energy efficiency in buildings and is likely to substantially decarbonise the power sector.

Question 2: How will the costs, including those on the environment, of accessing the UK's shale gas and oil deposits compare to those of other sources of energy?

Projected breakeven price of UK shale gas

20. Despite the BGS' upwards revisions of potential UK shale gas reserves, it is highly unlikely that the breakeven price for shale gas production in the UK and the rest of EU will be anywhere near as low as what has been observed of late in the United States.

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[87] **http://www.worldenergyoutlook.org/media/weowebsite/2013/energyclimatemap/RedrawingEnergyClimateMap.pdf**
[88] **http://www.worldenergyoutlook.org/media/weowebsite/2013/energyclimatemap/RedrawingEnergyClimateMap.pdf** Table 1.1, p. 40
[89] **https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/223492/navigant_consulting_report.pdf**
[90] **http://www.poyry.com/sites/default/files/imce/files/shale_gas_point_of_view_small.pdf**

21. At the EU level, the International Energy Agency (IEA) published the indicative costs of shale gas developments in Europe and suggested that the costs will be up to three times higher per unit of gas than in the US and similar to those of conventional gas[91]. This was followed by analysis from Deutsche Bank in early 2013, which argued that the *"development of shale-gas resources in Europe, the Middle East and Africa are considerably more expensive"* and that *"given current estimates, it appears to be a far stretch to expect that shale-gas production could bring about an equalisation of global gas prices towards the US level."*[92]

22. Given the different set of circumstances applying to shale gas extraction in the United States and the UK (see answer to question 1 for more detail), Bloomberg New Energy Finance *"estimate the cost of shale gas extraction in the UK – including allowance for the cost of capital – at between $7 and $12/MMBtu, against comparable costs for (dry) US plays of $5-6/MMBtu."*[93] Importantly, the predicted range for UK shale gas prices *"is close to the $8-11/MMBtu range in which spot UK gas prices have traded over the past two years"* at a time where UK gas prices and energy bills have been particularly high.

23. It is important to note here that one of the additional reasons why expected UK shale gas prices are significantly above some of the lowest prices observed in the US (which has seen gas prices fluctuating between $1.80 and $3.50/MMBtu during the course of 2012) is that UK shale gas in unlikely to be extracted as a by-product of shale oil as it has been in several locations in the United States[94].

A note of caution on US gas prices

24. When comparing the gas price in the UK to that in the US, the Committee should note that the low prices in the US – which fell to lows of $1.80/MMBtu during parts of 2012 (compared to an EU price fluctuating between $8 and $12/MMBtu) – are unlikely to continue for a long period of time going forwards as they are particularly uneconomic for shale gas operators, as well demonstrated in an intervention in 2012 from the Chief Executive of Exxon Mobile[95]. In fact, the price of gas in the US has increased markedly in 2012 and was at around $3.40 in early 2013. As observed by Bloomberg, there are various reasons why operators have been forced to continue to produce shale gas at times of very low gas prices, including the existence of 'Held By Production' leases, which result in operators losing their lease if they stop drilling. Half of the drilling activity of one major US driller, Chesapeake, was reportedly simply to keep their licences alive and keep valuable assets on the balance sheet[96].

Costs on the local environment

25. In addition to our main concern relating to greenhouse gas emissions and climate change set out in answer to question 8, evidence available to date suggests that the most significant local environmental risks linked to shale gas production are the following:

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91 IEA, 2012, "Golden rules for a Golden Age of Gas", **http://www.worldenergyoutlook.org/goldenrules/**

92 Deutsche Bank, 25 January 2013, *"European Gas: The Changing Landscape for Shale Gas"*, **http://www.commodities-now.com/reports/power-and-energy/13677-the-changing-landscape-for-shale-gas.html**

93 Bloomberg New Energy Finance, 7 February 2013, "Is UK Shale Gas all it's fracked up to be?"

94 Professor Paul Ekins, University College London, UKERC Current Event Blogs, *"The Fracking Battle: No way to conduct energy policy"*, August 2013: **http://ukerc.wordpress.com/**

95 Exxon CEO:'Losing our shirts' on natural gas price **http://www.marketwatch.com/story/exxon-ceolosing-our-shirts-on-natural-gas-price-2012-06-27**

96 Club de Nice 5 décembre 2012 « Point de vue d'un géologue pétrolier »
Jean Laherrère président ASPO France **http://aspofrance.viabloga.com/files/JL_2012_NICE-gazrochemere.pdf**

- *Surface and groundwater contamination:* according to an EC study[97], there is a high risk of surface and groundwater contamination at various stages of the well construction, hydraulic fracturing and gas production processes, and after well abandonment. Academic studies have suggested that the issue of well integrity, meaning the effective sealing of the well from the surrounding environment, which may include groundwater zones, is of significant concern. Studies have shown that well integrity issues may affect around 5% or more of wells drilled[98]. Poor well design or construction can lead to subsurface groundwater contamination arising from aquifer penetration by the well, the flow of fluids into, or from rock formations, or the migration of combustible natural gas to water supplies.

During the drilling stage, contamination can arise as a result of ineffective site management, well blowout or component failure. Further, runoff and erosion during early site construction, particularly from storm water, may lead to silt accumulation in surface waters and contaminants entering water bodies, streams and groundwater. This is a problem common to all large-scale mining and extraction activities. However, unconventional gas extraction carries a higher risk because it requires high-volume processes per installation and the risks increase with multiple installations.

- *Freshwater availability:* According to the IEA, *"in areas of water scarcity, the extraction of water for drilling and hydraulic fracturing …….can have broad and serious environmental effects. It can lower the water table, affect biodiversity and harm the local ecosystem. It can also reduce the availability of water for use by local communities and ……in agriculture"*[99], an issue that should be considered seriously in those regions of the UK such as the South-East that can be prone to periods of water scarcity.
- There are also concerns around disposal of flow back fluids[100] and air pollution.[101]

Question 4: What will be the impact of shale gas on the cost of electricity generated at gas-fired power plants and how will it compare to other forms of generations including coal, nuclear and renewables?

Impact of shale gas on the cost of gas-fired electricity

26. There is significant uncertainty on the future impact of shale gas on the cost of electricity generated by gas plants. However, the evidence published to date on the projected breakeven price for UK shale gas (see response to question 2) suggests that UK shale gas production will only have a limited impact on reducing the future price of gas in the UK or no such impact at all. Indeed, the Energy Secretary has admitted as much, saying *"we can't expect UK shale production alone to have any effect* [on UK gas prices]"[102]

27. Most forecasts agree that the EU breakeven price for shale gas will be higher than in the US and that there are considerable question marks as to whether gas prices will be lower with domestic shale gas production than they would have otherwise been, an issue that came

97 EC study on shale gas environmental impacts
http://ec.europa.eu/environment/integration/energy/pdf/fracking%20study.pdf
98 Watson and Bachu. Evaluation of the Potential for Gas and CO2 Leakage Along Wellbores. *SPE Drilling and Completion, March 2009*. Society of Petroleum Engineers.
99 IEA, Golden rules for a Golden Age of Gas, 2012
100 http://ec.europa.eu/environment/integration/energy/pdf/fracking%20study.pdf p56
101 http://ec.europa.eu/environment/integration/energy/pdf/fracking%20study.pdf
102 https://www.gov.uk/government/speeches/the-myths-and-realities-of-shale-gas-exploration

out clearly in a recent interview with Lord Nicholas Stern[103]. A key issue that is often forgotten when some commentators argue that the price of gas would fall dramatically in the UK with strong domestic shale gas production is that the UK gas market is an integral part of the wider European gas market. It is therefore the overall balance of demand and supply of gas in the European market as a whole which will ultimately set the price of gas.

28. Even under scenarios with ambitious shale gas production in the EU, in the absence of demand constraints such as vigorous carbon emissions abatement, gas prices across the EU are forecast to rise to 2035. The IEA projects a slightly increasing gas price in the EU out to 2035 under optimistic assumptions about the future supply of shale gas in the EU, with higher gas price increases being forecast under less optimistic assumptions about shale gas production[104] [105]. DECC's central gas price scenario for the UK is similar to the IEA's optimistic case, whilst its high scenario assumes future gas prices that are above the IEA's less optimistic case. This is of course against the backdrop that future gas forecasts can never be relied upon and that failing to reduce the UK's overall reliance on gas on the assumption that gas prices will be low is a highly risky strategy.

The economic case for rapidly decarbonising the UK power sector is strong with or without shale gas

29. **Importantly and regardless of where the UK may get its gas from to meet future demand, the economic case for rapidly decarbonising the power sector remains a strong one.** A recent report from Cambridge Econometrics showed for example that compared to another dash for gas generation, policies enabling a continued deployment of offshore wind farms in the UK over the next 20 years would increase UK GDP by £20bn/ year by 2030, create 70,000 more jobs by then, reduce gas imports by some £8bn/ year and produce emissions in the power sector that would be 3 times lower, with only minimum impact on UK electricity prices (in the order of 1% by 2030). Importantly, these conclusions remain valid under a wide range of assumptions on the future price of gas and the economic benefits remain the same with or without UK shale gas exploration[106].

30. This conclusion was supported by recent analysis from the Committee on Climate Change **on the UK's electricity market reform[107], which made clear that moving towards a low-carbon power sector by 2030 with a carbon intensity of 50gCO2/kWh was a low regrets policy for consumers even in the event of substantial shale gas exploration in the UK bringing down the price of gas.** Under almost all scenarios analysed, the Committee argued that a move towards a near-carbon free power sector in the next twenty years would result in substantial savings on UK consumer bills over the lifetime of that infrastructure (between £25bn and £45bn in its central scenario) compared to remaining in an alternative scenario where the UK remains highly dependent on electricity produced by gas plants. The CCC projects in its central scenario

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103 The Independent, 4 September 2013, "Baseless Economics: Lord Stern on the claims that UK fracking boom can bring down the cost of gas": **http://www.independent.co.uk/news/uk/politics/baseless-economics-lord-stern-on-david-camerons-claims-that-a-uk-fracking-boom-can-bring-down-price-of-gas-8796758.html**

104 *Golden Rules for a Golden Age of Gas*, the International Energy Agency, May 2012: **http://www.worldenergyoutlook.org/goldenrules/**

105 Also see analysis from the Committee on Climate Change in the "Next Steps on Electricity Market Reform" report, May 2013, pages 37-39**: http://www.theccc.org.uk/publication/next-steps-on-electricity-market-reform-23-may-2013/**

106 Cambridge Econometrics, A study into the Economics of Gas and Offshore Wind, November 2012: **http://www.wwf.org.uk/wwf_articles.cfm?unewsid=6342**

107 Committee on Climate Change, May 2013, Next Steps on Electricity Market Reform: **http://www.theccc.org.uk/publication/next-steps-on-electricity-market-reform-23-may-2013/**

that supporting investment in a portfolio of low-carbon technologies throughout the 2020s would add around £20 to annual consumer energy bills in 2030 compared to annual bills in 2020.

Question 6: Which forms of electricity generation is shale gas likely to displace and by how much?

31. When considering the forms of electricity generation that could be displaced by shale gas, it is important to bear in mind that there does not need to be a link between shale gas exploitation in the UK and the policies influencing the choices of power sources that should be developed in the UK. One of our concerns is that, at present, such a link appears to be being made[108]. This runs counter to the response of other countries who have an abundance of hydrocarbons but are now diversifying their domestic energy sources: for example, Saudi Arabia are reportedly looking to be *"the world's foremost market for renewable energy"*[109] and the UAE have significant renewable investment plans.

32. To the extent that the lifecycle greenhouse gas emissions of electricity generation from shale gas can be kept firmly under those of coal – on which there is still some uncertainty (see response to question 8) -, shale gas could have a positive impact by displacing coal generation. However, the extent of this potential benefit is far from clear-cut, with the IEA recently highlighting for instance that it is also the case that "*lower natural gas prices lead to slightly higher overall consumption of energy and, in some instances, to displacement of lower-carbon fuels, such as renewable energy sources*"[110]. The Chief Economist of the IEA recently said that greater use of unconventional gas *"is definitely not the optimum path"*, adding that "*the optimum path would be to see more renewables, more efficiency and more low carbon technologies"*[111].

33. In the UK, it is the expectation of the UK Government that while there are some concerns about the possible life extension of some coal power stations (a concern for our three organisations), the lifetime of existing coal power stations will be limited by air pollution regulations and technical constraints, not by displacement caused by increased gas production, which will not be cheaper except at high carbon prices[112]. Thus, additional gas burn will be likely to displace lower carbon sources of power.

34. It is worth noting here that the shale gas boom in the US, often hailed as a success story for reducing emissions cost-effectively by reducing the role of coal in the US, has not in fact replaced coal. The US drop in coal prices which followed the shale gas boom has simply resulted in coal being shipped to other markets in parts of Europe and Asia, where it is then burned, adding to global greenhouse gas emissions. According to the US Energy Information Administration, a record 12% of coal produced in the United States in 2012 (equivalent to 125.7 million short tonnes) was exported to markets in Europe and Asia – this compares to an average export share of production for US coal of 5% between 2000 and 2010[113]. The

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108 **http://www.theguardian.com/environment/2012/dec/05/gas-strategy-unveiled-george-osborne**
109 **http://www.arabnews.com/news/458342**
110**http://www.worldenergyoutlook.org/media/weowebsite/2012/goldenrules/WEO2012_GoldenRulesReport.pdf**
111 **http://www.euractiv.com/energy/fatih-birol-gas-definitely-optim-news-513043**
112 **http://www.greenpeace.org.uk/newsdesk/energy/analysis/exclusive-energy-bill-loophole-about-let-uk%E2%80%99s-dirtiest-power-stations-unexpectedly-stay-open**
113 US Energy Information Administration, What is the role of coal in the United States?, 16 August 2013: **http://www.eia.gov/energy_in_brief/article/role_coal_us.cfm**

Tyndall Centre estimates that more than half of the emissions avoided in the US power sector may have been exported through greater use of coal elsewhere[114].

35. More importantly and as made clear in response to question 8, a switch from coal to gas is far from sufficient **on its own** to prevent temperature increases in excess of 2C, the stated objective of the international negotiation process on climate change. This was made clear in the following observation by the IEA, regarding the implication of its central dash for gas scenario in the *Golden Rules for a Golden Age of Gas* report:

"The Golden Rules Case puts CO2 emissions on a long-term trajectory consistent with stabilising the atmospheric concentration of greenhouse-gas emissions at around 650 parts per million, a trajectory consistent with a probable temperature rise of more than 3.5 degrees Celsius (°C) in the long term, well above the widely accepted 2°C target. This finding reinforces a central conclusion from the WEO special report on a Golden Age of Gas (IEA, 2011b), that, ***while a greater role for natural gas in the global energy mix does bring environmental benefits where it substitutes for other fossil fuels, natural gas cannot on its own provide the answer to the challenge of climate change****."*[115]

36. As Fatih Birol, lead author of the WEO special report put it, recognising that high gas use would exceed the threshold for dangerous climate change, "*We are not saying that it will be a golden age for humanity – we are saying it will be a golden age for gas*".[116]

37. For the UK and as made clear in answer to question 1, it is worth noting that the bulk of shale gas flow would occur during a period when rapid decarbonisation of the power sector would be taking place if the advice of the Climate Change Committee were being followed.

Question 7: What impact will shale gas and oil have on household energy bills?

38. Please see response to question 4. Evidence published to date on the projected breakeven price for UK shale gas suggests that UK shale gas production will only have a limited impact on reducing the future price of gas in the UK or no such impact at all.

Question 8: What effect will the use of shale gas and oil have on carbon emissions compared to other combinations of energy sources?

39. While gas has a transitional role to play in the transition to a low-carbon economy, a dash for gas infrastructure is incompatible with meeting the UK's legally binding carbon reduction targets and preventing dangerous climate change globally. An analysis of energy infrastructure choices by staff at University of Stanford concluded that gas cannot have substantial impacts in mitigating global warming longer term compared to genuinely low carbon choices[117]. The transitional nature of gas therefore needs to be short.

40. It should be reiterated that rapidly decarbonising the UK's energy system makes economic as well as environmental sense. A recent report from Cambridge Econometrics

[114] http://www.tyndall.ac.uk/sites/default/files/broderick_and_anderson_2012_impact_of_shale_gas_on_us_energy_and_emissions.pdf
[115] http://www.worldenergyoutlook.org/media/weowebsite/2012/goldenrules/WEO2012_GoldenRulesReport.pdf
[116] http://www.scientificamerican.com/article.cfm?id=golden-age-natural-gas-might-prove-climate-challenge
[117] http://iopscience.iop.org/1748-9326/7/1/014019

showed for example that compared to another dash for gas generation, policies enabling a continued deployment of offshore wind farms in the UK over the next 20 years would increase UK GDP by £20bn/ year by 2030, create 70,000 more jobs by then, reduce gas imports by some £8bn/ year with only minimum impact on UK electricity prices. Under this scenario emissions in the power sector that would be 3 times lower. Importantly, these conclusions remain valid under a wide range of assumptions on the future price of gas and the economic benefits remain the same with or without UK shale gas exploration[118].

Impacts of gas on international emissions

41. The IEA warned in its latest *World Energy Outlook* report that two-thirds of the existing commercially viable fossil fuel reserves need to stay in the ground if the world is to stay well below the 2C limit, which scientific consensus says would constitute dangerous climate change. Those reserves still exclude to a large extent those "unconventional" shale gas and shale oil "resources" that increasingly enter the reserve base resulting from technological process.

42. This was followed by recent analysis from Carbon Tracker and the London School of Economics, which found that *"60-80% of coal, oil and gas reserves of listed firms are unburnable"*[119] if the world is to have a likely chance of staying below 2C. Importantly, the report highlights that the amount of fossil fuel reserves that can be burnt only increases marginally even under an optimistic deployment of carbon capture and storage technology (CCS). The analysis suggested that even under the IEA's idealised scenario for CCS (which assumes a very optimistic deployment of CCS out to 2050), the permissible amount of carbon emissions to stay under a 2C scenario only extends by about 12% in the period leading to 2050.

43. When looking at the role of gas specifically, the IEA's recent *Golden Rules for a Golden Age of Gas report*[120] made clear that **increased use of gas as a result of new unconventional reserves would have almost no climate advantage over business as usual and would put the world climate on a course for at least 3.5C of warming**. In particular the IEA pointed out that *"in countries where the average greenhouse-gas intensity of power generation is already close to that of natural gas, as for example in Europe, the addition of extra natural gas to the fuel mix has relatively little impact on the overall [business as usual] emissions trajectory."*[121]

The role of gas in the UK

44. As highlighted in response to question 1, the role of gas will also have to diminish substantially in the UK by 2030 if the UK is to meet its legally binding carbon budgets and its long-term obligations under the Climate Change Act 2008. In the power sector for instance, electricity coming from unabated gas plants will have to represent no more than 10% of UK electricity demand if the UK is to have a near-decarbonised power sector by 2030, a key recommendation of the CCC in the Fourth Carbon Budget.

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118 Cambridge Econometrics, A study into the Economics of Gas and Offshore Wind, November 2012: **http://www.wwf.org.uk/wwf_articles.cfm?unewsid=6342**

119 'Unburnable Carbon 2013: Wasted Capital and Stranded Assets', Carbon Tracker and Grantham Research Institute (LSE), April 2013: **http://www.carbontracker.org/wastedcapital**, page 4.

120 **http://www.iea.org/weo/docs/weo2011/executive_summary.pdf**

121 *Golden Rules for a Golden Age of Gas,* IEA, 2012, page 92.

45. It should also be mentioned here that the more shale gas is extracted in the UK (and in any other Member State), the more this adds to the pool of fossil fuel reserves that is made available to the European market. This is counterproductive at a time where momentum is building towards agreeing a climate and energy package for 2030 that can help the EU meet its objectives of reducing emissions of greenhouse gases by 80% to 95% by 2050.

46. A recent DECC report by Chief Scientist David McKay and Dr Tim Stone on the potential greenhouse gas emissions associated with shale gas came to a similar conclusion: *"The production of shale gas could increase global cumulative greenhouse gas emissions if the fossil fuels displaced by shale gas are used elsewhere (…). The view of the authors is that without global climate policies (of the sort already advocated by the UK) new fossil fuel exploitation is likely to lead to an increase in cumulative GHG emissions and the risk of climate change".* [122]
Shale gas: lifecycle emissions & the risk of methane leakage

47. This concerns the leaks or deliberate venting of gas over the shale gas extraction process, which may reduce or eliminate any advantage which shale gas has over coal from an emissions perspective. This is an area where there is still considerable uncertainty and more peer-reviewed scientific evidence is urgently needed to get a more reliable perspective on the lifecycle emissions of shale gas.

48. Both Howarth et al of Cornell University and a study by NOAA have suggested that shale gas emissions are significantly higher than reported by industry:

- Howarth's study found that *"compared to coal, the footprint of shale gas is at least 20% greater and perhaps more than twice as great on the 20-year horizon (20 year horizon puts global warming potential of methane at 72 times greater than CO2) and is comparable when compared over 100 years".*[123]

- The NOAA study (Petron et al)[124] found that rates of methane leakage from a gas field in Utah were 9%. This followed a study last year[125] which found leakage rates of 4% at a gas field near Denver, Colorado. A study by University of Texas[126] found that where measure had been taken to reduce leakage, rates of emission were low.

- **Research for the Environmental Defence Fund and Princeton University published in April 2012 suggests that shale gas only has a benefit over coal where cumulative emissions are 3.2% or lower**. US Environmental Protection Agency data suggest that in 2009 leaks from the natural gas industry were 2.4%[127]. However, other studies have contradicted these findings and the science is still extremely uncertain. To a large extent, it is likely to be the case that emissions vary widely and depend partly on whether gas is deliberately vented or whether it's flared or captured. However, it is also likely that in at least some cases, leaks occur even in the absence of deliberate venting.

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[122] Potential Greenhouse Gas Emissions Associated with Shale Gas Extraction and Use, Professor David Mackay and Dr Timothy Stone, DECC, 9 September 2013: **https://www.gov.uk/government/publications/potential-greenhouse-gas-emissions-associated-with-shale-gas-production-and-use**
[123] "Methane and the greenhouse-gas footprint of natural gas from shale formations", Cornell University, Itheca, NY, USA
[124] **http://www.nature.com/news/methane-leaks-erode-green-credentials-of-natural-gas-1.12123**
[125] **http://www.nature.com/news/air-sampling-reveals-high-emissions-from-gas-field-1.9982**
[126] **http://www.pnas.org/content/early/2013/09/10/1304880110.full.pdf**
[127] **http://www.nature.com/news/methane-leaks-erode-green-credentials-of-natural-gas-1.12123**

- There is also a degree of controversy about the time period over which the emissions from shale gas should be considered. It is standard to measure the warming potential of methane over 100 year period (the Intergovernmental Panel on Climate Change (IPCC) do this for example). However, in the example used above, Robert Howarth also uses an alternative twenty-year time period**.**

- A study by AEA[128] on the climate impact potential of shale gas stated that "*averaged over 20 years the Global Warming Potential (GWP) estimated by the IPCC is 72. This figure can be argued to be more relevant to the evaluation of the significance of methane emissions in the next two or three decades which will be the most critical to determine whether the world can still reach the objective of limiting the long-term increase in average surface temperatures to 2 degrees Celsius*".

Question 9: Will shale gas and oil increase UK energy security?

49. There are a number of meanings to the term energy security. They include integrity/reliability of the energy system, insulation from price shocks, and access to hydrocarbon resources. We do not believe that shale gas extraction in UK would contribute to the first two.

System integrity

50. As was pointed out in a review of gas security by University of Sussex, *"contrary to much of the energy security debate, the most significant recent threats to the UK's supplies have not been from geopolitical crises abroad but from domestic infrastructure weaknesses in the UK"*[129]. However, as evidenced by the recent Government decision not to extend support for gas storage[130] (based on analysis by Redpoint), there is little reason to believe that the UK system is highly vulnerable to interruption of gas supplies in the foreseeable future. Improving domestic infrastructure such as the gas network reliability would not flow from developing UK shale gas reserves.

Price shocks

51. As outlined in our answer to questions 2 and 4, there is little reason to believe that UK shale gas would affect prices or vulnerability to international gas price spikes. Indeed, research by Oxford Economics for DECC[131] has indicated that climate change policies are the ones that reduce UK economic sensitivity to international price shocks.

52. Further, shale gas production in itself is unlikely to offset the UK or the EU's rising import dependency. In its recent *'Golden Rules for a Golden Age of Gas'* report, the IEA indicated that even in the most optimistic "gas" scenario (one in which there is rapid growth in shale gas production and emissions are consistent with global temperature rises of 3.5 degrees), "*the upward trend in net gas imports into the EU continues throughout the projection*

[128] **http://ec.europa.eu/clima/policies/eccp/docs/120815_final_report_en.pdf**
[129] **http://www.sussex.ac.uk/Users/prpp4/Gas_Security.pdf**
[130] **https://www.gov.uk/government/news/fallon-no-new-subsidy-needed-for-gas-storage-decision-saves-bill-payers-up-to-750-million**
[131] **https://www.gov.uk/government/news/davey-climate-change-policies-could-halve-negative-impacts-of-energy-price-shocks**

period (to 2035)[132]". **The implications are clear – even in the most 'optimistic' shale gas scenario, the EU will only succeed in slowing down its increasing gas dependency**.

53. At the UK level, *"no matter how large the resource, in order to have a substantial effect on UK gas prices, the rate of growth production must be high enough to displace imports."* As explained in answer to question 1, evidence to date suggests that *"UK shale gas will not be available fast enough, cheaply enough or in enough volume to take over the price-setting role from imported gas"*[133].

Access to hydrocarbons

54. The only way in which shale gas could be seen to contribute to UK security is access to hydrocarbon sources. However, it is unclear that this aspect of energy security is particularly problematic as the University of Sussex review[134] concluded that supply diversity was increasing in UK and that this was potentially the least problematic dimension.

55. If the prospect of UK shale gas extraction were linked to changes in 'use policy' in, particularly, the power sector (as implied by the form of question 6), then shale gas could damage UK security by promoting an increased lock-in to gas infrastructure.

56. Given the limited potential that UK shale gas production is likely to have in terms of offsetting the UK's imports of gas and reducing the UK gas price, an excessive focus on building new gas-dependent infrastructure would be problematic as it would increase even further the UK's future exposure to gas price shocks. This is particularly concerning given the long operational life time of this infrastructure, which ranges from 25 to 35 years in the case of gas power stations.

57. Signs that this concern is starting to take shape were well evidenced in the UK Government's recent Gas Strategy (December 2012)[135] and its Electricity Market Reform Delivery Plan (July 2013)[136], which both contained a scenario where the carbon intensity of the UK power sector was at around 200gCO2/kWh in 2030. Whilst such a scenario would allow a significant expansion of the UK's gas fleet, it also corresponds to four times the level of carbon intensity recommended by the CCC for 2030 and would severely undermine any demand for low-carbon technologies in the 2020s.

Limiting the UK's vulnerability to international gas prices

58. A final point to note is that if the UK is indeed committed to the decarbonisation ambitions set out in the CCC's Fourth Carbon Budget and its own Carbon Plan (as detailed in answer to question 2) in the heating and power sectors, this would significantly reduce the UK's demand for gas and therefore its vulnerability to the volatility of international gas prices over the next twenty years. In other words, a clear decarbonisation pathway based on increased energy efficiency and home grown sources of low-carbon power are the best

[132] **http://www.worldenergyoutlook.org/media/weowebsite/2012/goldenrules/WEO2012_GoldenRulesReport.pdf**
[133] Bloomberg New Energy Finance, 7 February 2013, "Is UK Shale Gas all it's fracked up to be?"
[134] **http://www.sussex.ac.uk/Users/prpp4/Gas_Security.pdf**
[135] UK Government, Gas Generation Strategy, 5 December 2012: **https://www.gov.uk/government/publications/gas-generation-strategy**
[136] UK Government, Consultation on the Draft Electricity Market Reform Delivery, July 2013: **https://www.gov.uk/government/consultations/consultation-on-the-draft-electricity-market-reform-delivery**

answers to increasing the UK's energy security, not a dash for new gas infrastructure fuelled by hopes of high domestic shale gas production.

59. This is all the more the case as evidence suggests that even under optimistic assumptions on the deployment of shale gas in the UK, production levels are unlikely to be significant within a decade. Notwithstanding the clear public disquiet with fracking which will prove an obstacle to developers, a report by Poyry for Cuadrilla anticipated that significant flows of shale gas would not be forthcoming until towards the mid-2020s[137].

Question 13: What lessons can be learnt from the US experience of shale gas and oil?

60. As outlined in various answers in this evidence, the analogy between the UK and the US should not be exaggerated. Shale gas won't begin to make a significant contribution to our energy mix until the mid-2020s. Fracking took off much quicker in the United States given its long established on-shore drilling industry. The context could not be any more different in the UK. The bulk of our drilling expertise and infrastructure has been offshore. This means it will take many years to develop the expertise and supply chains for fracking to take place on scale.

61. Development of shale in the US has left a legacy of mistrust owing to a series of technical and regulatory failures. Claims around spills, accidents or contamination of water from fracking are legion in US[138]. It is claimed that tougher regulations will mean none of that happens in the UK, as fracking firms will have to apply for several permits and will not be allowed near sensitive water tables. However, most of the monitoring will ultimately be down to self-monitoring by the firms concerned. There are examples of where such an approach has gone badly wrong before[139] and from which lessons need to be learnt.

2 October 2013

137 **http://www.poyry.com/sites/default/files/imce/files/shale_gas_point_of_view_small.pdf**
138 **http://www.greenpeace.org.uk/blog/climate/3-reasons-why-we-could-all-be-fracked-fracking-20130812**
139 **http://www.bbc.co.uk/news/special_reports/oil_disaster/**

The Geological Society of London (GSL) and the Petroleum Exploration Society of Great Britain (PESGB)—Written evidence

1. This submission has been produced jointly by the Geological Society of London and the Petroleum Exploration Society of Great Britain:

    i. The Geological Society of London (GSL) is the UK's learned and professional body for geoscience, with more than 11,000 Fellows (members) worldwide. The Fellowship encompasses those working in industry, academia and government with a broad range of perspectives on policy-relevant science, and the Society is a leading communicator of this science to government bodies and other non-specialist audiences.

    ii. The Petroleum Exploration Society of Great Britain (PESGB) represents the national community of Earth scientists working in the oil and gas industry, with over 5,000 members worldwide. The objective of the Society is to promote, for the public benefit, education in the scientific and technical aspects of petroleum exploration. To achieve this objective the PESGB makes regular charitable disbursements, holds monthly lecture meetings in London and Aberdeen and both organises and sponsors other conferences, seminars, workshops, field trips and publications.

