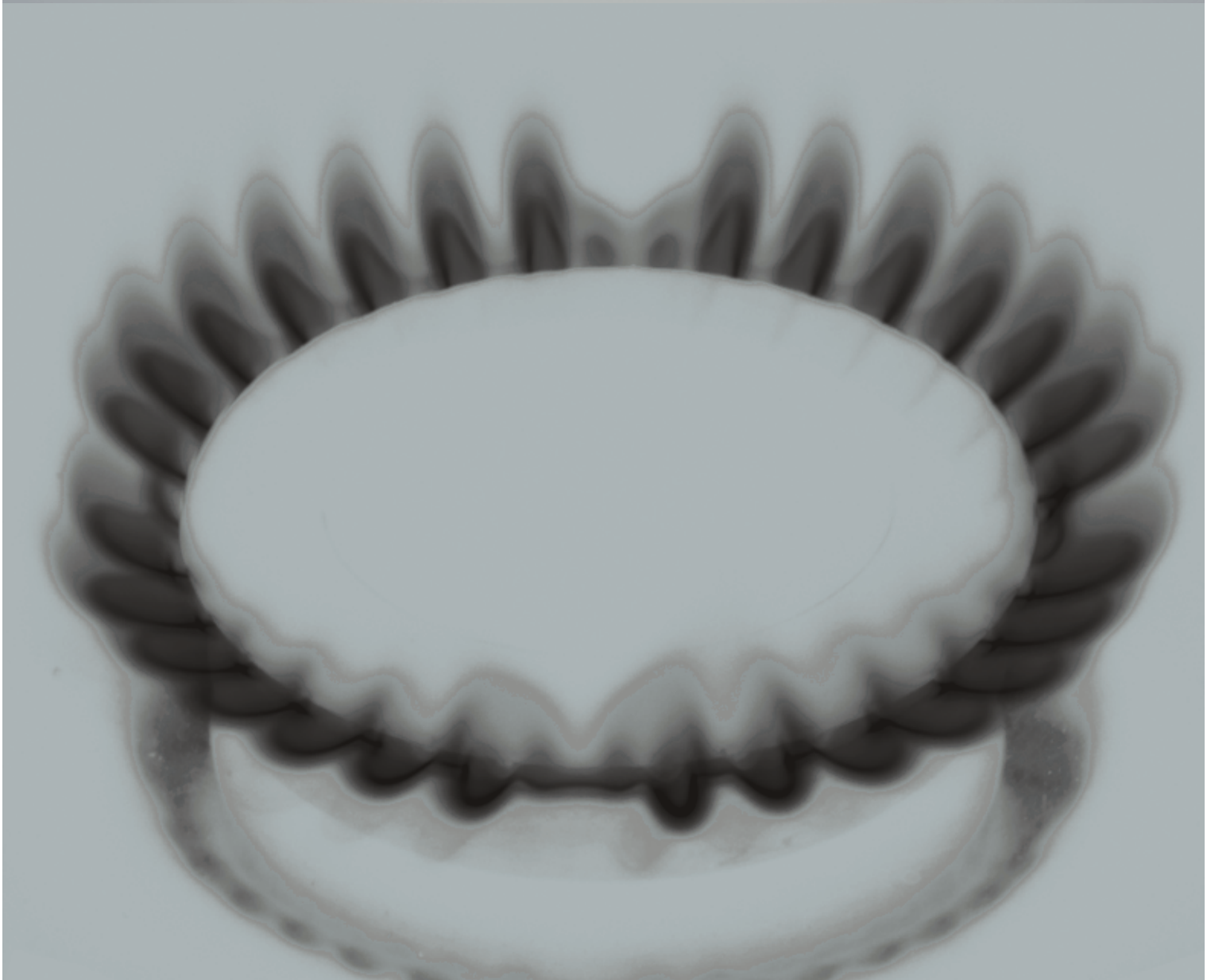




Infrastructure for Business

# Britain's shale gas potential





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# Executive summary

- The UK has not had many positive energy stories in recent years, but the discovery and exploitation of the country's potentially huge shale gas reserves could prove to be just the boost the economy needs.
- The IoD believes that the UK has a major opportunity to develop a cheap and reliable domestic source of energy, creating jobs, reducing the need for gas imports and improving the environment by replacing coal in electricity generation.
- Cheap gas-fired turbines powered by UK shale resources could also prove to be the perfect complement to renewable generation, providing power when the wind isn't blowing and the sun isn't shining.
- The IoD hopes that the Government's forthcoming gas generation strategy will be similarly enthusiastic about what could be a vital part of Britain's future energy mix.

NB: All figures in the executive summary are referenced in full in the appropriate section of the main body of the report.

## THE US SHALE BOOM

The UK is not the US, but there can be no understanding of the shale gas opportunity without a grasp of how unconventional production has transformed America.

### Production

- Since its 2005 low, US natural gas production has increased by 28%. Shale gas production has accounted for the bulk of this rise, increasing from 0.39 trillion cubic feet (tcf) in 2000 to around 5 tcf in 2010.
- Shale gas now accounts for 23% of all US natural gas production, or 22% of consumption.
- By 2035, shale gas is expected to account for 49% of US natural gas production.

### Prices

- We need not be resigned to constantly rising power prices. US natural gas prices are now at a 10-year low, contributing to a fall in peak wholesale electricity prices of 24-39% in the first six months of 2012. Shale gas is not the only reason for this fall, but it certainly helps.
- US natural gas prices are now de-indexed from oil prices. When oil prices began to increase again in 2009, natural gas prices continued to fall.
- Natural gas prices in the US are around a third of those in the UK.

### Industry

- US industry now benefits from some of the lowest natural gas prices in the world, leading to production moving back to the US, especially in the chemical industry.



- By 2020, up to 3.6 million new jobs could be created in the US energy sector and the wider economy from the shale energy boom, boosting GDP by 2.0-3.3%.
- In the manufacturing sector alone, shale gas could save US manufacturers up to \$11.6 billion a year in natural gas costs by 2025, while one million new manufacturing jobs could be created.

### **Exports**

- The US Energy Information Administration expects the country to become a net exporter of LNG by 2016 and a net exporter of natural gas overall by 2021.
- LNG import terminals, constructed before the shale gas boom, are now being refitted for export.

### **Environment**

- US CO<sub>2</sub> emissions have fallen by 450 million tonnes over the last five years, more than any other country.
- Between 2007 and 2011, US electricity generation from coal fell by 13%, while electricity from natural gas rose by 20% and electricity from renewables rose by 26%. Natural gas and renewables can complement each other.
- An increasing number of vehicles are switching from diesel to natural gas, which emits up to 90% fewer particulates and other pollutants, helping to improve air quality.

### **Shale oil potential**

- US unconventional production is not limited to shale gas. Shale oil production is forecast to increase more than four-fold by 2020, from 0.7 million to 3 million barrels a day. Conventional deep water production is also forecast to increase rapidly.
- Rising US production could transform global oil markets, perhaps re-localising oil prices. West Texas Intermediate and Brent Crude oil prices have already started to diverge.

## **A “GOLDEN AGE” OF GAS**

Globally, there are large reserves of unconventional natural gas; unconventional production is likely to account for an increasing share of global gas production; and natural gas will become an increasingly important energy source, as demand for coal and oil flattens out. Gas and renewables are likely to be the biggest energy growth stories over the next few decades.

### **Reserves**

- The International Energy Agency estimates technically-recoverable gas reserves at 27,000 tcf, including 12,000 tcf of unconventional reserves, of which shale accounts for 7,000 tcf. Shale reserves alone are sufficient to account for 60 years of total global natural gas production.
- These reserves are widely distributed, with almost every region of the world, apart from the Middle East, possessing large shale gas deposits.

### **Production**

There is of course a difference between technically-recoverable reserves and those that are economic to extract, but production forecasts are similarly impressive:

- According to the International Energy Agency, provided shale gas is developed at scale outside of the US, world natural gas production could rise by more than 50% by 2035, with unconventional production accounting for around a third of the total.
- In this scenario, gas accounts for 34%, and renewables 31%, of global energy demand growth.
- BP's forecasts are similar, with gas accounting for 31% of global energy demand growth by 2030, and renewables and nuclear 34%. BP projects that shale gas and coalbed methane will account for 65% of North American gas production by 2030, with major potential outside of North America as well.

## BRITAIN'S POTENTIAL

The UK may not experience a US-style shale boom, but Britain's shale resources have enormous development potential. UK shale gas could help to support a cleaner, cheaper and more secure energy system.

### LNG imports from the US – not viable

- Pacific Basin gas prices are far higher than those in the UK, so the most profitable export route for US gas will always be to Asia rather than Western Europe.
- With the costs of export (liquefaction, transportation etc) around \$4 per million British Thermal Units (MMBTU) and US natural gas prices forecast to rise to around \$5 per MMBTU, US LNG is likely to be no cheaper than the UK's own National Balancing Point gas price, which is currently around \$8-9 per MMBTU.
- The UK is therefore unlikely to be importing US gas at scale anytime soon. As a country, we have to look to our own resources.

### UK shale resources

Estimates of UK shale resources are being constantly updated, as the UK is still in the exploration stage, but the prospects look very promising indeed:

- In 2010, the British Geological Survey (BGS) estimated the UK's onshore shale reserves at 5.3 tcf. The BGS is set to revise its onshore data substantially upwards later this year, possibly to as high as 200 tcf.



Nexen's two shale gas rigs at Dilly Creek in the Horn River Basin, British Columbia in Canada.

- The exploration companies themselves have far higher estimates from their onshore fields: Cuadrilla – 200 tcf; Dart Energy – 66 tcf; Eden Energy – 12.8 tcf; IGas – 10 tcf. This adds up to around 300 tcf in total.
- Offshore reserves could be far higher still. The BGS has said that they could be 5-10 times larger than onshore reserves – potentially up to 1,000 tcf. Offshore reserves are, however, far harder to extract.

### Possible recovery rates

- Recovery rates do vary by location and geology. In the US, shale gas recovery rates average 18%. There may be reasons to expect recovery rates in the UK to be lower, stricter planning requirements being one of them, although technological improvements are increasing the proportion of reserves that are economic to extract.
- According to Cuadrilla, the Bowland Shale is around 10 times thicker than leading US shale gas plays – although it is still early days, extraction in the UK could potentially be quite rapid.

### An economic boost

The UK is experiencing and will experience a number of problems with its energy supply:

- Gas production from the UK Continental Shelf has declined rapidly over the last decade, from 103 to 41 million tonnes of oil equivalent per annum. By 2030, production is expected to fall to just 18 million tonnes of oil equivalent. The number of people employed directly and indirectly by the oil and gas industry, currently 440,000, will therefore fall.
- Gas imports are rising rapidly. In 2000, net gas exports equalled 13% of consumption. In 2011, net imports equalled 49% of consumption. By 2030, imports are projected to increase to 74% of consumption.
- The UK's energy and climate policies are adding more to industrial electricity prices than comparable programmes in competitor countries, putting UK industry at a disadvantage and making a rebalancing of the economy more difficult. By 2020, US policies are projected to add nothing to industrial electricity prices, Chinese policies to add £10 per MWh, German policies to add £17 per MWh and British policies to add £28 per MWh, of which £20 per MWh will be accounted for by the costs of the renewables programme.
- The proportion of households in fuel poverty has risen from 6% in 2003 to 16% in 2010. So far, most of the rise has been due to the impact of higher gas prices, but the latest DECC projections show that renewables subsidies and other climate and energy policies are set to add 7% to domestic gas prices and 27% to domestic electricity prices by 2020. Improved energy efficiency may reduce the bill impact, but fuel poverty could rise still further.
- By 2020, the UK is set to lose around 20GW of coal and nuclear generation, around a fifth of total electricity generating capacity. A new nuclear programme is crucial, but will not achieve scale until some time after 2020, while CCS, which is vital for coal generation to continue, is not yet proven commercially.

Developing UK shale does not solve all of these energy problems on its own, but it could make a major contribution to mitigating their impact, providing a major economic boost:

- In the US, in only a decade, shale gas production increased from virtually zero to sufficient to meet over a fifth (22%) of US natural gas consumption. In the US, shale gas recovery rates average 18%.



- If, over the next 10 years, the UK is roughly half as successful on both measures as the US has been over the last 10 years, it would mean that shale gas could account for around 10% of 2011 UK gas consumption, and that around 10% of the UK's onshore shale reserves prove to be economic to extract.

If, in this way, the UK is half as successful at developing shale gas as the US, the benefits could be enormous. Note that the following are very indicative calculations, designed to provide an appreciation of the big picture surrounding UK shale:

- In 2011, the UK consumed 2.9 tcf of gas. 10% of 2011 UK gas demand is therefore 0.29 tcf. If 10% of the 300 tcf of onshore reserves estimated by the exploration companies were economic to extract, then 30 tcf would be sufficient to meet 10% of current UK gas demand for 103 years.
- 10% of 2011 UK gas demand is equal to 8 million tonnes of oil equivalent, 8% of total UK oil and gas production in 2011. The UK oil and gas industry provides direct and indirect employment for 440,000 people. Assuming that jobs are directly proportional to production, then an extra 8% of 2011 production would generate 35,000 extra jobs, helping to offset job losses from a decline in conventional oil and gas production in the UK.
- Between 2011 and 2022, conventional UK gas production is forecast to decline by 13 million tonnes of oil equivalent. If shale production rose to 8 million tonnes of oil equivalent, it would offset 60% of the projected fall in conventional production.
- 8 million tonnes of oil equivalent also represents 20% of projected UK gas imports in 2022. This would be sufficient to keep gas imports at the 2011 level of 49% of demand, rather than imports rising to a projected 59% of demand.

## THE ENVIRONMENT

It is impossible to talk about shale gas without discussing the environmental concerns. Using gas in place of coal for electricity and in place of petrol and diesel for road transport would lead to big improvements in air quality and a reduction in CO<sub>2</sub> emissions. The process of extracting shale gas, however, has been heavily criticised on environmental grounds. But if carried out carefully and under thorough regulation, hydraulic fracturing ("fracking") is no more dangerous than conventional hydrocarbon extraction.

### Air quality and carbon emissions

- In 2011, the UK used 42 million tonnes of coal in electricity generation, emitting around 90 million tonnes of CO<sub>2</sub>. Were this to be replaced with gas, which emits around half as much carbon, the UK could save around 45 million tonnes of CO<sub>2</sub>, around 8% of the 2011 total. Although UK shale is unlikely to be sufficient to replace all coal-fired generation, it could make a major contribution to decarbonisation in its own right, as well as supporting the further development of renewables.
- According to DECC's projections, around 25GW of renewable generation will be added to the grid by 2020, much of which will be in the form of intermittent sources such as wind and solar. UK shale gas can support this development, ensuring that the lights stay on when the wind isn't blowing and the sun isn't shining.
- Natural gas emits far fewer particulates and other pollutants than coal and diesel. Using natural gas in place of coal for electricity generation and switching over buses and other vehicles to natural gas could reduce the 29,000 annual deaths from poor air quality in the UK.

