



Infrastructure for Business

Getting shale gas working





About the report

On 21 September 2012, the IoD published a report, *Britain's Shale Gas Potential*,¹ which concluded that shale gas has the potential to create jobs, generate tax revenues, reduce imports, accelerate the move away from coal and support the growth of renewables. Although exploration is still at an early phase, the UK has substantial quantities of shale gas in place that have the potential to support the creation of an important new industry in parts of the country that need it most. The report also detailed the results of a survey of over 1,000 IoD members, which found that businesses are in favour of careful, well-regulated shale gas development in the UK.

On 13 December 2012, the Government lifted the temporary moratorium on exploratory hydraulic fracturing, the technique used for extracting shale gas, and announced new seismic controls.²

Following the lifting of the moratorium, the IoD has studied in detail how a new shale gas industry could develop. This report, which has been sponsored by Cuadrilla Resources Ltd, examines the history of comparable developments; the economic potential of a UK shale gas industry, focusing on Lancashire as an example of a part of the UK that could gain substantially; and the main barriers to its establishment and growth. It also investigates the partnerships that will need to be set up between the industry, its supply chain, local and national government, education and training institutions, and communities to ensure that local businesses, and local people, benefit from exploration and production.

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Scope of the report

This report examines the potential of a shale gas industry in the UK, and how to overcome the barriers to its establishment and growth.

In order to remain focused, this report does not examine the safety of hydraulic fracturing, either in the UK or overseas. Other expert bodies have looked into the process in detail, including the Royal Society,³ the International Energy Agency,⁴ the Energy and Climate Change Select Committee⁵ and the report commissioned by the Department of Energy and Climate Change (DECC) on seismic issues.⁶ We support their calls for strong regulation of all aspects of the drilling and hydraulic fracturing process, and also note the exploration and appraisal guidelines issued recently by the UK Onshore Operators Group (UKOOG).⁷

For the same reason, this report concentrates on the potential of shale gas. Other unconventional hydrocarbon resources in the UK, including unconventional oil⁸ and coal-bed methane, also have considerable potential, and they will be examined in future publications.

Finally, there are potentially large offshore shale gas resources, but as extraction would be considerably more expensive, we focus on the potential of onshore shale gas.

Conversions

In this report, for simplicity and consistency, we have tended to convert gas measurements into billion cubic feet (bcf) or trillion cubic feet (tcf). A helpful converter for many of the various energy measures can be found here: <http://www.bp.com/conversionfactors.jsp>

Acknowledgements

This report has been sponsored by Cuadrilla Resources Ltd. Its purpose is to:

- Study and apply the lessons of previous energy developments;
- Investigate the economic impacts of potential UK shale gas production at scale;
- Work out the practical steps, for both government and the private sector, to overcome the barriers to the establishment and growth of a UK shale gas industry.

This report represents the independent assessment of the IoD. The IoD is exclusively responsible for this report and its content, analysis and conclusions.

We would like to thank the numerous people we have met and spoken to during the course of the research for this report, including from national and local government agencies, academic institutions, business development bodies, representative bodies of the UK offshore and onshore oil and gas industry, exploration and production companies, supply chain partners, heavy industry, investors, and other experts. We are also grateful to the Members of Parliament who have taken the time to share their thoughts and concerns.

We are also very grateful to the many people who took the time to review earlier drafts of this report, provide valuable feedback and point out errors. All conclusions and remaining errors are ours alone.

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Finally, we would like to thank Dan Byles MP, Chair of the All Party Parliamentary Group for Unconventional Oil & Gas and member of the Energy and Climate Change Select Committee, for writing the foreword to this report and for his work, on behalf of both the APPG and the Select Committee, to ensure that the UK debate around shale gas is carried out in a level-headed way.

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Foreword

By Dan Byles MP, Chair of the All Party Parliamentary Group for Unconventional Oil & Gas, and member of the Energy and Climate Change Select Committee

Unconventional gas is simply natural gas. There is nothing unusual or mysterious about the product. It is the gas we already use to generate 28% of our electricity and heat 83% of our homes. Much of the controversy around shale gas comes, not from the product, but from the extraction technique used to access that gas. Hydraulic fracturing (fracking) is widely and mistakenly seen as a new technology and some fear the potential impact of fracking for shale gas on their local environment. In fact hydraulic fracturing has been used commercially in the US since 1949, and many people might be surprised to learn that around 200 onshore wells have already been fracked in the UK for conventional gas extraction – out of some 2,000 onshore wells in total. Worldwide, the total is around 1.1 million.