2. Between September 2012 and April 2013, the House of Commons Energy and Climate Change (ECC) Select Committee held an inquiry into 'The Impact of Shale Gas on Energy Markets'. Although some of the detailed questions it addressed differed from those set out in the terms of reference for the present inquiry, its focus was similar. It investigated the widely differing estimates which have been made of the amount of shale gas resource under the ground in the UK, how much of this might constitute reserves (i.e. the amount which can be economically recovered), and the possible implications for UK energy markets[140]. It reviewed similarities and differences between prospects in the UK and the US experience, and considered possible impacts on climate change and on investment in renewable/low-carbon energy technologies. The report of the ECC Committee inquiry was widely regarded as an authoritative and realistically comprehensive assessment of the policy environment and economic factors relating to shale gas development in the UK. The Geological Society responded to that inquiry and we subsequently identified a witness to appear in an oral evidence session, Professor Richard Davies (Durham University). Following the evidence session, we provided supplementary written evidence at the request of the committee. It is not clear to us why the present inquiry is being held on a very similar topic so soon after that of the ECC Committee. With this in mind, we believe that the initial and supplementary written evidence we provided to that committee last year is relevant to the present inquiry.

140 **Resource** is the amount of gas underground. **Reserve** is the amount of gas which can be produced economically – that is, which we can realistically expect to extract from the ground given current technological, economic and social/regulatory constraints. Another term which is sometimes used is 'technically recoverable' resource – this is the amount which could be extracted given current technology, but without reference to economics (cost of extraction and price) or social acceptability.

3. As recognised in the terms of reference for this inquiry, the British Geological Survey (BGS) released updated estimates of shale gas resources in the Bowland Shale in Northern England in June 2013. Its report gives a central estimate of the gas resource in place in the Bowland Shale of 1329 trillion cubic feet (tcf), a considerable increase on the previous 2010 estimate of 4.7tcf (though this was in respect of the Upper Bowland-Hodder unit only). The report also notes that the revised estimate remains highly uncertain. The extent of reserves which can be extracted economically is even more difficult to quantify. The reasons for this uncertainty are discussed in our submissions to the earlier inquiry (attached – see paragraphs 4-12 of our October 2012 original submission and paragraphs 2-4 of our December 2012 supplementary memorandum). The revised BGS estimate represents an important step in developing understanding of the shale gas resources of the UK. However, it does not in itself significantly change the economic basis for decision-making about shale gas exploration, regulation or production from that which pertained when the report of the ECC Committee inquiry was published in April 2013, particularly as it was already widely anticipated at that time that the new BGS estimate would be much higher than the earlier figure.

4. We would be pleased to discuss or provide further information on any of the issues raised in this document and the attached earlier documents, or any other matters relevant to the present inquiry which the Committee does not consider are adequately addressed here.

30 September 2013

The Government—Written evidence

This response has been prepared by the Department of Energy and Climate Change (DECC) with input from HM Treasury, Department for Business, Innovation & Skills (BIS), the Department for Communities and Local Government (DCLG), the Environment Agency and the Department for Environment, Food and Rural Affairs (DEFRA).

Introduction

1. The Government is pleased to submit its views for the Committee's consideration as it takes forward its Inquiry into this important subject.

2. Unconventional gas and oil reserves, and particularly shale gas reserves, have the potential to have a significant impact on future gas markets. This has been apparent in the United States. Between 2007 and 2012, US net gas imports fell by 55 per cent and by 2020 the US is expected to be a net exporter of natural gas. This has increased US security of supply and improved the US balance of payments, as well as significantly reducing the costs to consumers of gas and electricity, particularly helping the competitiveness of energy-intensive industries. The extent to which the US experience can be replicated in the UK is uncertain. However, the Government is committed to ensuring that a world-leading framework for investment is in place so that if the geology should be favourable, the industry can prosper.

The industry is still in an early phase of development

3. We are at an early stage of development of unconventional gas and oil production in the UK. At present, there is limited exploration activity. Scientists from the British Geological Survey (BGS) have estimated that the total volume of gas in place in the Bowland-Hodder shale in northern England is some 1300 trillion cubic feet (central estimate). To put that figure in context, if one tenth could be produced, that would be equivalent to more than 50 years' current consumption. The BGS study is the first in the UK to provide investors, operators and regulators with an indication of where to target future exploratory drilling. But only further exploration and appraisal activity can determine the extent to which the resources are capable of commercial production. The industry estimates that it will have to drill up to 50 wells over the next 2 years in order to establish the commercial viability of extracting shale gas.

4. It would be irresponsible of the government not to do everything it can to promote the safe and sustainable exploration and development of shale gas. Accordingly, it is putting in place the regulatory conditions, planning regime and fiscal framework necessary to encourage the development of these exploration wells. Only once this activity has taken place will it be possible to answer more confidently questions about the potential for production and the expected costs of any potential production.

Potential energy security benefits from UK production of unconventional oil and gas

5. There are considerable potential energy security benefits to increased levels of unconventional hydrocarbon production in the UK. These apply in particular to potential production of gas.

6. Recent assessments by Ofgem and by independent consultants for DECC have found that the chances of a disruption to gas supplies affecting protected customers are very low. A diverse

range of gas sources contributes to this positive supply security picture, ensuring we have alternate supply sources if there is a problem anywhere in the market. The UK receives gas from the UK continental shelf, Norway, the EU, global markets via LNG and storage facilities.

7. Given the important role gas plays in our energy mix it is essential that we maximise gas security of supply where it is good value for money to do so. Unconventional gas production would provide a new source of gas supply for UK consumers. Increasing reliance on imported gas brings new sources of gas and adds to diversity, but can expose the UK to new gas supply risks, whether from geopolitical events disrupting long import supply chains, or from diversions of gas supplies driven by higher prices in other markets. As UK conventional production continues to diminish, so the potential impact of these risks increases. Onshore unconventional production could mitigate these risks.

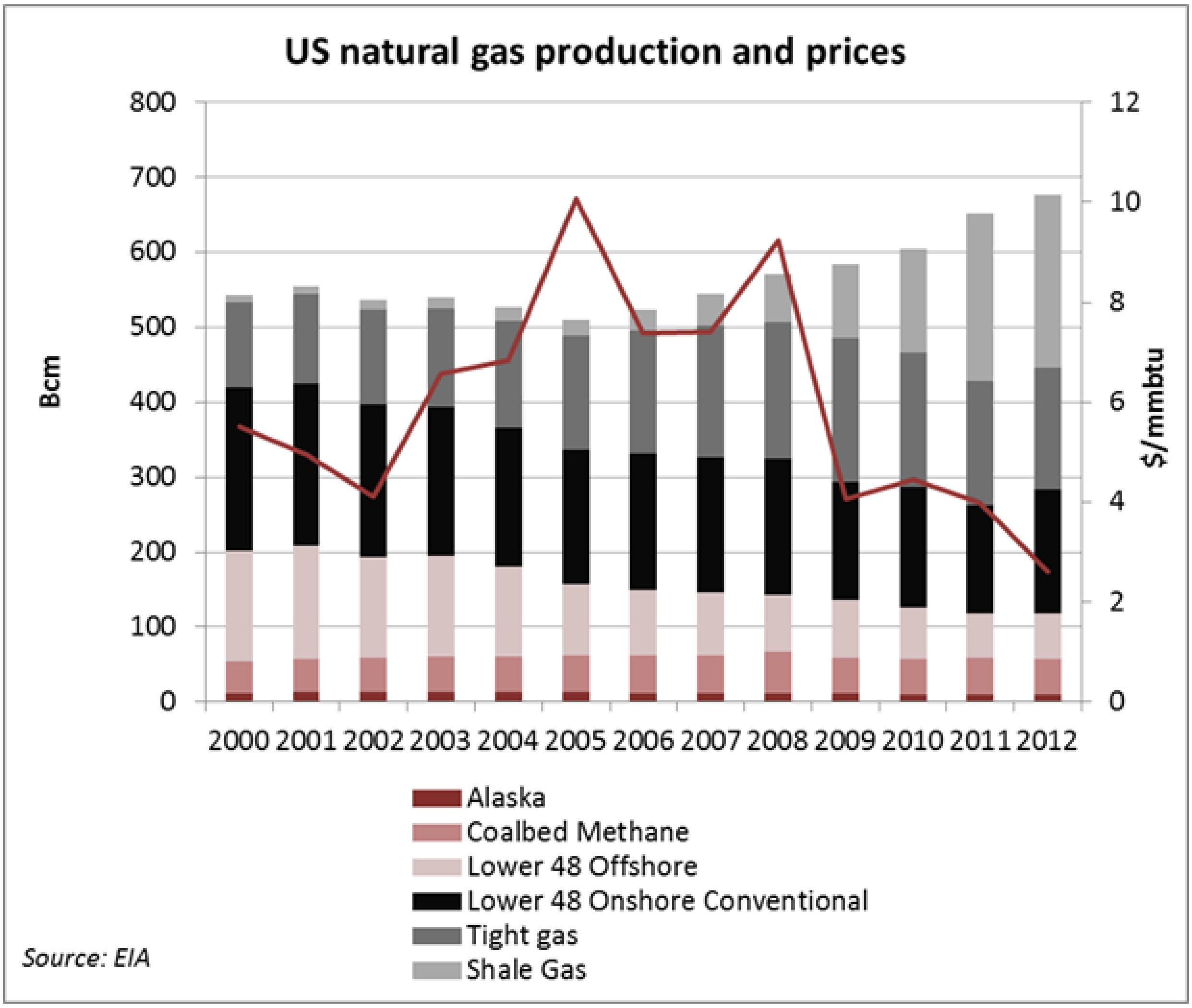
8. The same benefits attach to unconventional oil production, although to a lesser extent given the higher levels of oil stocks and greater portability of oil and oil products compared to natural gas. We are also much better able to regulate production techniques of domestic compared to foreign production to ensure that associated emissions, impact on the environment and so on are acceptable to us.

9. Shale gas activity in the UK is very much in its infancy and it is too early to make any useful assessment on the extent of the impact of domestic shale gas production on UK energy security. DECC will continue to monitor the potential effect of shale gas on the UK's security of energy supply.

10. However, the Government is clear that if significant resource could be developed in a safe and environmentally sustainable way, this would bring energy security benefits to the UK. The Government is therefore committed to enable the exploration of UK shale gas in a safe and environmentally sustainable way to establish its potential.

Potential for unconventional production to lead to lower prices for gas and for oil

11. The potential for increased levels of unconventional production of gas to lower market prices has been clearly demonstrated in the US (see chart).



12. There are significant differences between the US and the UK. Unlike the US, the UK is also closely integrated with other energy markets in our region. Accordingly, we would not expect a repeat of the US experience if UK production increased. Studies including by Navigant[141] suggest that in a number of scenarios, price impact may be small, though there are also scenarios where the impact is higher, noting that the Navigant report found that shale gas production outside the UK might have an even greater impact than UK production in putting downward pressure on UK prices. Failure to explore the potential of shale gas could result in UK gas prices being higher than they might otherwise be, as large volumes of shale gas production in the UK could be expected to exert downward pressure on UK gas prices.

13. International gas markets have already been influenced by unconventional gas production in the US. Because of reducing US import demand, LNG supplies from third countries were able to satisfy increasing demand in Japan following the Fukushima earthquake in 2011, and associated rising demand for gas for power generation. In this way, the rising level of US production has already had an influence on global gas markets. We would expect this influence to increase, whether in the form of direct supplies of shale gas to the UK or onto international markets from the US and in the further distant future, potentially other states, or satisfaction of domestic demand in other states that reduces global import demand below what it would otherwise have been.

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141 https://www.gov.uk/government/publications/unconventional-gas-the-potential-impact-on-uk-gas-prices

14. Oil is globally traded and conceivable levels of UK unconventional oil production are unlikely to significantly influence prices. However, the IEA predicts that an increasing proportion of global oil production is likely to be unconventional; prices are likely to be lower if such production materialises than if it fails to increase at the rate projected.

Changes to domestic arrangements to encourage activity

15. The Government is determined to ensure that our fiscal and regulatory arrangements should facilitate investment in exploration and, should that be successful, production. In March 2013 it launched the Office of Unconventional Gas and Oil which aims to promote the safe, responsible, and environmentally sound recovery of the UK unconventional reserves of gas and oil.

16. The Office is not a regulator, but plays a key role in co-ordinating activity on shale across Government. We have taken important early steps since the establishment of the Office. The Department for Communities and Local Government (DCLG) has published planning guidance that clarifies the interaction of the planning process with the environmental and safety consenting regimes. The Treasury is consulting on fiscal measures to incentivise shale exploration and development, recognising the high upfront costs associated with shale gas projects. The Environment Agency (EA) has announced actions to streamline and simplify the regulation of exploratory activity while maintaining environmental protection. As a first step it has published technical guidance for consultation.

17. The Office has also led on working with industry to ensure communities will benefit from shale development in their area, and is now developing plans for engaging the public in a well-informed debate on shale.

Making sure communities benefit where unconventional oil activity takes place

18. We are determined that there should be local as well as national benefit from unconventional oil and gas activity in the UK. The industry has now come forward with a scheme of community benefits so that communities which host shale gas developments can share in any proceeds. This package includes: £100,000 in community benefits to be provided per well-site where hydraulic fracturing takes place at exploration stage; 1% of revenues in community benefits at production stage; publication of evidence each year of how these commitments have been met; and regular reviews of this package as the industry develops.

19. Potential employment impacts of unconventional oil and gas activity in the UK will depend on the level of activity, which as explained above is uncertain, but the Government notes that the Institute of Directors in its 2013 study, "Getting shale gas working," estimated that the industry could directly employ an average of 74,000 workers once production reaches the levels set out in its medium case. Much of this employment woud likely be in rural communities, including some where alternative well-paid employment is difficult to find.

Potential role of shale gas in electricity generation

20. The role that gas produced from shale resources, either in the UK or elsewhere, may have in the future generation of electricity, as with the levels of electricity generation from other fuel sources, will be determined by the market within the constraints of the emission limits set by the Carbon Budgets. However, the Government's Electricity Market Reform is designed to incentivise investment in low carbon forms of generation.

21. Analysis for the Government's draft EMR Delivery Plan shows that whilst we may need more gas capacity in 2030 than we have today, the role of gas will increasingly become one of balancing a system with increasing amounts of intermittent and inflexible low carbon generation (i.e. wind and nuclear).

22. Within this projected lower use of gas in electricity generation, there is clearly potential for shale gas to contribute, whether produced in the UK or overseas. The potential contribution of UK shale will depend upon the speed of development of production here. With regard to imported supplies, UK companies including Centrica are already seeking supplies of gas in the US for importation to the UK.

Potential new infrastructure requirements, and supply-chain opportunities

23. Great Britain already has effective and well-developed infrastructure for gas transmission and distribution. Gas network operators are required under condition of their licence to operate safe, reliable and efficient supply infrastructure and to meet all reasonable requests to connect. There will need to be additional infrastructure if there is to be extensive production at numerous sites on shore. The infrastructure requirement will depend upon the location of production and its extent.

24. If gas producers wish to buy additional capacity to supply the gas network (known as incremental capacity), gas network operators will automatically receive additional funding to support its investment in delivering that capacity.

25. BIS is working with DECC, with stakeholders from the regions and from the onshore sector to develop a supply chain mapping exercise. This will highlight the potential opportunities and identify the capacity and capability needed to meet this new industry. BIS is working to convene a steering group for the shale gas supply chain which will develop the specification and oversee the study.

Learning lessons from the US

26. The Government believes that there are many lessons to learn from US experience, although allowance has to be made for the many differences in regulatory practice and requirements between the UK and the US, and between different States within the US. We have already benefited from many valuable reports from the US, including from the Secretary of Energy's Advisory Board and the National Academy of Sciences. DECC officials have also visited Washington, Houston and Pennsylvania over the last twelve months to learn at first hand from regulators, industry and other interest groups. We will continue to maintain close dialogue with US counterparts and to follow developments in the US closely, both in terms of science (much valuable work is being carried out in researching the development of the more mature industry there) and regulatory thinking.

26 September 2013

Grantham Research Institute on Climate Change and the Environment and Centre for Climate Change Economics and Policy (CCCEP)—Written evidence

Submission to be found under Centre for Climate Change Economics and Policy (CCCEP) and Grantham Research Institute on Climate Change and the Environment—Written evidence

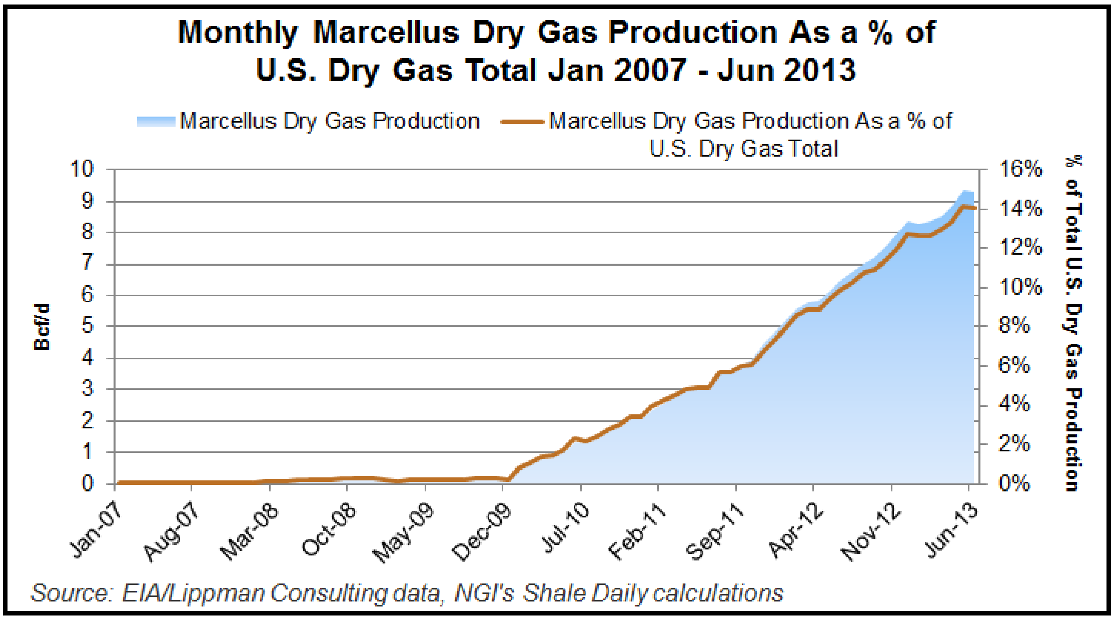
Nick Grealy, No Hot Air—Written evidence

How much scope is there for shale gas and oil - from domestic and overseas sources - to be used in the UK? Over what time frame?

1. Absent any significant exploration for gas or oil onshore in the UK, any estimates can only be the subject of speculation, but given the BGS resource survey estimates of approximately 1300 TCF for the Bowland Basin alone, they are likely to be able to provide a substantial contribution to the UK energy mix, and thus, energy security, retail prices, carbon emission targets and the viability of other generation technologies.
2. However, the shale revolution in North America is changing rapidly and studies of costs and production levels prior to 2013 cannot provide an accurate picture of the costs or results that may be achieved, or not, in the UK.
3. It must be understood that the UK does not have the option to sit out the shale revolution. The UK is neither an energy nor economic island, and it would be a fundamental error to maintain that allowing actual UK production, *or not,* may have much material impact either way.
4. Almost all energy observers note that the UK will depend on varying levels of natural gas in generation, heating and industrial use for several decades. Thus the choice revolves around whether to produce gas domestically or to import it. The subordinate choice is then whether to pay the UK to produce it, or to decide that we can pay other
5. The size of the Bowland Basin resource is substantial in comparison to other shale plays. It is appears to be larger than any play in North America apart from the Marcellus Shale. For comparison purposes, the Barnett Shale centered on Fort Worth Texas is estimated to hold 43 TCF of recoverable gas. The ratio of resource to reserves, Gas in Place to Estimated Ultimate Recovery is different for each play, and is subject to considerable variation, but even a low range estimate of 5% could mean the Bowland alone could have an EUR of 65TCF.
   http://www.eia.gov/analysis/studies/usshalegas/pdf/usshaleplays.pdf page viii
6. US experience shows that it is unknown for a shale formation of the Bowland's size not to be produce commercial quantities or either natural gas or oil..
   It is thus clear that any discussion of EUR in the Bowland is irrelevant in many respects. Many observers, such as the Institute of Directors, have for example used a 10% rate, but others have said this is conservative. But even a 65TCF EUR would over the course of a 40 year field life (which again is on the cautious side) yield an average of 1.625 TCF (46.02 BCM) out of a total UK demand in 2012 of 78.3 BCM (2.765TCF)
7. 46 Billion Cubic meters is a prodigious amount of gas. Some have actually tried to dismiss UK gas resources/reserves as inconsequential on grounds that they would not ensure energy security, but the entire UK North Sea produced 41 BCM in 2012 (BP Statistical Review of World Energy). If North Sea production were to plateau at the 35 BCM level it would not be unreasonable to assume that the UK could in fact be energy independent even of Norwegian and Netherlands North Sea production, and certainly from all LNG imports.
8. It has always been my contention that the UK must consider importing energy as analogous to exporting money. The value at present day prices of 46 BCM of

approximately 23 pence per cubic meter (£10.58 billion) needs to be consider two key points. £10.58 Billion off the UK Balance of Payments deficit is not a number to be dismissed lightly. Similarly, dismissing UK shale potential, dismisses over £6BN in tax and royalty revenue alone. The multiplier effect of the shale gas exploration and production industry and the economic impact of a reduction in domestic prices leading to an increase in disposable income also need to be considered.

9. The above discussion is only about natural gas. The UK used 499 thousand barrels of oil per day more than it produced in 2012 (967 thousand bbld), an annual cost of at $105bbl of £12 billion added to the current account deficit and a possible £7.2 Billion in foregone tax revenue. Decarbonisation, electric vehicles, vehicle efficiency and natural gas consumption in HGV and buses will mean that oil consumption falls over time, but so too will North Sea production. There is very little anyone is willing to say in public about the potential for UK onshore oil production ahead of the 14th Onshore Exploration round, but given the North American, Argentina, Russian, and Australian experience of using hydraulic fracturing techniques to produce oil from rocks previously considered fallow or un-prospective, it appears that at least some oil, and thus commercial advantage could accrue to the UK via onshore oil.
10. On the subject of time frame, conventional wisdom appears to believe that UK shale gas or oil production may be a matter of many years away. The reasons proposed include alleged environmental opposition, resource constraints in the drilling and service sector and a lack of pipeline capacity. However, much of the opinion stems simply from extrapolating US experience. Under that scenario, the UK will repeat the multi year emergence of the US shale industry from Mitchell Energy's initial efforts 20 years in the Barnett Shale to today's production levels in areas such as the Marcellus.
11. Thus predicting the future by using the past as example for today is unwise for several reasons. One is that while UK exploration will inevitably move ahead - and back – in sometimes unsteady steps, just as Poland's shale effort appears to have, many fundamental scientific advances in petroleum exploration and production in the US have already been achieved and the rest of the world need not re-invent the wheel, thus shortening development times considerably.
12. The attached chart from Shale Daily, September 25, 2013 illustrates the speed of the transformation in the Marcellus Shale of Pennsylvania. The very first exploratory wells in Pennsylvania date from 2004, and the period from then to commercial production was not decades long but only a matter of five years. That was followed by a period of rapid growth that has accelerated in 2012/13. The Marcellus then went to produce 9BCF a day (93BCMY) within a period of only 42 months from standing start. Current predictions are for the Marcellus to produce 20BCF a day by 2017 onwards.


Monthly Marcellus Dry Gas Production As a % of U.S. Dry Gas Total Jan 2007 - Jun 2013
Marcellus Dry Gas Production
Marcellus Dry Gas Production As a % of U.S. Dry Gas Total
Bcf/d
% of Total U.S. Dry Gas Production
0
1
2
3
4
5
6
7
8
9
10
0%
2%
4%
6%
8%
10%
12%
14%
16%
Jan-07
Aug-07
Mar-08
Oct-08
May-09
Dec-09
Jul-10
Feb-11
Sep-11
Apr-12
Nov-12
Jun-13
Source: EIA/Lippman Consulting data, NGI's Shale Daily calculations

How will the costs, including those on the environment, of accessing the UK's shale gas and oil deposits compare to those of other sources of energy?
US Shale experience informs us that US shale economics and production change rapidly, yet also differ from area to area and often within it. Thus it is difficult, and perhaps even pointless, to engage in conjecture as to what UK production costs may be. US experience does show that drilling is far more efficient than even two years ago and that there have been substantial improvements in drilling times, lateral lengths and concomitant increases in production. Dr Terry Engelder of Penn State University stated on September 24 2013

The average Marcellus well is going to have a production history that looks to me like it will net somewhere on the order of three times as much gas as the average Barnett [Shale] well

http://shaledaily.com/news/engelder-marcellus-production-proving-early-detractors-wrong-sd20130924b.shtml

Much of the US improvement stems not only from geological factors but also from improved micro-seismic techniques that allow operators target "sweet spots" of gas concentrations with far greater accuracy. Thus studies such as the OIES shale study of 2010, Chatham House (Stephens 2010) and Pøyry for Ofgem (2012), which study US shale production costs current at those times, are unlikely to provide a guidepost for UK production cost estimates.

A September 2013 view of UK costs is more likely to follow developments noted in Bank of America Merrill Lynch's Global Energy Weekly 21 August 2013 "Still Choking on Natural Gas" which noted the following on costs in the Marcellus:

North America simply remains awash with dry natural gas. The latest natural gas producer earnings reports indicate that the structural uptrend in output remains firmly in place. Producers with a strong footing in the Marcellus reported remarkable well performance, improved efficiencies from pad drilling, upgraded production estimates and, perhaps more importantly, significantly upgraded estimates of the underlying resource potential of their acreage. Some producers show IRRs in the Marcellus of 96% at $4/MMBtu! The strong results are now leading us to upgrade our dry production growth forecast to 0.6 bcf/d in 2013 and to 1.5 bcf/d in 2014, likely placing a cap on US nat gas prices for the time being.

Prices for the UK cannot be solely estimated as being repeatable from the Barnett in 2009, but more likely to follow advances in the Marcellus and other formations today – and the inevitable improvement likely even on those levels.

What impact will shale gas and oil have on household energy bills?

The basic issue of UK energy bills is that there is no mechanism to discover the true wholesale component of household bills. This is analogous to petrol stations not posting prices on either motor fuel, bread or milk, but the UK regulator has stated that they believe that 67% of gas bills come from commodity costs.

https://www.ofgem.gov.uk/information-consumers/domestic-consumers/understanding-energy-bills

Electricity bills commodity is 58% and in an even more murky market it is believed that gas nevertheless plays an important factor in electricity costs.
The question then is how could the average commodity only cost of £385 for gas and £248 for electricity based on average use at 2013 prices be reduced. The current UK gas price of 65 pence per therm on the wholesale market is equal to $10.34 MMBTU, whereas US Henry Hub gas prices have not exceeded $3.90 so far in 2013

It has been widely noted that UK gas prices will follow internationally traded gas prices in North West European hubs. Simply put prices tend to follow the declining amount of oil indexed prices with the margin prices set as LNG gas costs influenced by Asian, predominantly, Japanese, LNG import requirements.

However, US LNG exports will enter world markets from 2015 onwards and whether they come to Europe or not, the price affect of the molecules will be substantial. With US LNG costs depending on Henry Hub +15%, plus processing and shipping costs at exporting and receiving terminals, the costs are estimated to be in the area of $8MMBTU into European markets and we can expect that conservatively European prices will reflect this 22% drop in prices. As stated above, we cannot be guaranteed that UK retail prices will reflect this drop under the present light touch regulation practiced by Ofgem.

I also must point out that the increase of shale volumes internationally, will inevitable lead to an unraveling of the oil link in the present form. It is the contention of several international experts that we may be entering a period of lower and less volatile gas prices based not only on lower natural gas, but on lower oil prices as the shale oil effect in the US causes a drop in US demand. Evidently, Chinese and other demand will continue to support oil prices, but perhaps at lower levels than previously held in the Peak Oil era which shale energy has now thoroughly discredited.

I have stated in the past that if Benjamin Franklin were alive today, he would update his famous maxim to include utility bills along with death and taxes as being certain.
If wholesale cost falls were passed on to consumers, this could lead to at least a £120 pound a year increase in disposable income. The multiplier of the echo effect of what would be effectively a tax cut for consumers would have a noticeable impact on the economy which should also be considered.
Time prevents a discussion of the impacts of more lower energy costs on businesses, which would both increase their profitability (and government revenue) while lowering or moderating costs to consumers in both food and durable goods.

What effect will the use of shale gas and oil have on carbon emissions compared to other combinations of energy sources?

UK natural gas resources will not only displace coal, but my conceivably affect the use of diesel in transportation. As natural gas vehicles are inherently 30% less CO_2 producing than diesel this will have a clear effect on UK CO_2 levels. The substantial health effects of particulate pollution and other greenhouse gases found in diesel but broadly absent in cleaner, cheaper and quieter natural gas engines can only lead to other savings in carbon, money and most of all in human life, as the NHS has stated that 13,000 premature deaths happen each year due to air pollution stemming from coal and diesel use.

http://www.nhs.uk/news/2012/04april/Pages/air-pollution-exhaust-death-estimates.aspx

Will shale gas and oil lead the UK to be less dependent on energy from less reliable regions of the world such as the Middle East and Russia?

Yes

What lessons can be learnt from the US experience of shale gas and oil?
The essential lessons from the US experience have been positive for consumers, energy security and CO2 levels. The United Kingdom, as do Europe, Canada, Australia and many other jurisdictions, have a history of effectively regulating not only the oil and gas industry but a wide range of other everyday industrial processes, at even greater levels than in the US.

No process, policy or economic choice can ever be risk free. The UK must follow the US in showing successful mitigation of risk, but perhaps needs to be more forthright in explaining energy policies to the public. It has been my experience during five years of experience in the issue that those who concentrate on catastrophic problems often believe in magical solutions.

Shale energy provides a path to a lower, but not lowest, carbon world and does so where the costs of energy production accrue, for good or bad, to those who actually consume it. We need to have a pragmatic energy policy that depends on the physically, economically and socially acceptable. Shale gas has been described by Michel Rocard, former Prime Minister of France, a blessing from the gods.
http://abonnes.lemonde.fr/politique/article/2012/11/10/michel-rocard-avec-le-gaz-de-schiste-la-france-est-benie-des-dieux_1788711_823448.html

It may also be a Pandora's Box, but we do have the benefit that the United States has already taken a very long peep inside.

It would foolish, if the United Kingdom were to be so imprudent as to not at least explore.

30 September 2013

Greenpeace UK, World Wildlife Fund (WWF-UK) and Friends of the Earth England, Wales and Northern Ireland—Written evidence

Submission to be found under Friends of the Earth England, Wales and Northern Ireland, Greenpeace UK, and World Wildlife Fund (WWF-UK)—Written evidence

INEOS ChlorVinyls—Written evidence

EXECUTIVE SUMMARY

- The UK has vast shale gas resources, which could provide energy security for decades to come, while creating thousands of jobs, improving energy prices, and generating significant tax revenues.

- The UK will be reliant on gas for the next few decades to keep the lights on. There can be no question that indigenous shale gas is preferable to gas and coal imports, given the economic and security benefits, and the fact that studies have shown the carbon footprint is the same or slightly better.

- Shale gas could reduce the amount of coal-fired generation in the UK, improving emissions in the medium term. It could also have a long-term role in the green economy in conjunction with CCS and non-firm renewables.