## Hydraulic fracturing

- There are environmental issues associated with hydraulic fracturing. They are not to be taken lightly, but they must be put into perspective. For instance, chemicals used in the fracking fluid have many industrial and household uses, and in these contexts also need to be disposed of properly. In the last 50 days, the UK experienced three earthquakes as large or larger than the bigger of the two earthquakes caused by Cuadrilla in 2011. None of them caused any damage.
- Good practice can significantly reduce many of these environmental risks. Multiple casing of wells ensures that fracking fluid cannot enter the water table, while proper site construction and disposal of fracking fluid will ensure that there are no surface leaks. Real-time seismic monitoring minimises earthquake risks.
- The UK has numerous regulatory bodies – including DECC, the Environment Agency and the Health and Safety Executive – and regulations – including the Environmental Permitting Regulations, the Mining Waste Directive, the Water Framework Directive, the Water Resources Act, Borehole regulations and Petroleum Licenses – to monitor and oversee the drilling process.
- Several scientific reports on safety in the UK have also been published, including by the Energy and Climate Change Select Committee, DECC, and the Royal Society and Royal Academy of Engineering. The findings of these reports include:
  - Carried out properly and under strict regulation, hydraulic fracturing is safe;
  - Problems that have occurred have generally been due to non-compliance with industry standards, rather than the hydraulic fracturing process itself;
  - Environmental issues are generally little different from those of conventional hydrocarbon extraction;
  - Earthquakes caused by hydraulic fracturing are no larger than those that have been caused by coal mining for years.
- In the US, over 20,000 shale wells have been drilled. The US Environmental Protection Agency is currently undertaking a major study on the safety of hydraulic fracturing, with a preliminary report due later this year. According to a study by the Massachusetts Institute of Technology, “the environmental record of shale gas development is for the most part a good one.” Although there have been problems at a small number of wells, these are generally due to poor practice, rather than the nature of the process itself. The UK, of course, has the opportunity to learn from mistakes made in the US.
- The International Energy Agency has also set out a number of “golden rules” for unconventional gas exploration to address environmental concerns. Following these golden rules would add at least 7% to costs, but would make significant shale gas development outside of North America far more acceptable.
- According to the major insurance broker Willis, insurers are happy to provide cover to shale wells, provided good practice is followed.
- According to evidence given to the Energy and Climate Change Select Committee by the British Geological Survey, extracting shale gas is no more dangerous than any other form of hydrocarbon extraction.
- Hydraulic fracturing is improving as an extraction technique – waterless fracking, which has great potential, reduces consumption at the wellsite and reduces the risk of ground water contamination.
- The IoD’s view is that the evidence shows that the environmental risks of hydraulic fracturing should be placed alongside those of conventional hydrocarbon extraction. The risks of fracking should not be put in a class of their own.

## IoD MEMBER VIEWS

Shale gas and the technique used to extract it attract strong views on either side of the debate. 1,095 IoD members were polled on the subject in April 2012. Their views are not unanimous, but are positive overall:

- 58% think that extensive development of the UK's shale reserves would have a positive impact on British businesses, compared to just 7% believing that it would have a negative impact.
- Just over a third (36%) thinks that the risks of hydraulic fracturing are significant. By comparison, 17% think that the risks are insignificant, 27% think that they are neither significant nor insignificant and 19% don't know.
- Almost half (48%) agree that the benefits outweigh the risks, compared to 18% who think that the risks outweigh the benefits.
- Opinion is similar across the regions. In all regions of the UK, more than 50% of members think that shale gas will have a positive impact on business; less than 40% think that the risks of fracking are significant; and at least 45% think that the benefits outweigh the risks.

Overall, IoD members are in favour of careful, well-regulated shale gas development in the UK.

# Introduction:

## Why Britain needs shale

The Department of Energy and Climate Change (DECC) will shortly be publishing a gas generation strategy. It comes at a vital time, when the UK could do with some good energy news. North Sea production is declining; our mostly foreign-owned utilities are over-indebted, putting a major hurdle in the way of a new nuclear programme; fuel poverty is a serious worry; the renewables programme is adding far more to industrial energy costs than comparable programmes in our competitor countries; and there is still a major question mark over carbon capture and storage, without which coal has little future.

Gas will no doubt play a major role, not just as a bridging fuel or a back-up to wind, but in its own right, providing relatively clean, cheap and secure energy. Globally, we are poised to enter what the International Energy Agency (IEA) has described as a "golden age of gas".<sup>1</sup> But that may come as little comfort to the UK, if it has to import the vast bulk of its supply.

Fortunately, Britain has huge quantities of gas still to be tapped. And advances in shale extraction technology are bringing these resources closer by the day. Shale gas has the potential to make up for a good part of falling North Sea gas production, generating local jobs, keeping energy prices down, bringing in tax revenues and cutting carbon and improving air quality by replacing coal in electricity generation.

The UK has a massive opportunity, if the Government chooses to embrace it.

<sup>1</sup> International Energy Agency, Golden Rules for a Golden Age of Gas, 2012  
[http://www.worldenergyoutlook.org/media/weowebsite/2012/goldenrules/WE02012\\_GoldenRulesReport.pdf](http://www.worldenergyoutlook.org/media/weowebsite/2012/goldenrules/WE02012_GoldenRulesReport.pdf)

# 1. The US shale boom – a trailblazer for the world

The UK is not the US, but there can be no understanding of the shale gas opportunity without a thorough grasp of how unconventional production has transformed America and trailblazed a path for the rest of the world.

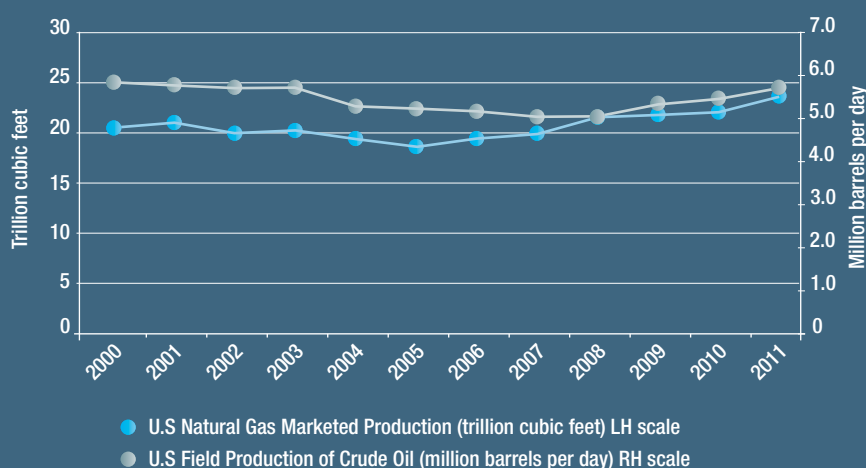
## PRODUCTION

US gas and oil production has increased dramatically in the last few years, putting into reverse its previous decline:

- After several years of relatively flat production that reached a low in 2005, US natural gas production has increased by 28%;
- Since its 2008 low, US crude oil production has increased by 15%.

CHART 1.1

US crude oil and natural gas production, 2000-2011

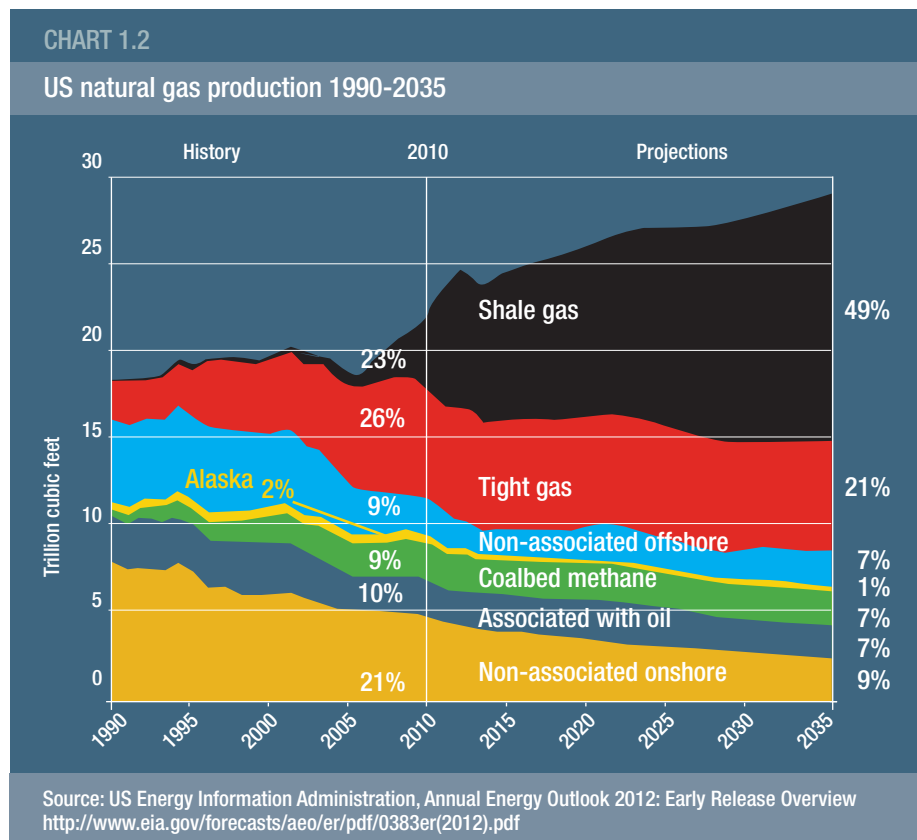


Sources: US Energy Information Administration, US Natural Gas Marketed Production <http://www.eia.gov/dnav/ng/hist/n9050us2a.htm> and US Field Production of Crude Oil <http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=MCRFPUS2&f=A>



We will return to the oil story later, but the increase in US natural gas production has been largely accounted for by shale:

- In 2000, shale gas production, at 0.39 trillion cubic feet (tcf)<sup>2</sup> accounted for less than 2% of total US natural gas production;
- In 2010, shale gas production had increased to around 5 tcf,<sup>3</sup> accounting for 23% of all US natural gas production, or 22% of consumption.<sup>4</sup>
- By 2035, shale gas is projected to account for 49% of US natural gas production, even as total production rises towards 30 tcf.



## PRICES

Over the last few years, natural gas prices have fallen rapidly as Chart 1.3 shows.

The recent decline in natural gas prices has been due to a number of reasons. Other than the staggering increase of shale gas production from almost zero to nearly 25% of all US gas in under a decade, there were other more subtle changes at work. A crucial part of this is a highly liquid trading hub – Henry Hub – which is located at the crossover point of many major pipelines governing gas markets on the East Coast of America. Combined with extensive gas pipelines that brought the gas in quantity to market fast, this sophisticated market accelerated the de-indexation of oil and gas prices.

Were oil and gas to be priced purely according to their energy content, then oil would cost six times as much as gas. And as Chart 1.4 shows, historically, prices moved largely in line because both gas and oil were somewhat interchangeable products. The shock was that when oil prices started going up again in 2009, US Henry Hub prices

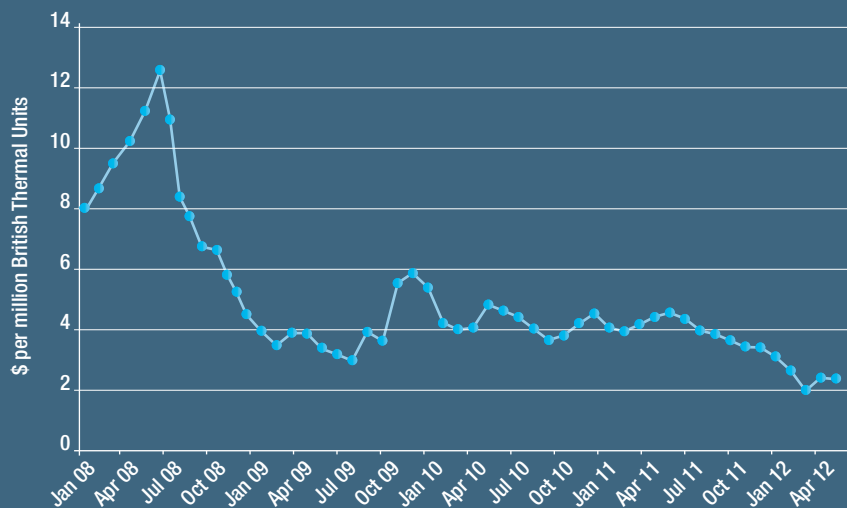
<sup>2</sup> US Energy Information Administration, Shale gas is a global phenomenon, 5 April 2011 <http://www.eia.gov/todayinenergy/detail.cfm?id=811>

<sup>3</sup> US Energy Information Administration, Shale Gas Production [http://www.eia.gov/dnav/ng/ng\\_prod\\_shalegas\\_s1\\_a.htm](http://www.eia.gov/dnav/ng/ng_prod_shalegas_s1_a.htm)

<sup>4</sup> US Energy Information Administration, US Natural Gas Consumption [http://www.eia.gov/dnav/ng/ng\\_cons\\_sum\\_dcu\\_nus\\_a.htm](http://www.eia.gov/dnav/ng/ng_cons_sum_dcu_nus_a.htm)

CHART 1.3

Henry Hub Gulf Coast natural gas spot price

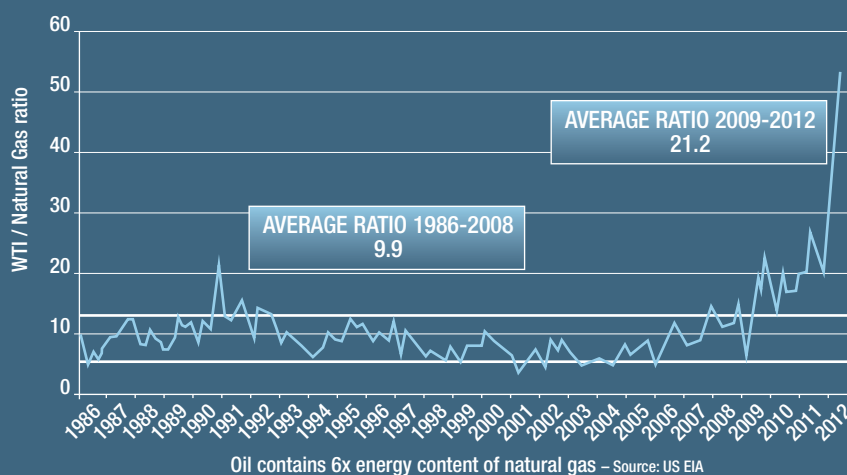


Source: US Energy Information Administration, Natural gas spot and futures prices  
<http://www.eia.gov/naturalgas/data.cfm#prices>

started going down. At one point, oil became an amazing 50 times more expensive than natural gas. All over America, oil-linked gas contracts have been torn up.

CHART 1.4

US oil/gas price ratio, 1986-2012



Source: ICIS.com, cited in SeekingAlpha.com, 12 April 2012  
<http://seekingalpha.com/article/492991-oil-and-natural-gas-ratio-explodes-to-52-1>

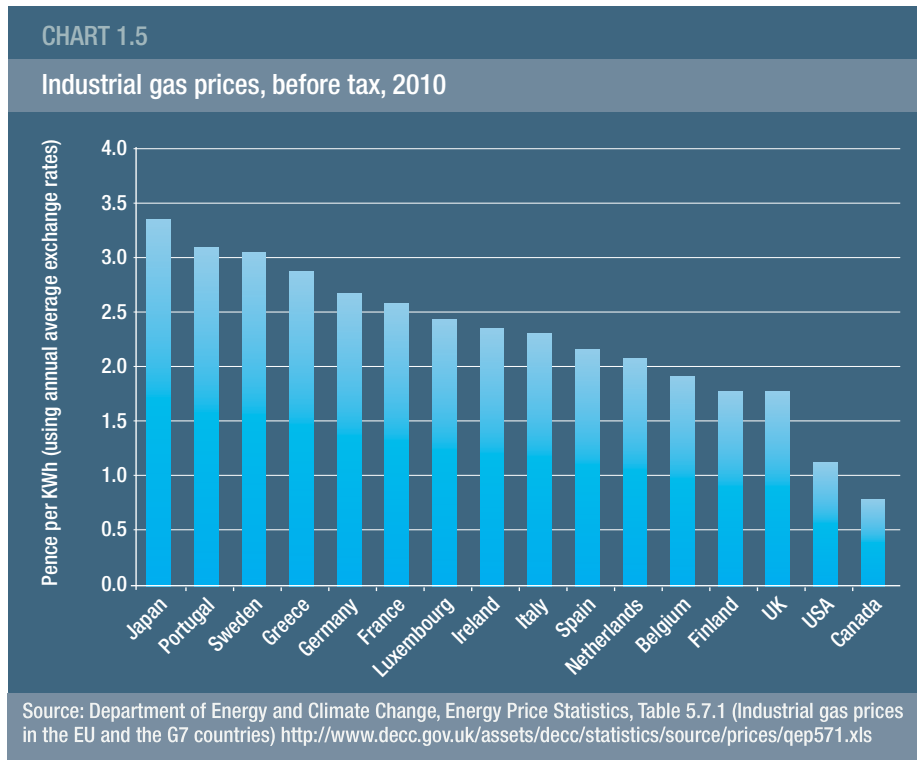
US price reductions are not limited to natural gas. To the extent that gas is used as an electricity source, cheaper natural gas will also feed through to electricity prices. Between January and June of this year, average peak wholesale electricity prices fell by 24-39%, at the same time as natural gas spot prices fell to a decade-low.<sup>5</sup> Shale gas is not the only reason for this fall, but it certainly helps.