The safety record of fracking is outside the scope of this report, but there is a growing library of research from reputable expert organisations such as the Royal Society, the International Energy Agency, the Royal Academy of Engineering and others looking at the safety and regulatory issues. The weight of evidence so far suggests that unconventional gas can be developed safely with effective regulation, and I have no doubt that we will see further and more detailed work in this area. The UK now has the opportunity to marry up our gold standard oil and gas regulatory experience from the North Sea with lessons from existing shale gas industries abroad to give us a strong second mover advantage.

However, this is about more than simply gas; and more than energy security – though this is a serious concern the UK must address. As this report powerfully contends, as a nation we must also examine the potential economic impact that a well regulated domestic shale gas industry and supply chain could have in the UK, including potentially tens of thousands employed in highly skilled jobs and the opportunity to replace a proportion of the estimated £15.6 billion of gas the UK will be importing per year by 2030. The tax gap from declining North Sea and Fuel Duty revenues is expected to reach around 1.25% of GDP over the next twenty years. Replacing falling North Sea production with domestic shale gas could help to plug part of that gap. These are considerable economic impacts we cannot afford to ignore.

This is also about wider British industry, helping to manage energy costs for core sectors like manufacturing. Growing shale gas production could play a key role in reducing potential upwards pressure on gas prices from rising demand in rapidly developing countries such as China and India. In petrochemicals alone, replacing our dwindling domestic supply of chemical feedstocks (such as ethane, butane and propane) could safeguard up to 100,000 jobs. The evidence from the US, where utilising shale gas based feedstock has led to billions of dollars of new investment into the petrochemical industry alone, suggests this could be a significant economic benefit from developing UK shale gas.

This report highlights a number of barriers to developing shale gas, several of which could be summarised under the heading 'political'. Until recently the principle political hurdle has been at the national level, with an outright ban on fracking imposed by DECC until December last year following minor seismic activity at a Lancashire site in 2011. After a robust official inquiry by an independent body of scientific experts, that ban has now been lifted. With new work underway on community benefits and a favourable fiscal regime in place, the triumvirate of DECC, DEFRA and the Treasury are all officially in favour of developing shale gas. The political hurdles that remain, therefore, are local. If we are to see local authorities grant the planning permissions required to allow exploratory drilling to resume, we now need to see the Office of Unconventional Gas and Oil work with communities, industry and with the Department for Communities and Local Government to overcome concerns at a local level. That includes answering two very valid questions that many local communities are asking: "is this safe?" and "what's in it for us?"

Developing a UK shale gas industry will not happen overnight, and as lessons learned from the United States show us, nor should it. We need to allow exploratory drilling to go ahead in order to answer the many questions that still remain. Just as importantly, we need a rational debate on community benefit and safety. If people don't have confidence that shale gas can be developed safely with clear benefits for local communities, then we may never see the economic benefits described in this report. I chair the new All Party Parliamentary Group for Unconventional Oil & Gas, which will play a key role in that debate by bringing together the experts and the evidence in a rational forum for discussion. Reports such as this one, by credible organisations such as the Institute of Directors, are essential to help inform that debate. At the moment, the world is looking to the United States as an example of a shale gas industry at work. If we get this right, in future I believe the world could look to the UK as the gold standard for a well regulated and safe shale gas industry that benefits local communities and the nation.



Executive Summary

This report studies and applies the lessons of previous energy developments; investigates the economic impacts of potential UK shale gas production at scale; and works out the practical steps, for both government and the private sector, to overcome the barriers to the establishment and growth of a UK shale gas industry.

All references for data presented in the Executive Summary can be found in the relevant sections of the main body of this report. The key findings and recommendations include:

1. CONTEXT

The UK faces three problems that are particularly relevant to shale gas: an energy problem, a tax problem and a jobs problem.

Energy

- The UK is not expected to engage in a “dash for gas”. According to DECC’s central forecasts, overall **natural gas demand** (for heating and industry as well as electricity generation) is projected to remain roughly at today’s level over the next two decades – falling from 3,055 billion cubic feet (bcf) in 2011 to 2,621 bcf in 2020, before rising to 3,049 bcf by 2030.
- These gas demand projections are consistent with DECC’s central forecasts for **greenhouse gas emissions**, which project the net UK carbon account to fall, relative to 1990 levels, by 37% by 2020 and 45% by 2025.
- **Gas imports** are projected by DECC to rise dramatically. In 2000, the UK was exporting gas equivalent to 14% of UK gas demand. By 2011, net imports had risen to 45% of demand and by 2030, net imports are expected to increase to 76% of demand.
- This represents a large **import bill**. Multiplying net gas import volumes by DECC’s central wholesale gas price projections gives an estimated cost of imports of £7.2 billion in 2011, which more than doubles to £15.6 billion (in 2012 prices) in 2030.