- Energy prices in the UK are already uncompetitive and this is set to worsen drastically up to 2020. This is a serious threat to the future of energy-intensive industries in the UK that employ 225,000 people and generate 1% of GDP. Shale gas could help secure the long-term future of these valuable industries in the UK.
- Shale gas would particularly benefit the UK petrochemicals industry, which is not only energy-intensive, but could also use shale gas as a source of secure and competitively priced essential raw materials (ethane and propane). The double saving on energy and raw materials has rejuvenated the petrochemicals industry in the USA and this could be replicated here.

- With established gas and petrochemical infrastructure, the UK is well placed to take full advantage of shale gas and develop quickly over the next few years as gas supplies from the North Sea continue to decline. The country also has an excellent record of regulating this sort of technology. It will be important to ensure communities are convinced of the merits of extraction, however, if development is to proceed effectively.

About us

1. INEOS is a global manufacturer of refined oil products, petrochemicals and plastics. INEOS was founded 15 years ago in the UK, and is now one of the largest chemical companies in the world. Worldwide INEOS operates 51 manufacturing sites in 11 countries, employing 15,000 people. INEOS has six sites in the UK, employing 3500 people, including a refinery at Grangemouth, and a chlorine plant in Runcorn
2. INEOS ChlorVinyls is one of INEOS' 15 businesses. We are a leading manufacturer of chlorine and PVC, employing around 3,300 people at nine production facilities in the UK, France, Germany, the Netherlands, Belgium, Norway and Sweden.
3. INEOS has direct experience of using shale gas in the USA as a source of energy and the key chemical raw materials, ethane and propane. INEOS has the expertise and infrastructure to separate out and use high value chemical raw materials found in shale gas in the UK.

How much scope is there for shale gas and oil - from domestic and overseas sources - to be used in the UK? Over what timeframe? What infrastructure investment will be

necessary to cope with the development of shale gas and oil? How will this investment be financed?

4. The British Geological Survey estimates that central Britain has shale gas resources (gas-in-place) of 1,329 trillion cubic feet. The proportion of this gas that can be viably extracted is as yet unknown and will depend on economic, geological and social factors. It is clear, however, that there is very significant scope for extraction in the UK. Assuming conservatively that only 10% of resources could be extracted, this would be equivalent to over 50 years of gas requirements for the UK at current usage rates. It is important to move forward with exploration to better understand the scope for shale gas production capability in the UK.
5. The UK has significant natural gas and hydrocarbon infrastructure already in place. As North Sea gas declines this supply must be replaced. This has already happened through increasing UK imports through pipelines (Langeled, IUK and BBL) and LNG imports. Without question domestic shale gas production could easily be brought into the mix through existing and well developed infrastructure. The UK has a strong track record of building new infrastructure. The development of a massive oil and gas production and transmission infrastructure was achieved in a relatively short period in arguably a much more challenging environment (the North Sea). There is no reason that this could not be replicated for shale gas production. Transport infrastructure should not be considered the key issue – it is developing and demonstrating production capability.
6. Shale gas is not just a fuel; it is also a source of valuable chemical raw materials (ethane and propane) that the chemicals industry uses to make commodity compounds and plastics such as polyethylene and polypropylene. The UK is well positioned to make use of shale gas as a chemical feedstock, extracting maximum value from the resource. The UK has effective petrochemicals infrastructure, and INEOS' ethylene cracker at Grangemouth is one of only four in the EU capable of processing gas liquids in this way.
7. INEOS recently completed supply and infrastructure agreements that will enable the company to use chemical raw materials sourced from US shale gas from 2014/15. Under the arrangement, ethane and propane from shale gas in Houston will be piped to Marcus Hook. Ethane will then be separated by fractionation and shipped to INEOS' gas cracker at Rafnes in Norway, where ethylene product can be used by INEOS' European sites. INEOS is also considering investing in import infrastructure at its Grangemouth cracker to receive ethane sourced from US shale gas.

How will the costs, including those on the environment, of accessing the UK's shale gas and oil deposits compare to those of other sources of energy?

8. INEOS is not in the business of extraction, or energy generation, so cannot comment with authority on the economic viability of competing technologies. We would note, however, that there seems to be no shortage of commercial interest in extracting shale gas despite the absence of subsidies or price mechanisms that support other forms of energy. Indeed shale gas would provide significant long-term revenue to the exchequer.
9. The scientific and engineering consensus is that the environmental risks associated with extraction are minimal and manageable, and no greater than those associated with other extraction technologies. Indeed the technologies and processes involved are not novel or unfamiliar to regulators. A study conducted by the Royal Society and Royal Academy of Engineering concludes that seismic risks associated with hydraulic fracturing are low, with any events likely to be smaller in magnitude than natural geological events and those caused by coal

mining. It similarly concluded that fracture propagation is unlikely to lead to groundwater contamination. With appropriate monitoring of seismicity and robust regulation of well integrity, extraction can be managed safely.

10. The UK will continue to require gas for the next few decades to meet energy needs in the face of coal/nuclear closures, and intermittency issues with renewables. The only issue is whether to use indigenous shale gas or imports of conventional natural gas and LNG. Using indigenous shale gas rather than imported gas would have no additional environmental cost (and significant economic and energy security benefits). The Committee on Climate Change calculates that the carbon footprint of shale gas is equivalent to conventional gas and slightly better than imported LNG (assuming well integrity).
11. Coal-fired power stations emit roughly twice the amount of carbon dioxide as gas-fired stations. Due to low coal prices and high imported gas prices, coal-fired generation has increased in recent years, worsening the UK's carbon footprint – the exact opposite of what has been happening in the US. Extracting indigenous shale gas would provide generators with a more secure and competitively priced source of gas, encouraging a switch from coal generation, and potentially reducing emissions.
12. In the longer term, the development of CCS technology could mean that shale gas is more than just a transition fuel for the UK, and could form a vital part of the energy mix in the green economy into the long term.

What is the potential impact of shale gas and oil on the local economies in areas where development is possible?

13. The Institute of Directors estimates that during the production phase, investment in extraction could peak at £3.7bn a year, supporting 74,000 jobs, including geologists, drilling specialists, construction workers, truck drivers, cement manufacturers, water treatment experts, and people working in retail and services.
14. Energy intensive industries need secure supplies of competitively priced energy to survive and prosper in international markets. Similarly, the UK petrochemicals sector requires secure and competitively priced raw materials. These industries employ around 225,000 people in regional economies across the UK but face decline because energy prices are set to increase dramatically in the UK up to 2020, at a faster rate than in other countries, due to policies such as EMR and the carbon price floor. Using shale gas in the UK is an opportunity to address this competitiveness gap, promoting jobs and growth in the manufacturing sector.
15. Unlike in the USA, landowners in the UK do not own rights to minerals beneath their land. Local communities may also be inconvenienced by increased traffic during development. For these reasons, INEOS welcomes the proposal from extractors to offer £100,000 to the community for each well drilled, and 1% of revenues. It is also important that more is done to communicate the benefits of shale gas to local communities, and address misconceptions about environmental risks. Benefits could include new jobs, local economic growth, revenues for the community, and lower energy bills.
16. Shale deposits are geographically dispersed and are located close to key industrial clusters around the UK (for example Central Scotland and the North West of England). As a consequence there is significant scope for developing shale extraction on brown field locations. These developments should be fast-tracked and supported by the government to demonstrate the potential of shale gas.

What will be the impact of shale gas on the cost of electricity generated at gas-fired power plants and how will it compare to other forms of generation including coal, nuclear and renewable? What impact will shale gas and oil have on household energy bills?

17. The gas price is critical in determining the price of wholesale electricity. Increasing wholesale gas prices have caused wholesale electricity prices to increase. With the UK generation mix being more dependent on gas than most other European markets, this has resulted in UK wholesale prices rising to highly uncompetitive levels.
18. INEOS is not an authority on consumer bills, but as a large industrial energy user, we expect shale gas to put downward pressure on gas and electricity prices, by increasing supply in the market. The effect is unlikely to be as dramatic as in the USA, because the UK is connected to the wider European market, and falling North Sea reserves will offset increased supply. Nevertheless, extracting shale gas in the UK is likely to have a beneficial effect and at the very least stem price rises. Depending on the amount of shale gas that can be extracted viably in the UK, and whether other European countries extract reserves, benefits could be very significant, especially for energy-intensive industries that are vulnerable to price increases.
19. Shale gas would also help stabilise prices, which is vital to provide the long-term certainty that industry needs to invest. By providing a secure indigenous supply of gas, the UK would be better protected from volatile import prices, which have been a problem in recent years as countries compete for LNG shipments when supply is low in the market.
20. Wholesale gas and electricity prices in the UK are already uncompetitive, and as BIS acknowledges, UK decarbonisation policies will severely widen this competitiveness gap with Europe and the rest of the world in the next decade. Energy-intensive industries are seriously at risk of being pushed out of the UK, resulting in thousands of job losses, lost GDP, and lost tax revenues. Global emissions meanwhile, will not improve and could even worsen as production simply moves to other countries. Shale gas could help address this problem, preserving the competitiveness of energy-intensive industries.
21. To conclude, there is clear evidence from the United States that shale gas has the potential to be the most competitively priced hydrocarbon – cheaper than coal which has double the carbon intensity and significantly cheaper than the prices being suggested as "strike price" for new nuclear in the UK.

Which forms of electricity generation is shale gas likely to displace and by how much? What effect will the use of shale gas and oil have on carbon emissions compared to other combinations of energy sources?

22. North Sea reserves of gas are declining, while the need for gas generation is increasing due to coal-fired stations being decommissioned, and the fact that renewables and nuclear will be unable to meet electricity needs for some time. It is already clear that gas will continue to be hugely important in the medium term for both heat and power generation – and indeed there is already a significant amount of gas power plant currently moth-balled. Shale gas would help meet this demand for gas generation, in a more competitive and secure way than importing conventional natural gas or LNG.
23. Since 2000, coal-fired power stations have been used to cover for unavailable nuclear-fired stations, and gas-fired stations while gas prices have been high. This has led to a significant increase in carbon emissions. Insofar as shale gas would put downward pressure on gas prices it would encourage a switch from coal-fired generation to gas-fired generation, reducing

emissions.

Will shale gas and oil increase UK energy security? Will shale gas and oil lead the UK to be less dependent on energy from less reliable regions of the world such as the Middle East and Russia?

24. As North Sea reserves have declined steadily over the last decade the UK has become increasingly dependent on imports and is now a net importer. This has resulted in prices being higher on average, and more vulnerable to fluctuations in the market. About 80% of our gas imports come from Norway, and the rest from Qatar in the form of LNG. IMechE predicts that the UK will be importing 80% of its gas by 2030, meaning we will become increasingly reliant on the Middle East and Russia. This is a political and economic risk, and will lead to further price uncertainty, which is bad for consumers and deters manufacturers from investing in the UK.
25. The discovery of vast shale gas resources in the UK, which can be compared to the discovery of natural gas in the North Sea, is an opportunity to return to a position of energy security for many decades to come. This is especially important given forecasts from Ofgem that the UK is heading for an energy crunch and potential blackouts. The Government recognises (through its Gas Generation Strategy) that natural gas will necessarily play a major part in the UK's energy mix in the medium term (for both power generation and heat) if we are to keep the lights on ahead of the wider development of new nuclear and renewables. In this situation, it very clearly makes sense to use indigenous supplies that are more secure.

What changes to public policies are necessary to maximise the potential of any shale gas development?

26. It is important to move forward as quickly as possible with extraction, while meeting robust standards. Development should be facilitated through supportive policy, efficient regulation, and by addressing misconceptions about risks. The Government has already announced plans to support shale gas in the tax system and simplify regulatory processes, which INEOS welcomes.
27. Local support is also crucial to overcome planning obstacles. The Government should focus on communicating the benefits of shale gas and define what communities can expect to receive in return for hosting extraction sites. Support for energy bills and development of community projects would help win hearts and minds.
28. Government should also support local "off-grid" supply arrangements to quickly demonstrate the wider benefits of shale while supporting critical energy intensive manufacturing sectors.

What lessons can be learnt from the US experience of shale gas and oil?

29. The growth of shale gas in the US has had a profound impact. Natural gas prices have fallen dramatically and are now among the lowest in the world—certainly of the transparent liquidly traded gas markets. Rather than being a net importer, the US is now expected to be a net gas exporter, with a number of major liquefaction projects announced (in part using the terminals that were constructed to import gas). Thus, rather than exporting money to buy gas, the US will have a large new revenue stream.
30. Extraction has directly created thousands of jobs and regional growth. In just four years,

Pennsylvania, a state with a population of around 12 million, has gone from producing no natural gas, to producing more gas than the entire UK North Sea and employing almost 160,000 people in the sector.

31. Lower gas prices have also resulted in lower electricity prices, giving a massive competitive advantage to US electro-intensive industries and manufacturers more broadly. The increased availability of competitively priced chemical raw materials has also caused a boom in the petrochemicals industry, with almost 100 investment projects announced as of March 2013, primarily to expand production capacity for ethylene, and ethylene derivatives such as PVC. This is unprecedented in recent US history.

32. A recent report from the American Chemistry Council published in May 2013 finds that 97 chemical industry projects worth $71.7 billion have been announced as a result of the shale gas boom. It calculates that these will deliver the following economic benefits up to 2020: 485,000 direct jobs, 258,000 indirect jobs, and a further 442,000 payroll-induced jobs, as well as $20 billion in tax revenues.

33. Natural gas is now far more competitive than coal for power generation in the US. In direct contrast to the situation in the UK and Europe, gas has displaced coal in the power generation sector and the US has seen a significant reduction in CO_2 emissions.

34. The UK can replicate these benefits, delivering energy security, promoting industry, countering rising energy bills, and even reducing emissions in the medium term. In particular, the US example shows that indigenous shale gas could be transformational for UK energy-intensive industries, and especially the petrochemicals industry, which would benefit from secure and competitive energy and raw materials.

35. The fact that individuals in the USA own the rights to the minerals on their land has proved essential in the pace of development. This suggests the UK must ensure local communities benefit from extraction to more forward successfully.

1 October 2013

Dr David Lowry, Environmental Policy and Research Consultant—Written evidence

Fracking's radiation risk

Along with many banners saying 'Could you kindly Frack Off', 'Police say no to fracking!' 'For a frack-free future', protestors at Balcombe, Sussex in August highlighted their concerns over contamination of the local water table, fugitive emissions of fracked methane gas that could exacerbate climate change dangers, and worries over community disruption from many lorries that will have to come to areas hosting fracking platforms with toxic liquids used to flush out shale gas.

Earlier this year, also in August, in an article in the Daily Telegraph, The Prime Minister, David Cameron tried counter concerns over prospective environmental hazards such as water contamination by referring to a "stringent regulatory system." ("We cannot afford to miss out on shale gas", 12 August 2013, http://www.telegraph.co.uk/news/politics/10236664/We-cannot-afford-to-miss-out-on-shale-gas.html)

Mr Cameron's coalition partners also give cautious support for shale gas in a motion debated, and endorsed, at the LibDem conference in September 2013 saying limited shale gas extraction should be allowed, provided that "regulations controlling pollution and protecting local environmental quality are strictly enforced, planning decisions remain with local authorities and local communities are fully consulted over extraction and fully compensated for all damage to the local landscape".

But neither of the Coalition partners, nor indeed the protestors in Balcombe, make any mention of radioactive risks arising from fracking.

However, Mr Cameron's own Health minister, Anna Soubry, has told Labour MP Paul Flynn in a written answer in May that Public Health England (formerly the Health Protection Agency) is preparing a report identifying potential public health issues and concerns, *including radon (release/emissions, my emphasis)*) that might be associated with aspects of hydraulic fracturing, also referred to as fracking. The report is due out for public consultation in the summer. Once released for public consultation, the report will be freely available from the PHE website." (Hansard, 20 May: Column 570W)

PHE have told me they now do not expect their report to see the light before the end of the year, which is hugely disappointing considering its prospective importance to the public debate.

PHE is concerned to evaluate the concerns raised over potential risks of radon gas being pumped into citizens' homes as part of the shale gas stream. Unless the gas is stored for several days to allow the radon's radioactivity to naturally reduce, this is potentially very dangerous.

Radon is unquestionably the leading cause of lung cancer in non-smokers. A report

produced by the HPA in 2009, Radon and Public Health. (Report of an independent Advisory Group on Ionising Radiation: Docs RCE 11, HPA 2009: www.hpa.org.uk) states:
"Radon is a naturally occurring colourless and odourless radioactive gas that can seep out of the ground and build up in houses, buildings, and indoor workplaces. Epidemiological studies have established that exposure to radon is a cause of lung cancer, with a linear dose-response relationship. Exposure to radon is now recognised as the second largest cause of lung cancer in the UK after smoking and analysis for the Health Protection Agency indicates that about 1100 UK deaths from lung cancer each year are caused by exposure to radon (most caused jointly by radon and smoking)".

Initially radon released from its virtually sealed underground locations will be in monatomic suspension, but then it accretes onto dust particles, pipework, etc, and some of it may remain suspended in the gas and come out in our cookers.

US concerns

The current concern about how much radon is likely to be piped into people's kitchens was spurred by a report last year by Dr Marvin Resnikoff, of Radioactive Waste Management Associates (http://rwma.com/aboutus.htm). Dr Resnikoff estimated radon levels from the Marcellus gas field - the nearest one being exploited to New York - as up to 70 times the average. Dr Resnikoff's group, now based in Vermont, used be to be based in Brooklyn, New York, hence its work on shale gas being piped to New York consumers. RWMAs suggest some shale gas deposits contain as much as 30 times the radiation that is found in normal background.(http://gdacc.org/2012/01/10/radon-in-natural-gas-from-marcellus-shale-by-marvin-resnikoff-radioactive-waste-management-associates/). New scientific evidence on these concerns was published in the US journal Environmental Science & Technology in September 2013 ("Impacts of Shale Gas Wastewater Disposal on Water Quality in Western Pennsylvania," http://pubs.acs.org/doi/abs/10.1021/es402165b)

Moreover, Professor, James W. Ring, Winslow Professor of Physics Emeritus, Hamilton College in New York State (http://www.hamilton.edu/index.cfm) stresses:
"The radon and natural gas coming from the shale mix together and travel together as the gas is piped to customers. This is a serious health hazard, as radon—being a gas—is breathed into the lungs and lodges there to decay, doing damage to the lung's tissue and eventually leading to lung cancer."

Radon has a half-life of 3.8 days. Using the general rule of thumb of 10 half-lives to decay to 1/1000 of original concentration, that would be 38 days, or roughly one month, depending on how radioactive it was to start.

Fracked gas would thus need to be stored for at least a month before being distributed to peoples' homes, to allow for this radioactive decay of radon.

The Radon Council, formed in 1990, is an independent non-profit making self-regulatory body for the radon protection industry. Its formation was welcomed in the Interim Report of the Parliamentary Select Committee on Indoor Pollution, which called upon industry to provide a solution to the radon problem. The first objectives were to identify the "cowboy" operators and dubious training courses then in practice. Later there followed a first edition of a training manual and an agreed Code of Practice for the industry.

It does not seem ministers have read any of the Radon Council's literature, so keen are they to press ahead with fracking, as the Prime Minister and Chancellor's speeches at the Conservative Party Conference on 30 September and 2 October 2013 –backed up by the Mayor of London - respectively demonstrated.

At the end of July 2013 the Communities Department published its *Revision of building regulation policy on radon***.** In the impact assessment it explains the reason for the revised regulation is:

"Radon is a naturally occurring radioactive gas linked to lung cancer. Alongside a health and awareness programme and testing and remediation of existing buildings, current Government policy includes targeted intervention through the Building Regulations which requires radon protection in new buildings in areas of elevated radon risk. We intend that the Building Regulations and supporting statutory guidance is clear on current radon risks, and ensures buildings are fitted with proportionate measures to prevent the ingress of radon and thus reduce radon-related lung cancers. "

It later adds "The respective cumulative risks of lung cancer [from radon exposure] affecting people by age 75 years in the UK at 100 and 200 Bq m-3 are 0.42% and 0.47% for non-smokers and 17% and 19% for continuing smokers."
(https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/225640/Radon_IA.pdf)

It also states boldly: "The chosen policy will maintain a targeted regulatory intervention (aligned to the most up-to-date radon maps), to ensure that all buildings in higher-risk areas incorporate appropriate radon measures."

In light of this clear precautionary approach, it is odd that all ministers seem to be uncritically cheerleading for expanded fracking, despite its possible radon risk.

In January 2012 the European Commission Energy Directorate released a 100-page report on 'Unconventional Gas in Europe,' primarily assessing the situation in France, Germany, Poland and Sweden. It has a section on environmental liability, but no mention of radon pollution.

(http://ec.europa.eu/energy/studies/doc/2012_unconventional_gas_in_europe.pdf)

Nuclear waste too

In addition, both RWMA in the US and the internationally respected Norwegian environmental consultancy, DNV (Det Norske Veritas have identified radioactive waste contamination as one problem with fracking, arising from contaminated rock cuttings and cores to which have the potential for exposure to radioactivity on health. Risks relating to NORM (naturally occurring radioactive materials) contaminated downhole and surface equipment should also be considered, both suggest.

(Risk Management of Shale Gas Developments and Operations January 2013 DNV-RP-U301; http://www.dnv.com)

The Commission report also records that in Sweden, the handling of radioactive shales requires a permit in accordance with the Radiation Protection Act and the Radiation Protection Ordinance. This is the case when the uranium content exceeds 80 ppm (parts per million), it points out. This permit is granted by the Swedish Radiation Safety Authority. "Non-compliance with the permit can lead to it being revoked and, if done intentionally, the responsible person can be fined or even imprisoned," it warns.

It adds that in Sweden, the possible occurrence of radioactive materials (NORMS), heavy metals or saline brines is taken into account by the permit for the environmentally hazardous activity, required for the disposal of waste water.

Green MP Dr Caroline Lucas, who was arrested as a result of her protesting against fracking in Balcombe during August 2013, initiated a wide-ranging Parliamentary debate (www.publications.parliament.uk /pa/cm201314/cmhansrd /cm130718/ hallindx/130718-x.htm)
on fracking on 18 July 2013 in Westminster Hall, drew attention to the radon risk and the outstanding PHE report. She asked the minister, Michael Fallon, pointedly: "Will the Minister explain the delay in publishing this research report when the public debate over fracking is moving ahead apace?"

Mr Fallon replied to several of Caroline Lucas' questions on environmental hazards of fracking, but gave no response to her queries on radon risks. I wonder why?

3 October 2013

Professor Richard Muller, Professor of Physics, University of California, Berkeley—Written evidence

1. Environmentalists should and must support the development of shale. Their opposition is ill-informed and needs to be reversed. Other than energy conservation, fracking is the most essential approach towards mitigating and reversing the emissions of greenhouse gases and air pollutants. The salient arguments are these:

Greenhouse emissions of natural gas are 1/3 to 1/2 those of coal
Pollution of local water pollution can be controlled with regulation and fines
Earthquakes can be avoided by recycling flowback water
Fugitive (leaked) methane is less of a problem than often portrayed
Killer smog can be drastically reduced by using natural gas in place of coal

The UK needs to set an example that the developing world can afford to follow.

2. I will now discuss each of these reasons in more detail.

3. **Greenhouse** gases and Global Warming. Anybody who believes greenhouse emissions need to be mitigated must recognize that there are two very big steps that can be taken. The first is increased energy conservation. The second is a switch from coal to natural gas. For the same energy produced, carbon (the main component of coal) produces *twice* the CO_2 that does methane (the main component of natural gas). The reason is simple: every molecule of C, when burned with oxygen (O_2) produces CO_2. But methane is CH_4. Every molecule of carbon comes with four of hydrogen, and half of the energy comes from the burning of hydrogen to produce harmless water vapor, H_2O. (Although water vapor is a greenhouse gas, so much is available from evaporation from the oceans and rivers that its level in the atmosphere is not affected by human emissions.)

4. The advantage of natural gas can be even greater, since methane can be used with 60% efficiency in electricity generation (in a combined cycle power plant), whereas coal efficiency is at best about 44% (in a pulverized supercritical plant). This means that natural gas can reduce greenhouse emissions by almost 2/3.

5. I emphasize that natural gas's potential to reduce greenhouse gases is very important, and has not received the attention it deserves. Moreover, it has the capability of doing this around the world, not just in the UK. As a consequence, it would be proper for every environmentalist who is concerned about future global warming (and I consider myself to be in that list) to be enthusiastic about the substitution of natural gas for coal wherever and whenever possible. Although there are other environmental issues, as I will detail below, most of them are relatively easy to handle compared to the very difficult one of reducing greenhouse gas emissions. (One that is not easy to handle is air pollution, but that too is most readily addressed by a switch from coal to natural gas.)

6. **Pollution** of local water in the US has been the result of flowback water spillage in states that had insufficient penalties. (Note that these pollution problems have affected only surface water, not aquifers.) Since the proximate cause is the company's attempt to reduce expenses, the issue can easily be halted with suitable regulation, monitoring, and heavy fines for transgressions. If all companies followed what is known as "best practice" then the spillage would be eliminated. Would that all environmental problems be so easily solved.

7. **Fugitive (leaked) methane.** The leakage of methane into ground water has been inaccurately portrayed in the movie *Gasland* and that has led to outrage among uninformed environmentalists. In fact, as is well documented, the "flaming faucets" shown in the movie are a phenomena that pre-dated fracking, and are known to be the result of generation of "biogenic methane" by bacteria in the soil that gets into well water. These facts are readily verified. Nonetheless, the widespread misbelief that the flaming faucets are due to fracking can present a political challenge. Passions are high, and not all opponents of fracking are open to correction.

8. One way to respond to those misinformed by *Gasland* is to encourage them to see the movie *FrackNation*. *FrackNation* is also a compelling movie, but it exposes the misleading information in *Gasland*, and even shows in a interview with *Gasland* star, writer and director Josh Fox, that he was familiar with the fact that the flaming faucets were not caused by fracking.

9. Note that surface pollution from coal residue is a very serious problem all around the world. Coal ash has highly poisonous and carcinogenic components, including arsenic, lead, and mercury. Accidents with coal ash are common; I am most familiar with those in the US, including a 2008 coal ash dam collapse in Tennessee, and a recent landslide into Lake Michigan. In the US, nearly 200 communities have suffered water contamination from coal ash. In contrast, natural gas leaves behind no ash or residue.

10. **Earthquakes** are produced both by fracking and by the reinjection of flowback water into deep storage formations. An excellent review of this issue appeared recently in SCIENCE magazine (reference W. L. Ellsworth, Science 341, 1225942 (2013). DOI: 10.1126/science.1225942).

11. The earthquakes caused directly by fracking are very weak. For example, the 2012 Blackpool earthquakes had a maximum magnitude of 2.3, detectable by instruments but hardly noticeable by most humans on the surface.

12. In contrast to the tiny fracking earthquakes, larger earthquakes induced by injection of wastewater into deep strata or basement formations are of concern. A magnitude 5.5 earthquake that damaged homes and buildings in Oklahoma in 2011 may have been triggered by injection of wastewater into a deep storage well.

13. The dangers of wastewater earthquakes from fracking can be eliminated by the requirement that flowback water be recycled, that is, that rather than being stored at a new formation, the wastewater be substituted for fresh water for additional fracking. The technology for doing this has been developed; Shell Oil says it hopes to be able to recycle essentially all of its wastewater in this manner.

14. **Fugitive (leaked) methane** has about 70x the potency of CO_2 as a greenhouse gas, kilogram per kilogram. This has led many people mistakenly to think that even small leakages of a few percent negates the value of natural gas over coal. However that estimate is not correct. Methane has a short lifetime in the atmosphere, and when the calculations are done carefully it can be shown that even if the leakage is as high as 18%, natural gas still reduces greenhouse emission compared to those of coal. See the discussion in the New York Times: http://dotearth.blogs.nytimes.com/2013/08/01/two-climate-analysts-fault-gas-leaks-but-not-as-a-big-warming-threat/

15. **Killer smog** is a horrific issue in China, India, and the developing world. It is arguably the greatest environmental threat in the world today; at least in the short-term it even outranks global warming. According to an article published last year (Lancet 2012; 380: 2071–94), 1.2 million people die in China each year from the air pollution. According to a more recent article in the Proceedings of the National Academy of Sciences US (www.pnas.org/cgi/doi/10.1073/pnas.1300018110), the average loss of life in north China from coal-induced air pollution is 5.5 years. The UK is, of course, familiar with the issue of coal and air pollution, dating back to the industrial revolution and more recently the London killer smog of 1952.

16. A key and affordable way to address the air pollution problem is wide scale conversion in the affected countries from coal to natural gas; doing so can reduce the dominant pollutant, particles less than 2.5 microns in diameter, by a factor of 1/400. A switch from coal to natural gas was a major part of the solution to London's1952 smog.

17. Of course, currently the worst pollution is taking place in China, not the UK. Nevertheless, the development of shale in China has been very slow, undoubtedly in part because of the example being set by countries such as UK and France stalling its development due to the concern that fracking is potentially dangerous. The UK cannot support and encourage fracking in China when it stifles it at home. The UK should and must set an example that it will not slow the replacement of coal with natural gas.

18. Some will argue that the developing world should switch to renewables. Yet the growth of renewables is very slow, largely due to the high expense. Last year China installed 7 GW of solar, but that number is misleading. By convention, solar is described in terms of its peak power, that is, when the sun is bright and directly overhead. When nights and cloudy weather is included, the 7 GW of peak power is less than 1 GW average. Over the last few years, China has been adding 50 GW of coal power every year; thus solar is not only hopelessly behind, but it's capacity is being added far more slowly than that of coal. The problem is that renewables still need to be subsidized (with the exception of hydro, which causes other horrific environmental problems). Technologies which are not profitable are not sustainable, particularly in the developing world.

19. Renewables are ideologically attractive, and likely to be a large part of the long term solution. But we should not wait. Natural gas, substituting for coal, provides a rapid solution for the immediate future, and gives the renewable technologies time to develop and drop in cost. Subsidizing renewables in the UK and the US provides an example that China, India, and the rest of the developing world cannot afford to follow. And although the developed world has been responsible for most of the global warming so far, according to all projections, it is the developing world that will be the source of most of the greenhouse gases in the future.

26 August 2013

National Grid—Written evidence

1. Introduction to National Grid

1.1. National Grid owns and manages the grids to which many different energy sources are connected. In Britain we run systems that deliver gas and electricity across the entire country. We hold a vital position at the centre of the energy system. We join everything up.

1.2. National Grid is at the heart of one of the greatest challenges for the UK energy industry - to deliver low carbon energy in an affordable, secure and sustainable way. This is an industry wide challenge that will require an estimated £200 billion of investment up to 2020 to transform the UK's energy infrastructure. Ensuring the development of an energy system that can underpin our economic prosperity in the 21st century.

1.3. We develop scenarios, based on extensive industry and stakeholder feedback, which present pathways to decarbonisation. These scenarios are detailed in our **UK Future Energy Scenarios**[142] **(FES)**, the latest version of these were published in July 2013.