<sup>5</sup> Gas to Power Journal, 13 August 2012 <http://gastopowerjournal.com/index.php/markets/item/751-us-power-prices-plunge-up-to-39-in-first-half-of-2012-as-gas-prices-drop-to-10-year-low>

## INDUSTRY

The energy sector does create a significant number of jobs, but its main role is to support activity and jobs in the rest of the economy. The extraction of shale gas and oil has added huge economic value much further downstream in a number of ways.

Overall, US industry now benefits from some of the lowest natural gas prices in the world.



The chemical industry, which can now boast among the lowest natural gas feedstock costs in the world, has been at the forefront of US re-industrialisation. Ethylene production, a mainstay of the chemical industry for use in many derivative products, depends on a feedstock of either naphtha from crude oil or ethane from natural gas. American shale gas is particularly rich in ethane, and the fall in US natural gas prices has unleashed a huge cost advantage for the petrochemical industry, which can now produce ethylene at a third of the price of Western Europe or Asia, as shown in Chart 1.6.

The American Chemistry Council projects that a 25% boost in ethane supplies (from shale gas) could generate 17,000 jobs in the chemical industry, 395,000 jobs outside the chemical industry, \$132 billion in US economic output and \$4.4 billion in annual tax revenue.<sup>6</sup>

But the benefits of shale gas are not restricted to ethylene production. Methanol plants are moving back to the US or being restarted and a huge boost has been given to ammonia-based fertiliser production – 85% of the cost of producing ammonia is dependent on natural gas prices.<sup>7</sup>

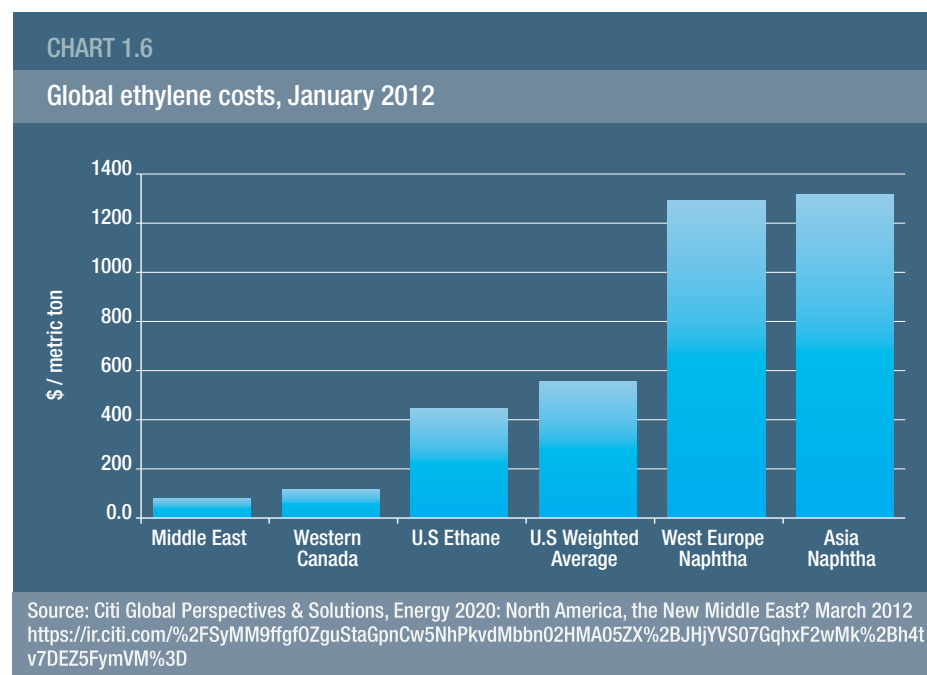
In a recent report, Citigroup concluded that the benefits of increased oil and gas production in North America would be huge:

*“We estimate that the cumulative impact of new production, reduced consumption and associated activity may increase real GDP by 2.0 to 3.3%, or \$370-\$624 billion (in 2005 \$)*

<sup>6</sup> American Chemistry Council, Shale Gas and New Petrochemicals Investment: Benefits for the Economy, Jobs, and US Manufacturing, March 2011 <http://americanchemistry.com/ACC-Shale-Report>

<sup>7</sup> Citi Global Perspectives & Solutions, Energy 2020: North America, the New Middle East? March 2012 <https://ir.citi.com/%2FSyMM9ffgfOZguStaGpnCw5NhPkvdMbbn02HMA05ZX%2BJHjYVS07GqhxF2wMk%2Bh4tv7DEZ5FymVM%3D>

respectively. \$274 billion of this comes directly from the output of new hydrocarbon production alone, while the rest is generated by multiplier effects as the surge in economic activity drives higher wealth, spending, consumption and investment effects that ripple through the economy. This potential re-industrialization of the US economy is both profound and timely, occurring as the US struggles to shake off the lingering effects of the 2008 financial crisis.”<sup>8</sup>



Citigroup anticipate that, in the best scenario, 3.6 million jobs could be created across a very wide range of sectors as a result of increased oil and gas production and lower prices, as shown in Table 1.1.

A recent PwC report came to a similar conclusion, pointing out that:

*“In 2011, 17 chemical, metal and industrial manufacturers commented in SEC filings that shale gas developments drove demand for their products, compared to none in 2008.”*

The report also projected that continued shale gas development could cut prices for industry and increase the number of manufacturing jobs:

- Lower feedstock and energy costs could help US manufacturers reduce natural gas expenses by up to \$11.6 billion annually by 2025;
- One million new manufacturing jobs could be created by 2025 through more affordable energy and demand for products used to extract shale gas.<sup>9</sup>

## FROM IMPORTS TO EXPORTS

Received opinion was convinced that America would become a gas-importing nation at the turn of the century and possibly \$100 billion was spent on constructing LNG import terminals with regasification plants. But the rapid expansion of US shale gas production has rendered many of these investments redundant.

A new economic avenue is, however, opening up – the export of surplus gas via LNG. This requires the construction of liquefaction plants for the gas to be offloaded to the

<sup>8</sup> Citi Global Perspectives & Solutions, Energy 2020: North America, the New Middle East? March 2012

<sup>9</sup> PricewaterhouseCoopers, Shale Gas: A renaissance in US manufacturing, December 2011  
[http://www.pwc.com/en\\_US/us/industrial-products/assets/pwc-shale-gas-us-manufacturing-renaissance.pdf](http://www.pwc.com/en_US/us/industrial-products/assets/pwc-shale-gas-us-manufacturing-renaissance.pdf)

TABLE 1.1

## Estimated breakdown of US jobs created in 2020

Employment sector	Thousands of jobs
<b>TOTAL</b>	<b>3,577</b>
Total Industrial	2,257
Total non manufacturing	1,109
Oil and gas extraction	549
Other non manufacturing	561
Total manufacturing	1,148
Petroleum refineries	24
Paper products	56
Chemicals	53
Stone, clay and glass	40
Primary metals	17
Iron and steel mills and products	13
Alumina and aluminium products	4
Fabricated metals	178
Machinery	88
Computers and electronics	55
Transportation equipment	108
Other manufacturing	528
Non-industrial non-agricultural goods and services	1,301
Construction	69
Utilities	5
Wholesale trade	58
Retail trade	153
Transportation and warehousing	47
Information	27
Financial activities	79
Professional and business services	193
Educational services	37
Health care and social assistance	208
Leisure and hospitality	135
Other services	65
Federal government	24
State and local government	199
Agriculture, forestry, fishing, hunting	19
Agriculture salaried	12
Agriculture self-employed	7

Source: Citi Global Perspectives & Solutions, Energy 2020: North America, the New Middle East? March 2012, Figure 73  
<https://ir.citi.com/%2FSyMM9ffgf0ZguStaGpnCw5NhPkvdMbbn02HMA05ZX%2BJHjYVS07GqhxwF2wMk%2Bh4tv7DEZ5FymVM%3D>



LNG tankers and takes a lot of time and money, but export permission has recently been granted.

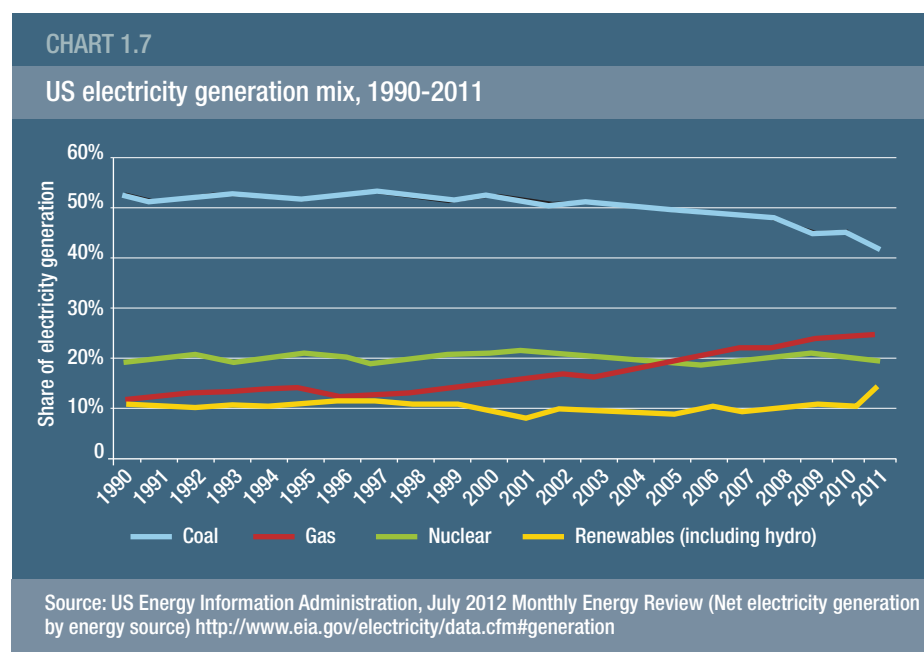
Leading the charge to export has been Cheniere's regasification – fast becoming a liquefaction – plant at Sabine Pass. The target market is very much the Pacific Basin, where gas prices can be as high as \$16 per million British Thermal Units (MMBTU). The costs of liquefaction, transport and regasification are estimated to be between \$4 and \$7, so this represents a very profitable trade if US natural gas prices remain low.<sup>10</sup>

Forecasts for future exports are enormous. Cheniere alone has agreements with four global buyers to export 2 billion cubic feet a day for 20 years – equivalent to over 0.7 tcf a year.<sup>11</sup> Meanwhile nine other companies, including Freeport LNG, Gulf Coast LNG and Cameron LNG, are seeking approval to export gas. According to the US Energy Information Administration, the capacity sum of potential exports from these nine companies and Cheniere amounts to 14 billion cubic feet a day or over 5 tcf a year<sup>12</sup> – about 1.5 times total UK annual gas consumption.

The US is expected to become an LNG net exporter in 2016 and a net exporter of natural gas overall in 2021.<sup>13</sup>

## ENVIRONMENT

According to the International Energy Agency (IEA), US CO<sub>2</sub> emissions have fallen by 450 million tonnes over the last 5 years, more than any other country.<sup>14</sup> There are



several reasons for this, including the recession, more efficient technology, increasing renewable generation, and, importantly, the displacement of coal by gas for electricity generation:

- **Between 2007 and 2011, electricity generation from coal fell by 13%, but over the same period electricity generation from natural gas rose by 20%. Electricity generation from renewables (including hydro) rose by 26%, but from a smaller base.**

<sup>10</sup> The Economist, LNG: A liquid market, 14 July 2012 <http://www.economist.com/node/21558456>

<sup>11</sup> Wall Street Journal, 9 August 2012 <http://online.wsj.com/article/SB10000872396390443991704577579631755572726.html>

<sup>12</sup> US Energy Information Administration, Project sponsors are seeking Federal approval to export domestic natural gas, 24 April 2012 <http://www.eia.gov/todayinenergy/detail.cfm?id=5970>

<sup>13</sup> US Energy Information Administration, Annual Energy Outlook 2012: Early Release Overview, p.2 [http://www.eia.gov/forecasts/aeo/er/pdf/0383er\(2012\).pdf](http://www.eia.gov/forecasts/aeo/er/pdf/0383er(2012).pdf)

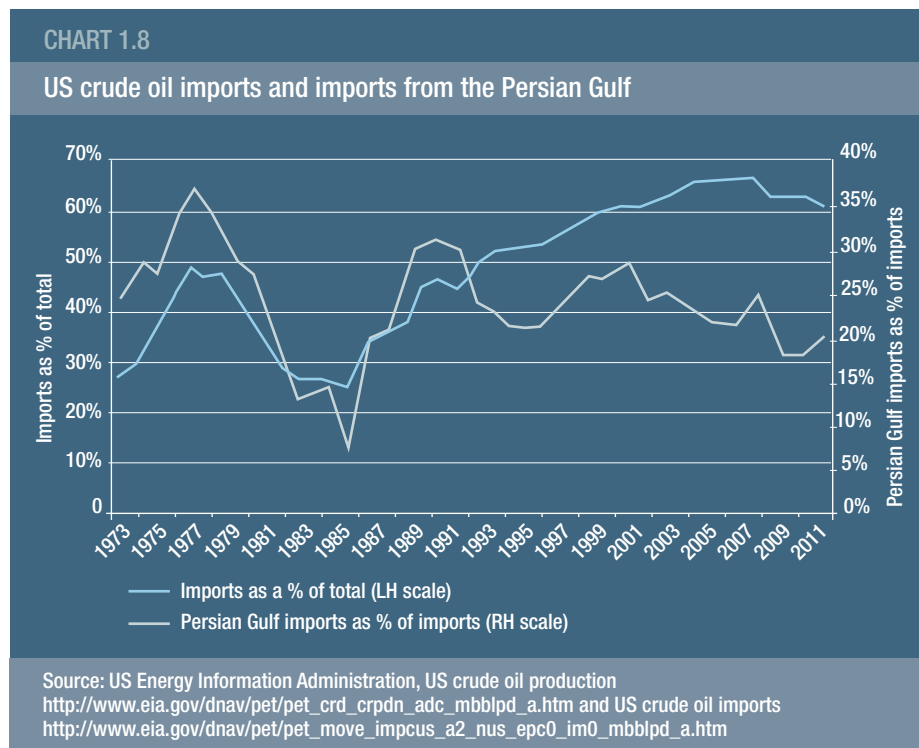
<sup>14</sup> Financial Times, 23 May 2012 <http://www.ft.com/cms/s/0/3aa19200-a4eb-11e1-b421-00144feabdc0.html#axzz1vaeSVRF5>

- Over the same period, as a share of US electricity, coal generation fell from 49% to 42%, while natural gas generation rose from 22% to 25% and renewable generation rose from 9% to 13%.
- As Chart 1.7 shows, the increasing importance of natural gas in electricity generation is a long-running trend, although the fall in coal's importance has been particularly rapid in the last few years. Renewable generation has also increased sharply since 2007.

In addition to electricity generation, an increasing number of vehicles in the US are switching over from petrol and diesel to natural gas – a cheap way to reduce not only CO<sub>2</sub> but particulate matter, carbon monoxide, nitrogen oxides and other air pollutants.<sup>15</sup> Today, nearly 15% of public transport buses run on natural gas,<sup>16</sup> while heavy goods vehicles are also starting to switch over.

## NOT JUST SHALE GAS

Since the oil shock of the 1970s, Americans have become hypersensitive to the security impact of imported energy. Every President since has talked of reducing imported oil, especially from the Middle East. The facts never quite fitted the resource nationalism argument however. As American oil production declined, imports rose, but they did diversify, with Persian Gulf imports reducing steadily as a share of total imports.



Today, the US has a diverse and relatively secure supply of crude oil, with well over two thirds coming from the American continent:

- In 2011, 38% of US crude oil was produced in the US;
- 23% came from elsewhere in North America (Canada and Mexico);

<sup>15</sup> Compared to vehicles powered by petrol or diesel, natural gas vehicles produce around 25% less CO<sub>2</sub> and up to 90% fewer smog-producing pollutants. See, for example <http://www.anga.us/issues--policy/transportation/clean-air>

<sup>16</sup> See <http://www.cngnow.com/vehicles/pages/information.aspx>

TABLE 1.2

## US production of liquid fuels – projections

m b/d	2011A	2015E	2020E
Deepwater	1.3	2.0	3.8
Shale oil	0.7	2.1	3.0
Alaska	0.6	0.7	1.1
Other conventional/heavy	3.2	2.7	2.3
<b>Oil</b>	<b>5.8</b>	<b>7.5</b>	<b>10.2</b>
NGLs	2.3	3.0	3.8
<b>Total petroleum</b>	<b>8.1</b>	<b>10.5</b>	<b>14.1</b>
Biofuels	0.9	1.1	1.5
<i>Mandated</i>	<i>0.9</i>	<i>1.3</i>	<i>2.0</i>
<b>TOTAL LIQUIDS</b>	<b>9.0</b>	<b>11.6</b>	<b>15.6</b>

Source: Citi Global Perspectives & Solutions, Energy 2020: North America, the New Middle East? March 2012, Figure 11  
<https://ir.citi.com/%2FSyMM9ffgf0ZguStaGpnCw5NhPkvdMbbn02HMA05ZX%2BJHjYVS07GqhxF2wMk%2Bh4tv7DEZ5FymVM%3D>

- 10% came from Venezuela, Colombia and Brazil (the three key South American producers).
- A further 8% came from Nigeria and Angola, the main African producers;
- By contrast, only 13% came from the Persian Gulf.<sup>17</sup>

And, although the US still imports nearly 9 million barrels of crude oil a day, it is now a net exporter of petroleum products for the first time. In 2011, net exports of petroleum products averaged 439,000 barrels a day.<sup>18</sup>

Up until this point, we have concentrated on the undeniable impact of shale gas. But a possibly more disruptive change is around the corner. Should oil prices remain above \$50 a barrel, widely thought to be the break-even price for US shale oil,<sup>19</sup> then domestic production will ramp up considerably.

- According to Citi, US oil production could increase from 5.8 million barrels a day in 2011 to 10.2 million by 2020, surpassing its peak in the 1970s;
- Shale oil production could increase more than four-fold from 0.7 million to 3 million barrels a day;
- Combined with increased conventional and deep water oil production, and expanding natural gas liquids production, total production of liquid fuels could rise by over 70% by 2020.

To say that this would be a massive change would be an understatement. It would effectively re-localise oil market pricing and signal the end of OPEC's ability to keep oil prices high. We have already seen this start to happen with the growing difference

<sup>17</sup> US Energy Information Administration, US crude oil production [http://www.eia.gov/dnav/pet/pet\\_crd\\_crpdn\\_adc\\_mbbldpd\\_a.htm](http://www.eia.gov/dnav/pet/pet_crd_crpdn_adc_mbbldpd_a.htm) and US crude oil imports [http://www.eia.gov/dnav/pet/pet\\_move\\_impdcus\\_a2\\_nus\\_epc0\\_im0\\_mbbldpd\\_a.htm](http://www.eia.gov/dnav/pet/pet_move_impdcus_a2_nus_epc0_im0_mbbldpd_a.htm)

<sup>18</sup> US Energy Information Administration, US net imports of petroleum products [http://www.eia.gov/dnav/pet/pet\\_move\\_net\\_i\\_a\\_EPPO\\_IMN\\_mbbldpd\\_a.htm](http://www.eia.gov/dnav/pet/pet_move_net_i_a_EPPO_IMN_mbbldpd_a.htm)

<sup>19</sup> See <http://www.theneweconomy.com/energy/non-renewables/oil-bonanza-after-shale-gas-boom>

between WTI (West Texas Intermediate) and Brent Crude oil prices – this is perhaps not dissimilar to the de-indexation of Henry Hub gas prices from the oil price.

The paradox, however, is that if oil prices were to remain lowish throughout the 2010s – from \$50-\$75, then many OPEC regimes could fall as they have progressively sought to balance their budgets at higher and higher oil price levels.

## 2. A “Golden Age” of gas

The recent development of shale gas has been undeniably positive for the US. Looking forward, US shale gas production is set to continue its dramatic rise, while US oil production is also likely to continue to increase, perhaps even surpassing its peak in the 1970s.

But it is not just the US. Shale and other unconventional gas resources have enormous global potential.

### RESERVES

Estimates of natural gas reserves are constantly being updated. At the time of writing, the most recent global estimates were published by the International Energy Agency (IEA):<sup>20</sup>

- In 2010, global natural gas production stood at 116 tcf, of which 16 tcf (14%) came from unconventional sources.
- At end-2011, world technically-recoverable gas reserves stood at 27,000 tcf – enough to supply the world for more than 200 years at current production levels.
- World reserves include 12,000 tcf of unconventional gas, of which shale accounts for 7,000 tcf. Shale reserves alone are sufficient to account for 60 years of total global natural gas production.

As Table 2.1 shows, these reserves are widely distributed.

TABLE 2.1

#### Remaining technically-recoverable natural gas resources at end-2011

Trillion cubic feet	Total reserves	Of which conventional reserves	Of which unconventional reserves	Of which unconventional reserves	Of which unconventional reserves	Of which unconventional reserves
Eastern Europe/Eurasia	6,145	4,626	1,519	424	353	706
Middle East	4,838	4,414	424	141	283	0
Asia/Pacific	4,520	1,236	3,284	2,013	706	565
OECD Americas	4,308	1,589	2,719	1,978	424	318
Africa	2,613	1,307	1,307	1,059	247	0
Latin America	2,507	812	1,695	1,165	530	0
OECD Europe	1,978	848	742	565	106	71
World	26,557	14,868	11,689	7,346	2,684	1,660

Source: International Energy Agency, Golden Rules for a Golden Age of Gas, 2012, Table 2.1 (converted to trillion cubic feet)  
[http://www.worldenergyoutlook.org/media/weowebsite/2012/goldenrules/WE02012\\_GoldenRulesReport.pdf](http://www.worldenergyoutlook.org/media/weowebsite/2012/goldenrules/WE02012_GoldenRulesReport.pdf)

<sup>20</sup> International Energy Agency, Golden Rules for a Golden Age of Gas, 2012, Tables 2.1 and 2.6 (converted to trillion cubic feet)  
[http://www.worldenergyoutlook.org/media/weowebsite/2012/goldenrules/WE02012\\_GoldenRulesReport.pdf](http://www.worldenergyoutlook.org/media/weowebsite/2012/goldenrules/WE02012_GoldenRulesReport.pdf)



There is of course a difference between technically-recoverable reserves and those that are economic to extract – and the latter will always be smaller than the former. The US Energy Information Administration (EIA) has revised downwards its estimate of technically recoverable reserves in the US, but at the same time it revised upwards the level of proved natural gas reserves:

- In 2011, the EIA estimated that the U.S. had 827 tcf of technically recoverable shale gas reserves, but has now revised that figure downwards to 482 tcf;<sup>21</sup>
- At the same time, the most recent data shows that proved reserves of natural gas have increased from 284 tcf at the end of 2009 to 318 tcf at the end of 2010;<sup>22</sup>
- This increase is entirely accounted for by increases to proved reserves of shale gas, which have risen from 61 to 97 tcf over a single year.<sup>23</sup>

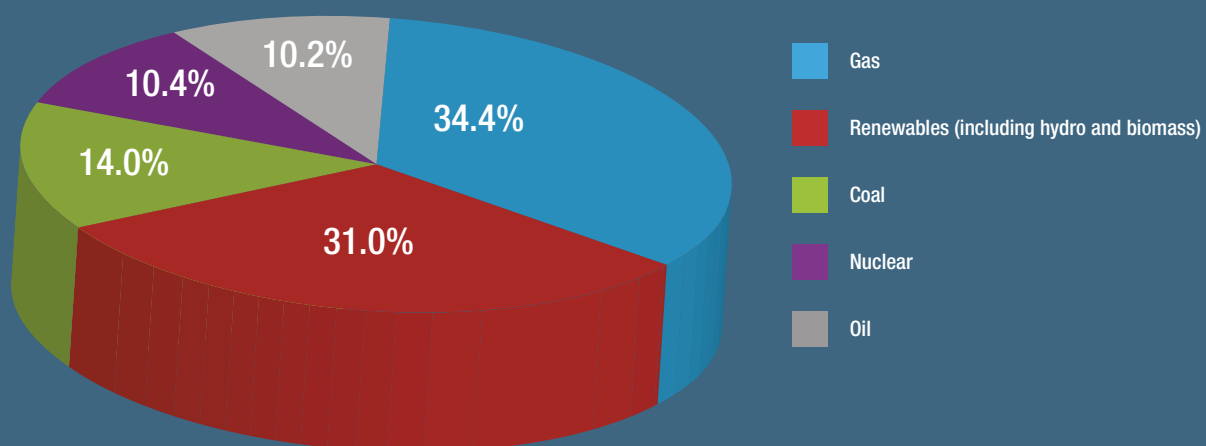
## PRODUCTION

Provided that enough countries agree to allow shale gas development to proceed, and provided that extraction is undertaken in an environmentally responsible manner, the IEA sees gas playing an increasingly important role in the world's energy mix:

- By 2035, world natural gas production could increase from 116 to 181 tcf, with 58 tcf (32%) coming from unconventional sources;
- Natural gas could increase as a share of world primary energy demand from 21% in 2010 to 25% in 2035;
- In this “Golden Rules” scenario, while demand for all energy sources increases, gas and renewables take an increasing share, with coal and oil diminishing in significance. In this scenario one third of the increase in primary energy demand is accounted for by gas, and a further one third by renewables (including hydro and biomass).<sup>24</sup>

CHART 2.1

Share of increase in global primary energy demand, 2010-2035



Source: International Energy Agency, Golden Rules for a Golden Age of Gas, 2012, Table 2.5  
[http://www.worldenergyoutlook.org/media/weowebsite/2012/goldenrules/WE02012\\_GoldenRulesReport.pdf](http://www.worldenergyoutlook.org/media/weowebsite/2012/goldenrules/WE02012_GoldenRulesReport.pdf)

<sup>21</sup> US Energy Information Administration, Annual Energy Outlook 2011 and Annual Energy Outlook 2012 <http://www.eia.gov/forecasts/aeo/>

<sup>22</sup> US Energy Information Administration, US Crude Oil, Natural Gas, and NG Liquids Proved Reserves, August 2012 <http://www.eia.gov/naturalgas/crudeoilreserves/>

<sup>23</sup> Ibid.

<sup>24</sup> International Energy Agency, Golden Rules for a Golden Age of Gas, 2012, Tables 2.5 and 2.6 (converted to trillion cubic feet)  
[http://www.worldenergyoutlook.org/media/weowebsite/2012/goldenrules/WE02012\\_GoldenRulesReport.pdf](http://www.worldenergyoutlook.org/media/weowebsite/2012/goldenrules/WE02012_GoldenRulesReport.pdf)

BP's most recent *Energy Outlook 2030* report made a similar set of projections:

- Natural gas accounts for 31% of global energy growth between 2010 and 2030, while renewables (including hydro) and nuclear account for 34% of demand growth;
- Natural gas will account for 13% of transport energy demand growth over the same period, compared to electricity accounting for only 2% of growth;
- Shale gas and coalbed methane will account for 65% of North American gas production by 2030;
- Outside of North America, unconventional gas production is likely to play a growing role, although major production is unlikely to take place in Europe before 2020.<sup>25</sup>

The basic story, then, is quite straightforward. There are large global reserves of unconventional natural gas; unconventional production is likely to account for an increasing share of global gas production; and natural gas will become an increasingly important energy source, as demand for coal and oil starts to flatten out. Gas and renewables are likely to be the biggest energy growth stories over the next few decades

<sup>25</sup> BP, *Energy Outlook 2030*, January 2012  
[http://www.bp.com/liveassets/bp\\_internet/globalbp/STAGING/global\\_assets/downloads/O/2012\\_2030\\_energy\\_outlook\\_booklet.pdf](http://www.bp.com/liveassets/bp_internet/globalbp/STAGING/global_assets/downloads/O/2012_2030_energy_outlook_booklet.pdf)

## 3. Britain's potential

The UK may not experience a US-style shale boom, but Britain's shale resources have enormous development potential. UK shale gas could help to support a cleaner, cheaper and more secure energy system.

### LNG IMPORTS FROM THE US – NOT VIABLE

Chapter 1 described the immense benefits that shale gas has brought to the US and the future export potential. Given that UK gas currently costs around \$8-9 per MMBTU, compared to US gas costing \$2-3 per MMBTU, it might be tempting to believe that the UK can import large quantities of cheap US gas in the years ahead. Unfortunately, at current production, liquefaction and shipping costs, it doesn't look likely.

Firstly, Pacific Basin gas prices are far higher than those in the UK, so the most profitable export route will always be to Asia rather than Western Europe.

Secondly, and more importantly, more than a few energy analysts forecast a return from the current \$3 Henry Hub gas price to \$5 in the near future. With the costs of export currently around \$4 per MMBTU, exporting gas to the UK would actually be a loss-making enterprise, unless UK gas prices increased substantially.

TABLE 3.1

#### Estimated cost of delivered LNG to Europe from Cheniere's Sabine Pass Project

(\$MMBtu)	Low	High
Henry Hub Gas	4.00	6.00
Fuel (15%)	0.60	0.90
Liquefaction	2.25	2.25
Shipping	1.00	1.50
<b>Delivered Cost</b>	<b>7.85</b>	<b>10.65</b>

Source: Citi Global Perspectives & Solutions, Energy 2020: North America, the New Middle East? March 2012, Figure 39  
<https://ir.citi.com/%2FSyMM9ffgf0ZguStaGpnCw5NhPkvdMbbn02HMA05ZX%2BJHjYVS07GqhxF2wMk%2Bh4tv7DEZ5FymVM%3D>

This view was confirmed in a recent Deutsche Bank report, which forecast that, once transportation costs were taken into account, US LNG would be no cheaper than the UK's own National Balancing Point (NBP) gas price. The report projected that, starting from 2016, NBP and US LNG export to Europe will both hover in a narrow price band between \$8-10 per MMBTU, meaning that the spread for traders to take the arbitrage would be reduced to "virtually nil".<sup>26</sup>

The UK is therefore unlikely to be importing US gas at scale anytime soon.

<sup>26</sup> Gas to Power Journal, 3 August 2012 <http://gastopowerjournal.com/index.php/markets/item/728-price-of-us-lng-export-will-be-at-parity-with-uk-nbp-prices-from-2016---deutsche-bank>

## UK SHALE POTENTIAL

So we need to look to our own resources. How much shale gas does the UK have, and how quickly can we exploit it?

### Resources

In calculating the size of the shale resource base, Britain starts from a good 20 years behind the US. To date, apart from three deep wells dedicated to shale appraisal drilled recently by Cuadrilla, less than a handful of exploration wells are known to have tested shale plays in the UK. Because this is still a matter of exploration, the quantity of UK shale gas is very much open to debate, but the prospects look very promising indeed.