1.4. These scenarios are used as a reference point for a range of modelling activities, enabling us to identify strategic network investment requirements for the future. Our scenarios do not predict the future. They explore a range of plausible outcomes and the complete scope of potential drivers that might have an impact on that outcome. This year we have developed two scenarios:

- **Gone Green** has been designed to meet the environmental targets; 15% of all energy from renewable sources by 2020, greenhouse gas emissions meeting the carbon budgets out to 2027, and an 80% reduction in greenhouse gas emissions by 2050.

- **Slow Progression**, where developments in renewable and low carbon energy are comparatively slow, and the renewable energy target for 2020 is not met (Slow Progression reaches this level sometime between 2020 and 2025). The carbon reduction target for 2020 is achieved but not the indicative target for 2030.

2. Shale Gas Overview

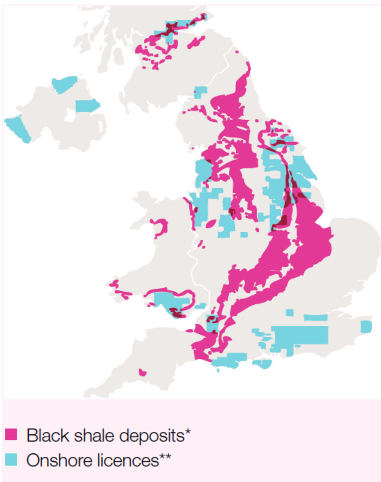
2.1. As explained in our Future Energy Scenarios[143], shale gas is natural gas that is found trapped within shale formations. It can be recovered through a process called 'fracking' which involves drilling wells deep into the dense shale rocks that contain natural gas, then pumping in at very high pressure quantities of water mixed with sand and chemicals. This opens up tiny fissures in the rock, through which the trapped gas can

[142] http://www.nationalgrid.com/NR/rdonlyres/A3A03257-3CCC-40DD-99C8-500A149D997D/61591/UKFES2013FINAL1.pdf
[143] http://www.nationalgrid.com/NR/rdonlyres/A3A03257-3CCC-40DD-99C8-500A149D997D/61591/UKFES2013FINAL1.pdf

then escape. It bubbles out and is captured through the wells that bring it to the surface, where it can be piped off.

2.2. Shale gas has become an increasingly important source of natural gas in the United States of America since the start of this century. In 2000 shale gas provided only 1% of US natural gas production; by 2010 it was over 20% and the United States government's Energy Information Administration (EIA) predicts that by 2035, approximately 50% of the United States' natural gas supply may come from shale gas. The evolution of shale gas production in the USA has altered the market dynamics of America's domestic gas market (downward pressure on wholesale gas prices) and global energy markets (US coal exports making gas-fired power stations the marginal fuel source for electricity generation in Europe).

2.3. Given the impact of shale production on the US domestic gas market, other countries, including those in Europe, have been investigating their indigenous shale gas sources. In the UK in 2010, a British Geological Survey/DECC Shale Gas report identified significant potential areas of shale gas reserves in northern England, including Widmerpool Gulf near Nottingham and a large area centred on the Elswick Gasfield, near Blackpool. The illustration below shows the potential shale formation across the UK.



2.4. However there are considerable uncertainties regarding the development of UK gas supply, these include:

- Further clarity on UK shale gas reserves
- Government policy and initiatives
- Test drill results
- Environmental and planning consents
- Structure of UK gas market
- Production economics
- Supply chain logistics, for example availability of drilling rigs.

2.5. If UK produced shale gas can be developed economically then it is recognised that the shale gas reserves could provide a material contribution to the UK gas supply mix in the future.

2.6. When considering shale gas from a networks perspective, it is important to note that existing network arrangements for gas entry to the National Transmission System (NTS) and Distribution Network (DN) will apply to shale gas, as they do for all gas sources. Therefore, shale gas injected into the network must meet UK thermal energy regulations and gas quality criteria.

2.7. The application of the current regulations and requirements to new sources of gas will continue to be reviewed, and updated where possible. For example, a class exemption for oxygen content has recently been issued by the Health and Safety Executive.

2.8. Fundamentally shale gas should be considered as being no different to other gas produced; hence developers need to follow the existing arrangements for gas entry that apply to all gas sources.

2.9. As such National Grid believes that network entry to the NTS and DN (subject to meeting existing arrangements) should not be seen as a barrier for UK shale gas development.

2.10. If shale gas becomes a significant contributor to UK gas supplies, this would represent an important development that we would need to take account of in relation to future network investment - potentially in relation to both the NTS and DNs, therefore it will be important that developers provide us with a clear understanding of the scale, timing and locations of potential shale gas developments.

3. Questions posed by this Inquiry

3.1. **How much scope is there for shale gas and oil to be used in the UK? Over what timeframe?**

3.2. The exact volume of shale reserves within the UK is subject to a considerable amount of uncertainty. A recently published report[144] from the British Geological Survey (BGS) in association with DECC, stated shale gas reserves in central Britain[145] of 1,329 trillion cubic feet (tcf), equivalent to over 37,000 bcm. It is anticipated that only a modest proportion of these reserves may be extracted, ranging from 10% to 30%. At a conservative recovery rate of 10% and annual UK gas consumption rates of about 80 bcm, this could provide 46 years of gas supply. However, none of this has yet been developed so there is no UK based evidence on which to draw.

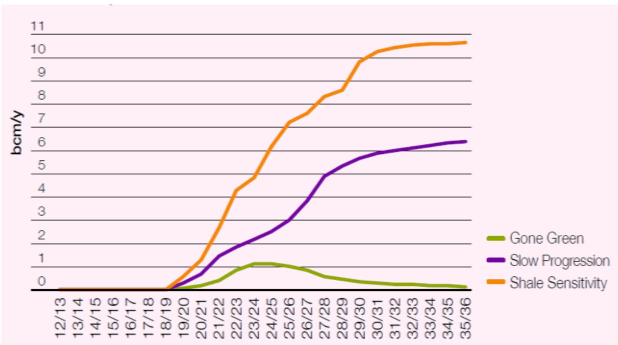
3.3. In our FES Slow Progression scenario we assume that wells will be drilled in line with the public projections of shale developers. We then assume that production from each well will be similar to the average performance from wells in the US, the only market where significant development has taken place. In this scenario production rises to around 6 bcm/yr by 2035, around 15% of total gas demand. In the Gone Green scenario there is less demand for gas so there is less incentive to develop shale gas. In this scenario the total production from shale peaks at around 1 bcm in the mid 2020s but declines to zero by 2035.

3.4. It is recognised that the development of shale gas reserves could provide a material contribution to the UK gas supply in the future, and as such as part of FES we have

144 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/209021/BGS_DECC_BowlandShaleGasReport_MAIN_REPORT.pdf

145 An area between Wrexham and Blackpool in the west, and Nottingham and Scarborough in the east.

considered a specific sensitivity case study for shale gas alongside core scenarios. We have developed high shale sensitivity in which more wells are drilled and in which the rate of production from each well is in line with the best seen case from US operations, rather than the average. In this sensitivity shale production rises to around 11 bcm/yr by 2035. It must be stressed that due to the uncertainty of shale developments, even this sensitivity may not capture the full development potential. Our scenarios do not include any assumptions about shale oil production.



3.5. **What forms of electricity generation is shale gas likely to displace and by how much?**

3.6. The effect that shale gas will have on the UK gas price is not clear, but at the volume included in our scenarios, where even in the high shale sensitivity, shale makes up around 15% of the total, the price is unlikely to be depressed to the same extent as has been seen in the US.

3.7. At this level of production it is more likely that the gas price will be strongly influenced by the price of gas on the European market and by the price of LNG on the world market. Currently the relative prices of coal and gas mean that coal fired generation earns a much better return than gas fired generation, so that gas is now the marginal fuel for generation. In the short term there would need to be a 50% fall in the price of gas or the international coal price to double before gas became the favoured fuel for generation. In our scenarios with common fuel prices, gas remains more expensive than coal as far as 2035. In the Gone Green scenario the Carbon Price Floor, introduced in April 2013, shifts the balance back towards gas from coal, but by the time there is a significant volume of shale gas available it is likely that most of the coal fired generating capacity will have closed under the Industrial Emissions Directive (IED). Shale gas is therefore unlikely to displace coal fired generation.

3.8. As part of the Electricity Market Reform (EMR) low carbon generation will be supported by contracts for differences. It is therefore not clear to what extent cheaper shale gas could displace low carbon generation.

3.9. **Will shale gas and oil increase UK energy security?**

3.10. Gas produced in the UK can increase security of supply, hence if UK produced shale gas can be developed economically then it is recognised that the development of shale gas reserves could provide a contribution to the UK gas supply mix in the future. However, as detailed previously, there is considerable uncertainty as to how much shale will be developed in the UK.

3.11. **What lessons can be learnt from the US experience of shale gas and oil?**

3.12. Anecdotal evidence from the venture capital and cleantech communities in the US who we work with closely suggests that the emergence of shale gas has had a negative impact on cleantech investments. Business cases for new and emerging clean technologies are based on the high cost of traditional fossil fuels. As this falls, the business case for cleantech erodes and they find difficulty in attracting investors. As the corollary to high and uncertain gas prices driving investment in alternative fuels and solutions, it appears low and sustained gas prices have the opposite effect.

3.13. A number of venture capitalists, in the US, seem to shifting their investment trends towards smaller more distributed technologies and looking for oil and gas technologies to replace traditional renewable technology investments. They believe the risk associated with large scale renewable technologies and projects is too great against the backdrop of a shale gas dominated energy future, in the US.

3.14. Shale gas and low carbon generation can co-exist providing there is certainty in policy around overall carbon emission targets and that the majority of fossil fuel generation has carbon capture and storage.

1 October 2013

The Petroleum Exploration Society of Great Britain (PESGB) and Geological Society of London (GSL)—Written evidence

Submission to be found under The Geological Society of London (GSL) and the Petroleum Exploration Society of Great Britain (PESGB)—Written evidence

Policy Exchange—Written evidence

Introduction

1. Policy Exchange is one of the UK's leading think tanks. We are an educational charity whose mission is to develop and promote new policy ideas that will deliver better public services, a stronger society and a more dynamic economy.
2. Our vision is for climate and environment policies that are sustainable - achieving society's environmental goals at least economic and social cost. Scientific evidence shows the natural environment is under considerable pressure from human development. This poses risks to both the variety of nature and human prosperity. Environmental challenges need to be tackled while minimising adverse impacts on living standards. The social and economic needs of the present should be met without compromising the ability of future generations to meet their own needs. A pluralist approach usually provides the best way to achieve outcomes for society. Well-designed, regulated markets – with competing decision-makers given the freedom to innovate, respond to new information and fail – have been far more successful in achieving benefits for society than private or government monopoly decision-making.
3. In 2012, Policy Exchange published *Gas Works? Shale gas and its policy implications*. Much of the material in this submission is based on the findings of that report.[146]
4. Shale gas, and gas more generally, has the potential to serve as a transitional fuel while remaining consistent with required emissions reductions. However, commentators who argue with great certainty that shale gas is the answer to future energy needs fail to recognise uncertainty about the future and neglect the importance of developing zero carbon technologies to meet long term emissions reduction goals. But gas sector developments do present the prospect of gas becoming a cheaper than previously expected transition fuel to a low carbon future.

Specific questions

1. ***How much scope is there for shale gas and oil - from domestic and overseas sources – to be used in the UK? Over what timeframe?***

5. At present, the prospects for shale production in the UK remain unknown. The work carried out by the British Geological Survey and others has demonstrated that the resource in the ground is substantial. However, establishing the economic viability of those resources requires commercially-oriented exploratory drilling, which is only just getting started. It is simply too early to say whether the abundant resources can translate into ample production.
6. The industry has moved relatively slowly and painstakingly so far. While undoubtedly frustrating to those who advocate in favour of shale gas as a solution to UK energy policy challenges, and to the companies concerned in exploration, it may prove beneficial for the industry's development that it take these early stages with great caution. Problems or mistakes while the industry is still in its infancy can be amplified, and long-term prospects potentially jeopardised if public opinion is lost.
7. The UK gas market could also experience consequences of shale development in other places. The US shale glut has had a dramatic impact on the energy market – the USA has moved from being a major consumer of LNG to eliminating LNG imports. That this coincided with Japan's recovery from the 2011 tsunami and the Fukushima nuclear disaster

[146] Moore, Simon; *Gas Works?* Policy Exchange; 2012; http://www.policyexchange.org.uk/publications/category/item/gas-works-shale-gas-and-its-policy-implications?category_id=24

meant that the rapid increase in Japanese LNG demand could be handled by the market without too much disruption. As new sources of gas supply (including shale sources) reach the market, and as national markets become increasingly interconnected via LNG shipments, developments in other parts of the world have an increasing bearing on each other. While the cost of LNG shipping probably mitigates against the LNG market becoming as comprehensive as the oil market, it does mean that 'gas islands' are increasingly scarce. The UK market will be influenced more by changes to demand and supply patterns overseas.

8. The size of the global oil market, and of UK shale oil resources, means UK shale oil production is less likely to have a noticeable effect on prices overall. Nonetheless, if domestic production can be cost-competitive, it may help, to a small extent, to alleviate security of supply concerns, or provide spare capacity that can be produced in the event of an extended disruption to overseas supplies (such as a prolonged conflict in the Middle East).

2. ***How will the costs, including those on the environment, of accessing the UK's shale gas and oil deposits compare to those of other sources of energy?***

9. Without any indication of the cost of shale production in the UK, a definitive answer to this question is not possible (indeed, I would be suspicious of anyone claiming to know exactly how cheap or expensive UK shale production is going to be – they're usually trying to sell something).

10. Many of the local environmental problems cited with shale gas are perhaps better understood as problems with the featherweight regulation prevalent in parts of the US. Future production in Europe (and elsewhere) will be able to learn from the US, not just about best and safest production practices, but also about appropriate regulation. Industry could also do more: perception that the shale gas industry is a bad neighbour is likely to hinder its ability to secure drilling sites.

11. Concerns about risks from shale gas production in relation to water quality, seismic activity and water scarcity need to be taken seriously, but, on the basis of current evidence, do not justify imposing a moratorium on shale gas production. Government and the industry should focus on effective and more rigorous regulation than has been seen in parts of the US. Groundwater protections and waste treatment regulations are stronger in the UK. Likewise, requirements about chemical disclosure are much more forceful.

12. The costs of complying with such regulation should be a price worth paying for the industry, to protect investments in exploration and production, and something that the industry should actively seek where there are any gaps. Looking to the future, it is important that the UK maintains a strong and effective regulatory regime, which addresses any new issues that arise, and enables a safe shale production sector to develop.

3. ***What is the potential impact of shale gas and oil on the local economies in areas where development is possible?***

13. It is difficult to assess precisely the direct impact of shale gas and oil for local communities, which could range from extremely minimal to the more significant (particularly if the drilling takes place in small villages). However, it is important to stress that local communities should benefit more directly from new development, such as shale, in their area. This depends on the planning structure that is put in place. Currently, the UK has great difficulty in building any type of new infrastructure, be it new housing or new energy infrastructure. This is partly the result of restrictions on how we use different pieces of land. But it is also the result of our failure to properly incentivise communities that are affected by new development to accept it. Our current system provides 'community' benefits, but often fails to provide direct benefits to those who lose out economically through new development (perhaps through reduced house prices). We should be more comfortable with

incentivising people to welcome and encourage development near them. This is particularly the case for new energy development, such as shale or windfarms. The government has made some sensible steps in this area, but it remains limited.

4. ***What will be the impact of shale gas on the cost of electricity generated at gas-fired power plants and how will it compare to other forms of generation including coal, nuclear and renewable?***

14. At present, the gas generation (plus carbon price) is cheaper than any other major generation type except coal (again, plus carbon price). Despite sharply rising gas costs over recent years (at least in the European market), and falls in the costs of some renewable technologies, they have yet to reach the point where they can out-compete gas generation in an unsubsidised market. Nuclear, meanwhile, remains a mystery, as cost estimates cannot be deemed reliable until demonstrated by a real-world project –the ongoing uncertainty around the state of the Hinkley Point project does little to support the idea that nuclear offers a definitively cheap electricity source.

15. The impact of shale on this is, once again, uncertain. In the US, shale gas has had a drastic impact in reducing prices (cutting them from over US$10/tcf at their 2007 peak to around $4/tcf today), to the extent that much existing coal and some nuclear generators have been driven to closure. If the most optimistic appraisals of the UK potential were to come true, then a similar scenario could be seen in the UK. A more modest price impact would have a more modest impact on the fortunes of gas generators and their rivals. At this stage, it is impossible to judge the scale of the impact of shale on UK gas prices, and consequences for the generation market. The best approach would be to ensure that the generation market remains flexible enough to take advantage *if* shale reduces gas prices significantly (or, for that matter, if the costs of other technologies change). The Government's EMR programme, however, looks likely to have the opposite effect, making the market less flexible and more dependent on Government projections of future technology costs.

5. ***Will the UK electricity market be easily able to incorporate shale gas in future or will generators be locked into long-term contracts with other energy sources? Are there any other potential barriers to the use of shale gas in electricity generation?***

16. The Government's Electricity Market Reform programme has seriously undermined the ability of the UK electricity sector to adapt to changing circumstances in the future, including, for example, significant shale gas production. The sector will be much more reliant on central government decision making, about the size of the generation sector, the technologies that will operate in it and the prices different technologies (and even different power stations) will be able to earn. The Government will need to decide how many Contracts for Difference (CfDs) it is willing to offer to different low-carbon generation types. These decisions will affect how much of the market remains for conventional generation, including gas generation, which will also be supported in the capacity market simultaneously created under EMR. The complicated interaction of the different arms of EMR then combine with the price of carbon emerging from the ETS and the commodity prices of coal and gas as generators attempt to work out how much gas generation capacity to invest in, and how much of it to run. In the last couple of years, depressed prices for coal and carbon have combined to leave gas generation out of the money and often idle, while coal generators use up the hours they have remaining while profit margins are highest (before they have to close due to EU regulations).

17. The Government portrays its choice of CfDs as being a way of reducing risk, by reducing exposure to future high (and volatile) gas prices. But if gas prices fail to rise by as

much as the Government has anticipated, its preferred approach to Electricity Market Reform will impose very large additional policy costs on the public, on top of unnecessarily high carbon reduction policy costs already in place in the Renewable Energy Strategy. Using DECC's own figures, opting for CfDs exposes bill payers to potential policy costs more than £10bn higher, if gas prices are low, than a carbon pricing approach would if gas prices turned out instead to be high. As such, it represent a gamble on gas prices a decade and more from now - one being made with bill-payers' money.

18. The Government's preferred (CfD) approach also carries another important type of risk. The approach requires a central decision maker (government or a quasi-government agency) to take decisions on capacity levels, generation mix and prices paid, instead of the market. This substantially reduces the market's role in responding to price signals and new information as that emerges, including about fossil fuel prices, technology costs. Such new information should be feeding into market decision-making in a timely way, so that market players can begin to respond by altering investment and innovation plans and portfolios, and operation decisions. Instead, a central planner has less information and fewer incentives to make and adapt decisions in a way that minimises the costs of keeping the lights on and reducing carbon.

19. The Government's proposals for Electricity Market Reform based on Contracts for Difference are unsuited to a world of considerable uncertainty, in particular about future gas prices. They gamble with bill-payers money on a high gas price future and risk imposing a high policy cost on consumers if that does not materialise.

20. As long as the UK is part of the EU ETS, no unilateral action to drive faster UK electricity decarbonisation, including CfDs, will result in lower EU emissions than set by the ETS cap. All it can do is to alter how much of the burden for meeting that cap is borne within UK borders. Higher UK-only carbon prices and all other national emissions reduction policies in industrial sectors covered by the ETS, have zero impact on overall EU carbon emission up to 2020.

21. So, given the assumption that the ETS will continue and the desirability of a geographically broad carbon market, the right policy should be to focus on bolstering carbon pricing using the ETS mechanism. Focusing on a strengthened EU ETS would, if gas prices turn out to be cheaper than previously expected, allow gas generation to play a substantial role as a transition fuel, while ensuring required emissions reductions are achieved. Lower gas prices could feed through to lower energy costs. And lower energy costs enable more resources to be devoted to stimulating the low carbon innovation needed to achieve 2050 carbon targets.

6. ***What form of electricity generation is shale gas likely to displace and by how much?***

22. It is too early to say whether shale gas will have any material effect on UK electricity generation patterns. However, if we assume that UK shale can be produced cost-effectively, the answer to the question of how it should be used will depend on the state of energy policy. Ideally, a strong carbon cap or price would steer electricity production from using coal to gas. Similarly, a policy based on carbon pricing rather than target-based support for particular technologies would be unlikely to develop as much of expensive renewable technology options such as solar PV and offshore wind. With widespread low-cost gas availability, reliance on these cost-ineffective decarbonisation options could also be reduced or scrapped.

7. ***What impact will shale gas and oil have on household energy bills?***

23. As with most other questions, it is simply too early to be able to meaningfully quantify the impact shale gas will have on energy bills. All that we can say at this stage is that, if shale production can be achieved economically (a big if), it is displacing some more expensive source, (at the moment LNG imports are the most expensive marginal supply source). In other words, if it is more expensive than any other way of getting gas, then shale gas will not be produced. So, in that sense, shale gas production will lower prices, at least compared to what they would otherwise have been. However, the extent of the price reductions is unknown.

8. What effect will the use of shale gas and oil have on carbon emissions compared to other combinations of energy sources?

24. In our report *Gas Works?* we surveyed the range of research that had been carried out on emissions from shale gas compared with both 'conventional' gas production, and emissions from coal. The report concluded, that while fugitive emissions from shale gas production meant a very slight increase on 'conventional' gas production, claims that shale gas was 'worse than coal' (most prominently made in arguments by Cornell University researcher Robert Howarth) were not justified.[147] Further analysis, including the recent report by DECC Chief Scientific Advisor David MacKay supports our findings.[148]

25. The more important questions are whether shale gas (and increased use of gas more broadly) is compatible with climate change objectives, and how policy can best enable it to be. The best tool for achieving this is the EU's Emissions Trading System. A sufficiently tight cap on emissions (i.e. one that is in keeping with both UK and EU stated ambition for emissions reductions by 2050) is very likely to see gas generation displace coal generation in the short term. In the longer term, the ever-tightening cap would also provide a clear signal to investors in gas generation as to how long they can expect to operate before they too will need to close. A reformed ETS should provide the policy to ensure that gas functions as a transition fuel, by providing both the short-term signal needed to bring in into the mix, and the longer term signal that will eventually lead to it coming out again.

26. If gas prices reduce as a result of shale production, savings in energy costs from utilising gas generation could provide a large pot of resources that society can choose to deploy. Invested in effective innovation support – research, development and demonstration, and early stage deployment of a range of low carbon technologies with global potential. The climate impact could be far greater than spending the money mass deploying hugely expensive offshore wind, which seems unlikely to become a cost-competitive major global contributor to carbon reduction. Carbon emissions from electricity, under the EU ETS cap, would be the same under either approach.

9. Will shale gas and oil increase UK energy security?

27. Arguments about energy security – and security of gas supplies in particular – have tended to be overplayed in the UK policy context. Responding to the rapid decline in North Sea gas production (Figure 1), the liberalised gas market has delivered a 500% increase in import capacity over the past decade, all built privately.[149] Access to LNG imports gives the UK great diversity of supply sources (Table 1). In the event that one supplier proves to be unreliable, or is forced offline, many others can fill the gap.

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147 Moore, pp 39-44

148 MacKay, David and Stone, Timothy; *Potential greenhouse gas emissions associated with shale gas extraction and use*; DECC; 2013; https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/237330/MacKay_Stone_shale_study_report_09092013.pdf

149 HM Treasury; *Energy Market Assessment*; 2010; p. 12

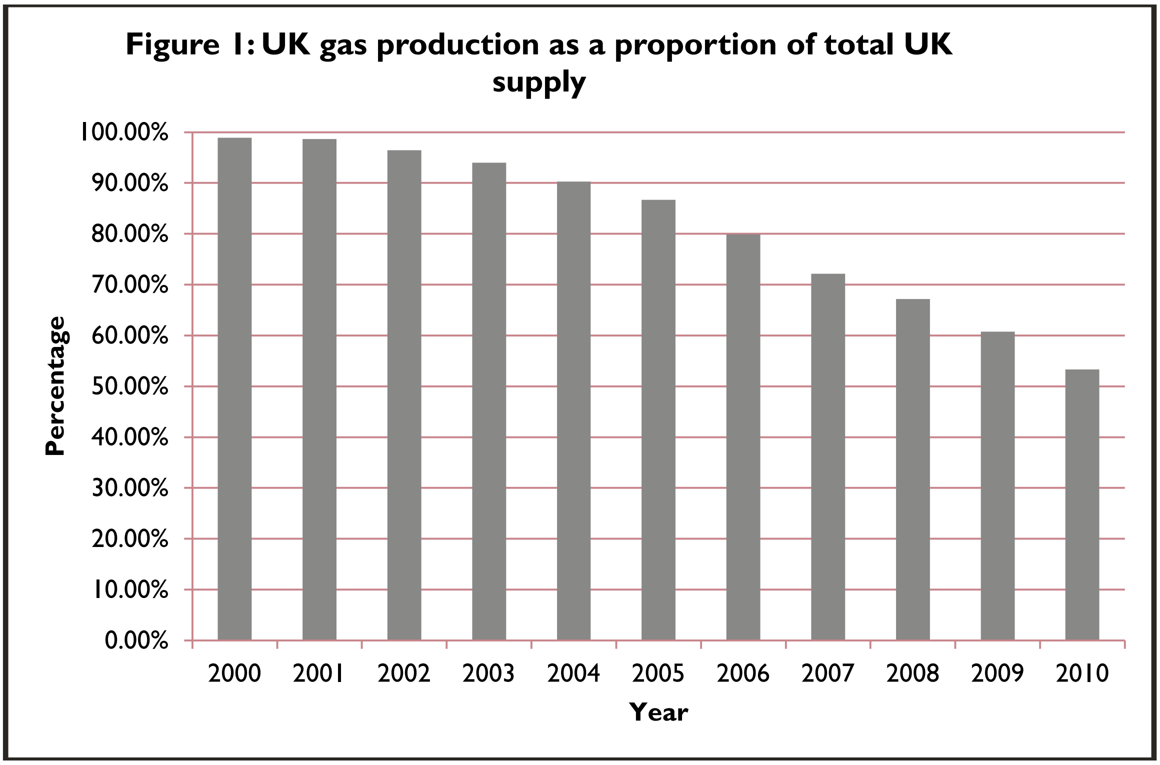
Figure 1: UK gas production as a proportion of total UK supply
Percentage
100.00%
90.00%
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Year

Table 1: UK gas sources in 2010[150]	
Country (LNG if specified)	**Volume (bcm)**
UK production	57.1
Norway	26.6
Qatar (LNG)	13.9
Netherlands	8.1
Trinidad and Tobago (LNG)	1.6
Belgium	1.3
Algeria (LNG)	1.3
Nigeria (LNG)	0.4
Yemen (LNG)	0.3
USA (LNG)	0.2
Egypt (LNG)	0.1
TOTAL	**110.7**
TOTAL MINUS EXPORTS	**95.1**

28. Concerns about the behaviour of Russia and some of its neighbours, while troublesome for some central and eastern European countries, with less access to alternative sources of supply, have little direct consequence for the UK. The UK is not a destination for Russian or Caspian volumes. The countries at the other end of our major gas pipelines – Norway and the Netherlands – are not prone to capricious interference with their energy exports.

29. Of course, the UK gas market is linked to other European markets and may thus to a degree be affected by those markets. The main effect to date has been for UK gas *exports* to Europe to rise in recent years, despite decreasing North Sea production. The UK has become Europe's 'Western Gas Corridor'. Domestic shale gas production (and deeper European integration of gas markets) would further solidify this position.

30. DECC, in its response to a 2011 House of Commons enquiry into shale gas, said it "does not believe that security of supply considerations will be the main driver of policy in relation to the exploitation of shale gas in the UK".[151] It would be reassuring if a similarly measured approach were taken in relation to wider political debate and energy policy formation.

10. What infrastructure investment will be necessary to cope with the development of shale gas and oil? How far will it help to ensure sufficient UK energy supplies? How will this investment be financed?

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150 BP; *Statistical Review of World Energy 2011*; London; 2011; pp. 22-28

151 Department for Energy and Climate Change; Shale Gas: Government Response to the Committee's Fifth Report of Session 2010-12; London; 2011; http://www.publications.parliament.uk/pa/cm201012/cmselect/cmenergy/1449/144904.htm

No response

11. What changes to public policies are necessary to maximise the potential of any shale gas development?

31. EMR presents significant barriers to shale gas development. By undermining the responsiveness of the market to changes in technology costs, it reduces the incentive to lower costs in several areas, including in gas prices. However, despite our reservations, it looks like EMR is going to be introduced. The next important step is to try and navigate a way back to a competitive, liberalised market as soon as possible. This is not straightforward, but is a necessity if the UK is not to lose the benefits that privatisation and liberalisation bought. The centrally-planned approach of EMR is also less likely to deliver the kind of cost-effective decarbonisation efforts that are imperative if we want other countries to follow the UK's example and reduce risks from increased carbon emissions.

32. There also needs to be an increasing focus on credible, consistent and long-term carbon pricing frameworks, which enable gas to play a positive role as a cheap, lower carbon transition fuel, but ensure that investors have clear signals about the long-term carbon reductions needed. Given that the UK and other member states are going to continue with the ETS, their focus should be on creating a longer term, more certain carbon cap. Creating effective banking and borrowing mechanisms should also have the effect of bringing permit prices up today – one of the objectives of those arguing for a tighter 2020 cap. There should at all times be clarity about the cap or price at least 15 years in advance. Work should begin immediately on establishing the Phase IV cap, with the intent to establish that cap through to at least 2035 at a level in accordance with scientific understanding about required emissions reductions. If, after Phase IV negotiations, it becomes clear that the political or market design challenges to the ETS have not been overcome, and the ETS, in the wider policy context, remains inadequate to the task of providing a long-term, credible carbon pricing framework, then the arguments for shifting to an EU-wide carbon tax are likely to become stronger. Either way, the key is to have a credible long term pricing framework.

12. Will shale gas and oil lead the UK to be less dependent on energy from less reliable regions of the world such as the Middle East and Russia?

33. The simple answer is, yes, if the UK were to produce shale gas or oil in any quantities they would almost certainly displace imports, some of which may come from "less reliable" countries. However, the more complex answer is, yes but it doesn't matter much.

34. The amount of gas the UK presently imports from Russia is negligible. Russian gas supply interruptions can have knock-on effects for the UK market, as supplies to Central Europe from the East tighten, exports from the UK to the Continent can rise, with some consequence for price. However, as the UK still has decent amounts of domestic (conventional) production, access to reliable pipeline supplies from Norway and the Netherlands, and copious LNG import capacity, it is very well-placed to withstand supply interruptions even in the absence of shale production. A hypothetical low-probability high-impact disruption that shut off access to a key LNG exporter (Qatar being the most obvious example) would have consequences for global LNG prices, which would certainly rise. Again, with its diverse range of sources, the UK would be comparatively well-placed to withstand such an event (although costs would rise in the UK as well as for other LNG importers). While gas use in the electricity sector may be able to be substituted by other generation technologies, industrial and heating uses are less easily switched at short notice. The best protection against such a possibility would be ensuring the widest possible range of gas supply is available to the world market, which may be achieved through overseas shale

production as well as expanding LNG liquefaction facilities. Increased domestic production (conventional or unconventional) would help, but this should not be the main driver behind shale policy.