In 2010, the British Geological Survey (BGS) estimated the UK's onshore shale reserves at 5.3 tcf. The BGS is set to revise its onshore data substantially upwards later this year, possibly to as high as 200 tcf.

TABLE 3.2

#### Companies prospecting for UK shale gas

Company	Company	Company
Cuadrilla Resources	Lower and Upper Carboniferous (Bowland Shale)	Lancashire, Kimmeridge Clay, Weald Basin - England
Tamboran Resources	Lower Carboniferous	Lough Allen Basin – Ireland
Dart Energy	Lower and Upper Carboniferous	Scotland
I-Gas	Lower and Upper Carboniferous (Holywell and Bowland Shale)	NE Wales/S Lancashire
Eden/UK Methane/Coastal	Carboniferous Shales	Mendips, S Wales, Kent
Egdon/eCorp/Greenpark	Carboniferous Shales	Gainsborough Trough, East Midlands

The exploration companies themselves have far higher estimates from their onshore fields.

Cuadrilla, by itself, is a showstopper. In September 2011 it announced that it had identified a resource of 200 tcf just outside Blackpool.

Cuadrilla's estimates, however, only cover its exploration area in Lancashire. Other companies have also reported large resources:

- **Eden Energy reported 12.8 tcf in June 2011;**<sup>27</sup>
- **In April 2012, IGas doubled its estimate to 10 tcf;**<sup>28</sup>
- **In May 2012, Dart Energy International reported a best estimate of shale gas assets of 66 tcf.**<sup>29</sup>

All of these estimates are only onshore. Offshore reserves could be 5-10 times higher, according to the British Geological Survey.<sup>30</sup> For now, little is known about how to extract offshore shale gas but it does suggest that the UK does not need to worry about running out of gas if it were to apply itself to proven technology.

An optimistic estimate of UK unconventional gas reserves, then, would add up to 300 tcf onshore, and possibly as much as 1,000 tcf offshore.

<sup>27</sup> Platts, 2 June 2011 <http://www.platts.com/RSSFeedDetailedNews/RSSFeed/NaturalGas/8947310>

<sup>28</sup> The Telegraph, 3 April 2012 <http://www.telegraph.co.uk/finance/newsbysector/energy/oilandgas/9181942/IGas-doubles-estimates-of-UK-shale-gas-reserves-to-10-trillion-cubic-feet.html>

<sup>29</sup> Energy-pedia News, 10 May 2012 <http://www.energy-pedia.com/news/united-kingdom/new-150262>

<sup>30</sup> Nigel Smith, Geophysicist, British Geological Survey, Oral evidence to the Energy and Climate Change Select Committee, 9 February 2011 <http://www.publications.parliament.uk/pa/cm201012/cmselect/cmenergy/795/11020902.htm>

### Possible recovery rates

Recovery rates do vary very much by the location and what companies are prepared to say, but according to the Centre for Global Energy Studies, shale gas recovery rates in the US average 18%.<sup>31</sup> To use the jargon, "ultimate recovery rates" keep increasing as the technology advances, so 15 years from now, 30% might be a more likely recovery rate.

It may be that conditions in the UK are more complex than those in the US, however, with several issues standing out:

- UK shale gas may or may not be harder to extract, given the different geological conditions and greater population density;
- UK planning laws are more stringent;
- In the UK, unlike in the US, mineral ownership rights belong to the Crown Estate and not the landowner, meaning that the landowner may have less incentive to allow shale drilling.

While planning and ownership rights are certainly issues, they are not insurmountable. Mineral rights also belong to the Crown in Canada, for example, but that hasn't prevented large-scale development. And although the planning process does take a considerable amount of time in the UK, there is no reason why sensible applications should be refused.

It is too early to tell whether, compared to the US, UK shale gas will be harder to extract. There are, however, some encouraging signs. What is especially remarkable about the Bowland shale that Cuadrilla plan to exploit is its quality, as expressed by the average resource per square mile. According to Cuadrilla, it is actually greatly superior to leading US gas shale plays because it is more than 10 times thicker.

TABLE 3.3

#### The potential of Bowland versus US shale gas plays

Play	Age	Depth feet	Net thickness feet	Approx average resource billion cu.ft / sq. mile (GIIP)
Barnett	Mississippi	6500 - 8500	100 - 600	240
Marcellus	Mid Devonian	4500 - 8500	50 - 350	13
Fayetteville	Mississippi	3000 - 5000	20 - 200	54
Haynesville	Upper Jurassic	10500 - 13000	200 - 300	113
Woodford	Mid Devonian	6000 - 11000	120 - 220	87
Eagle Ford	E. Cret	8000 - 14000	150 - 300	102
Bowland (Grange Hill)	Carb.	5200 - 10700	3967	1391 = 1.4 tcf / sq.m

Source: AJ Lucas, AJ Lucas European Shale Assets Update, Presentation to JP Morgan Shale Corporate Access Day, 10 May 2012  
<http://www.asx.com.au/asxpdf/20120510/pdf/4265zmjsb9n7g2.pdf>

## THE PROBLEMS THAT SHALE COULD HELP SOLVE

Developing UK shale does not solve all of the following energy problems on its own, but it could make a large contribution to mitigating their impact, providing a major economic boost.

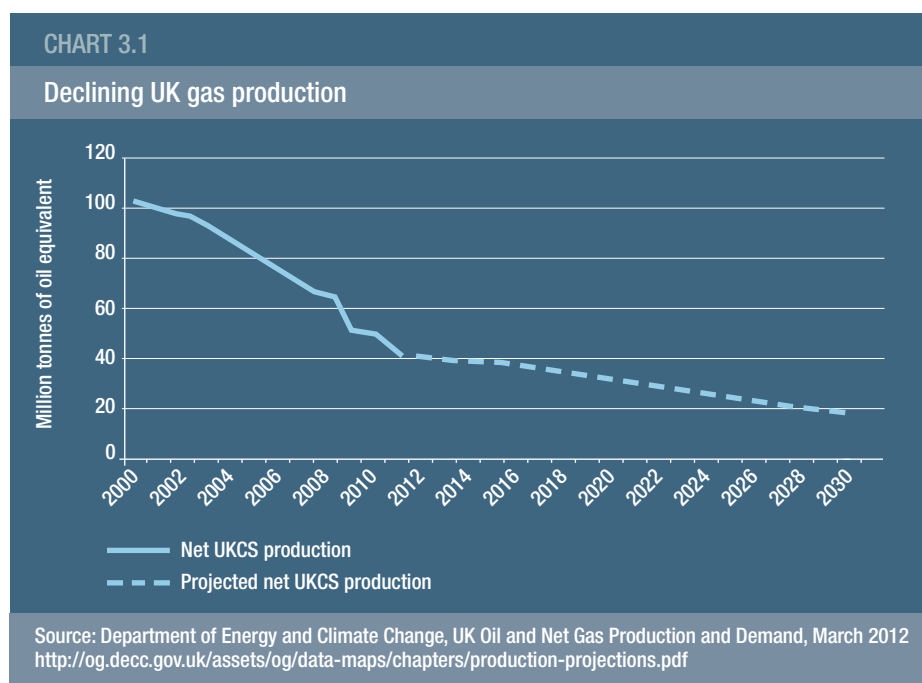
<sup>31</sup> Centre for Global Energy Studies, July 2010 <http://www.cges.co.uk/resources/articles/2010/07/22/what-is-shale-gas>



## UK gas production declining

Gas production from the UK Continental Shelf has declined rapidly over the past decade, and is set to continue to fall:

- Between 2000 and 2011, gas production fell from 103 to 41 million tonnes of oil equivalent;
- By 2030, North Sea gas production is projected to fall to just 18 million tonnes of oil equivalent.



The UK oil and gas industry provides direct and indirect employment for 440,000 people, including 32,000 directly employed by oil and gas companies and their major contractors.<sup>32</sup> As production of both gas and oil declines the job count will also fall.

## UK gas import dependency rising

Falling production means that gas imports will have to rise, even though DECC projects that net gas demand will fall by at least 10% over the next 20 years:

- In 2000, net gas exports equalled 13% of consumption. In 2011, net imports equalled 49% of consumption.
- By 2030, imports are projected to make up 74% of the UK's gas needs.

If DECC's projections for gas demand are too low, then imports could rise to an even higher share than detailed below.

## Energy policies placing higher costs on UK industry

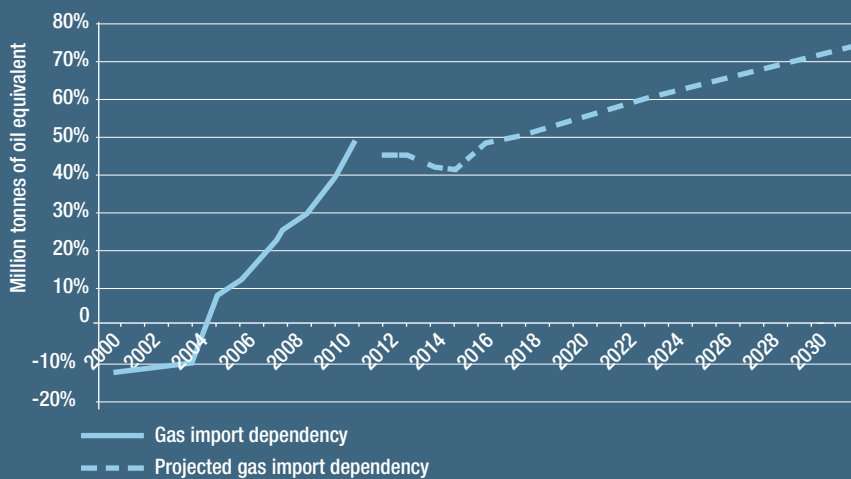
The UK's energy and climate change policies, especially the renewables programme, are adding more to electricity prices paid by intensive users than comparable programmes in competitor countries:

- In 2011, the UK's energy and climate policies added £14 per MWh to industrial electricity prices;

<sup>32</sup> Oil and Gas UK <http://www.oilandgasuk.co.uk/employment.cfm>

CHART 3.2

### Gas imports as a percentage of gas demand



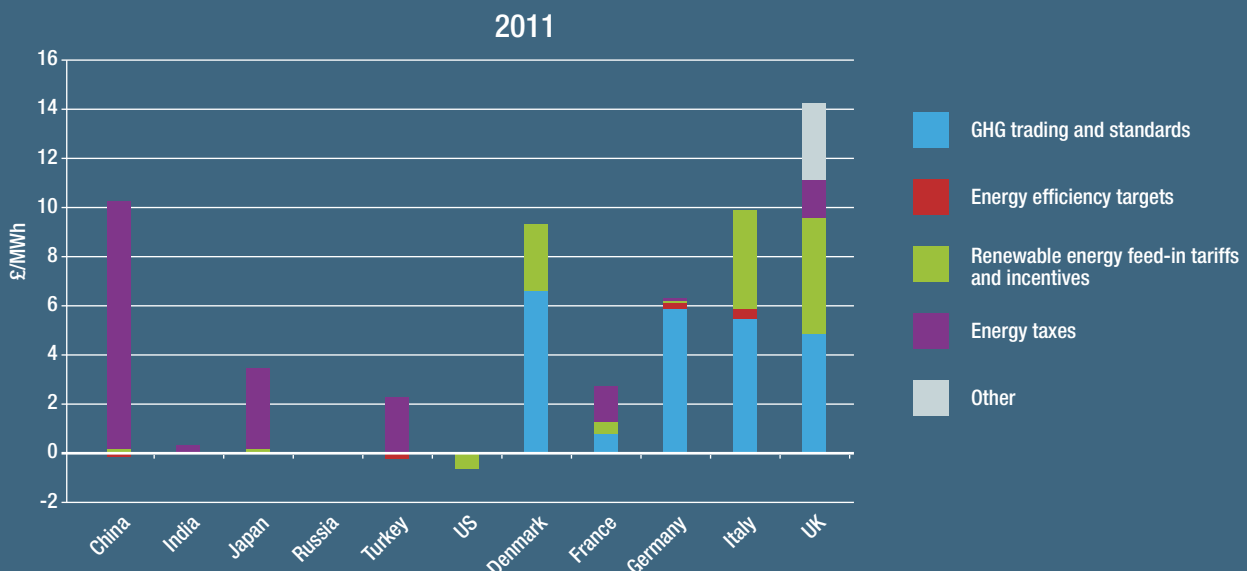
Source: Department of Energy and Climate Change, UK Oil and Net Gas Production and Demand, March 2012  
<http://og.decc.gov.uk/assets/og/data-maps/chapters/production-projections.pdf>

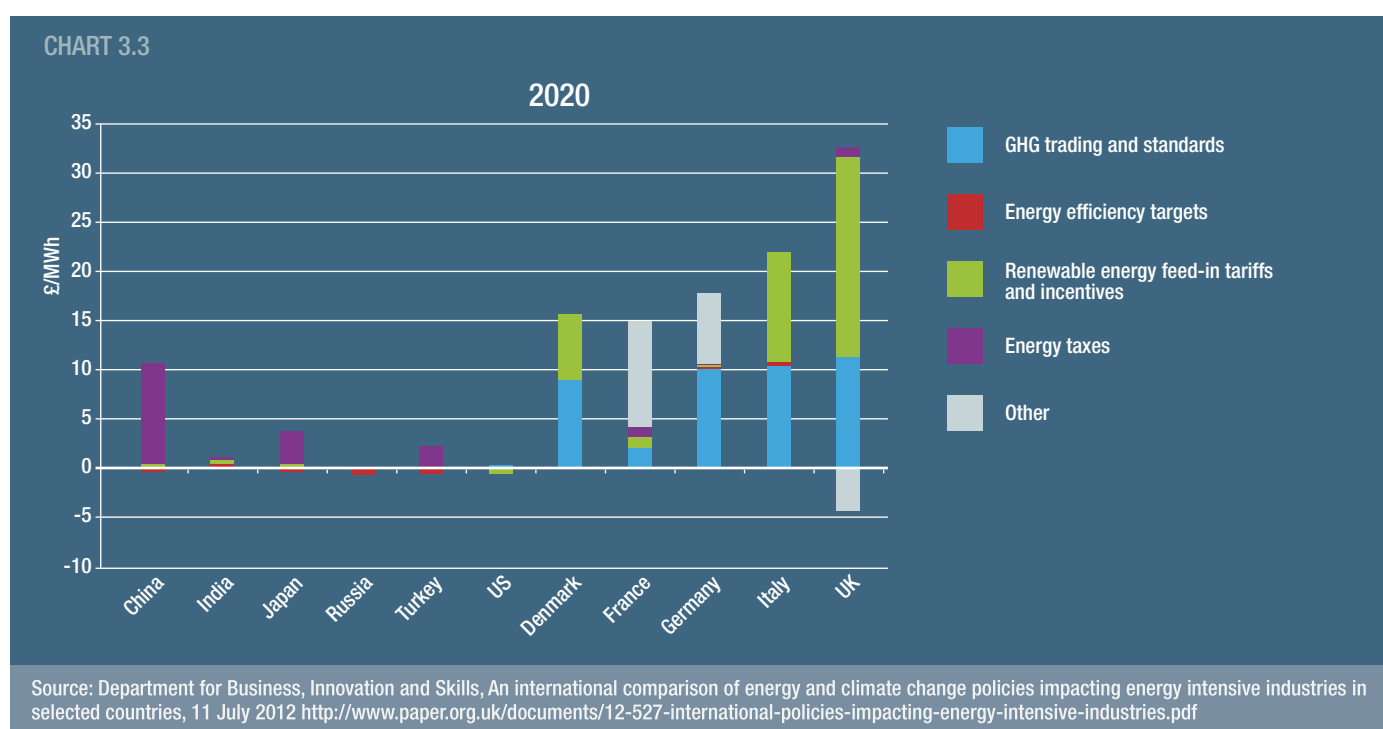
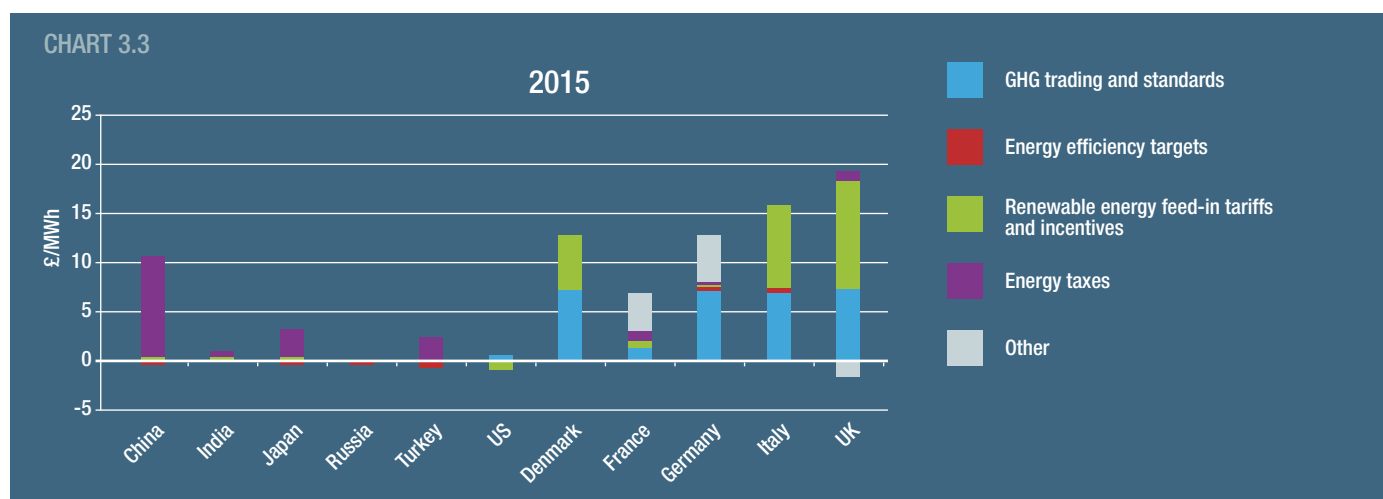
- By 2015, the impact of policies is projected to rise to £18.50 per MWh, of which £11 will come from the renewables programme;
- By 2020, these figures are projected to increase to £28 and £20, respectively;
- By comparison, US policies are projected to add nothing to industrial electricity prices, Chinese policies to add £10 per MWh, and German policies £17 per MWh by 2020.