13. What lessons can be learnt from the US experience of shale gas and oil?

35. There are many lessons to be learnt from US experience, both positive and negative. They include:

- In the right circumstances, shale gas can help reduce greenhouse gas emissions while simultaneously lowering energy costs. In this sense, it is a hugely beneficial technological breakthrough and one that should be welcomed.
- Regulation matters. Much of the regulation of shale gas in the US occurs at the state level, meaning there can be significant variations in environmental compliance. Ensuring that environmental protections are rigorous and that well engineering is state-of-the-art is important, both for the environment and for public confidence in the industry.
- Public relations matter. Especially early on in an industry's development, small problems can take on outsize significance. As an example, unwillingness to disclose the composition of fracking fluids (for commercial reasons) gave the impression of an industry with something to hide, which has only belatedly been recognised and only partially been addressed. While UK operators have been more open, the damage done by US practices has not been fully repaired.

Policy Exchange Environment & Energy Unit

What we stand for

Scientific evidence shows the natural environment is under considerable pressure from human development. This poses risks to both the variety of nature and human prosperity.

Environmental challenges need to be tackled while minimising adverse impacts on living standards. The social and economic needs of the present should be met without compromising the ability of future generations to meet their own needs.

A pluralist approach usually provides the best way to achieve outcomes for society. Well-designed, regulated markets – with competing decision-makers given the freedom to innovate, respond to new information and fail – have been far more successful in achieving benefits for society than private or government monopoly decision-making.

Tackling environmental problems can strengthen local communities. Civil society has a rich history of protecting and improving the natural environment. This sense of stewardship should be harnessed to both tackle environmental problems and strengthen community ties.

About Policy Exchange

Policy Exchange is the UK's leading think tank. We are an educational charity whose mission is to develop and promote new policy ideas that will deliver better public services, a stronger society and a more dynamic economy. Registered charity no: 1096300.

Policy Exchange is committed to an evidence-based approach to policy development. We work in partnership with academics and other experts and commission major studies involving thorough empirical research of alternative policy outcomes. We believe that the policy experience of other countries offers important lessons for government in the UK. We also believe that government has much to learn from business and the voluntary sector.

Policy Exchange—Written evidence

27 September 2013

Viscount (Matt) Ridley, British Scientist and Journalist—Written evidence

1. My name is Matt Ridley. I am a writer who has covered science, energy and climate issues for more than 25 years for The Economist, the Telegraph, The Times and the Wall Street Journal. My interest in shale gas was first sparked in 2010 as I began to read about its effect on coal use in the United States. As somebody with an indirect interest in coal mining in Northumberland, I decided to look into the issue in greater depth. In early 2011 while in the US, I travelled to Pennsylvania to research a column for the Wall Street Journal and a report for the Global Warming Policy Foundation (for which I refused payment) about the potential of shale gas and its environmental costs. This was the beginning of my interest in shale gas. See http://www.thegwpf.org/images/stories/gwpf-reports/Shale-Gas_4_May_11.pdf
2. I quickly concluded that shale gas represented a greater threat to the coal industry worldwide than any renewable energy technology. Although it was against my interests, I wrote that shale gas promised three benefits to humankind: lower energy prices, lower carbon emissions and an end to the threat of peak gas. All this at an environmental cost far lower than either coal or renewable energy. I wrote that "a surge in gas production and use may prove to be both the cheapest and most effective way to hasten the decarbonisation of the world economy, given the cost and land requirements of most renewables."
3. The opposition to shale gas, I concluded after looking into the evidence, was based almost entirely on myth making, driven by special interests including conventional gas producers, coal producers, renewable-energy champions and environmental organisations with an eye to publicity and fund raising.
4. Throughout 2011 and even 2012 it was hard to interest British newspaper editors in articles about the technology. This changed in 2013.
5. The shale gas revolution has demolished the widespread belief that supplies of natural gas were about to run out. This belief has a long history. In 1922 President Warren Harding's US Coal Commission, after interviewing 500 experts over 11 months, stated: "Already the output of [natural] gas has begun to wane. Production of oil cannot long maintain its present rate." In 1956, M. King Hubbert predicted that gas production in the United States would peak at about 14 trillion cubic feet per year sometime around 1970. In 2002, an Exxon executive pointed out that US gas discoveries had peaked before 1980. All of these predictions proved greatly misleading. Yet energy policies in the UK are still assuming a rising gas price caused by increasing scarcity.
6. That most natural gas originates in shales – formed on the beds of stagnant seas, then compressed and heated – is not news. "Conventional" natural gas reservoirs were created when this gas seeped into porous rocks. Until the late 1990s, however, it had not seemed possible to make shales sufficiently porous, even by fracturing, to extract gas from them. This changed with the development of slick-water fracturing combined with horizontal drilling, developed by Pinnacle Technologies for Mitchell Energy in the Barnett shale. Within five years the Barnett shale, in and around the city of Forth Worth, was producing half as much gas as the whole of Britain consumes. And the Barnett proved to be a baby compared with other shales. In 2004, the first results from the Marcellus shale in Pennsylvania caused a sensation with realization that the field was possibly as big as those in Qatar.

7. The cost of drilling for shale gas and the recovery rates have both improved steadily in the past 20 years. The time taken to drill and fracture a well is now about one-third of what it was initially. The yield from a typical shale gas well has been climbing steadily. Britain therefore has the opportunity to learn from all the pioneering development that has occurred in America.
8. The impact of shale gas on the American economy is immense. It is estimated that residential, commercial, industrial and electricity-generating customers of natural gas have saved $250 billion over just three years as a result of lower gas prices. By cutting the cost of gas far below the cost in Europe or Asia, the shale gas revolution has dramatically increased investment in chemical plants, manufacturing plants and all energy dependent sectors. No reputable economist denies that shale gas is a major factor in these trends. See more at: http://mjperry.blogspot.co.uk/2012/05/shale-gas-boom-slashes-co2-emissions.html#sthash.2ZTyIvLx.dpuf
9. It has been argued that shale gas would not have a similar effect on gas prices in Europe, because there is a single European gas market linked by pipelines. This makes little sense, because the US also has an integrated gas market with pipelines. One paper argued that the benefits of UK shale gas would be shared across Europe and the Bowland shale would only shift Europea's gas prices downwards (or prevent them rising) by 4%. But 4% savings for 150 million households for people is £7.5 billion per year. And in practice, as in the US, proximity to the source of shale gas will mean much greater gains for British consumers from British gas. Indeed, manufacturers and chemical firms have tended to cluster round shale gas centres in the United States. See http://www.adamsmith.org/blog/energy-environment/about-the-effect-of-the-uks-shale-gas-on-prices
10. Shale gas replacing coal as a fuel in electricity generation is the chief reason for the steep fall in America's carbon dioxide emissions over recent years. Energy related carbon dioxide emissions in the United States have now fallen back to levels last seen in 1994, and per capita emissions to levels last seen in the early 1960s. This is probably the fastest fall in emissions in any part of the world. See http://www.aei-ideas.org/2013/04/energy-fact-of-the-day-us-co2-emissions-per-capita-in-2012-were-the-lowest-since-1964-main-reason-shale-gas/
11. Gas is also starting to replace oil as a transport fuel in buses and trucks. United Parcels Service and other truck fleets are converting to gas, and gas consumption for transport has trebled in a decade in the United States. Gas-fuelled trucks are cheaper to run, produce less pollution and have a smaller carbon footprint. This trend is likely to continue. http://www.nytimes.com/2013/04/23/business/energy-environment/natural-gas-use-in-long-haul-trucks-expected-to-rise.html?pagewanted=all&_r=1&
12. Gas prices nowadays behave quite differently from oil prices. Because gas is costly to transport by sea, America's shale gas revolution is a threat to the British economy. America's gas prices, which used to be similar to ours, are now consistently one-third to a quarter of ours; oil prices, by contrast, are similar in the two countries. America's shale-oil revolution is less of a threat to us because of the global oil price. That is to say, we can sit back and gather the benefits of others exploiting shale oil, but if we try to do so for gas, we will destroy jobs in this country. Developing domestic shale gas is vital if other countries are developing theirs. The shale gas revolution is therefore either a boon to our economic competitiveness if we join in, or a threat to it if we do not.
13. Based on the British Geological Survey's estimates, Britain's shale gas reserves are immense, even compared with those of Pennsylvania. The Bowland shale is similar in

organic content and physical properties to the Marcellus shale but much thicker, perhaps five times as thick in many places. This implies that more gas can be produced from fewer well pads because of the possibility of horizontal drilling at several depths.

14. Shale gas production is proving to be safe and clean in the United States. All of the environmental objections are proving to be either mythical or greatly exaggerated. In evaluating claims, it is necessary to remember that the renewable energy industry, the Russian gas industry and the fund-raising arms of the environmental movement all have strong incentives to exaggerate in this area.
15. Tens of thousands of shale gas wells have been drilled and two million fracking operations completed, yet there has been not a single proven case of groundwater contamination as a result of hydraulic fracturing. (Failure of well casings may have contaminated water in some cases, as with conventional gas production.) Case after case has been alleged and found to be untrue. The Environmental Protection Agency closed its investigation at Dimock, in Pennsylvania, concluding there was no evidence of contamination; abandoned its claim that drilling in Parker County, Texas, had caused methane gas to come out of people's taps; and withdrew its allegations of water contamination at Pavilion in Wyoming for lack of evidence. Two recent peer-reviewed studies concluded that groundwater contamination from fracking is "not physically plausible." The movie Gasland showed a case of entirely natural gas contamination of water and the director knew it. Ernest Moniz, the US Energy Secretary, said earlier this year: "I still have not seen any evidence of fracking per se contaminating groundwater." http://www.propublica.org/article/epas-abandoned-wyoming-fracking-study-one-retreat-of-many http://thehill.com/blogs/e2-wire/e2-wire/315009-energy-secretary-natural-gas-helps-battle-climate-change-for-now
16. The claim that shale gas production results in more methane release to the atmosphere and hence could be as bad for climate change as coal is also false. Study after study has refuted it. As a team from Massachusetts Institute of Technology put it: "It is incorrect to suggest that shale gas-related hydraulic fracturing has substantially altered the overall [greenhouse gas] intensity of natural gas production." http://iopscience.iop.org/1748-9326/7/4/044030/pdf/1748-9326_7_4_044030.pdf. And a 2013 study by the University of Texas found that leakage was just 0.42 percent of all produced gas.
17. The claim that fracking uses too much water is highly misleading. In the United States as a whole 0.3% of water use is for hydraulic fracturing -- less than is used by golf courses. Farming is by far the biggest user. http://theenergycollective.com/jessejenkins/205481/friday-energy-facts-how-much-water-does-fracking-shale-gas-consume
18. The use of chemicals in "fracking fluid" is also greatly exaggerated. Fracking fluid is 99.51% water and sand. In the remaining 0.49% there are just over ten chemicals, all of which are highly diluted and can be found in higher concentrations in your kitchen, garage or bathroom: citric acid (lemon juice), hydrochloric acid (swimming pools), glutaraldehyde (disinfectant), guar (ice cream), dimethylformamide (plastics), isopropanol (deodorant), borate (hand soap); ammonium persulphate (hair dye); potassium chloride (intravenous drips), sodium carbonate (detergent), ethylene glycol (de-icer), ammonium bisulphite (cosmetics), petroleum distillate (cosmetics). http://www.redriversecurities.com/fracingchemicals.htm
19. As for earthquakes, Durham University's definitive survey of all induced earthquakes over many decades concluded that "almost all of the resultant seismic activity [from fracking] was on such a small scale that only geoscientists would be able to detect it"

and that mining, geothermal activity or reservoir water storage causes more and bigger tremors.

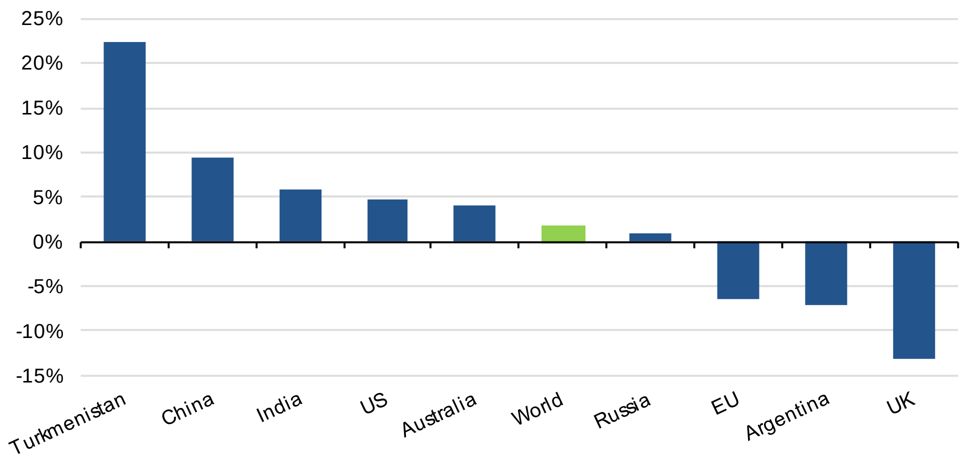
20. In conclusion, the shale gas revolution offers a huge opportunity to the British economy and its hard pressed energy consumers if we choose to exploit it, but if we decide not to exploit it, a major competitive threat. Precautionary resistance to new technologies has proved a big mistake in the UK in recent years. For example, it has prevented Britain leading the genetic modification of crops, in which it was once a pioneer, with the result that yields are almost certainly lower, pesticide use is higher and the environmental impact of agriculture is worse than it would otherwise have been. This illustrates the flaw in the precautionary principle: that it weighs the costs but not the benefits of innovation. For the sake of Britain's pensioners, employers and working people, it is vital that we at least try to find out if the Bowland shale can lower gas prices, lower carbon dioxide emissions, and create jobs.

22 September 2013

Société Générale—Written evidence

The option to develop shale in the UK comes at a time of falling hydrocarbon production, increasing imports and reduced oil & gas tax revenues for HM Treasury

2002-2012 CAGR of gas proven reserves in selected countries

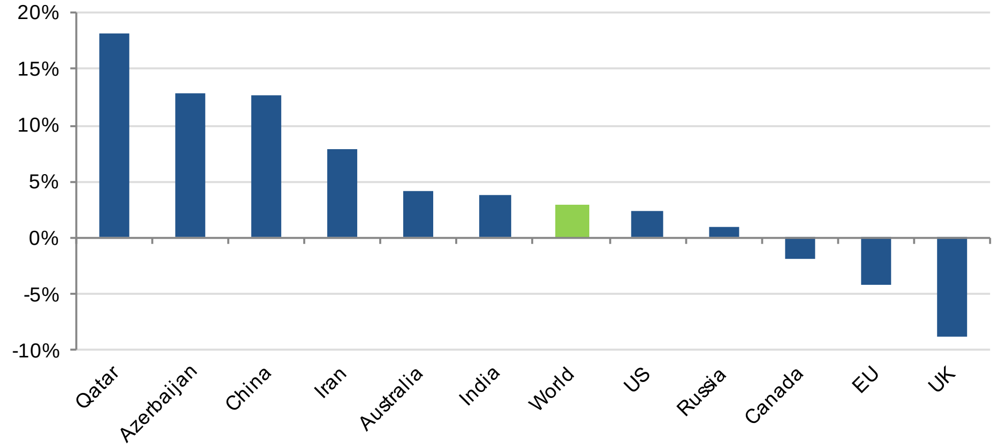


Source: BP Statistical Review

US growth, more than twice the world average, comes from the unconventional gas resources that have now been deemed recoverable thanks to innovative technologies. This high growth has allowed the US to overtake Saudi Arabia as the fifth-largest reserves holder in the world. Turkmenistan's huge growth comes from an area in the country that wasn't explored much under the Soviet regime and that is estimated to hold the world's second-biggest gas reservoir. Albeit from a very low level, China's high gas reserves growth is laying a solid foundation for the further expansion of its domestic production. Australia's growth is recent (2008) and comes from the huge capex private companies are dedicating to new LNG projects. The EU (and particularly the UK with -13.1% CAGR) saw its gas proven reserves reduce over 2002-2012 as it was producing more gas than it was finding reserves. The world record for the largest decline in gas proven reserves is held by the UK, beating even Argentina, where the government decided in 2012 to nationalise the local oil company (YPF).

For the top-four reserve holders (Iran, Russia, Qatar and Turkmenistan), the reserves-to-production ratio (R/P) is over 55 years. Then comes the US where the R/P is 'only' 12 years. This is because, in the US, private companies are geared towards monetising resources rapidly; hence, there is less time between booking and production than anywhere else. This doesn't mean that in 13 years the US won't have any more gas reserves because by then some resources should have been booked into reserves thanks to companies' capex programmes. For the EU, the R/P is 12 years but, if the EU continues to fail to replace its gas production, this could mean that in 13 years' time, EU domestic production could be insignificant.

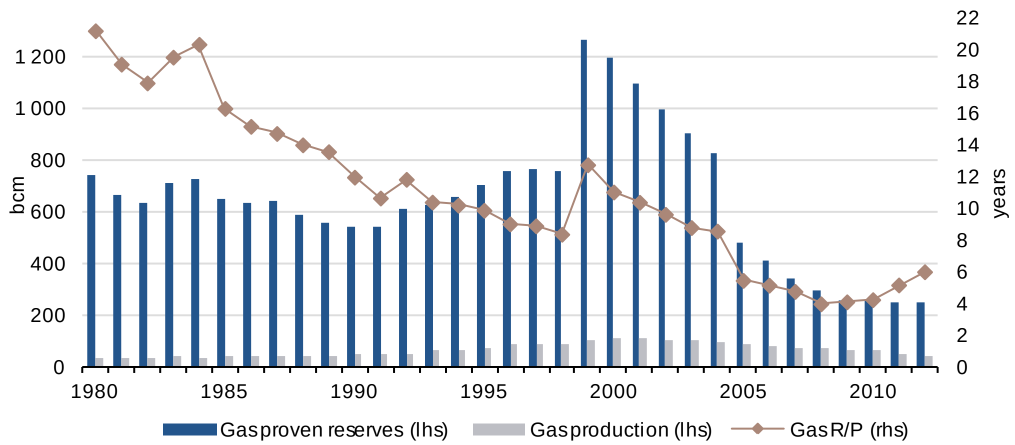
2001-2011 CAGR of gas production in selected countries



Source: BP Statistical Review

For the UK, the R/P gas ratio is just six years. This ratio has been growing in the last five years thanks solely to the fast decline in gas production as the proven reserves have gone down steadily.

UK gas proven reserves (R) & gas production (P)



Source: BP Statistical Review

Between 2002 and 2012, the CAGR for UK gas production was -8.9% with record drops witnessed in 2011 (-20.3%) and 2012 (-14.1%). With a further fall of 15.4% in Q1 13 vs Q1 12, we expect UK gas production to continue to decline in the years to come, even if new conventional fields are anticipated to come onstream thanks to record offshore capex spending.

North America to become the third-largest LNG exporter thanks to shale gas

Between 2005 and 2012, US gas production increased by 30% thanks to shale gas, which today represents more than 40% of total domestic production. To access new markets to balance this supply (and to benefit from low US gas prices), many companies want to build liquefaction facilities to export Liquefied Natural Gas (LNG). However, a wide range of authorisations are needed before a liquefaction facility can be built in the US, including:

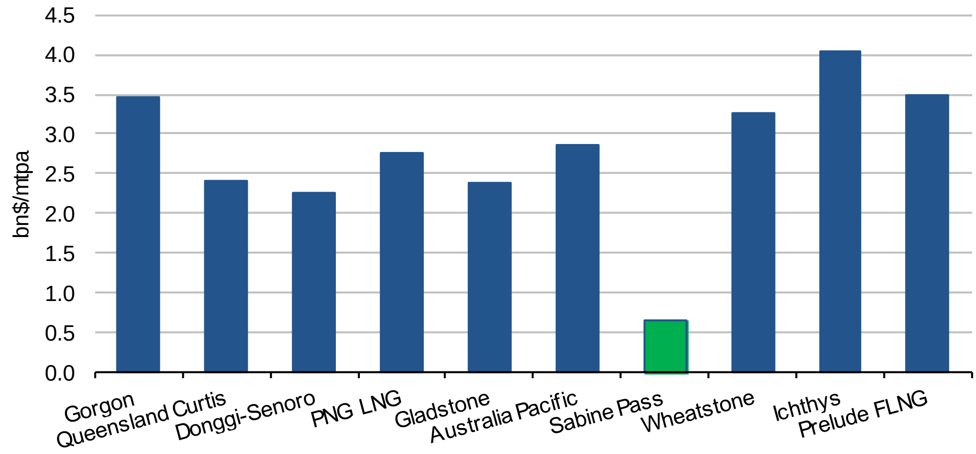
- An important one granted by the US Department of Energy (DoE) to allow exports, as all nation states have permanent sovereignty over their natural resources. The US DoE can grant authorisation either to countries with which the US has a free trade agreement (FTA countries are Australia, Bahrain, Canada, Chile, Colombia, Costa Rica, Dominican Republic, El Salvador, Guatemala, Honduras, Israel, Jordan, Mexico, Morocco, Nicaragua, Oman, Panama, Peru, Singapore and South Korea) or to all countries with which trade is not prohibited by US law.

- One granted by the US Federal Energy Regulatory Commission (FERC) to site, construct and operate facilities for the liquefaction and export of domestically-produced natural gas. This process takes more than a year and costs tens of millions of dollars.

Cheniere was the first company, in May 2011, to be granted all export authorisations. It has managed to sell 16 mtpa (22 bcm/y) of LNG under a US spot-linked (Henry Hub) formula (LNG delivered Free On Board: 115% HH + fixed fee). The 115% HH covers the gas sourcing (100% at the hub), the cost of fuel gas needed for the process (10%) and additional costs of transportation to the liquefaction terminal (5%). The fixed fee is for the remuneration of the liquefaction plant, which will therefore operate as a tolling plant. As Cheniere took a Final Investment Decision in July 2012 on Sabine Pass Phase 1 (and in May 2013 on Sabine Pass Phase 2), LNG should be in production in the US as early as 2016e.

In August 2013, the US DoE authorised Lake Charles to export US LNG to non-FTA countries from its terminal in Louisiana at a rate of 15 mtpa (20 bcm/y). The US DoE granted a further authorisation, in May 2013, to Freeport in Texas at a rate of 9 mtpa (12 bcm/y). Lake Charles and Freeport are still waiting for the FERC authorisation. Several other projects with a total capacity of around 200 mtpa (270 bcm/y) have filed applications seeking export authorisation. So our estimate of 50 mtpa (67 bcm/y) in exports in 2020e from North America (US and Canada) is now very likely to materialise.

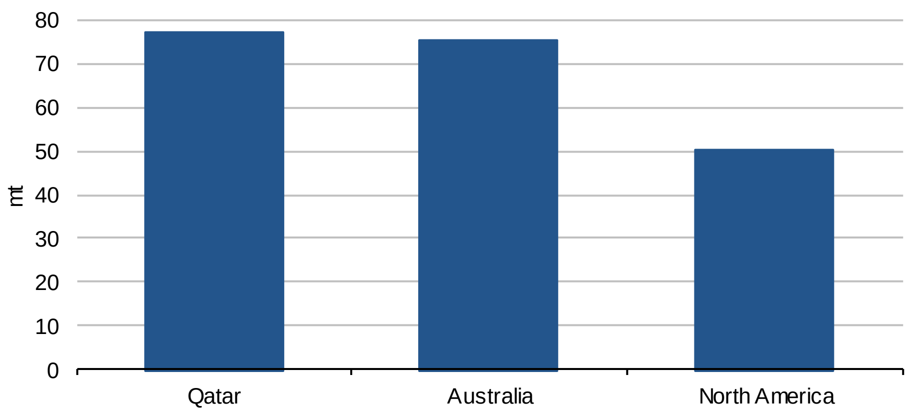
Disclosed capex of sanctioned LNG projects



Source: SG Cross Asset Research, companies data

Thanks to unconventional gas, Australia is set to become the next growth area for LNG from 2015e. Its current 24 mtpa (33 bcm/y) capacity is set to grow, as 53 mtpa (71 bcm/y) capacity is already under construction. But Ichthys could be the last greenfield LNG project sanctioned in Australia because, with rampant cost inflation and faced with an increasingly price-sensitive customer base, these large-scale, expensive projects simply look cumbersome and out-dated in the context of intensifying global competition. As a result, Australian projects are being priced out of the market by US ones that are much cheaper as: 1/ the upstream, transportation and LNG infrastructure (jetty, tanks) are already there; and 2/ the cost of labour is lower than in Australia.

2020e LNG production: three largest producers



Source: T. Bros, After the US shale gas revolution

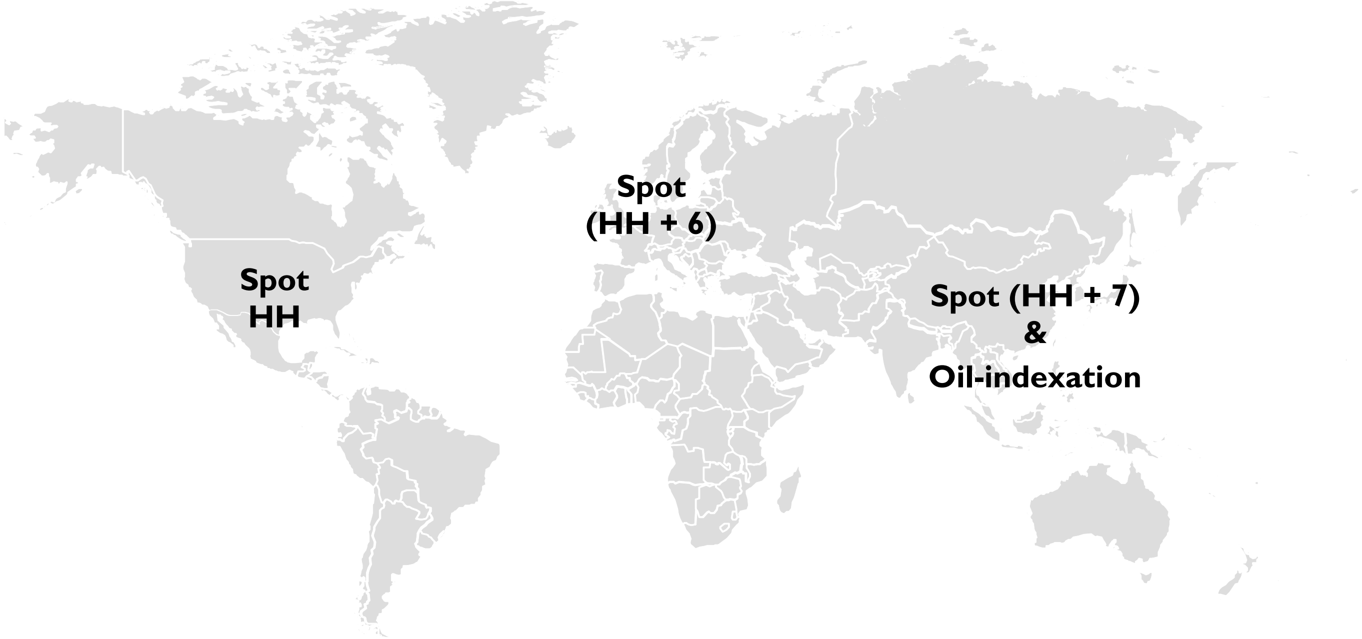
Markets could be linked via the cost of LNG arbitrage

By directly sourcing US LNG priced under an HH formula, Asian customers are cutting out the middle man, the LNG aggregator. And, if the US becomes a major LNG producer as we believe, then this change in business model could start to reduce oil indexation in Asia, as we are seeing in Europe.

If we assume no other country can replicate, before 2020e, the US's success, the US could remain the cheapest gas market at least for the rest of the decade; other markets will be linked via the cost of arbitrage (liquefaction, transport and regasification). For a unified global gas market to be achieved, all countries will need to follow the US path by producing their own domestic shale gas, something that looks improbable before 2020e.

In 2012, the difference between US and European gas saw Europe paying $130bn (or 0.8% of GDP) more for its gas than it would have if it had paid US prices. This spread is there to stay for this decade as Europe will not be able to produce shale in any significant quantities before 2020. The low level of European shale production should therefore have only a limited impact on European prices (be it wholesale or at the residential level).

Overview of gas prices in 2020e (with estimated spreads in $/MBtu)



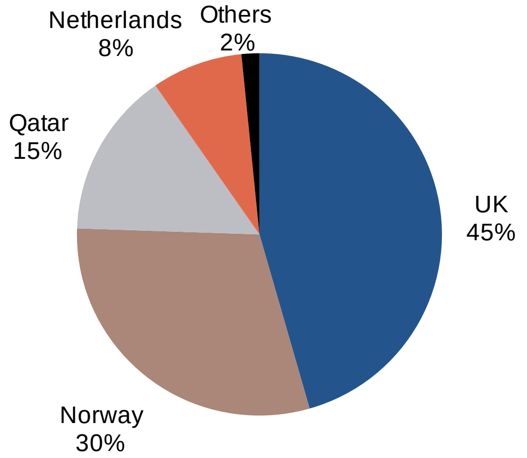
Source: T. Bros, After the US shale gas revolution

UK: a leader for shale gas in Europe

Like any human activity, shale needs a 'social licence' to operate and the industry should be aware that its least successful player, in the eyes of the general public, defines the industry as a whole. The way the industry operates in the first countries to allow fracking will have a major impact on further shale oil & gas production throughout Europe. A tightly regulated production process, with a systematic programme for the disclosure of chemicals used in unconventional gas production, could help the industry to expand in Europe. The International Association of Oil and Gas Producers launched in June 2013 www.ngsfacts.org to provide information concerning hydraulic fracturing of natural gas from shale wells and other issues, including voluntary disclosure of chemical additives on a well-by-well basis in the European Economic Area. This site includes wells which have been hydraulically fractured since January 2011 by participating operators (six wells in Poland so far). This is in line with the wider US www.fracfocus.org initiative. A comprehensive disclosure programme allows citizens and communities to consider the technology. Only this can lead to informed discussion about environmental protection and risk management, and the potential benefits of shale development in Europe. Any environmental issue would have a dramatic effect on shale production throughout Europe. Thanks to its long history of conventional exploration and production, the UK has well-established rules on the environmental issues that could help local acceptance.

Tighter environmental standards will mean that this business will not be as profitable as conventional gas production in major resource-holder countries, but the risks (financial, security, etc.) are much lower in Europe than in other gas-producing countries. The UK industry is a pragmatic price taker, which means that it will proceed with shale gas production only if it perceives it could be profitable. The above map shows that if the full cost to produce 'green' shale gas in the UK is less than HH +6 $/MBtu then it should go ahead as it will be profitable for private companies to extract it. As in hydrocarbon production, taxes are very high, therefore the tax regime will have an impact on the level of investment (and hence the production). It is too early to estimate the amount of UK shale production but it is possible that the UK will produce some as soon as 2020e.