In certain countries, such as Germany, this may be because consumers are paying a higher share of the burden. But it puts UK industry at a severe disadvantage.

CHART 3.3

### Incremental impacts of energy and climate change policies on electricity price paid by energy intensive industries





## Fuel poverty rising

Fuel poverty<sup>33</sup> has risen substantially over the past decade, although it remains below the levels of the mid-1990s. Between 2003 and 2010, the proportion of households in fuel poverty rose from 6% to 16%. So far, most of the rise has been due to the impact of higher gas prices, but the latest DECC projections show that renewables subsidies and other energy and climate change policies are set to add 7% to domestic gas prices and 27% to domestic electricity prices by 2020. Although improvements to energy efficiency could reduce the bill impact, fuel poverty could rise still further.<sup>34</sup>

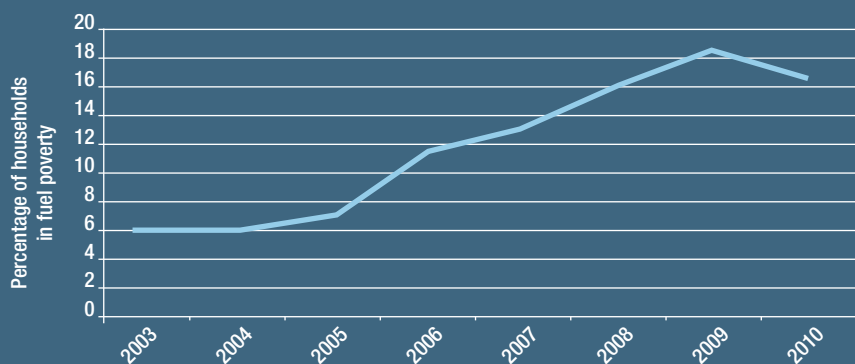
<sup>33</sup> NB: "A household is said to be in fuel poverty if it needs to spend more than 10% of its income on fuel to maintain a satisfactory heating regime (usually 21 degrees for the main living area, and 18 degrees for other occupied rooms)." [http://www.decc.gov.uk/en/content/cms/statistics/fuelpov\\_stats/fuelpov\\_stats.aspx](http://www.decc.gov.uk/en/content/cms/statistics/fuelpov_stats/fuelpov_stats.aspx)

<sup>34</sup> Department of Energy and Climate Change, Estimated impacts of energy and climate change policies on energy prices and bills, November 2011, Table 2 <http://www.decc.gov.uk/assets/decc/11/about-us/economics-social-research/3593-estimated-impacts-of-our-policies-on-energy-prices.pdf>.

NB: The impacts on prices from the measures outlined in the Draft Energy Bill may be different to those indicated – should the Bill be enacted.

CHART 3.4

Proportion of households in fuel poverty



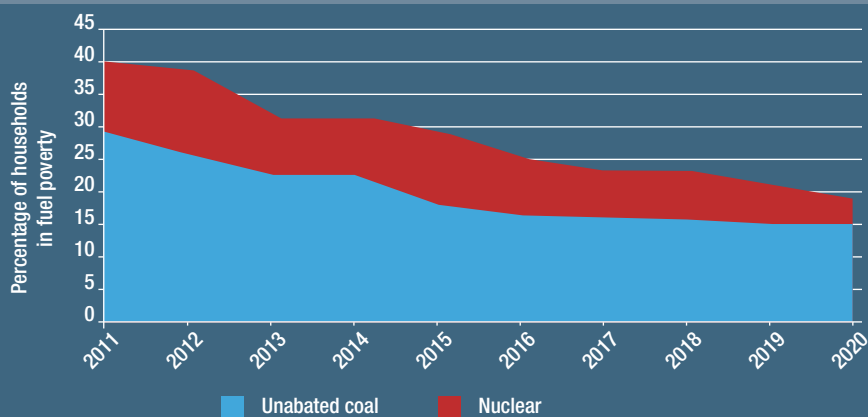
Source: Department of Energy and Climate Change, Fuel poverty statistics  
[http://www.decc.gov.uk/en/content/cms/statistics/fuelpov\\_stats/fuelpov\\_stats.aspx](http://www.decc.gov.uk/en/content/cms/statistics/fuelpov_stats/fuelpov_stats.aspx)

### Declining capacity of coal and nuclear

Over the next decade, the UK will experience a rapid decline in the generation capacity of two key sources of baseload power – coal and nuclear. This decline is expected to exceed 20GW, representing more than a fifth of total generation capacity. Although rapid renewables deployment could theoretically replace this lost capacity, it would need to be complemented by reliable back-up generation, underlining the growing importance of gas. A new nuclear programme is also vitally important, but it is unlikely to reach scale quickly enough.

CHART 3.5

The declining capacity of coal and nuclear



Source: Department of Energy and Climate Change, Updated Energy & Emissions Projections, October 2011, Annex J – total capacity (central scenario)  
[http://www.decc.gov.uk/en/content/cms/about/ec\\_social\\_res/analytic\\_projs/en\\_emis\\_projs/en\\_emis\\_projs.aspx](http://www.decc.gov.uk/en/content/cms/about/ec_social_res/analytic_projs/en_emis_projs/en_emis_projs.aspx)

## The potential contribution of UK shale

Shale gas development can reverse some of these trends and provide a big economic boost:

- As detailed earlier in this report, in only a decade in the US, shale gas production increased from virtually zero to sufficient to meet over a fifth (22%) of US natural gas consumption. In the US, shale gas recovery rates average 18%.
- If, over the next 10 years, the UK is roughly half as successful on both measures as the US has been over the last 10 years, it would mean that shale gas could account for around 10% of 2011 UK gas consumption, and that around 10% of the UK's onshore shale reserves prove to be economic to extract.

If, in this way, the UK is half as successful at developing shale gas as the US, the benefits could be enormous. Note that the following are very indicative calculations, designed to provide an appreciation of the big picture surrounding UK shale:

- In 2011, the UK consumed 2.9 tcf of gas.<sup>35</sup> 10% of 2011 UK gas demand is therefore 0.29 tcf. If 10% of the 300 tcf of onshore reserves estimated by the exploration companies were economic to extract, then 30 tcf would be sufficient to meet 10% of current UK gas demand for 103 years.
- 10% of 2011 UK gas demand is equal to 8 million tonnes of oil equivalent, 8% of total UK oil and gas production in 2011.<sup>36</sup> The UK oil and gas industry provides direct and indirect employment for 440,000 people.<sup>37</sup> Assuming that jobs are directly proportional to production, then an extra 8% of 2011 production would generate 35,000 extra jobs, helping to offset job losses from a decline in conventional oil and gas production in the UK. Many of these posts would be in some of the most economically depressed regions of the country. Recently, Lord Browne, former Chief Executive of BP, told the Independent that UK shale could create 50,000 direct jobs.<sup>38</sup>
- Between 2011 and 2022, conventional UK gas production is forecast to decline by 13 million tonnes of oil equivalent.<sup>39</sup> If shale production rose to 8 million tonnes of oil equivalent, it would offset 60% of the projected fall in conventional production.
- 8 million tonnes of oil equivalent also represents 20% of projected UK gas imports in 2022. This would be sufficient to keep gas imports at the 2011 level of 49% of demand, rather than imports rising to a projected 59% of demand.<sup>40</sup>

Shale gas development could also have other benefits:

- The US experience shows that shale gas does not have to displace completely other conventional natural gas resources to bring the price down substantially. The current proportion of a fifth of total consumption clearly does the job, as pricing can be decisive at the margins. If shale gas helps to reduce gas prices, it would provide a big boost to industry, potentially creating thousands of jobs in addition to those in the oil and gas industry, and reduce the number of households in fuel poverty.
- UK shale gas, together with renewables and new nuclear, can offset the planned closure of around 20GW of coal and nuclear stations, helping to ensure that the lights stay on.

<sup>35</sup> Department of Energy and Climate Change, DUKES Table 4.2 (converted to trillion cubic feet) [http://www.decc.gov.uk/en/content/cms/statistics/energy\\_stats/source/gas/gas.aspx](http://www.decc.gov.uk/en/content/cms/statistics/energy_stats/source/gas/gas.aspx)

<sup>36</sup> Department of Energy and Climate Change, UK Oil and Net Gas Production and Demand, March 2012 <http://og.decc.gov.uk/assets/og/data-maps/chapters/production-projections.pdf>

<sup>37</sup> Oil and Gas UK <http://www.oilandgasuk.co.uk/employment.cfm>

<sup>38</sup> The Independent, 26 March 2012 <http://www.independent.co.uk/news/business/news/fracking-could-bring-uk-50000-jobs-says-browne-7585027.html?afid=af>

<sup>39</sup> Department of Energy and Climate Change, UK Oil and Net Gas Production and Demand, March 2012 <http://og.decc.gov.uk/assets/og/data-maps/chapters/production-projections.pdf>

<sup>40</sup> Department of Energy and Climate Change, UK Oil and Net Gas Production and Demand, March 2012 <http://og.decc.gov.uk/assets/og/data-maps/chapters/production-projections.pdf>

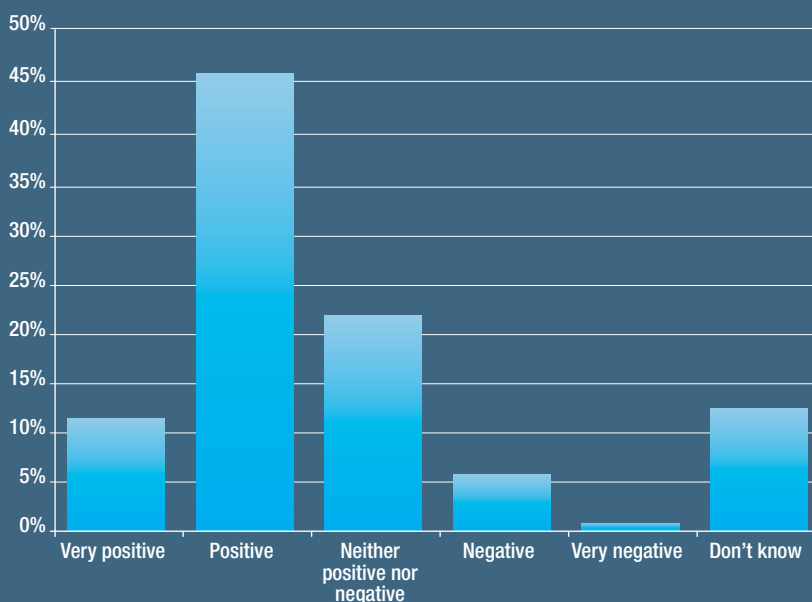
## THE VIEWS OF IOD MEMBERS

In April 2012, the IoD polled 1,095 IoD members for their views on the potential of UK shale gas. While there were some mixed views, and a degree of uncertainty, members were positive overall:

- 58% said that extensive development of the UK's shale gas resources would have a positive or very positive impact on British businesses. By contrast, just 7% thought it would have a negative or very negative impact on business, while 22% said it would be neither positive nor negative.

CHART 3.6

"What is your view on the potential impact on UK businesses of extensive development of the UK's shale gas resources?"

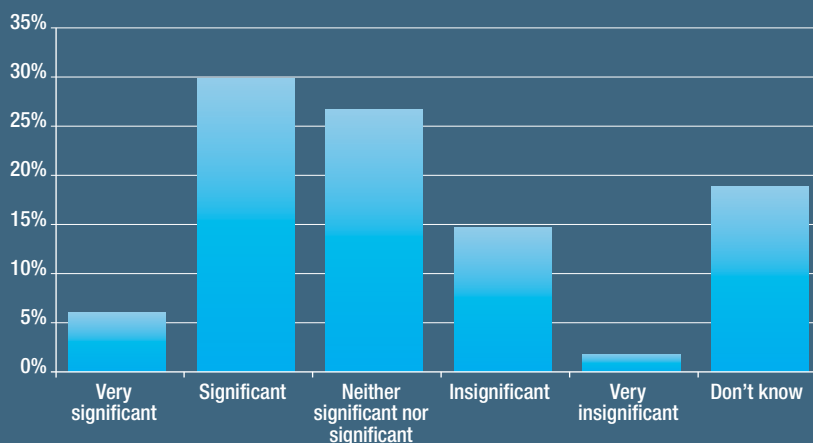


Source: Policy Voice poll of 1,095 IoD members, April 2012

- Views were mixed on the possible safety and environmental risks of hydraulic fracturing (which are covered in Chapter 4). 36% thought that the risks were significant, compared with 17% who thought they were insignificant and 27% who felt they were neither significant nor insignificant.
- Overall, almost half (48%) of IoD members agreed that the benefits outweighed the risks, compared to 18% who thought that the risks outweighed the benefits, and 15% who neither agreed nor disagreed with the question.
- There is, however, some uncertainty amongst IoD members. 13% said they didn't know what the impact of shale gas development on business would be; 19% said they didn't know what the risks of fracking would be; and 20% said they didn't know whether the benefits outweighed the risks.
- Regionally, IoD member views are very similar. In all regions of the UK:
  - More than 50% of members think that shale gas will have a positive impact on business;
  - Less than 40% of members think that the risks of fracking are significant;
  - At least 45% of members think that the benefits outweigh the risks.