Split of 2012 UK gas supply

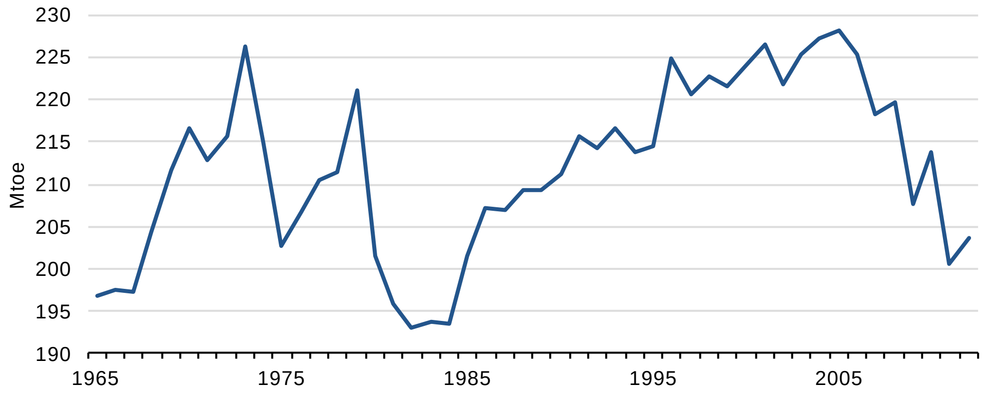


Source: BP Statistical Review

Until the shale gas revolution, net importers were fated to become more and more energy dependent. The shale gas revolution changed this dependency paradigm forever and is offering an alternative. The US has chosen to reduce its dependency on foreign oil & gas. China will try to use it to mitigate its growing gas dependency. The UK (like Poland) could use it to mitigate its growing dependency on importation of gas, leading it to displace Qatari LNG, whereas Poland could displace Russian pipe gas, which is viewed by the Poles as not fully reliable. In the UK, shale gas could lead to a useful diversification of supply which would boost energy security and have a positive impact on jobs and the trade imbalance.

If this is done successfully in the UK, other European states that actually ban this technology could follow with production after 2020e (to curb their own deficits). With shale gas development in its early stages in Europe, the resource is unlikely to play more than a marginal role in helping to meet Europe's energy requirements in the next decade. European shale gas production could also be the only answer to the ill-functioning EU gas market in which four foreign national oil companies (Gazprom from Russia, Statoil from Norway, QP from Qatar and Sonatrach from Algeria) control c.50% of supply, allowing the wholesale price to be way above the marginal cost of production. And when market participants view material shale gas production in Europe as possible (meaning around 25 bcm or 10% of domestic supply or 5% of demand), the price curve could move down to reflect this new world.

UK primary energy consumption



Source: BP Statistical Review

UK primary energy consumption peaked in 2005. Since then, consumption has declined by 1.6% pa. Such a peak in primary energy consumption is also visible for the US (2007), Japan (2006) and the OECD countries as a whole (2007) as well as for Russia (1989). Poor economic growth, high fuel prices and greater energy efficiency should continue to cap UK primary energy consumption. This tends to show that, like other OECD countries, the UK has entered a new world where energy efficiency has kicked in. The question now is no longer how much consumption of each energy fuel is going to grow, but which one is not going to decline for the foreseeable future. In this context, the inter-fuels competition that currently favours renewable (on the policy side) will exacerbate the decline of other types of fuel. So this 'new' gas will displace imported gas first and could be used in power generation but also in transport (either via LNG, CNG or electric vehicles powered by gas-fired power stations). It could also lower wholesale gas prices thanks to increased competition. UK/European shale oil if produced could, after 2025e, mitigate a growing dependency on the less reliable Middle East.

9 September 2013

Professor Paul Stevens—Written evidence

Professor Paul Stevens Distinguished Fellow, Chatham House; Emeritus Professor, University of Dundee; Visiting Professor, University College London (Australia)

INTRODUCTION

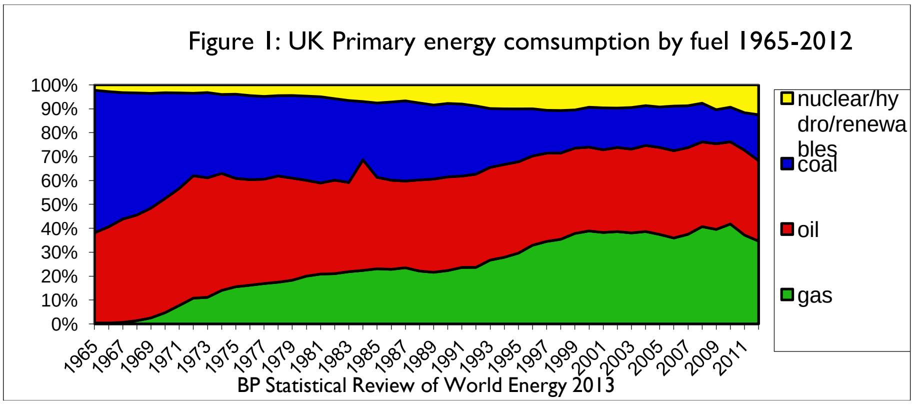
1. The call for evidence lists 13 questions that are to be addressed. This paper addresses a number of them listed below. While the inquiry includes shale oil, this paper concentrates only on gas. For further details, there are two reports by this author already published by Chatham House that may be of interest. These are

Paul Stevens The "Shale Gas Revolution" Hype and Reality. A Chatham House Report. Chatham House, London. 2010.

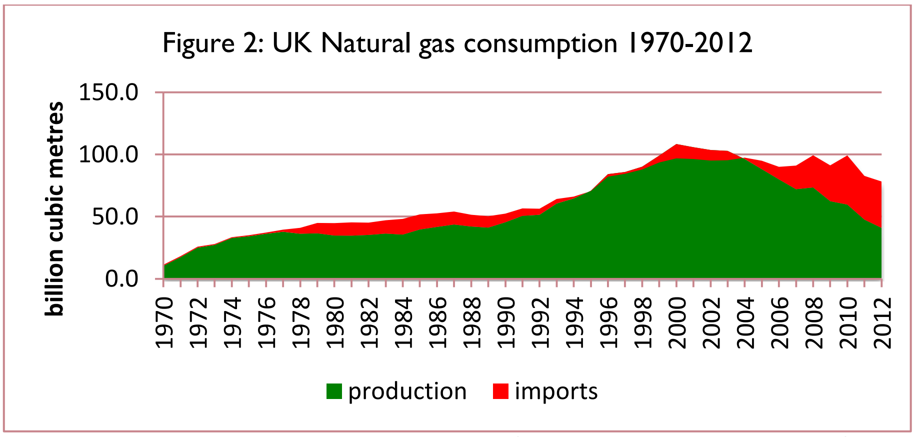
Paul Stevens The 'Shale Gas Revolution': Developments and Changes. Briefing Paper, Chatham House, London. August 2012

WHAT IS THE SCOPE FOR SHALE GAS TO BE USED IN THE UK?

2. As Figure 1 shows, the consumption of natural gas in the UK has doubled since 1990.



However, as can be seen from Figure 2, domestic production of conventional gas has declined leading to a significant increase in gas imports. Of these imports, in 2012 5 percent came from net pipeline imports from Europe and 95 percent from Liquefied Natural Gas (LNG) largely from Qatar.



In such a context there is a clear potential market for natural gas produced from shale operations.

WHAT ARE THE COSTS OF ACCESSING SHALE GAS COMPARED TO OTHER ENERGY?

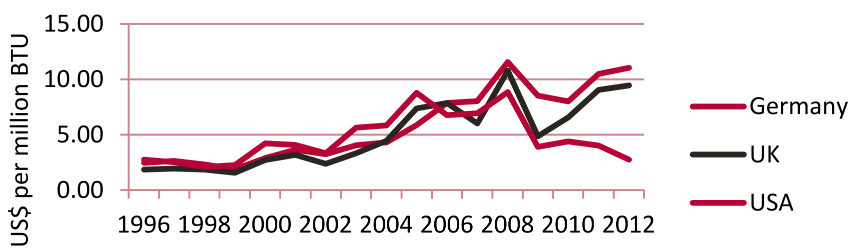
3. There are considerable uncertainties over the cost of producing shale gas in the UK. Hard information is very difficult to find. The two key determinants of production costs are the geology of the shale plays and the state of the service industry to undertake the horizontal drilling and the hydraulic fracturing. Currently knowledge of the geology of shale plays in the UK is in its infancy. Furthermore shale gas operations are notoriously differentiated. Not only are shale plays very different, so too are wells on the same play. Also costs change as the shale gas operations move down the learning curve. This uncertainty is compounded because of uncertainty over the externalities of environmental damage that may be associated with shale gas operations. This should be accounted for in the "cost". While all the evidence suggests that hydraulic fracturing is environmentally safe if well regulated and done properly, little is yet know about the level of fugitive methane emissions. This represents a potentially significant addition to greenhouse gas emissions. However, in the absence of data it is impossible to value this in order to internalize the costs.

4. The state of the service industry in the UK to undertake onshore shale operations is very weak with few drilling rigs and even fewer units that can hydraulically fracture. In the US Barnett shale play at the height of the operations in 2008, 199 rigs were drilling while in 2010 there were only 34 rigs in all of Western Europe. Estimates in Poland, where the service industry is in a similar state to the UK, suggest a shale well costs three times more than in the U.S. The relative costs of energy alternatives are equally uncertain. The future of the nuclear industry in the UK is uncertain and the future of LNG markets is very controversial, because of the fall-out from the shale gas revolution in the US and its potential replication elsewhere.

WHAT MIGHT BE THE IMPACT OF SHALE GAS ON THE UK GAS PRICE?

5. Views on the impact on gas prices have been strongly influenced by the U.S. experience. seen in Figure 3. The dramatic fall in domestic prices since 2008 has given a major boost to U.S. manufacturing industry, especially petro-chemicals. It is clearly the prospects of replicating this experience in the UK that has made the Treasury such a fan of UK shale gas.

Figure 3: Natural Gas Prices 1996-2012



BP Statistical Review of World Energy 2013

6. However, such optimism is seriously misplaced. The UK is physically linked into the Continental European gas market via the Bacton Interconnector. If UK prices fall, once the gap with higher European prices is large enough, gas begins to flow to the higher price market pushing up UK prices. This type of arbitrage can be observed in Figure 3. In the case of the U.S. there is no market for lower priced gas so the price stays low. This could change if the U.S. begins to export substantial quantities of LNG. Equally, the large gas suppliers in

the UK are very unlikely to leave any money on the table for consumers. The idea that a shale gas revolution in the UK would lead to significantly lower gas prices is a myth.

WHAT MIGHT BE THE IMPACT OF SHALE GAS ON CARBON EMISSIONS?

7. Methane is a far more potent greenhouse gas than Co2 – something like 70 times more potent over a twenty years period. Therefore if fugitive emissions from shale operations are high, this could impact climate change policies. Producing shale gas, because it is more energy intensive, will produce more Co2 than conventional gas but studies by the Tyndall Centre at the University of Manchester suggest the extra is insignificant at only 4 percent more. The key issue is what energy source might be replaced by shale gas. If coal or oil is replaced, given methane emits less Co2 than either - roughly half the emissions of coal for the same energy content - obviously this would reduce the UK's carbon footprint. This has already been seen in the U.S. where shale gas is pushing out coal from power although it is the replaced coal is being exported to and burnt in Europe. However, there is a serious danger that UK consumers, growing increasingly concerned about their domestic energy bills, may press for shale gas to substitute for renewables which they see (probably incorrectly) as being responsible for these higher energy bills. This would be bad news for carbon reduction targets if it impacted the drive for renewables. Ultimately, methane produced by shale gas operation is a hydrocarbon and while it emits less than coal or oil, it still emits Co2.

WHAT MIGHT BE THE IMPACT OF SHALE GAS ON ENERGY SECURITY?

8. Clearly this depends upon the amount of shale gas produced and over what period. There are two ways in which energy security –defined as physical access to energy sources – can, at least in theory, be enhanced by shale. First it represents a diversification of gas supplies away from offshore UK production and imports of gas by pipeline or LNG. Furthermore, the potential of significant shale gas supplies can enhance the bargaining power of the UK when negotiating for long-term gas supply contracts. In economics, the theory of contestable markets suggests the threat of market entry is often sufficient to force monopoly suppliers to behave as though they were in a more competitive market. If the threat of significant supplies from shale is credible this could allow UK buyers to secure more favourable terms. Second, shale gas represents a domestic source of energy. It is always tempting to assume domestic supplies are more secure than foreign imports. This may not be the case as successive miners' strikes in the UK and threats of industrial action by French nuclear engineers suggest.

WHAT LESSONS CAN BE LEARNT FROM THE US EXPERIENCE WITH SHALE GAS?

9. The shale gas revolution of the U.S. happened because of a coincidence of characteristics that were present. The main ones are listed in Table 1

Table 1: Factors creating the 'shale gas revolution' in the United States

1. GEOLOGY	Compared to the UK?
1. Large shallow, material plays, implying large technically recoverable resources. Also much of the shale had low clay content, making it easier to fracture.	Reported to have a higher clay content
2. After many years of oil and gas drilling, there were plenty of drill core data publicly available to allow explorers to find the 'sweet spots' on the plays.	NO

3. The shale gas had a high liquids content, which greatly enhanced the economics of the operations, especially at a time when gas prices were low.	Not known at this stage
2. 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.	NO
3. REGULATION	
1. 2005 Energy Act explicitly excluded hydraulic fracturing from the Environmental Protection Agency's Clean Water Act – the so-called 'Cheney-Halliburton Loophole'. Much shale gas operations were done with little environmental impact assessments.	Strong environmental legislation
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. These economic incentives were very important in the early stages of the industry, based upon small, relatively cash strapped, entrepreneurial companies.	The UK government is claiming to introduce some tax break
3. Property rights in the United States make the shale gas the property of the landowner, creating a strong financial incentive for private owners to permit the disruptions associated with shale operations. Also, the population is used to being in proximity to oil and gas operations.	NO
4. The system is used to licensing large areas for exploration with fairly vague work programme commitments, which is what is needed when dealing with shale plays.	NO
4. THE NATURE OF THE GAS MARKET	
1. Pipeline access is based upon 'common carriage', so gas producers have at least some access to pipelines, transforming the economics of shale gas production. The U.S. also has a very large and extensive gas pipeline grid.	NO Access by Third Party Access.
2. The U.S. is a 'commodity supply gas market', i.e. a lot of buyers and sellers and good price transparency. Gas is easy to sell.	Not as easy as the US
3. The US domestic gas market experienced strong rising prices in the period after 2002, culminating in a price over $10 per thousand cubic feet (mcf) in May 2008.	See Figure 3
5. INDUSTRY	
1. The industry was dominated by small, entrepreneurial companies, the so-called 'momma and poppa' companies.	NO
2. The majority of the work was done by a dynamic, highly competitive service industry. At the height of the Barnet Play in 2008, 199 rigs were operating.	NO

10. A key point is that the American "revolution" in reality happened over a very long period of time – over 20 years - although it is only in the last five years or so that the share of shale gas in domestic production increased significantly. It also happened because of a unique coincidence of conditions that will be difficult to replicate in the UK.

WHAT CHANGES TO PUBLIC POLICY WILL BE NEEDED TO PROMOTE SHALE GAS IN THE UK?

11. Geology - Obviously, geology cannot be changed by policy but policy can certainly affect the commerciality of the geology. The first option is to improve the fiscal terms under which companies operate. This was important in the US story of shale gas in the early days with the tax breaks for unconventional operations in the 1980 Energy Act in place until 2002. More recently, the UK government has offered what it views as attractive fiscal incentives to shale gas operations in the hope of kick-starting the industry. The new proposed system acknowledges there is a slower cost of recovery for shale gas projects compared to conventional offshore developments, and that costs are often spread over a much wider area than a traditional oil or gas field. Whether this will provide a sufficient carrot, remains to be seen. Another obvious policy contribution for government to improve the commerciality would be to fund basic scientific research relating to shale gas operations making the results available to the industry. The sort of research envisaged is fundamental science that would not and should not be undertaken by private companies. Fundamental scientific research is a "public good". No private company would fund Isaac Newton to sit under his apple tree in order to "discover" gravity since it has no commercial value and once "discovered" cannot be patented to allow the funder to recover their financial outlay.

12. Shale gas service industry – The U.S. shale revolution benefitted from operators and service companies working together as an alliance, sharing infrastructure and vital technological enhancements. This decreased the cost of developments significantly. Pad drilling, improved fracking mechanisms and improved rig mobility are such technologies leading to increased efficiency and growth. Information sharing is key for new entrants to the market. For example, in the U.S., the Marcellus shale coalition with 300 partnering operators and service companies is such an alliance proven to increase the production exponentially within a shorter time span. It has also helped to push the industry up the technological learning curve at a faster rate. Currently only a handful of service companies are involved in the shale gas operations in the UK. This needs policies to get more service companies such as offering a more attractive tax regime by altering capital allowances and depreciation. It is worth pointing out that given the growing interest in shale gas in Europe more generally; the development of a UK shale gas service industry on any scale could be a major export earner.

13. Environmental Concerns - Community acceptance is vital to secure and maintain the shale gas operations. The shale operations have been widely criticized in environmental terms in the context of water pollution, greenhouse gas emissions, noise, dust and pollution. Therefore, it is important to ensure there is an effective credible regulatory framework to mitigate these concerns. While there are regulations covering oil and gas, they are not specific to shale operations. There needs to be a specific regulatory regime for shale gas operations. In particular attention needs to be paid to the quality of well completion and the treatment of waste fracking water. At the very, least such a regime, if strictly enforced, would do much to address the concerns of local communities proximate to the shale gas operations.

14. At the same time as developing a regulatory regime specifically for shale, there is a need for a credible public relations campaign. Most of the scientific evidence suggests that there does not need to be problems with fracking[152] but this is not sufficient to persuade many concerned locals. A policy of public disclosure of the chemicals used would help reduce public concerns. The implementation of such policies leading to increased transparency is key to engage with community concerns. It is also important to convey the message to communities about the economic prosperity that could flow from shale gas operations. Currently there are lots of negative messages about shale gas operations, which ignores the existing scientific evidence. The government could fund such advertising campaigns. However, messages funded by government may carry little credibility. Far more effective would be to mobilize the Universities and Research Institutes to promote such messages given the very large body of scientific evidence in existence that is not anti-fracking.

15. Policies leading to community development with increased local community participation in shale gas development process will help also to promote confidence in shale gas projects. Currently, unlike the U.S., landowners do not have the incentives of ownership of hydrocarbon resources to encourage them to facilitate surface access. Short of changing the underlying property rights along the lines used in the U.S. it would be possible to force companies to "compensate" local communities for the disruption from shale gas operations and also to make them feel as though they are sharing in the economic benefits of the project. A good example of such a mechanism is the Shetland Charitable Trust which covers crude oil landed at Sullom Voe in the Shetland Islands. The Government recently announced a compensation scheme specific to shale gas operations in an attempt to assuage local opposition. Under this scheme, local communities will receive £100,000 per well drilled (although some reports indicate this will be per well site) plus one percent of the revenues. How effective this may be remains to be seen.

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[152] For example see the special report by the Royal Society and the Royal Academy of Engineering in the UK Shale gas extraction in the UK: A review of hydraulic fracturing– published in June 2012.

Tyndall Manchester Climate Change Research—Written evidence

Submission to HoL Select Committee on Economic Affairs inquiry into: The Economic Impact on UK Energy Policy of Shale Gas and Oil

Tyndall Manchester has been investigating the climate change implications of shale gas developments for the past three years. We have raised concerns around the cumulative quantities of emissions that may be released by the extraction and combustion of shale gas and the implications for climate change mitigation of a widespread expansion of the industry in two reports. The most recent report (Broderick et al., 2011, attached) contains research of relevance to two specific questions raised by the committee, namely:

2) How will the costs, including those on the environment, of accessing the UK's shale gas and oil deposits compare to those of other sources of energy?
8) What effect will the use of shale gas and oil have on carbon emissions compared to other combinations of energy sources?

And in light of the answers to these and a supplementary report (Broderick and Anderson, 2012, attached) we provide additional insights into questions:

1) How much scope is there for shale gas and oil - from domestic and overseas sources - to be used in the UK? Over what timeframe?
13) What lessons can be learnt from the US experience of shale gas and oil?

All views contained within this submission and the reports attached are attributable to the authors and do not necessarily reflect those of other researchers from the wider Tyndall Centre, the University of Manchester or the organisations themselves.

1. This submission is a précis of the arguments and evidence presented in Broderick et al (2011) with additional material from a supplementary report (Broderick and Anderson, 2012) examining the impact of shale gas on US energy system emissions. For background on the emissions budget analysis, considering also the incompatibility of the UK's present commitments under the Climate Change Act (short-term carbon budgets and the 80% reduction pathway) with our explicit international commitment on 2°C, please see our recent submission to the HoC Environmental Audit Committee Inquiry into Progress on Carbon Budgets (Anderson et al 2013).

2. Our work on shale gas has concluded that novel sources of gas production (or indeed any new fossil fuel source) are problematic for climate change mitigation generally and more specifically are incompatible with the UK's explicit contribution to international commitments to stay below a 2°C rise. The recent global emissions trajectory is at the high end of IPCC emissions scenarios, and correlates with a 50:50 chance of 4°C rise by 2100. Such a rise would exceed any warming level thought to have occurred in the past 5 million years. It is clear that the production of fossil fuels of all sorts needs to be curtailed in the absence of strict and coordinated international greenhouse gas emissions caps.

3. If carbon and capture storage technologies are proven to work at scale and with high levels of capture (90% or higher), gas fired powerstations would be compatible with the UK's carbon budgets, but remain incompatible with the UK's 2°C international commitments, under the Copenhagen Accord and Cancun Agreements. *Understanding the quantitative scale of inconsistency between the UK's domestic and international*

commitments on climate change is pivotal to developing any informed conclusion on unconventional hydrocarbons. In many respects the response of the UK Government to the prospect of large scale indigenous shale gas production is a bellwether of the veracity or otherwise of the UK's commitments and leadership on climate change.

Regarding Q2) How will the costs, including those on the environment, of accessing the UK's shale gas and oil deposits compare to those of other sources of energy?

4. The Energy and Climate Change Committee (2011) has previously noted that a substantial move to exploit new shale gas reserves could attract investment that might otherwise go to renewable energy. The 2011 report states that *"…shale gas has the potential to shift the balance in the energy markets that the Department has tried to create away from low carbon electricity generation"*.

5. In our updated report (Broderick et al. 2011) we estimated the potential scale of such a diversion by assessing the capital costs of gas powerstations burning the output of a mature shale gas industry, which for illustrative purposes we take to be ~9bcm/year sustained over a 20 year time period. We refer the committee to Section 3.4 of Broderick et al. (2011) for full details and summarise the conclusions below.

6. In total, potential resource substitution was found to be £19bn to £31bn, depending upon the discount rate applied to future investment. The higher figure relates to a Treasury Green Book discount rate of 3.5%, arguably the most appropriate rate for assessing public policy.

7. Table 3.11, reproduced below, illustrates the scale of potential wind generating capacity foregone if capital is diverted to shale gas infrastructure. Given the need for climate mitigation, the costs of gas generating plants (CCGT) with carbon capture and storage (CCS) was also considered. CCS substantially increases capital costs and has an energy penalty in operation, in the order of 10% to 20%, hence 7GW capacity, rather than 8GW conventional CCGT, is assumed to be sustained with 9bcm/year shale gas. In the absence of large scale demonstration plants there are considerable uncertainties in the technology's cost and efficiency parameters. Nevertheless, even with the CCS gas fired powerstations are likely to have lifecycle emissions in region of 50 to 80gCO_2/kWh; approximately 5 to 10 times higher than either wind or nuclear.

Table 3.11: Investment equivalents in gas and renewable capacity				
	10% Discount rate		**3.5% Discount rate**	
	8GW CCGT	**7GW CCGT +CCS**	**8GW CCGT**	**7GW CCGT +CCS**
Onshore wind (GW)	12.5	16.5	16.8	20.8
Onshore wind (3MW turbines)	4,172	5,503	5,594	6,925
Offshore wind (GW)	7.0	9.2	9.4	11.6
Offshore wind (5MW turbines)	1,401	1,849	1,879	2,326

8. The potential scale of displacement is comparable to the 2020 ranges in UK Renewable Energy Road Map; 10-13 GW onshore wind and 11-18 GW offshore (potentially 40 GW).

9. If the cost of CCS is included and a 3.5% public discount rate used, then the equivalent 21 GW of onshore wind capacity could be constructed. This would be expected to generate up to 27% more electricity per annum considering representative capacity factors of 70% for gas and 30% for wind. Approximately 12GW of offshore turbine capacity, for the same investment, would be expected to generate 5% less electricity than the equivalent gas infrastructure. It is also worth noting that the larger generation of wind turbines (onshore and offshore) being installed and planned are likely to drive up the capacity factor of wind, potentially to around 40%.

10. So as not to renege on UK climate change commitments, it is imperative that investment is directed towards very low and zero carbon energy infrastructure. Construction without CCS would place much greater pressure on other parts of the economy to decarbonise and risk gas infrastructure worth £19 to £26bn becoming 'stranded assets'. However, as we describe below it cannot be assumed that CCS will provide sufficient levels of abatement for gas-fired electricity to continue to be a major energy source in the long term.

11. Our analysis considered only capital costs, not operating costs; a simplification that significantly favoured gas over wind as the latter has much lower operating costs as a percentage of total costs. The levelised cost estimates for gas CCGT (Parsons Brinkerhoff, 2011), with 10% discount rate, suggest that fuel costs account for 88% of the total cost per MWh of electricity. In contrast, the operating costs for wind generation make up only 6% of total costs (Arup 2011). Costs of transmission, distribution and balancing infrastructure for both gas and electricity were also excluded.

Regarding Q8) What effect will the use of shale gas and oil have on carbon emissions compared to other combinations of energy sources?

12. Much of the discussion on the climate change impact of shale gas centres on its relative emissions intensity compared with other fuel sources. This issue is of interest, and is described well in the DECC Chief Scientific Advisor's recent report on the matter

(MacKay & Stone, 2013), with an overview provided in paragraphs 13 and 14 below. However, it must not distract from the most climatically relevant issue of *absolute* quantities of emissions from the global energy system.

13. There are important concerns about the possibility of additional climate change impacts from gas produced by hydraulic fracturing; this remains a contentious topic in the academic literature. Life cycle analysis studies include inter alia emissions from energy required to produce and distribute the gas, for instance those embodied in water transported to the well pad, and releases of methane itself to the atmosphere both deliberately and inadvertently during the full fuel production, transmission and distribution cycle.

14. Methane itself is an important greenhouse gas, however, there is a shortage of independent primary research on the actual quantities of methane released during shale gas production and many studies use the same underlying empirical data that is recognised to be limited in scope and applicability. Our previous research provides a fuller discussion of this topic (Broderick et al. 2011, Section 3.2.4) as well as an estimate of the additional emissions due to hydraulic fracturing. A recent comparative statistical approach has concluded that it is difficult to distinguish between the life cycle emissions impact of different gas production and distribution methods and that greater attention should be paid to energy system impacts (Weber & Clavin 2012).

15. Regardless of the unavoidably contextual framing of life cycle GHG impact, either per unit of gas produced or per unit of electricity generated, the direct carbon content of shale gas means that its widespread use is incompatible with the UK's international climate change commitments.

Therefore, considering Q1) How much scope is there for shale gas and oil - from domestic and overseas sources - to be used in the UK? Over what timeframe?

16. The absolute necessity of decarbonisation means that technologies with orders of magnitude lower emissions are required to provide energy to UK households and industry in the short to medium term. The Committee on Climate Change (2008) has advised "that any path to an 80% reduction by 2050 requires that electricity generation is almost entirely decarbonised by 2030", although it is important to recall that challenging though this 80% pathway may be, it still falls far short of what is the UK's obligation under its international commitments, including the 2012 Camp David Declaration. Decarbonisation of the electrical supply is an effective way of rapidly reducing emissions. Renewable supply technologies, with very low associated emissions, are available now and are compatible with existing infrastructure. The efficiency of transport and heating can be improved through the deployment of new electric vehicle and heat pump technologies respectively.

17. Understanding timescales is pivotal from a cumulative emission (carbon budget) perspective. The CCC argues that the transition to a very low carbon grid, with an intensity of the order of 50g CO2/kWh, should take place by 2030. Scenarios described by the MARKAL economic optimisation model identify this point as being on the way to a zero carbon grid soon after. It is worth noting that the CCC acknowledges a low probability of keeping below 2°C of warming on the basis of their budgets, this is despite their assumption of unrealistically early global peaking dates (~2016).

18. Accounting for an emissions floor for food production and making fair (but still very challenging) allowance for emissions from non-Annex 1 nations, Anderson and Bows

(2011, C+6 scenario) find that complete decarbonisation of Annex 1 energy systems must be accomplished rapidly (i.e. within a decade) for even a 50% chance of avoiding 2°C of warming.

19. It is sometimes argued that shale gas could be burned safely in the short term, however this is not the case for any 2°C framing of climate change. Given that shale gas is yet to be exploited commercially outside the US, limitations on the availability of equipment mean that it is very unlikely it could provide other than a marginal contribution to UK supply before 2020. However, gas fired power stations produce emissions of approximately 440gCO2e/kWh of electricity and typically have a lifespan of over 25 years. Therefore, unless allied with carbon capture and storage (CCS) technologies, as yet unproven at a large scale, all new powerstations intended to burn shale gas would need to cease generating within five to fifteen years of construction, and at the latest be decommissioned by 2030. Green Alliance scenarios (2011) indicate that if there is a second "dash for gas", emissions from the grid could still be 302gCO2e/kWh in 2030 necessitating 95% deployment of CCS to meet our fourth period emissions budgets (2023-2027). In this respect, the "golden age" may turn out to be a gilded cage, locking the UK into a high carbon future

20. Even CCS is problematic when such low carbon electricity is required. At commercial scale CCS will be significantly less than 100% effective at capturing carbon dioxide. Moreover, it will always add costs to electricity production by reducing the efficiency of the power station requiring additional energy input in transportation and injection of the captured carbon dioxide. Best case emissions performance for gas CCS is in the range 35-75gCO2/kWh (80-90% capture efficiency on 55% efficient CCGT with 10% energy penalty for capture).

21. CCS therefore also increases the net quantity of upstream emissions of gas or coal production and transport; reduced efficiency means that greater quantities of fuel must be used for equal electricity output, increasing life-cycle emissions over and above those from the fuel combustion. For unconventional gas production these have the potential to be significant if mitigation is not in place; Broderick et al (2011) estimate up to an additional 17gCO2e/MJ of gas produced, equivalent to an additional 120gCO2e per kWh of electricity generated depending upon mitigation during production.

22. With regards to using shale gas for heating purposes, the CCC (2008) note that as the grid decarbonises it is "more carbon efficient to provide hot water and space heating with electricity than with gas burned in a condensing boiler". Non-energy uses accounted for less than 1% of total UK demand for natural gas in 2010 (DUKES 2010). It is therefore reasonable to assume that new gas production in the UK will be combusted in power generation and, in the absence of carbon capture and storage, released to the atmosphere.

Finally, regarding Q13) What lessons can be learnt from the US experience of shale gas and oil?

23. Shale gas has the potential to contribute substantial additional emissions to the atmosphere. Global estimates of reserves suggest this may be up to 30% of a global emissions budget with a 50% chance of avoiding dangerous climate change (Broderick et al. 2011, Section 3.3.2).

24. Substitution between fuel sources cannot necessarily be assumed to reduce emissions in absolute terms. We have examined the CO2 emissions consequences of fuel switching

in the US power sector using two simple methodologies (Broderick and Anderson, 2012). The analysis presented is conditional upon its internal assumptions, but provides an indication of the scale of potential impacts. It suggests that emissions avoided at a national scale due to fuel switching in the power sector may be up to half of the total reduction in US energy system CO2 emissions of 8.6% since their peak in 2005. Since 2007, the production of shale gas in large volumes has substantially reduced the wholesale price of natural gas in the US. The suppression of gas prices through shale gas availability is a plausible causative mechanism for at least part of this reduction in emissions. Although we were not able to isolate the proportion of fuel switching due to this effect, other studies note that between 35% and 50% of the difference between peak and present power sector emissions may be due to shale gas price effects. Substantial increases in renewable generation and capacity appear to have had an effect of similar magnitude through policy and cost competitiveness. Air quality regulations, energy efficiency and demand management, and the impact of the recession are cited to have played a considerable part in driving this change.

25. It is essential to note that there has also been a substantial increase in coal exports from the US over this same time period. Much of this coal has been burned in the UK and Europe, increasing our annual emissions. Without a meaningful cap on global carbon emissions, the exploitation of shale gas reserves is likely to increase total emissions. For this not to be the case, consumption of displaced fuels must be reduced globally and remain suppressed indefinitely, in effect *displaced coal must stay in the ground*.

26. Our calculations suggest that more than half of the potential emissions avoided in the US power sector may actually have been exported as coal. Summing the quantity of implicit emissions exported over the period 2008 to 2011 suggests that approximately 340 MtCO2 of the 650 MtCO2 of potential emissions avoided may be added elsewhere. The continued oversupply of permits in the EU ETS means that this is likely even of exports to the UK and Europe.

27. Discussing the cumulative impact of emissions from shale gas, MacKay and Stone conclude in their report for DECC (2013) that *"…without global climate policies (of the sort already advocated by the UK) new fossil fuel exploitation is likely to lead to an increase in cumulative GHG emissions and the risk of climate change."* Even in the International Energy Agency 450 Scenario, based on a 50% chance of exceeding 2°C, more than two thirds of already proven fossil fuel reserves are not commercially exploited (IEA 2013). It is clear that the production of fossil fuels of all sorts, not only shale gas, needs to be curtailed in the absence of robust and coordinated international GHG emissions caps.

References

AEA (2012) *Climate impact of potential shale gas production in the EU.* Reference number: CLIMA.C.1./ETU/2011/0039r.

Anderson, K. & A. Bows (2011). "Beyond 'dangerous' climate change: emission scenarios for a new world." *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* 369(1934): 20-44.

Anderson, K. et al (2013) Submission to HoC EAC Inquiry: Progress on carbon budgets, Tyndall Centre for Climate Change Research

Arup (2011) *Review of the generation costs and deployment potential of renewable electricity technologies in the UK*, Study Report REP001, Department of Energy and Climate Change, London

Broderick, J. et al. (2011) *Shale gas: an updated assessment of environmental and climate change impacts.* A report commissioned by the Co-operative and undertaken by researchers at the Tyndall Centre, University of Manchester.
Broderick, J. & Anderson, K. (2012) *Has US Shale Gas Reduced CO_2 Emissions?,* A report commissioned by the Co-operative and undertaken by researchers at the Tyndall Centre, University of Manchester.
Committee on Climate Change (2008) *Building a Low-Carbon Economy - the UK's Contribution to Tackling Climate Change*, The Stationery Office, London.
Green Alliance (2011) *Avoiding gas lock-in: Why a second dash for gas is not in the UK's interest*, Available at http://www.green-alliance.org.uk/grea_p.aspx?id=5857
International Energy Agency (2013) *Redrawing the Energy-Climate Map,* World Energy Outlook Special Report, IEA Paris.
MacKay & Stone (2013) *Potential Greenhouse Gas Emissions Associated with Shale Gas Extraction and Use,* Department of Energy and Climate Change, London
Parsons Brinkerhoff (2011) *Electricity Generation Cost Model - 2011 Update Revision 1*, Department of Energy and Climate Change, London
Weber, C.L. & Clavin, C. (2012) *Life Cycle Carbon Footprint of Shale Gas: Review of Evidence and Implications.* Environmental Science & Technology, 46(11), pp.5688–5695

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UK Energy Research Centre (UKERC)—Written evidence

UK Energy Research Centre

The UK Energy Research Centre carries out world-class research into sustainable future energy systems.

It is the hub of UK energy research and the gateway between the UK and the international energy research communities. Our interdisciplinary, whole systems research informs UK policy development and research strategy.

www.ukerc.ac.uk

Introduction

This response is largely based on research carried out within the UKERC project: *The Geopolitical Economy of Global Gas Security and Governance: Implications for the UK.* It also draws on UKERC's energy system modeling research which has explored the changes that are necessary to meet the UK's climate change targets. Below we have provided a question-by-question response to the Call for Evidence made by the Select Committee on Economic Affairs.

Responses to the Committee's questions

1. **How much scope is there for shale gas and oil - from domestic and overseas sources - to be used in the UK and over what timeframe?**

The current unconventional oil and gas revolution originated in North America, but its effects have been felt in the UK. We can think of this first phase as one of 'indirect impact' and it relates to shale gas, rather than shale oil. Less than 10 years ago the US was expecting to become a major importer of natural gas and was building a large number of terminals to received liquefied natural gas (LNG). However, the rapid ramp up of domestic shale gas production in the US reduced the need to import LNG and many of those terminals are now sitting idle. A number of LNG projects - particularly in Qatar - were built in anticipation of there being a growing LNG market in this US. This did not materialise, instead some European gas-importing countries (more precisely private companies invested in this capacity) seized the opportunity to expand their LNG import capacity and were able to attract this displaced LNG. This was certainly the case in the UK where new LNG terminals opened, first at the Isle of Grain in 2005 and then at Milford Haven in 2009 (Dragon LNG and South Hook).

In a short period of time, the UK has become one of the largest LNG importing countries in the world. This is, in part, an indirect consequence of the growth of shale gas production in the US. More recently our LNG deliveries have fallen, partly because of economic recession, but also because more LNG has been attracted to Asian markets since 2011. The increase in LNG demand in Asia is due to both the Fukushima accident (immediately after which gas traders brought up a lot of LNG, anticipating increased Japanese demand, but this did not happen straight away and a lot of LNG was dumped on European markets) and growing gas demand in Asia. At the same time, as shale gas has displaced coal in the US power generation sector, cheap US coal has come to the UK and Europe and this has displaced higher-priced gas. UK coal imports increased by 37.7% between 2011 and 2012, and imports from the US increased by 65.4%. Consequently total UK gas demand fell by 6% in 2012.

The next phase could be that of direct impacts, first from the imports of shale-gas based LNG from the US and then, potentially, from domestic shale gas production. At present, the US gas market is over-supplied and prices are low. The gas industry wishes to export gas as LNG to increase revenues and sustain domestic production. Just as there was a long list of LNG reception terminals being built in the US in the past, now there is an equally long list of over 20 LNG export terminals seeking approval from the US Government.[153] At present, four terminals have been given federal approval. To date, Asian buyers have shown the greatest interest in importing US LNG, but some of it could come to the UK. For example, last March, Centrica signed an agreement with Cherniere Energy Partners PLC to import 1.75 mtpa of LNG for 20 years from 2018. However, there is no guarantee that Centrica would ship its LNG to the UK.

The second stage of direct impacts could involve domestic shale gas production in the UK. As will become clear below, at present we have no way of knowing whether or when that might happen and what the potential volume of production might be. All of the best estimates suggest that it won't be until the early 2020s at the very earliest. National Grid's latest *UK Future Energy Scenarios* include a modest contribution from onshore UK gas production from zero today to 2-4% of demand by 2020. This share rises to 15-20% by 2035[154]. While there is considerable uncertainty about what the future level of UK gas demand will be, we do know that production from the UK continental shelf (UKCS) is likely to continue to decline (from a peak of 108bcm in 2000 to a projected level of 19bcm by 2030); thus, our level of import dependency is likely to increase (DECC suggest 70% import dependency by 2025). In sum, the most immediate possibility for shale gas to be used in the UK is as imported US LNG.

2. How will the costs, including those on the environment, of accessing the UK's shale gas and oil deposits compare to those of other sources of energy?

In a recent speech at the Royal Society, the Secretary of State Ed Davey emphasised the uncertainties associated with shale gas in the UK: "Nobody can say, for sure, how much onshore UK shale gas resource exists. Or how much of it can be commercially extracted."[155] It is impossible to know what the costs will be and how much of the 'gas in place' in the UK that was identified by the British Geological Survey[156] will turn into 'proven' reserves. Proven reserves are defined as "those quantities that geological and engineering information indicates with reasonable certainty can be recovered in the future from known reserves under existing economic and operating costs"[157]. Those costs will include the cost of obtaining a 'social licence to operate' that is the environmental, social and economic costs associated with exploration and development. Until developers have carried out a meaningful exploration programme and have a good idea of operating costs in the UK we

153 The US Department of Energy's Federal Energy Regulatory Commission (FERC) complete list of projects: www.ferc.gov/industries/gas/indus-act/lng.asp

154 National Grid (2013) *UK Future Energy Scenarios: UK gas and electricity transmission*. National Grid: Warwick, p. 119.

155 Davey, E. (2013) 'The Myths and Realities of Shale Gas Exploration'. Speech to the Royal Society, 9th September.

156 Andrews, I.J. (2013) *The Carboniferous Bowland Shale gas study: geology and resource estimation.* British Geological Survey for Department of Energy and Climate Change, London, UK.

157 BP (2013) *Statistical Review of World Energy 2013*. London: BP.

cannot answer this question. According to the Energy Information Administration in the US, the economic recoverability of oil and gas resources depends on three factors[158]:

1. The cost of drilling and competing wells (which we don't know in relation to UK shale gas and oil);
2. The amount of oil or gas produced from an average well over its lifetime (which we don't know this for the UK. It is highly variable across a shale 'play');
3. The prices received for oil and gas production (again, we don't know this).

Thus, any estimate of how much shale gas and oil can be produced at present is unknown. There is no basis to say that there is 'x' amount of gas in place and at a recovery rate of 20% that means 'y' amount of gas, because the recovery rate is unknown and will vary greatly across the shale deposits. It could be that the greater depth of UK shale deposits, compared to the US, results in higher possible flow rates, but it could also be the case that production costs are higher.

3. What is the potential impact of shale gas and oil on the local economies in area where development is possible?

This is very difficult to know with any certainty owing to the limited level of development underway in the UK. Clearly, there is much that could be learnt from the US case, particularly the development of the Marcellus shale in Pennsylvania. It is no surprise that the advocates of shale gas development in the UK make much of the potential economic benefits and a strong case is made in the Institute of Director's report on *Getting Shale Gas Working*, which was sponsored by Cuadrilla Resources Ltd[159]. The shale gas industry in the US is evolving very quickly and there are many lessons that can be learnt in terms of maximising the economic benefits to local economies, while minimising the safety and environmental costs. The ability of UK industry to develop an onshore shale gas and oil supply chain will be a key factor shaping both the pace of development and the economic benefits and this is an issue that requires independent research.

4. What will be the impact of shale gas on the cost of electricity generated at gas-fired power plants and how will it compare to other forms of generation including coal, nuclear and renewable?

Once shale gas enters the national gas transmission system (NTS) it will be no different from other sources of gas **-** domestic production from the UKCS, imported gas from the Norwegian Continental Shelf, gas through the interconnector from Europe, imported LNG **-** it will be traded on UK and international gas markets. This is why domestic shale gas alone is unlikely to reduce the domestic price; it is an open trading system subject to gas-to-gas competition and is exposed to price risks in the domestic, European and LNG markets. Thus, shale gas will be the same price as other sources of gas.

The development of shale gas globally could, in principle, have an impact on the price of gas. But this will only be the case if shale gas production is very significant. It is important to remember that the future trajectory of gas prices will depend primarily on other factors – i.e. trends in the production of more conventional sources of gas and in the demand for gas.

[158] See www.eia.gov/analysis/studies/worldshalegas/
[159] Institute of Directors (2013) *Getting Shale Gas Working*. London: IOD.

The extent to which gas-fired power generation will be cheaper than other forms of generation depends partly on the price of gas – both in absolute terms and relative to the price of other fossil fuels. It also depends on the details of the Electricity Market Reform package of policies, most of which are being implemented through the Energy Bill that is currently being considered. These include the level of strike prices agreed for new investments in low carbon power generation using renewables, nuclear power and carbon capture and storage (CCS), the future evolution of the carbon price floor and the incentives available from the new capacity market. As things stand, unabated gas-fired generation will be able to take advantage of incentives from the planned capacity market – but, once again, this is not dependent on the source of the fuel that will be used in gas-fired power stations.

All these factors are subject to uncertainty. A recent report by the Committee on Climate Change shows that unabated gas-fired generation (without CCS) is likely to be cheaper than most low carbon technologies in 2013[160]. This comparison includes the impact of the carbon price floor, which is projected to rise as set out by the Treasury. However, this cost advantage may not continue if the carbon price floor is increased as planned (a course of action that is not guaranteed) and the provisions of the Energy Bill are implemented.

All this uncertainty is leading the power generation sector to hold off on investments in new gas power generating capacity until the impacts of the Energy Bill are much clearer. This uncertainty is also likely effecting investment in LNG import capacity and gas storage.

5. Will the UK electricity market be easily able to incorporate shale gas in the future or will generators be locked into long-term contracts with other energy sources? Are there any other potential barriers to the use of shale gas in electricity generation?

As explained above, shale gas is likely to be treated as just another source of gas coming into the NTS, and this gas will be traded alongside other supplies at the market price. It is highly unlikely that any generating company would tie itself to a particular source of supply and the ability of the industry to shift from gas to coal recently demonstrates how readily the generators respond to price signals.

One of the major benefits of the development of the UKCS is that the UK, for the most part, benefits from a well-developed NTS. The areas most likely to develop shale gas production are areas well served by the NTS, thus the cost of connecting new producers to the NTS will be minimal. However, the shale gas producers will have to ensure that their gas meets the standards required of the NTS (this will require processing), and that it enters the NTS at the appropriate pressure. Given the disparate nature of shale gas production, this could mean significant infrastructure investment will be required for shale gas producers to collect their production and make it compatible for entry into the NTS. An alternative might be to sell the gas directly to a local customer.

6. Which forms of electricity generation is shale gas likely to displace and by how much?

Shale gas is a fuel and not a form of electricity generation. As noted above, any domestic shale gas that is produced will contribute to the gas resources available for the UK and for

[160] Committee on Climate Change (2013) *Next Steps on Electricity Market Reform*. London: CCC.

international markets – and for that reason, gas-fired power plants fuelled by shale gas will not be any different to gas-fired power plants fuelled by other sources of gas. The question should therefore be what forms of generation might be displaced by gas-fired generation should that become (or remain) cheaper than other sources. As noted in our answer to question 4, the answer to that question depends on a range of uncertain factors. However, it is important to note that the role of unabated gas fired generation will need to be limited during the 2020s due to the UK's legally binding climate change targets (see answer to question 8 below). The successful commercialisation of CCS technologies would be required for gas to continue to play a major role in that decade and beyond.

7. What impact will shale gas and oil have on household energy bills?

Obviously, in the US at present shale gas and oil have resulted in lower prices. But this is a very particular situation that is not likely to last and which cannot easily be replicated in other markets. For all the reasons explained above, UK shale gas and oil production is likely to have a minimal impact on our household energy bills. Longer-term, if shale gas production impacts on global gas markets it could be part of a wider set of processes that brings down the price of gas (the high price of oil and the dominance of oil-indexed gas pricing is more of a problem in Continental Europe at the moment). But this is a complex issue that is currently only in the realms of informed speculation. Similarly, if shale oil made a significant impact on global oil supplies (at the moment it is reducing US imports of light crude) it could help moderate the price, but there are a host of other factors likely to have greater influence on the future price of oil, which nobody can predict. In summary, there is no evidence that UK shale gas will have a particular impact (positive or negative) on household energy bills in the short to medium-term.

8. What effect will the use of shale gas and oil have on carbon emissions compared to other combinations of energy sources?

This is a highly contentious issue that has two important dimensions. The first is the carbon footprint associated with the production of shale gas - both from the energy and materials consumed in the production process (so-called life cycle emissions) - and so called fugitive emissions from the production process. Emissions are not just made up of carbon dioxide. Methane – the main constituent of shale gas - is itself a potent greenhouse gas. Fugitive methane emissions can leak from wellheads during the extraction process and during transportation.

Emissions estimation is an emerging area of research, with contradictory results coming from studies in the US that require careful review. A recent report for DECC by their Chief Scientific Advisor David Mackay and Tim Stone concludes that: 'If adequately regulated, local GHG emissions from shale gas operations should represent only a small proportion of the total carbon footprint of shale gas, which is likely to be dominated by CO_2 emission associated with its combustion'[161].

This is important because one of the benefits of natural gas is that it emits about half the amount of carbon dioxide compared to coal when used to generate electricity. Thus, if increased gas consumption in the power sector reduced coal consumption it would have a

161 MacKay, D. and Stone, T. (2013) *Potential Greenhouse Gas Emissions Associated with Shale Gas Production and Use* Report for the Department of Energy and Climate Change. London: DECC.

positive de-carbonising effect. However, that positive effect is reduced if shale gas is shown to have higher life cycle and fugitive emissions than other forms of natural gas. In fact the MacKay and Stone report concludes that UK shale gas would have a lower emissions profile then imported LNG.

The second dimension of this issue concerns the carbon emissions associated with burning natural gas. This is not about shale gas *per se*, but is a bigger question about the future role of gas in the UK energy system. In the US, shale gas has replaced a significant amount of coal in the power generation sector over the last few years, and this contributed to a substantial reduction in US emissions. The UK is different. We have already had a 'first dash for gas' in the 1990s and early 2000s that reduced emissions in a similar way. However, UKERC research shows that there are limited further decarbonisation benefits to be had from a 'second dash for gas' without the commercialization of CCS technologies. Significant amounts of unabated gas-fired generation in the UK power generation mix in the 2020s and beyond would make it very difficult to comply with the UK's legally binding carbon targets.[162]

9. Will shale gas and oil increase UK energy security?

It depends on what you mean by energy security. In their recent Energy Security statement, DECC distinguished by 'physical security' and 'price security.' Domestic production of shale gas and oil could contribute to physical security of gas supply, as it would reduce import dependency. However, this only holds true if shale gas is more reliable that other sources of gas (domestic or foreign). Whilst there is a tendency to believe that domestic sources of gas (and energy in general) are more secure than gas from abroad, there is very little empirical evidence to support this assumption. Threats to gas security over the past few years have largely occurred for technical reasons, not geopolitical reasons – and many of the technical problems have occurred within the UK. Furthermore, this assumption does not take into account one of the primary reasons for importing energy in the first place – that it allows UK consumers to access cheaper sources of energy than could be produced in the UK. Domestic production would bring some economic advantages by having a positive impact on the UK's balance of payments.

One difficulty with these security arguments is that the anticipated levels of UK shale gas production are impossible to predict and they are unlikely to significantly reduce our growing import dependence any time soon. As explained above, domestic shale gas and shale oil production is unlikely to have a significant impact on the price paid by consumers and the level of volatility, this is because of the open nature of our energy markets that are exposed to global market conditions. In sum, increased domestic production of oil and gas could help improve physical security of supply (though only if you believe that it will be more reliable than gas from Norway, the UK continental shelf and other locations), but will do little to influence price security.

10. What infrastructure investment will be necessary to cope with the development of shale gas and oil? How far will it help ensure sufficient UK energy supplies? How will this investment be financed?

The first part of this question, relating to infrastructure, is impossible to answer as we are not close to knowing that extent of proven reserves and the possible level of commercial

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[162] Ekins, P. *et al.* (2012) *The UK energy system in 2050: Comparing Low-Carbon, Resilient Scenarios*. UKERC, London.

development. Most of the infrastructure impacts are likely to be local in relation to the exploration, development and production activities. The UK already has a developed NTS and significant gas-fired power generating capacity (note that only a third of UK gas consumption is in the power sector, another third is in industry and the remaining third is consumed in household sector). As noted above, the shale gas industry is developing quickly and 'pad drilling' (multiple wells being drilled from a single site) will reduce the infrastructure demands, but this a question that requires further research based on an understanding of the US experience and the plans for exploration and production in the UK.

As to who should finance it, the UK Treasury has already indicated a willingness to provide production tax breaks (i.e. subsidies) for shale gas development. But this is not something that the industry requested and, for understandable reasons, it has not been well received by environmentalists. The general direction of travel in developed economies, and the UK is no exception, is to place a cost on carbon emissions and to subsidise low carbon sources of energy. In our view, there is no justification for the tax breaks that have been offered. Given the uncertain benefits that any domestic shale gas developments would bring, it would be better to focus government spending on low carbon energy sources and energy efficiency.

11. What changes to public policies are necessary to maximise the potential of any shale gas development?

At the moment public opinion seems to be divided on shale gas and there is a strong and vocal opposition movement. The recent debate that has polarised around events at Balcombe in Sussex is not helpful. Both sides of the argument have engaged in rhetoric and misinformation. It is unclear if it is possible to regain public trust around the issue of onshore shale gas and oil drilling in the UK.

There needs to be a more 'rational' debate about the issues and what it might take for shale gas developers to obtain a 'social licence to operate.' A simple appeal on the basis of a unfounded promises of lower energy bills, employment opportunities and local pay-offs is not going to work, nor is resorting to exaggerated claims about the risks associated with exploratory drilling operations.

Research by UKERC into public attitudes towards energy system transformation suggests that there is public support for low carbon energy, but not for further fossil fuel development.[163] The study did not ask about shale gas. The Balcombe protests have clearly raised the visibility of the issue, but it is also clear that the public is confused by the current situation. We believe that the academic community has an important role to play in providing the public and the policy making community with independent and scientifically rigorous research on shale gas – including on public attitudes to shale gas drilling in the UK.

12. Will shale gas and oil lead the UK to be less dependent on energy from less reliable regions of the world such as the Middle East and Russia?

A cursory examination of the data in DECC's Digest of UK Energy Statistics (DUKES) reveals that the UK is not currently overly dependent on these regions for its oil and gas imports. According to the official data, in 2012 the UK imported 54,357 thousand tonnes of

[163] Parkhill, K.A. *et al.* (2013) *Transforming the UK Energy System: Public Values, Attitudes and Acceptability-Synthesis Report.* UKERC: London.

crude oil and 98.6% of that came from non-Middle Eastern sources, with Russia providing 11.4% of total imports. Norway provided 50.2% of total crude oil imports. In the case of natural gas, in 2012 the UK imported 47% of the gas it required. Norway provided 40.5% of total imports as pipeline gas and Qatar 40% of imports as liquefied natural gas (LNG). Qatari imports equate to about 23% of total gas supply. However, the LNG industry is flexible and there are other sources of supply that could be attracted to the UK if the price was right.

The significant decline in UK gas production and coal's continued importance in power generation means that we have a high level of coal-import dependence, but this is never discussed in relation to energy security. In 2012 the UK imported 44,796 tonnes of coal, nearly 41% of which came from Russia, 26.6% from Columbia and 23.4% from the US. Thus, while Russia is always raised in relation to UK gas security, we do not directly import Russian gas. Some Russian gas is likely to come through the interconnector from continental Europe as a result of trading activities. By contrast, we do import a lot of Russian coal.

The UK has a well-developed infrastructure for importing gas, with more than sufficient capacity. However, as the level of import dependence continues to increase, there will be an increasing rationale for increasing the UK's gas storage capacity which is low when compared to our European neighbours. At present, the Government has concluded that there is no economic rationale for public subsidies for gas storage[164].

13. What lessons can be learnt from the US experience of shale gas and oil?

The short answer is a great deal. We would extend that to the whole of North America because Canada has extensive experience of shale gas drilling in a regulatory system that it is more akin to that in the UK. However, as we note several times in this submission, great care needs to be taken when seeking to draw lessons or conclusions for the UK from the development of shale gas and oil in other countries.

To our knowledge, there has been no substantial academic research undertaken in the UK on this issue and this is something that needs to be addressed in the proposed Research Council funded programme on Unconventional Oil and Gas. If we had to choose one lesson it would be the importance of baseline social, economic and environmental research <u>before</u> the onset of commercial shale gas drilling in the UK. Without this it is impossible to monitor, manage and mitigate the impact of shale gas and oil development.

27 September 2013

[164] DECC (2013) 'Fallon: no new subsidy needed for gas storage - decision saves bill payers up to £750 million'. Press release, 4th September.

United Kingdom Onshore Operators Group (UKOOG)—Written evidence

UKOOG is the representative body for the UK onshore oil and gas industry including exploration, production and storage. The organisation's objectives are to enhance the profile of the onshore industry, promote better and more open dialogue with key stakeholders, deliver industry wide initiatives and programmes and to ensure standards in safety, the environment and operations are maintained to the highest possible level. Membership is open to all companies active in the onshore industry including those involved in the supply chain.

About UKOOG

The United Kingdom Onshore Operators Group is the representative body for the onshore oil and gas industry in the UK. Our objectives are to:

- enhance the profile of the whole onshore industry (both conventional and unconventional);
- promote better and more open dialogue with key stakeholders;
- deliver industry wide initiatives and programmes;
- ensure the highest possible standards in safety, environment management and operations.

Summary

The UK Onshore oil and gas industry has been producing oil and gas onshore, safely, environmentally sensitively and in collaboration with communities for decades. The UK is the international gold standard in safe and highly regulated exploration and production.

Our detailed response highlights that at present the industry does not have sufficient data to answer conclusively a number of questions in this consultation regarding shale. The key to answering these questions and unlocking the economic benefits for the UK is the rapid and successful development of early shale gas sites.

Everyone; industry, politicians, regulators and officials have a role to play to build public acceptance for these early projects because unless we have the opportunity to explore or drill we are never going to compile the data necessary to know the UK potential for shale.

UKOOG recommends the following course of action:

1. Industry and the Office for Unconventional Gas and Oil (OUGO) should spearhead work in the early shale sites to create better public understanding where acceptance will be more cautious. Regulators and experts need to go out into the relevant communities in order to build the scientific case, because scientific evidence holds the key to assuring the local community about the safety of shale exploration. This includes specific enquiries and focuses on key concerns for people, such as water.

2. More work is required to map the supply chain opportunities and the jobs that could be created alongside a better understanding and strategy for the skills required. These too need to be communicated to local communities.

3. Planning regulations need to be robust but must reflect that much of the activity takes place well below the surface and well away from aquifers and other areas of public interest. Recent guidance has helped but more could be done to facilitate the industry without removing any of the safeguards in place.

4. The need for a supportive tax regime has already been highlighted by the recent Treasury consultation and the industry supports the approach and awaits further announcements.

Introduction

The Lord's inquiry has come at an interesting time in the industry's development. Recent actions instigated by both government and industry have included a community benefit scheme designed to reward communities that host sites on behalf of the nation, guidance on planning and a proposed tax incentive scheme.

The impact of these initiatives will not be felt immediately but are designed to improve the overall chance of success that the industry can develop further sources of onshore energy in the UK.

The onshore oil and gas industry in the UK has been in existence for well over 100 hundred years, drilling some 2000 wells of which 10% have been hydraulically fractured to date.[165]Today there are c.120 sites with c.300 operational wells producing in excess of 20,000 of barrels of oil equivalent per day or about 1% of UK's consumption, safely and with adherence to the most stringent environmental regulation in the world.

The scale of the opportunity for UK shale-gas as recently outlined in the BGS report is potentially huge. The industry is beginning the exploration phase for new sources, which UKOOG currently estimates will include the drilling of 50 exploration wells within the next 2 to 3 years. These wells will differ in nature depending on the operator, some will be designed to core and log data and some will test gas flow rates and the impact of hydraulic fracturing. But all will give the industry vital information about the extent of the hydrocarbons and the potential in a commercial environment.

The questions in this inquiry are the obvious ones, however getting to the answers for the UK is what the next 2 to 3 years is really all about. The honest answer to many of the questions, is we simply don't know yet. However the track record of the industry in the UK suggests we will get the answers.

There are of course many forecasts based on predominantly the US experience and the range in those estimates is significant. However we should sound a word of caution which is that shale geology and extraction methods and regulation are different wherever you go and this has a major impact on many of the questions raised in this inquiry.

[165] Shale gas extraction in the UK: a review of hydraulic fracturing, The Royal Society/Royal Academy of Engineering, June 2012.

Our document attempts to summarise the main arguments and some of the forecasts, however the real answers will only come from drilling and testing exploration wells.

1. How much scope is there for shale gas and oil to be used in the UK? Over what timeframe?

The scope for shale gas and oil is significant. Recent numbers produced by the British Geological Survey (BGS) has indicated that there could be 1300 trillion cubic feet (tcf) of gas in the Bowland and Hodder shale. This compares to an average UK annual demand of 3tcf. Not all the gas in place will be economically or technically extractable. Recovery rate assessments depending on the US experience vary between 10% to 40%.

We expect further studies to be completed by the BGS in other areas of the country starting with the Weald Basin, to be published early next year which will also show the extent of shale oil in place.

Natural gas has played a significant role in heat and electricity production and providing feedstock into industry over the last 20 years and natural gas from shale will continue to do so as shown by the following factors:

Gas Imports to rise to 70%
One of the major influencers on the UK energy market over the next 20 years will be the increasing dependency on gas imports as the production of domestic sources from the North Sea continues to decline. Many forecasts including the Government's central estimate project an import dependency of c.70% or greater by 2025[166] as compared with 14% in 2000.

Increasing reliance on imports generates both physical and political energy security issues. In addition as imports are increasingly filled by LNG, the UK will also become a price taker and subject to risk of price spikes caused by a physical disaster elsewhere in the world such as recently experienced during the problems at Fukushima. The disaster highlights what could happen, Japanese LNG imports went up by 25%[167] and the prices rocketed 50%[168]. Recent reports estimate that electricity costs have gone up by 30%.[169]

Coal supplies 39% of total electricity in 2012
Electricity supplied from gas decreased from 40% to 28% between 2011 and 2012, as gas prices increased, particularly in relation to coal. Electricity supplied from coal rose from 30% to 39% primarily as a result of global prices falling due to US shale gas displacing US coal to other parts of the world.[170]

Continued role for Gas in the UK
35% of all energy consumed in 2012 came from Gas[171]. We are likely to need significant investment in new gas generation plant. Modeling by DECC suggests that

[166] Energy Security Strategy, DECC, November 2012
[167] Federation of Electric Power Companies of Japan
[168] US Energy Information Administration
[169] http://www.reuters.com/article/2013/09/26/us-japan-survey-power-idUSBRE98P18P20130926
[170] Digest of United Kingdom Energy Statistics, DECC, 2013
[171] https://www.gov.uk/government/publications/energy-consumption-in-the-uk

up to 26 GW[172] of new gas plant could be required by 2030 (in part to replace older coal, gas and nuclear plant as it retires from the system). It also indicates that, in 2030, we may need more overall gas capacity than we have today, although operating at lower load factors.