CHART 3.7

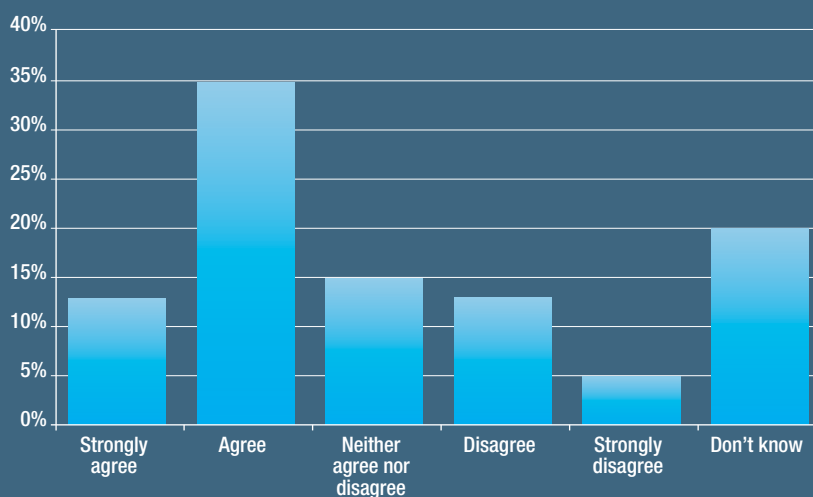
"What is your view on the safety and environmental risks of hydraulic fracturing ('fracking'), the technique used to extract shale gas?"



Source: Policy Voice poll of 1,095 IoD members, April 2012

CHART 3.8

"To what extent would you agree or disagree with the following statement: the potential benefits of shale gas development outweigh the potential risks of hydraulic fracturing ('fracking')?"



Source: Policy Voice poll of 1,095 IoD members, April 2012

## 4. The environment

It is impossible to talk about shale gas without discussing the environmental concerns. Using gas in place of coal for electricity and in place of petrol and diesel for road transport would lead to big improvements in air quality and a reduction in CO<sub>2</sub> emissions. The process of extracting shale gas, however, has been heavily criticised on environmental grounds. But if carried out carefully and under thorough regulation, hydraulic fracturing (“fracking”) is no more dangerous than conventional hydrocarbon extraction.

### AIR QUALITY AND CARBON EMISSIONS

In 2011, the UK used 42 million tonnes of coal in electricity generation,<sup>41</sup> emitting around 90 million tonnes of CO<sub>2</sub>.<sup>42</sup> Were this to be entirely replaced with gas, which emits around half as much CO<sub>2</sub> as coal,<sup>43</sup> the UK would quickly and cheaply save around 45 million tonnes of CO<sub>2</sub>, around 8% of the 2011 total. Although UK shale is unlikely to be sufficient to replace all coal-fired generation, it could make a major contribution to decarbonisation in its own right, as well as supporting the further development of renewables.

According to DECC's projections, around 25GW of renewable generation will be added to the grid by 2020,<sup>44</sup> much of which will be in the form of intermittent sources such as wind and solar. UK shale gas can support this development, ensuring that the lights stay on when the wind isn't blowing and the sun isn't shining.

Replacing coal with gas would also help to improve Britain's poor air quality, which is responsible for 29,000 deaths annually,<sup>45</sup> as gas emits far fewer particulates and other harmful pollutants than coal.

Should shale gas in the UK prove to be as disruptive to pricing as in the US, then we could also quickly move to buy off the shelf buses that run on natural gas rather than diesel. These would start to clean up city air with much lower particulate and other emissions, complementing electric cars. The switch would pay for itself in helping to reduce the 5,000 annual premature deaths from road pollution alone.<sup>46</sup> According to a recent Deutsche Bank report, “natural gas vehicles have good prospects of growing their market share in the years ahead”.<sup>47</sup>

<sup>41</sup> Department of Energy and Climate Change, DUKES Table 2.7 [http://www.decc.gov.uk/en/content/cms/statistics/energy\\_stats/source/coal/coal.aspx](http://www.decc.gov.uk/en/content/cms/statistics/energy_stats/source/coal/coal.aspx)

<sup>42</sup> Department of Energy and Climate Change, 2011 UK Greenhouse Gas Emissions, Provisional Figures, March 2012, Figure 3 <http://www.decc.gov.uk/assets/decc/11/stats/climate-change/4817-2011-uk-greenhouse-gas-emissions-provisional-figur.pdf>

<sup>43</sup> For a comparison of lifecycle emissions of coal and natural gas, see, for example: Worldwatch Institute, Comparing Life-Cycle Greenhouse Gas Emissions from Natural Gas and Coal, August 2011, Figure ES-2 [http://www.worldwatch.org/system/files/pdf/Natural\\_Gas\\_LCA\\_Update\\_082511.pdf](http://www.worldwatch.org/system/files/pdf/Natural_Gas_LCA_Update_082511.pdf). This report uses the 2011 methodology employed by the US Environmental Protection Agency, and finds that lifecycle emissions of natural gas equal 582kg of CO<sub>2</sub> per MWh of electricity, 47% less than coal's figure of 1,103kg of CO<sub>2</sub> per MWh.

<sup>44</sup> Department of Energy and Climate Change, Updated Energy & Emissions Projections, October 2011, Annex J – total capacity (central scenario) [http://www.decc.gov.uk/en/content/cms/about/ec\\_social\\_res/analytic\\_projs/en\\_emis\\_projs/en\\_emis\\_projs.aspx](http://www.decc.gov.uk/en/content/cms/about/ec_social_res/analytic_projs/en_emis_projs/en_emis_projs.aspx)

<sup>45</sup> Simon Moore and Guy Newey, The forgotten crisis of Britain's poor air quality, Policy Exchange, July 2012 <http://www.policyexchange.org.uk/images/publications/something%20in%20the%20air.pdf>

<sup>46</sup> BBC News, 17 April 2012 <http://www.bbc.co.uk/news/science-environment-17704116>

<sup>47</sup> Deutsche Bank, Natural gas as a fuel for road vehicles: The underrated alternative, 13 April 2012

[https://www.dbresearch.com/servlet/reweb2.ReWEB?document=PROD000000000287718&rnwobj=ReDisplay.Start.class&rnwsite=DBR\\_INTERNET\\_EN-PROD](https://www.dbresearch.com/servlet/reweb2.ReWEB?document=PROD000000000287718&rnwobj=ReDisplay.Start.class&rnwsite=DBR_INTERNET_EN-PROD)



## HYDRAULIC FRACTURING

### BOX 4.1

#### What is fracking?

In the early 1980s, George Phydias Mitchell, a Texan born to Greek parents, came up with the radical idea of drilling much deeper into the gas-bearing shale rock to extract natural gas. After nearly 20 years of experimentation, his company finally found the right formula for the economic exploitation of tight shale gas.

Hydraulic fracturing, or “fracking”, literally breaks open the rock along fractures and releases the trapped gas. This is done by firing a cheap combination of high pressure water, sand as a propping agent to open up the fractures and some chemicals. These follow after the vertical well has been drilled, which is encased with steel and concrete to prevent the well's collapse and the escape of gas or fracking fluid.

A more recent innovation has been to drill horizontally outwards from the vertical well as far as 5,000 feet. Hydraulic fracturing horizontally requires much more water but it also means that one drill pad can cover a much larger area and extract much more gas.

The fracking itself only lasts a few weeks but the well will keep producing gas for 30-40 years as it would typically be connected to the gas network.

#### The process in more detail

A good description of the fracking process can be found in a recent report from the insurance brokerage Willis:<sup>48</sup>

*“The technique of hydraulic fracturing is used to increase the rate at which natural gas can be produced from subterranean natural reservoirs. Hydraulic fracturing enables the production of natural gas and oil from rock formations deep below the earth's surface. At such depth, there may not be sufficient porosity, permeability or reservoir pressure to allow natural gas and oil to flow from the rock into the wellbore at economic rates. Fractures provide a conductive path connecting a larger area of the reservoir to the well, thereby increasing the area from which natural gas can be recovered from the targeted formation. The process can be summarised as follows:*

- *After the well is drilled and casing is fitted, steel pipes are inserted and cemented into place. Additional steel casing is fitted below the water level unlike local private and municipal water wells;*
- *A perforating gun is lowered into the well;*
- *Controlled electric charges pierce the pipe and cement, blasting into the shale where the gas is trapped;*
- *The treating fluid (mainly gelled water) which is injected into the well at high pressure creates and widens the shale fractures, then these created fractures are held open by proppant (usually in the form of sand) which is blended with the treating fluid and introduced to the fractures that are created during the fracturing process;*
- *Natural pressures then force the liquids back through the pipe to the surface;*
- *As the fluid recedes, the sand grains hold open the fractures and natural gas flows up the well.”*

There are several environmental issues associated with hydraulic fracturing, detailed in Table 4.1. They are not to be taken lightly, but at the same time must be put into perspective.

<sup>48</sup> Willis, All Fracked Up? Just how concerned should energy insurers be about hydraulic fracturing? Energy Market Review, April 2012, p.11 [http://www.willis.com/Documents/Publications/Industries/Energy/10396\\_EMR%202012\\_Complete.pdf](http://www.willis.com/Documents/Publications/Industries/Energy/10396_EMR%202012_Complete.pdf)

TABLE 4.1

## Environmental risks of hydraulic fracturing

Risk	Perspective
<b>Water</b>	
Methane migrating to the water table as a result of drilling	Methane can sometimes migrate naturally, although any suspicion of migration caused by fracking needs to be taken seriously.
Chemicals used in the fracking fluid polluting ground and surface water	The chemicals used in fracking fluid are generally less than 0.5% of the total, and are used in all walks of life. For example, Sodium Chloride is salt, Polyacrylamide is used for water treatment and in cosmetics, Borate salts are found in laundry detergent, Citric Acid is used in food additives and Sodium/Potassium Carbonate is found in ordinary detergents. Disposing of chemicals safely is not a unique problem for shale gas drilling.
Large quantities of water	Large quantities of water are, of course, used in many industrial and leisure activities, not least golf courses in areas of desert.
<b>Earthquakes</b>	
Earthquakes caused by the fracking process	In 2011, two earthquakes were caused by the activities of Cuadrilla, one measuring magnitude 1.5 and the other measuring magnitude 2.3. For comparison, the British Geological Survey publishes a record of earthquakes around the British Isles in the last 50 days. Based on a search conducted on 15 August 2012, in the previous 50 days there were five earthquakes measuring more than 1.5, of which two measured 2.3 and one 2.7. <sup>49</sup> Coal mining has also caused earthquakes of a similar magnitude for a long time. It should also be noted that earthquake magnitudes are exponential, not linear. According to the British Geological Survey, an earthquake below 3.0 is generally not even felt, let alone the cause of damage.
<b>Fugitive emissions</b>	
Leaks from the shale wells of methane or other pollutants	Not a problem uniquely confined to shale gas wells, but to coal mining and landfill sites as well. In the case of shale gas, fugitive methane emissions should only exist sporadically during the first few weeks of initial operations, not during the three or four decades of the well's life.

These issues can be dealt with in practice. Table 4.2 gives several examples.

<sup>49</sup> British Geological Survey, Earthquakes around the British Isles in the last 50 days, Last updated: 13.40, Wednesday August 15, 2012  
[http://www.earthquakes.bgs.ac.uk/earthquakes/recent\\_uk\\_events.html](http://www.earthquakes.bgs.ac.uk/earthquakes/recent_uk_events.html)

TABLE 4.2

## Practical steps to deal with the risks of shale gas exploration

Risk	Action
Contamination of drinking water supply	Industry best practice is for wells to have a surface casing and an intermediate casing that extends far below the depth of the aquifer as far as the regional seal (the layer of impermeable rock beneath which lie the vast majority of the gas deposits). The gap between the production casing and the intermediate casing is then cemented all the way to the surface. Any failure of the production casing above the regional seal is covered by the intermediate casing.
Gradual contamination of the soil from fracking fluid pumped down a disposal well or from seepage or spillage of drilling fluid at the drilling site	Standard oil and gas drilling practices and legislation apply. Industry best practice is to underlay the gravel or soil at the top of the well site with a very thick impermeable layer of plastic, which slopes into drainage ditches. Any spill from the well, a fuel tanker or the storage tanks on site will be covered. The plastic sheet is not removed when fracking operations are completed, but remains for the duration of the life of the well.  Secondly, rather than using a disposal well, best practice is to use steel tanks for the used fracking fluid. These tanks are emptied regularly and the contents taken to landfill or waste treatment sites. Testing is carried out to ensure that the fluid is compliant with what is permitted at the disposal site.
Earthquakes	Drillers can minimise earthquake risks. For example, real-time seismic monitoring in each individual well allows drillers to determine every seismic occurrence well in time to ensure that the fracking activity is shut down well before any tremor is caused.

## The UK

Despite having a mere three (and currently suspended) exploration wells in place across the whole country, thanks perhaps to its pervasive health and safety culture, Britain already has a multitude of reports into shale gas safety. Relatively onerous regulations are already in place for fracking in the UK, including an obligatory full disclosure of the fracking fluid composition.

The regulatory bodies include:

- Department of Energy and Climate Change;
- Environment Agency (England and Wales);
- Scottish Environmental Protection Agency;
- Health and Safety Executive;
- Local authorities.

There are also numerous regulations that deal with specific risks, as detailed in Table 4.3.

TABLE 4.3	
Environmental controls in England and Wales	
Risk	Controls
Groundwater pollution	Water Framework Directive and Groundwater Daughter Directive through the Water Resources Act and Environmental Permitting Regulations (EPR). These regulate discharges to groundwater and require disclosure of chemicals.
Surface spills	Planning regime for site construction standards. The EPR regulates discharges to surface water and groundwater.
Disposal of used fracking fluid	Mining Waste Directive through the EPR. A waste management plan must be approved by the Environment Agency. Euratom Treaty applies if there are naturally occurring radioactive materials, via the EPR.
Over abstraction of water	Abstraction licensing under the Water Resources Act.
Fugitive methane emissions	Borehole regulations (Health and Safety Executive) to protect human health. Conditions under Petroleum Licences (DECC) for flaring and venting. Mining Waste Directive may apply.
Source: Tony Grayling, Head of Climate Change and Communities, Environment Agency, Managing the environmental risks of shale gas extraction, Presentation to the UKERC Annual Assembly, University of Warwick, 20 June 2012 <a href="http://www.ukerc.ac.uk/support/tiki-download_file.php?fileId=2513">www.ukerc.ac.uk/support/tiki-download_file.php?fileId=2513</a>	

The UK-based safety reports come to similar conclusions. Their findings include:

- Carried out properly and under strict regulation, hydraulic fracturing is safe;
- Problems are generally due to poor standards, rather than the hydraulic fracturing process itself;
- Environmental issues are generally little different from those of conventional hydrocarbon extraction;
- Earthquakes caused by hydraulic fracturing are no larger than those that have been caused by coal mining for years.

#### **1. Energy and Climate Change Committee, May 2011<sup>50</sup>**

The Select Committee launched its investigation in November 2010. It took 24 submissions as evidence to consider the prospects for shale gas in the UK, the risks and hazards associated with shale gas, and the potential carbon footprint of large-scale shale gas extraction. The report, published in May 2011, concluded:

*“There is no evidence that the hydraulic fracturing process poses any risk to underground water aquifers provided that the well-casing is intact before the process commences. Rather, the risks of water contamination are due to issues of well integrity, and are no different to concerns encountered during the extraction of oil and gas from conventional reservoirs. However, the large volumes of water required for shale gas could challenge resources in regions already experiencing water stress.”*

<sup>50</sup> House of Commons Energy and Climate Change Committee, Shale Gas: Fifth Report of Session 2010-12, May 2011 <http://www.publications.parliament.uk/pa/cm201012/cmselect/cmenergy/795/795.pdf>

## 2. Government response to Energy and Climate Change Committee, July 2011<sup>51</sup>

The Government published a joint response to the Select Committee's report in July 2011, which included contributions from DECC, the Treasury, the Department for Environment, Food and Rural Affairs (DEFRA), the Health & Safety Executive (HSE), the Environment Agency (EA), and the Scottish Environmental Protection Agency (SEPA).