Gas is also important for balancing out the increasing levels of intermittent and inflexible low-carbon energy on the system. Unabated gas generation will continue to play a crucial role in our generation mix for many years to come, and the amount of gas capacity we will need to call on at times of peak demand will remain high.

Oil and natural gas provide the energy source or raw material to make a wide range of products. In fact, it is nearly impossible to get through a day without using multiple products that contain oil or gas. Natural gas is the raw material for plastics; a material found everywhere and is also a key component in the manufacture of fertilisers. The Haber-Bosch process uses natural gas to provide hydrogen, which is combined with nitrogen in air as part of the process to create ammonia. Ammonia is used as a feedstock for other nitrogen based fertilisers, and with up to 70%[173] of the costs of the fertiliser coming from natural gas, a cheap supply is essential for its production.

Gas to continue to heat our homes and drive our industry
Around 80%[174] of all the heat used in the UK – in homes, in commercial buildings and in industrial processes– comes from gas. According to DECC, natural gas will supply the majority of our heat demand for many years to come.

The Government has put in place a strategy of reducing reliance on natural gas in heating but this will take many years to develop as it involves not only new technologies but also modification in infrastructure and behavior. Gas and therefore shale gas has a major part to play in bridging the gap between now and then.

2. How will the costs, including those on the environment, of accessing the UK's shale gas and oil compare to those of other energy sources?

Costs are dominated by the drilling of wells and are usually higher than for conventional gas because of the additional expense of multistage hydraulic fracturing.

The shale industry in the UK is still at a very early stage and therefore it is impossible to be accurate about the cost to extract onshore hydrocarbons. There are a number of factors which will determine the cost of extraction

- Rate of recovery which is largely dependent on geology
- Development of a UK supply chain to generate price competition
- Climate change policies impacting on the cost of carbon
- Public perception and the impact on planning decisions
- Environmental and safety related costs

172 Gas Generation Strategy, DECC, December 2012
173 Agricultural industries confederation
174 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48574/4805-future-heating-strategic-framework.pdf

- Well success factors
- Well learning curve – time taken to reduce well costs
- Operator efficiency

In the US cost of extraction varies significantly based on a number of the factors above, in particular geology and the presence of hydrocarbon liquids.
Reports vary on how the UK shale extraction cost will compare to the US, with some commentators predicting the difference as high as three times more expensive in the UK.

Unlike the US however, the UK already has access to sophisticated gas distribution and transmission systems. Not only would it cost several billion pounds if these systems had to be built today, but it also means that the need for flaring will be far less than in the US.

Whilst it still needs to be fully tested, at this stage, it appears that in certain parts of the UK, the shale is significantly thicker than in the US. Consequently, this will allow more gas to be extracted per well site.

However the UK suffers from a number of potential cost pressures compared to the US in particular the current lack of shale supply chain. For example one recent rig count identified 1900 land rigs and 500 fracturing crews in the US compared with 77 rigs and 10 fracturing crews in the whole of Europe. This position will steadily improve as it did in the US. In addition to the immature supply chain there is also a bigger environmental and regulatory cost of doing business in the UK, longer lead times particularly around planning make scheduling difficult.

The industry is currently working closely with the Department of Business, Innovation & Skills with respect to identifying the potential for growing a UK supply chain; this will not only reduce the cost of doing business but also create UK jobs. This work is at an early stage but should be encouraged.

The increased cost burden in the UK particularly in the early stages of development result in shale projects being marginal for development and therefore the industry has welcomed the proposals for a specific tax regime along the lines given to marginal offshore fields.

In terms of planning, the recent guidance produced by the Department of Communities and Local Government has been welcomed by the industry. However more clarity is required with respect to the planning regime and underground workings; a fairer regime is required along the lines of similar industries so as not to increase the regulatory burden for underground workings which are already governed by a significant amount of environmental regulation. A clear demarcation within both the planning and legal regimes is required between surface and subsurface activities.

In terms of comparing other energy sources, most will attempt to compare shale oil and gas with renewable energies and nuclear power. This is not a real comparison as shale oil and gas firstly has multiple uses from heat and electricity through to feedstock supply. In addition the final use of the hydrocarbon whether it may be for heat or electricity will have a big determinant on the efficiency of conversion to other forms of energy.

The most obvious comparison therefore is with imported fuels. As explained in the answer to question 1, the cost of shale oil and gas in the UK is yet to be determined and will only be answered after a prolonged period of exploration and testing. However it should be noted that the cost of transport either by pipeline or by tanker adds substantially (between 10% and 50%[175] of the total delivered wholesale gas price depending on distance and method) to the cost both in terms of economics as well as environment. For example liquefaction and regasification consumes up to 13%[176] of gas being transported as LNG and therefore adds to the cost significantly.

3. What is the potential impact of shale gas and oil on the local economies in areas where development is possible?

The benefits of the shale industry will be felt across the UK in lower imports, higher revenues to the Exchequer, job creation, supply chain development and energy security.

The industry has made it clear from the outset that local communities that host our sites should be rewarded. As a result in June 2013 UKOOG announced its first industry-wide community benefits scheme. At the exploration phase for sites that involve hydraulic fracturing the local community will benefit to the sum of £100,000. During production communities will receive in total 1% of all gross revenues before costs are deducted. The industry estimates that this could amount to over £1.1bn in a 25 year period or £5m to £10m per site.

Alongside the direct and indirect benefits, developers will also be paying increased business rates as a result of their operations, 50% of which will go directly back to local councils, again benefiting local communities.

4. What forms of electricity generation is shale gas likely to displace and by how much?

If we are serious about reducing the impacts of climate change we need to radically look at the way we use coal. Many coal fired generators are actually in the process of closing as a result of the EU's large combustion plant directive and many more are considering moving to biomass as a feedstock.

Natural gas prices have now risen above the equivalent cost of coal for the generation of power. This has resulted in power generators increasing power from coal stations and reducing generation on gas stations. With coal stations emitting more carbon dioxide per unit of power generated, this has resulted in a significant increase in emissions.

Shale has the ability to firstly displace coal and then imported gas. However this depends largely on whether shale can be cost competitive against the other forms mentioned and whether any credit is given for its environmental benefits.

5. What impact will shale gas and oil have on household energy bills?

In the US, exploitation of shale gas has led to a dramatic reduction in gas prices, from highs of around \$12/MMBtu in 2008 to a low of \$1.80/MMBtu in March 2012, since when they have recovered to around \$3.40/MMBtu. This has been reflected in the price to the consumer.

175 Unconventional gas, the potential impact on UK Gas Prices, Navigant, 2013
176 Unconventional gas, the potential impact on UK Gas Prices, Navigant, 2013

Commentators are divided about the impact of shale on household bills in the UK.

In November 2012, Poyry estimated that gas and electricity prices could go down by as much as 4% assuming shale provided 50% of the UK's underlying indigenous gas production. This would seem to be an inconsequential amount but could be significantly bigger if the amount of shale produced goes beyond this conservative estimate. Even at 4% the annual saving to the UK economy is £800m.

Navigant in June 2013, estimated in their optimistic scenario that prices could go down to 50p/therm compared to the current 70p/therm based on an international shift to shale.

However Bloomberg New Energy Finance is less optimistic as it believes the price of gas will be set by imports and the amount of shale will not offset the decline in the North Sea and will be significantly more expensive to produce.

UKOOG notes that many of the current forecasts show a significant increase in European gas prices without the introduction of shale and that shale gas production in the longer term should result in lower prices when compared to a future with no shale gas production.

6. What effect will the use of shale gas and oil have on carbon emissions compared to other combinations of energy sources?

The use of natural gas extracted from shale reservoirs has significant scope to reduce the UK's overall carbon emissions, as natural gas from shale will probably displace coal and imported gas in the energy mix.

The burning of natural gas to produce energy releases around half the carbon emissions of coal.
A study by AEA Technology in 2012 for the European Commission concluded that the lifecycle CO_2 emissions for shale gas could be 2-10% lower than emissions from electricity generated from conventional pipeline gas located outside of Europe and 7-10% lower than that of electricity generated from LNG imported into Europe.

The Committee on Climate Change concluded in April 2013 that shale gas "could have lower emissions than imported LNG if regulatory arrangements are in place to manage methane released during its production."

Gas demand projections made by the Department of Energy and Climate Change (DECC) are consistent with forecasts made regarding the UK's net carbon account, which is expected to fall by 45% by 2025 (from a 1990 baseline)

However, plenty of scope still remains to reduce the UK's reliance on coal. DECC figures show that in 2012, coal power overtook gas to become the biggest single source of UK electricity generation.

7. Will shale gas and oil increase UK energy security?

For many years the UK has had access to locally sourced supplies of natural gas which have provided consumers with competitively priced energy supplies. As conventional reserves have declined, however, UK import dependency has increased with ever-greater volumes of gas being sourced from Norway and through LNG.

In addition to electricity generation and industrial and domestic heating, the UK energy intensive and petrochemicals sectors require certainty that energy and feedstocks will be secure and competitive in the medium term. Without that certainty, it is likely that these sectors will decline, reducing manufacturing capacity.

Replacement of North Sea capability with another indigenous source of fuel has to provide better security than reliance on a physical pipeline to Norway or political reliance on places like Qatar and Russia.

8. What lessons can be learnt from the US experience of shale gas and oil?

The UK has well established arrangements in a wide variety of industries for responsibly managing environmental and other risks. The US has demonstrated the technology which should be readily transferable.

Much Research and Development was undertaken in the US which has aided the US to be in a position to extract the maximum from its resources. Improvements in lateral drilling and the ability to locate areas of natural prospectively have improved recovery rates.

The UK will benefit from this experience. However not all shale is the same and we will need to ensure that we understand the shale in the UK with respect to the available technology.

Much has been made of some of the issues that the US has had with water contamination and air quality, with many studies contradicting each other. However we need to be clear that taking issues from one country and transposing them onto another country with a very different regulatory regime is not a correct comparison.

The UK regulatory regime is different and significantly more stringent and incorporates a quadruple layer of regulation from local mineral authorities, Department of Energy and Climate Change, the Health and Safety Executive and the Environment Regulators across the devolved regions (EA, SEPA and NSW).

Many of these issues are myths. There have been over 2 million hydraulic fracture operations carried out in the last 40 years with no incidence of hydraulic fracturing fluid having entered the water supply and limited examples of methane leakage.

Some of the issues around methane leakage are likely to be due to poor well design or control. The regulations in the UK are some of the most stringent in the world with respect to well integrity with an emphasis of reducing risk to as low as reasonably possible.

However the situation with respect to repudiating some of these myths has been more difficult by the lack of baseline monitoring in the US, making it difficult to prove that the industry has not been at fault. This situation will be rectified in the UK by baseline and continuous monitoring.

The promulgation of these myths has made local people cautious about the plans operators have in their areas and there is a real need to create better public understanding. Much can and will be done by the operators themselves in line with the UKOOG community engagement charter which stipulates early engagement. However regulators and experts need to go out into the relevant communities in order to build the scientific case, because scientific evidence holds the key to assuring the local community about the safety of shale exploration. This includes specific enquiries and focuses on key concerns for people, such as water.

27 September 2013

The Weir Group PLC—Written evidence

Introduction

The Weir Group PLC (Weir) is pleased to provide evidence to the Committee. Our observations address the lessons that can be learnt from the US experience of shale gas and oil, with a focus on how the critical oil services and engineering support industry has developed.

Weir is a global engineering business, operating in more than 70 countries and employing more than 14,000 people. Of particular relevance to the Committee are our leading market positions in equipment and services provided to the unconventional oil and gas markets of North America. Weir provides a broad range of surface equipment, from pump to wellhead, for use in drilling and well completion applications and has been active in North American unconventional oil and gas markets since 2007.

Weir Group evidence

1. Even in the US, shale gas development is a relatively young industry. Although hydraulic fracturing has been safely and widely used since the 1940s, it was its combination with horizontal drilling in the early 2000s that has driven the rapid growth of North American onshore unconventional exploration and production. An illustration of the growth of the industry can be seen in the case of SPM, a pressure pumping business acquired by Weir in 2007. In 2008, the business, based in Fort Worth, Texas, had around 700 employees and around $275m turnover. By 2012, SPM employed around 1500 people with turnover of around $800m. Should the UK develop domestic shale gas resources, it would stand to benefit from the experience of a US industry which has rapidly developed and continues to improve the efficiency, safety and environmental impact of shale operations.

2. The scale of unconventional oil and gas activity in North America has had broad economic benefits. According to IHS Global Insight, this supported 1.7m jobs in 2012. Employment has been created in the industries most closely involved in the process, such as drilling, extraction, equipment and services, but also in supporting sectors such as manufacturing, construction, financial and insurance services.

3. Unconventional development has been made possible by innovation and creativity, leading to the development of new partnerships between industry and academia and significant increases in patent filings. In Weir's case, the Group has worked with institutions in the US and the UK to develop new patent-protected technology for pressure pumping, the process by which fracturing fluid is delivered to the wellbore. As well as mechanical engineering developments, shale exploration and production has also stimulated investment in solutions for reservoir evaluation and enhanced mitigation of environmental impacts such as the treatment of wastewater. The US industry continues to develop new technologies and best practice, enhancing the safety and economics of unconventional resources.

4. As the US industry has grown, the critical oilfield services activity that supports the exploration and production processes has developed a number of highly professional large service companies. These companies are increasingly active in emergent international shale markets and it is likely that they would play an important role in supporting a nascent UK industry. This would complement the UK's very strong existing oil and gas industry and skills base which positions the UK to take a leadership position in shale production as opportunities develop across Europe.

5. While outside expertise will facilitate smooth initial development, a UK shale gas industry provides the opportunity to develop skills and a local supply chain. Differences exist between onshore and offshore techniques, but the established oil and gas services industry in the UK has readily transferable skills and technologies and a strong international reputation, reinforced by global leadership in subsea operations which is exported from the North Sea to areas such as the Gulf of Mexico. The UK supply chain is well positioned to satisfy both upstream and midstream requirements. Onshore rig sites will also require significant numbers of engineers, technicians and semi-skilled labour. Thought will need to be given to balancing the skills needs of the offshore industry with a potential shale gas industry, given the high demand for candidates in areas such as engineering and geoscience. Depending on the scale of recoverable resource, thought should be given to training requirements and capacity building.

6. Drilling and hydraulic fracturing is a process that requires high volumes of water. Figures vary, but it is estimated that in the US the drilling and fracturing of a horizontal well requires an average of three million gallons. Alongside concerns about water levels in areas of drought or shortage, water is often brought to rig sites by lorry which brings additional traffic and noise. The US industry is already taking a number of steps to mitigate this, with the now routine recycling of 'flowback' water, where up to 30% of the water used to fracture the well returns to the surface, alongside produced gas. While water usage should be an area considered in any regulatory or planning process, Weir does not consider this to be a significant issue for the UK. Notwithstanding the lessons already learned in the US and the continued efficiency in the use of water for shale operations, the UK has a more developed mains system and sewerage network, in contrast to the many more private water sources in the US.

7. In the US, financial incentives are provided directly to minerals rights owners, which have arguably helped to ensure the rapid acceptance of drilling development. Indeed, large hydraulic fracturing operations often take place in suburban areas. Individuals in the US receive royalties based on the production beneath their land. This is not the same as the current proposal in the UK whereby the community in general is expected to receive the financial benefit.

8. Debate about the environmental pros and cons of shale development is healthy and robust evidence to inform the debate is helpful. Establishing reliable baseline data in the UK will be important to determining the environmental impacts to air and water of any shale development. In the US, often for reasons of commercial confidentiality, the industry was slow to provide transparency on issues that vexed campaign groups and wider stakeholders. A good example would be the length of time taken to disclose the chemical content of fracturing fluid, used to help prop open the fissures

in shale which allow hydrocarbons to escape following the fracturing process. For thousands of wells across the US, this information is now available at Fracfocus.org, a publicly available portal where members of the public can establish the chemicals used. The industry has also recognised the need to involve stakeholders in decision making and many good examples of organisations committed to effective and meaningful engagement exist, such as the Marcellus Shale Coalition, the Barnett Shale Energy Education Council and the Centre for Sustainable Shale Development. UK regulators and planning authorities should ensure that consistent and reliable data can be drawn upon to enable a balanced debate on the environmental impact of shale operations, with science, rather than emotion, informing stakeholders.

27 September 2013

World Wildlife Fund (WWF-UK), Friends of the Earth England, Wales and Northern Ireland and Greenpeace UK—Written evidence

Submission to be found under Friends of the Earth England, Wales and Northern Ireland, Greenpeace UK, and World Wildlife Fund (WWF-UK)—Written evidence

Chris Wright—Written evidence

21. My name is Chris Wright. I have been a technology and energy entrepreneur for over 20 years. I have been fascinated with energy my entire life. I went to MIT when I was 17 to study plasma physics in the interest of hastening the arrival of commercial fusion energy. Realizing that I did not posses the patience for basic research, I received my bachelor's degree in mechanical engineering and pursued graduate work in electrical engineering in the MIT Power Systems Lab. Since then I have worked in geothermal energy, energy conversion and conservation, solar power, and most significantly in the shale revolution from the very start. My original company, Pinnacle Technologies, developed the first technologies to directly and in real-time map the growth of hydraulic fractures. These direct measurements enabled some fracture design changes – refracturing, network fractures, and high-rate slickwater fracturing – which led to the first commercial shale gas production from Mitchell Energy's Barnett Shale in 1998. We worked with Mitchell, and later Devon Energy who acquired Mitchell Energy, to expand the application to multi-stage horizontal wells in the Barnett shale.

22. I don't deserve much credit for what happened (blind squirrel finds nut), as the real credit is due to the entire team at Mitchell Energy who relentlessly pursued the shale gas concept for 16 years before it yielded economic gas production. But yield it did. Ten years after the breakthrough in 1998, the Barnett shale gas production was roughly 2 TCF per year making it by far the largest gas field in the United States and supplying an amount roughly equal to two-thirds of the entire UK gas consumption. Time would prove that the Barnett shale was a mid-grade shale at best as many other shale plays emerged by utilizing the same technology / approach that was developed in the Barnett.

23. This year the production from the Marcellus shale in Pennsylvania (not including the rapidly growing Marcellus production in West Virginia) will exceed 3 TCF and continues to grow rapidly. Shale gas production now represents roughly 40% of US natural gas production. This surge in US natural gas production catapulted the US past Russia as the world's largest producer of natural gas. While the breakthrough came first in shale gas production, the price drop in US natural gas prices that resulted from the abundant supply drove production companies to apply the same innovations to oil production. The result has been a dramatic rise in US oil production after thirty years of declining US oil production. The US imported 60% of our oil in 2005 and this year will import less than 40%. The oil production in the state of North Dakota, a modest producer prior to the shale revolution's 2006 arrival in the Bakken shale, now exceeds that of two OPEC Nations (Ecuador and Qatar) and the United Kingdom.

24. I should declare my strong interests in the shale revolution. Pinnacle Technologies, which I started in 1992, saw its business grow even faster with the launching of the shale revolution. I also recapitalized a tiny coalbed methane production company, Stroud Energy, in 2001 and turned it into a shale gas producer in the Barnett shale. I also co-founded and am currently the CEO of Liberty Resources, a shale oil producer most recently in the Bakken Shale of North Dakota. I am also the CEO and co-founder of a hydraulic fracturing services company, Liberty Oilfield Services, that

works in the Bakken Shale and the Niobrara shale in Colorado and Wyoming. I have no commercial interest in seeing shale gas development in the UK, but I do indeed have a great commercial interest in the US shale revolution.

25. To give but one example of the local economic impacts of the shale revolution, North Dakota ranked 39th among the US states in per capita income in 2006. Six years after horizontal shale oil drilling began in western North Dakota's Bakken shale North Dakota rose to 7th in US per capita income in 2012.

26. Much has been written about the surge in jobs, wages, and innovations in the US energy industry. It is there for all to see. But even more significant is the benefits to the greater US economy of abundant supplies of lower cost energy and the accompanying roughly $200 billion per year improvement in the US trade balance due to reductions in oil and natural gas imports. Perhaps best of all is the American manufacturing industry renaissance. Energy pipeline and infrastructure firm Enterprise Products Partners reports $40B dollar investment in 50 US gulf coast facilities under construction or in planning approval to exploit the US surplus of ethane, a by-product of shale gas which is dominantly methane. The economic impact of the vast new supply of methane is far larger than the investment in ethane-feedstock plants.

27. Methane gas is the dominant component of natural gas. Methane is the leading source of heating for residential and commercial buildings in the US. It also is used to generate more than one quarter of the electricity produced in the United States and as the marginal supplier of electricity it is responsible for the drop in US electricity prices in contrast to rising prices in all other industrialized nations. The third major use of methane gas is its dominant role in powering manufacturing. For energy intensive manufacturing, natural gas prices play a major role in deciding the most efficient location to build or expand a plant. I myself am a founding board member and investor in a project that just completed a large ($200M) ceramic proppant manufacturing facility in Wrens, Georgia. The last five or ten such plants were constructed in China, but now the energy cost advantage of the United States offsets the labor cost advantage of China.

28. Much has been said about the enormous economic advantages that have accompanied the United States shale gas revolution and that would surely accompany UK shale gas development. So I will move my comments now to the technology itself and the environmental impacts of shale development.

29. Shale gas originates from marine life buried in stagnant seas hundreds of millions of years ago. With additional deposition the sediments are buried deeper causing the temperature and pressure to rise, eventually converting the dead organisms into kerogen, the precursor of hydrocarbons. With time the kerogen "cooks" first into long-hydrocarbon chain "heavy" oil, followed by "light" oil, natural gas liquids and eventually methane. Cooking of kerogen into gas results in significant volumetric expansion that induces millions of hydraulic fractures that eventually link together the pore spaces in the shale and allow gradual migration of the gas out of the source-rock. The buoyant gas migrates upwards and will vent at the surface unless it is trapped by another "cap-rock" which creates a conventional natural gas reservoir. Shale gas involves less exploration risk as wells are drilled directly in to the source

rock and a series of man-made hydraulic fractures are performed to accelerate the gas migration out of the shale. However this controlled "migration" is directed into the wellbore that conducts gas flow to surface gathering lines, as opposed to gas naturally migrating upwards into other geologic strata. Shale gas production simply accelerates and controls gas migration out of source rocks.

30. Shale gas production was enabled by two recent technological innovations. One is advanced packers (doughnuts that attach outside of steel wellbores) and drillable bridge plugs that are placed inside wellbores and allow individual zone isolation along horizontal wellbores. The other is innovations in hydraulic fracturing that have allowed the creation of "network" fractures that create far more surface contact area with the gas-saturated shale rocks than was possible with conventional hydraulic fracturing. Ironically given the recent concerns, these innovations in fracturing for shale reservoirs led to the use of far less chemicals in shale fracturing versus conventional hydraulic fracturing!

31. Hydraulic fracturing began in the late 1940's in Oklahoma to "stimulate" increased oil and gas production from low permeability rocks that would not otherwise yield enough oil and gas to pay for the cost of drilling a well. Over the last forty years the vast majority of all wells drilled in the United States were hydraulically fractured after being drilled and before being put on production. Hydraulic fracturing has been key to the vibrancy of the United States oil and gas production since the 1970's. In the 1990's hydraulic fracturing has been employed regularly as a technique to dispose of drilling waste in remote areas (North Sea, Alaska, Indonesia, etc.). The safety record of hydraulic fracturing is nothing short of superlative. There is not a single instance of a hydraulic fracture contaminating ground water in the more than two million hydraulic fractures that have been performed over the last 65 years. The reason for this is that hydraulic fractures are executed deep underground far below the near-surface fresh ground-waters.

32. Great effort has been expended to convince the public that hydraulic fracturing is new, a threat to our water supplies and a significant seismic hazard. It is none of these.

33. Hydraulic fracturing has been going on for over 60 years. Fracturing has also spread geographically to include Canada, Mexico, China, Russia, Germany, Italy, Japan, Australia, Great Britain, Austria, Poland, Norway, Indonesia, Argentina, Columbia, Pakistan, India – a partial list of only the countries that I personally have been involved with hydraulic fracturing in. Two significant fracturing projects that my original company, Pinnacle Technologies, was involved with immediately before the shale innovations involved fracturing over a dozen wells in Beverly Hills and nearby Los Angeles, and another large project in Nigata, Japan. Hence fracturing in densely populated urban areas and remote wilderness areas was not problematic.

34. Two American movies, Gasland and Gasland 2, have received great publicity for showing purported cases of fracturing resulting in methane contamination so that tap water could be lit on fire. The example in the first Gasland was from a farm near my home in Denver, Colorado. There are some thin coal seams in the local aquifer for Denver. This is not uncommon. Hence there are locations where water wells can be drilled into groundwater containing methane outgassed from the coal seams. This

has been widely known in the Denver area since the first settlers arrived. The second Gasland film shows a hose in the Dallas, Texas, metro area being lit on fire. This latter case was ruled a fraud by the local courts as the perpetrators simply hooked a garden hose up to a residential gas line. State and Federal regulators in the U.S. have also cleared hydraulic fracturing these cases. At Pinnacle Technologies we have several times published composites of ALL the hydraulic fractures we have mapped in the principal shale gas fields: Marcellus, Barnett, Niobrara, Eagle Ford, and Fayetteville. The fracture mapping data shows compellingly that even the cases of exceptional upward fracture growth do not get within two thousand feet of the deepest possible fresh groundwater.

35. Seismic risk has also recently been raised as a risk of shale gas development. This risk gets particular attention as there were two seismic events around magnitude 2 induced by hydraulic fractures in the Bowland Shale. These induced seismic events were indeed significantly larger than normal for hydraulic fracturing. However even these anomalous events, almost certainly caused by fracturing immediately adjacent to an active fault, were still far below the magnitude able to be felt at the surface. A thorough study was prepared on these events and a sensible monitoring system was recommended to assure that seismic risk is mitigated. Mining and hydroelectric power have far greater seismic risk than shale gas drilling.

36. Is there an environmental impact from shale gas development? Of course. Development of ANY kind involves environmental tradeoffs. However the environmental impact of shale gas development is above ground, visible for all to see. And on this measure it compares quite favorably with alternative sources of energy production. As a lifelong climber, wilderness adventurer, and board member of an environmental group (Property and Environment Research Center) I am keenly interested in minimizing human impact on the environment. Liberty Resources, of which I am the CEO, uses roughly 10 acres to construct a "pad" which houses the drilling rig and after drilling is done is used to stage all the hydraulic fracturing equipment. After drilling and fracturing are done, the 10-acre pad contains the 16 total well-heads and surface production facilities. These 10 acres of land are used to produce the oil and gas from 2560 acres (four square miles). Meaning that we utilize a little under 0.5% of the land to produce the massive Bakken oil field. Which means that the other 99.5% of the land is still farmed, ranched, otherwise occupied (town or city), or remains native grassland or forest.

37. To expand on the above point about land utilization, let's take a shale gas example from the Marcellus shale in Pennsylvania and West Virginia. An average Marcellus shale well will ultimately recover about 10 Billion cubic feet of natural gas (BCF). The thermal energy from 10 BCF of gas is roughly 3 Terrawatt-hours (TWh). A 10-acre Marcellus well pad can easily host 10 wells meaning that the pad will ultimately produce about 100 BCF of gas, which equates to 30 TWh of energy. Factoring in the roughly 60% thermal efficiency of a combined-cycle gas turbine, yields about 18 TWh of electric power from this 10-acre well pad in Pennsylvania. This amount is roughly equivalent to the 19 TWh of electricity from the entire British wind industry in 2012. Shale gas and shale oil are amazingly land efficient sources of energy.

38. What about all the chemicals in fracturing fluids? The same could be said about the chemicals employed in making a couch, a sculpture, a wind turbine, a solar panel, or a

Starbucks. Except with shale gas you can increasingly access ALL of the chemicals used on each fracturing job from the Frac Focus website. The vast majority of these chemicals could also be found in household cleaning products, food additives, solvents, etc. Truth be told, the real hazard from oil & gas production has nothing to do with frac chemicals. Instead it comes from the foul nature of produced water that inevitably accompanies production of oil or natural gas liquids – dry gas sometimes is indeed produced without subsurface waters. Water from deep underground is far saltier than the oceans, often contains heavy metals and Naturally Occurring Radioactive Materials (NORM). This problem is as old as the oil industry. The United States produces far more water from its oil wells than it produces oil. This volume of foul produced water is typically piped to a nearby disposal well and re-injected deep underground where it came from. Unfortunately a Marcellus producer in Pennsylvania instead delivered its produced water to a nearby water treatment facility that was not equipped to handle the huge salt content and NORM from the produced water. This has made big news in the US and has rightly drawn condemnation as it needlessly contaminated streams nearby the water treatment plant. This was not a problem with fracturing per se, but instead a problem of produced water disposal.

39. In addition to careful regulation of produced water disposal, the other major concern is wellbore construction. A shale gas wellbore typically goes down 2 miles and then turns horizontal in the targeted shale zone and might go another mile or two within the targeted zone. The steel casing cemented inside the drilled borehole provides the conduit for fracturing fluids to travel down into the rock and subsequently for produced gas, oil, and water to flow back to the surface. These steel wellbores must be appropriately designed and cemented in place to prevent the migration of fluids upwards outside of the steel casing – for example via the annulus outside of the steel casing but inside of the drilled hole. This migration can be reliably prevented if the casing and cementing programs are properly designed and executed. US State Regulations in this area are continually placing stricter protocols on wellbore construction. I fully support this evolution.

40. Water consumption is another area of concern that is often raised. In short, the water consumption is quite modest for the energy produced. In Colorado, home to the booming Niobrara shale that now produces over 100,000 barrels of oil per day from my home state, water consumption for fracturing is 0.13 percent of Colorado total water consumption. Oil and gas production is roughly 7% of the Colorado economy, so one can conclude that shale gas / oil production is roughly 50 times more water efficient than our state's industry as a whole. Agriculture of course is by far the biggest consumer of water in the United States. Electricity production is also a major consumer of water. However, hydraulic fracturing for oil and gas production is far from a major consumer of water.

41. I will conclude with a few thoughts about Great Britain from this American outsider. I drove with my wife and son from northeast England across to northwest England and then down central England to London. I was struck by two things: a countryside that looked quite suitable to shale drilling and urban areas that looked in need of revitalization. England launched the industrial revolution due to leading engineering innovations and readily available low cost energy. Development of the Bowland shale gas could bring them both back to England again.

42. I apologize for the rushed and informal nature of my written testimony. I am passionate about this subject and not just because I have been involved in it from the start. I would happily come back to England for oral testimony if desired.

20 October 2013