Unsurprisingly, the report recommended an increased role and funding for the Environment Agency to monitor for contamination and pollution and that the HSE test the integrity of the wells before allowing drilling activity to commence. Once again, however, the report was anything but a red light to UK shale gas exploration. It concluded:

*"Hydraulic fracturing itself does not pose a direct risk to water aquifers, provided that the well-casing is intact before this commences. Rather, any risks that do arise are related to the integrity of the well, and are no different to issues encountered when exploring for hydrocarbons in conventional geological formations."*

## 3. Report commissioned by DECC on the Cuadrilla earthquakes, April 2012<sup>52</sup>

The big events that piqued a lot of interest were the earthquakes that occurred in the Blackpool area during Cuadrilla's exploratory operations. Two minor earthquakes of magnitude 2.3 and magnitude 1.5 were recorded and Cuadrilla volunteered to suspend drilling until an investigation yielded the cause. The report, which was published in April 2012, recommended that Cuadrilla be allowed to resume drilling, concluding:

*"Based on the induced seismicity analysis done by Cuadrilla and ourselves, together with the agreement to use more sensitive fracture monitoring equipment and a DECC agreed induced seismic protocol for future operations, the authors of this report see no reason why Cuadrilla Resources Ltd. should not be allowed to proceed with their shale gas exploration activities and recommend cautious continuation of hydraulic fracture operations at the Preese Hall site. In respect of future shale gas operations elsewhere in the UK, we recommend that seismic hazards should be assessed prior to proceeding with these operations. This should include:*

- 1. Appropriate baseline seismic monitoring to establish background seismicity in the area of interest.*
- 2. Characterisation of any possible active faults in the region using all available geological and geophysical data.*
- 3. Application of suitable ground motion prediction models to assess the potential impact of any induced earthquakes."*

## 4. Royal Society and Royal Academy of Engineering, June 2012<sup>53</sup>

In June 2012, a joint report from the Royal Society and the Royal Academy of Engineering was published. The report was by far the most prescriptive and endorsed much heavier regulation and oversight. It called for mandatory through-life Environmental Risk Assessments and monitoring before, during and after operations. It argued that regulatory capacity may need to be increased.

The report did not focus on whether fracking should go ahead or not, but rather looked at what the process involved. What was particularly interesting was the assessment of the negligible risk of earthquakes compared with usual earthquake activity or seismicity in Britain:

*"Natural seismicity in the UK is low by world standards. On average, the UK experiences seismicity of magnitude 5 ML (felt by everyone nearby) every twenty years, and of magnitude 4 ML (felt by many people) every three to four years. The UK has lived with seismicity*

<sup>51</sup> House of Commons Energy and Climate Change Committee, Shale Gas: Government Response to the Committee's Fifth Report of Session 2010–12, July 2011 <http://www.publications.parliament.uk/pa/cm201012/cmselect/cmenergy/1449/1449.pdf>

<sup>52</sup> Dr Christopher Green, Professor Peter Styles and Dr Brian Baptie, Preese Hall Shale Gas Fracturing: Review and Recommendations for Induced Seismic Mitigation, April 2012 <http://og.decc.gov.uk/assets/og/ep/onshore/5075-preese-hall-shale-gas-fracturing-review.pdf>

<sup>53</sup> The Royal Society and the Royal Academy of Engineering, Shale gas extraction in the UK: A review of hydraulic fracturing, June 2012 [http://royalsociety.org/uploadedFiles/Royal\\_Society\\_Content/policy/projects/shale-gas/2012-06-28-Shale-gas.pdf](http://royalsociety.org/uploadedFiles/Royal_Society_Content/policy/projects/shale-gas/2012-06-28-Shale-gas.pdf)

*induced by coal mining activities or the settlement of abandoned mines for a long time. British Geological Survey records indicate that coal mining-related seismicity is generally of smaller magnitude than natural seismicity and no larger than 4 ML. Seismicity induced by hydraulic fracturing is likely to be of even smaller magnitude. There is an emerging consensus that the magnitude of seismicity induced by hydraulic fracturing would be no greater than 3 ML (felt by few people and resulting in negligible, if any, surface impacts. Recent seismicity induced by hydraulic fracturing in the UK was of magnitude 2.3 ML and 1.5 ML (unlikely to be felt by anyone)."*

### **The US and globally**

Across the US, over 20,000 shale wells have been drilled. At state level, there have been a number of reports and plenty of publicity. Although there have been problems at a small number of wells, these are generally due to poor practice, rather than the nature of the fracking process itself. The UK, of course, has the opportunity to learn from mistakes made in the US.

A study by the Massachusetts Institute of Technology concluded:

*"With over 20,000 shale wells drilled in the last 10 years, the environmental record of shale gas development is for the most part a good one – one must recognize the inherent risks and the damage that can be caused by just one poor operation."*<sup>54</sup>

The really big report – the biggest and most comprehensive ever – is being prepared by the US Environmental Protection Agency (EPA). The EPA's study of hydraulic fracturing and its potential impact on drinking water resources started in April 2012 with a preliminary report due later this year and a final report in 2014.<sup>55</sup>

Meanwhile, a global regulatory picture is emerging, with encouragement from the International Energy Agency (IEA). The IEA's report, "Golden Rules for a Golden Age of Gas", published earlier this year, set out a range of measures to address the environmental and social impacts of shale gas.<sup>56</sup> The report found that "the technologies and know-how exist for unconventional gas to be produced in a way that satisfactorily meets these challenges" and summarised these golden rules as underlining that:

*"... full transparency, measuring and monitoring of environmental impacts and engagement with local communities are critical to addressing public concerns. Careful choice of drilling sites can reduce the above-ground impacts and most effectively target the productive areas, while minimising any risk of earthquakes or of fluids passing between geological strata. Leaks from wells into aquifers can be prevented by high standards of well design, construction and integrity testing. Rigorous assessment and monitoring of water requirements (for shale and tight gas), of the quality of produced water (for coalbed methane) and of waste water for all types of unconventional gas can ensure informed and stringent decisions about water handling and disposal. Production-related emissions of local pollutants and greenhouse-gas emissions can be reduced by investments to eliminate venting and flaring during the well-completion phase."*

The report estimated that applying the golden rules would increase the cost of a typical shale-gas well by 7% and perhaps more for operations with multiple wells. But it concluded that applying the golden rules would "allow for a continued global expansion of gas supply from unconventional resources, with far-reaching consequences for global energy markets". If, on the other hand, unconventional gas is not developed at scale outside of the US, the report projected that energy-related CO<sub>2</sub> emissions would actually be slightly higher.

<sup>54</sup> Massachusetts Institute of Technology, The Future of Natural Gas, 2010 <http://web.mit.edu/mitei/research/studies/report-natural-gas.pdf>

<sup>55</sup> US Environmental Protection Agency, EPA's Study of Hydraulic Fracturing and Its Potential Impact on Drinking Water Resources <http://www.epa.gov/hfstudy/index.html>

<sup>56</sup> International Energy Agency, Golden Rules for a Golden Age of Gas, 2012 [http://www.worldenergyoutlook.org/media/weowebsite/2012/goldenrules/WE02012\\_GoldenRulesReport.pdf](http://www.worldenergyoutlook.org/media/weowebsite/2012/goldenrules/WE02012_GoldenRulesReport.pdf)

## BOX 4.2

## Useful questions to consider when dealing with shale gas

The Willis report set out a list of questions to consider when dealing with shale gas.<sup>57</sup> Generally speaking, the more of these questions with a “yes” answer, the safer the operation will be:

**Wellbore integrity**

- *How far below groundwater (aquifer) is the surface casing set, what is the shoe (rock lithology), has cement been circulated to surface and has the wellbore been pressured tested (FIT or Formation Integrity Test) before drilling out?*
- *Based on the pressure gradient, lithology and drilling conditions is there the need to set intermediate casing before penetrating the target/pay zone? Has a Cement Bond Log been run (with and without pressure) prior to drilling out?*
- *Production Casing – once at total depth and production casing set, has cement been tied back (or circulated to surface) to the intermediate (or surface casing) and a Cement Bond Log been run (with and without pressure), and has a FIT been conducted?*

**Pre-drill well data**

- *Has the wellbore design taken into consideration pre-existing drilling data to establish a pressure gradient (under-, normal or over-pressured), natural artesian water zones/flows, caving intervals, etc?*
- *Has the wellbore design been approved by an independent examiner?*
- *Have surface waters surrounding the well pad been tested for chemicals and methane gas pre-spud to establish a natural baseline?*

**Pre-hydraulic fracture simulation data**

- *Is there adequate subsurface/geophysical data to determine the level of structural deformation to minimize the risk of triggering a seismic event on a pre-existing critically stressed fault/fault-zone?*
- *Has a (traffic light) system been put in place to detect minimally -1.0 to 0 magnitude seismic events?*
- *Will a microseismic mapping system be utilized to determine hydraulic fracture height growth; i.e., propagation of the fracture to intersect (contaminate) ground water?*

**Drilling**

- *Does the drilling contractor have a general and site-specific HSE plans/manual in place?*
- *Does the drilling contractor have a scheduled Blowout Preventer testing schedule and is it adhered to?*
- *Do the cement slurries meet or exceed recommended slurry design standards for thickening time, setting time, compressive strength, free water, and fluid loss?*
- *Is there an active gas monitoring system with alarm/communication to the drill floor?*
- *Is the disposal of drilling fluids and cuttings transported to a EA approved/certified tipping site? Is post-frac flow back water tested as it comes to surface (both by the Environment Agency and the operator)?*
- *Is the drill site underlain by an impermeable membrane and is there a spill response plan?*
- *Is there 24/365 site security?*

**Post-frac flow back**

- *Will flow back fluids be contained in explosion proof tankage?*
- *Will gas flows be vented or flared using a flare stack at safe distances from the wellbore?”*

<sup>57</sup> Willis, All Fracked Up? Just how concerned should energy insurers be about hydraulic fracturing? Energy Market Review, April 2012, p.28 [http://www.willis.com/Documents/Publications/Industries/Energy/10396\\_EMR%202012\\_Complete.pdf](http://www.willis.com/Documents/Publications/Industries/Energy/10396_EMR%202012_Complete.pdf)



### Insurers

Looking at the views of insurers is crucial to understanding the environmental risks of hydraulic fracturing, as their conclusions will affect their own profits. A recent report from the major insurance brokerage Willis found that, if best practice is followed, there is no reason for insurers to deny cover. The report concluded:

*"Much that is written about the shale gas industry should be taken, in the time honoured old English phrase, "with a pinch of salt". While hydraulic fracking operations will continue to pose a measure of pollution and contamination risk – just like the upstream oil and gas industry or any other industrial process in general – the extent of the problem has, in some quarters of the media at least, perhaps been blown somewhat out of proportion.*

*"There can be no doubt that regulators in the US, Europe and other domiciles will have their work cut out to keep abreast of developments in best practice in this rapidly expanding industry. The debate over whether further regulation of the shale gas industry will be a good or a bad thing is perhaps best left to the politicians; perhaps the broking community should instead turn its attention to playing our part in ensuring that our clients' risks are presented to the insurance market in the best possible light.*

*"Our study has shown that cover is much more likely to be provided to those buyers who can demonstrate that they have completely bought into the highest standards of the industry. Indeed, the contrast between contractors who do indeed adhere to these standards and those who do not is already very pronounced."*<sup>58</sup>

### Developments

Hydraulic fracturing is not standing still. As an extraction technique, it is constantly improving. For example, Chimera Energy Corporation of Houston, Texas, is the latest company to announce that it is licensing a new method for extracting oil and gas from shale fields that doesn't use water.<sup>59</sup>

Waterless fracking solves the issue of water supplies, and reduces the risk of ground water contamination. The technology has great potential.

## CONCLUSIONS

The extraction, transportation and combustion of hydrocarbons are not without risk. The oil tanker spill at Milford Haven in 1996 and the huge BP Gulf of Mexico spill in 2010 are good examples of major disasters from which the environment slowly recovers.

Hydraulic fracturing, as this chapter has shown, is also not without risk. But as the expert reports have made clear, the risks can be managed. The risks of hydraulic fracturing should be placed alongside those of conventional hydrocarbon extraction, not in a class of their own.

The following extracts from an oral evidence session at the Energy and Climate Change Select Committee sum up the issue well:<sup>60</sup>

*Professor Richard Selley: "Chairman, can I put this into perspective? There is a line of oil and gas fields around the Weald paralleling the North Down to the South Downs. There are fields there that have been producing oil and gas for 100 years. Not many people know that.*

*Q27 Dr Lee: "What—from shale gas?"*

*Professor Richard Selley: "No, this is conventional petroleum."*

<sup>58</sup> Willis, All Fracked Up? Just how concerned should energy insurers be about hydraulic fracturing? Energy Market Review, April 2012, p.23 [http://www.willis.com/Documents/Publications/Industries/Energy/10396\\_EMER%202012\\_Complete.pdf](http://www.willis.com/Documents/Publications/Industries/Energy/10396_EMER%202012_Complete.pdf)

<sup>59</sup> Gizmag, 31 July 2012 <http://www.gizmag.com/dry-extraction-fracking/23513/>

<sup>60</sup> Professor Richard Selley, Petroleum Geologist, Imperial College London and Nigel Smith, Geophysicist, British Geological Survey, Oral evidence to the Energy and Climate Change Select Committee, 9 February 2011 <http://www.publications.parliament.uk/pa/cm201012/cmselect/cmenergy/795/11020902.htm>



Nigel Smith: "Also it is true in the East Midlands as well. I mean, that helped in the Second World War effort. Does anybody know there was an oil field at Formby? These things were developed. BP have done a brilliant job at Wytch Farm drilling out laterally, even offshore, yet, quite a few people in the general public do not even know it is going on."

Q28 Dr Lee: "In terms of water contamination, how many tests have been done in those areas since?"

Nigel Smith: "I do not know of any water contamination in any of these onshore fields."

Q29 Dr Lee: "If you are not looking, forgive me, you are not going to find it, are you?"

Nigel Smith: "No, but it would be reported. You cannot keep anything quiet these days, I would say. The local authority would find out."

Q59 Dan Byles: "...Overall, is it a fair summary of your view that there is currently no real evidence that shale gas is any more dangerous than any other sort of hydrocarbon or exploration. It is another source of energy to be tapped for the UK when the economics say that it is right to do so, based on price and cost? Is that a fair assessment?"

Nigel Smith: "Yes, I agree."

If hydraulic fracturing is no more risky than conventional hydrocarbon extraction, then there can be net benefits to the environment from using unconventional gas in place of coal in electricity generation and oil in road transport.

# Conclusions

Shale gas development does not magically solve all the UK's energy issues. North Sea production will still fall, the renewables programme will still increase energy prices for industry, and coal and nuclear will still decline in capacity. But what shale gas development can do is mitigate the impact of these trends.

- Shale gas development can counter falling North Sea production, halting the increase in gas imports;
- UK shale gas can offer a cheap and reliable energy source for industry, potentially reducing the number of job losses;
- It can also help to reduce price rises for consumers, reducing the number of people in fuel poverty;
- Expanding renewables creates jobs directly, and so can developing shale gas, especially in less affluent parts of the country;
- With coal and nuclear set to decline in importance, at least before new nuclear power stations come on stream, new gas plants powered by UK shale can help to fill this electricity generation gap, as well as acting as a vital back-up to wind and other renewables.

A mix of power sources is vital, and domestic shale gas is unlikely to account for a majority of the UK's electricity generation, or even of its gas usage. But it could and should play an important role. In the US, shale gas accounts for around a fifth of overall gas demand, and yet that has been sufficient to revolutionise the gas market, cutting costs for industry and replacing coal in electricity generation. The same economic and environmental benefits could be realised in the UK, if we allow shale development to happen.

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