Tax

- Declining North Sea oil and gas production and more efficient car and truck engines will lead to a fall in **tax revenues**. The Office for Budget Responsibility expects that a tax gap of around 1.25% of GDP will open up over the next two decades from lower North Sea and Fuel Duty revenues.

Jobs

- **Regional economic divides** show few signs of closing, with the recent recession making little difference to the long-run trends. In the North East, Wales and North West regions, **inactivity rates** have averaged over 25% of the working-age population over the last 20 years, while in the South East, East and South West regions, inactivity rates have averaged less than 21%.

- Similarly, over the last decade, the proportion of working-age people claiming at least one **out-of-work benefit** has averaged 15% or more in the North East, Wales and the North West, compared with less than 10% in the South East, East and South West regions.
- In 12 **local authority areas**, including Blackpool, the proportion of working-age people claiming at least one out-of-work benefit has averaged 20% or more over the last 10 years.

2. HISTORICAL NARRATIVES

The experience of developing a new hydrocarbon resource is not new to the UK. In the 1960s and 1970s, Aberdeen welcomed the development of a new offshore oil and gas industry, which guaranteed Britain's energy security for several decades, while Western Europe's biggest onshore oil field – Wytch Farm – is located in the middle of a number of environmentally sensitive sites. And Lancashire is well placed to become a centre of shale gas expertise.

Lancashire

- Lancashire has for centuries had first- or **early-mover advantage** in nascent industries. These included wool, cotton, coal, canals and railways. In the 20th century, this continued with motorways, aerospace and nuclear fuel manufacturing. High-technology manufacturing is one of Lancashire's key strengths today, with BAE Systems Lancashire's largest private sector employer.
- Viewed from a historical long-run, a shift to exploit the **Bowland Shale** in Lancashire is not a radical departure out of keeping with the region. The county is absolutely no stranger to the exploitation of natural resources, technological progress and business acumen.

Aberdeen

- Within living memory, Aberdeen has become the **energy capital of Europe**. In the 1960s, before North Sea production began, Aberdeen's main industries, including granite, shipbuilding and fishing, had started to decline.
- Offshore oil and gas production could have been centred in other cities in Eastern Scotland, but **Aberdeen City Council** and the North East Scotland Development Authority actively courted the oil and gas sector. A critical component was the human capital dimension, in the shape of around 5,000 skilled North American oil workers who were the first to work on the early rigs in the 1970s.
- Aberdeen benefitted from having a large airport and a good port, which was then expanded, but other areas of **infrastructure**, most notably roads, have been in need of upgrades for some time.

Wytch Farm

- Wytch Farm in Dorset is by far the **largest onshore oil and gas field** in the UK, and is also Western Europe's largest onshore field. Up to and including 2011, it had produced 81 bcf of gas, almost half of the UK's onshore total, and 59 million tonnes of oil, around 85% of the onshore total.
- Wytch Farm is located in a designated **Area of Outstanding Natural Beauty**; amongst Sites of Special Scientific Interest; on a World Heritage Coastline; amongst Ramsar sites (designated wetlands); on National Trust Land; and on National Nature Reserves. A wide array of environmental abatement measures were used in order to minimise the impact of the development, and environmental opposition is now almost non-existent.
- The **world record** for horizontal drilling was broken at Wytch Farm, reaching a lateral distance of 10.1 km.

The US

- **Technological progress** to develop the horizontal drilling and hydraulic fracturing techniques necessary to extract shale gas at scale took decades and involved a great deal of trial and error.
- The long-term development of the technologies required for commercial shale gas production stands as a good example of a useful **partnership between the public and private sectors**. Government supported the technological development process, and private sector capital and entrepreneurial risk-taking was also critical to the eventual breakthroughs.
- The US constitutes **anything but a uniform story** in shale gas activity. In Texas, regulatory expertise and stability were crucial to early production. In New York State, which still imposes a moratorium on hydraulic fracturing, the key lesson is that it is not enough to have a valuable resource. Years of delay will ensue at great cost if there is no regulatory certainty and the public has not been convinced of the economic benefits over the perceived threat of environmental damage.

3. ENERGY DEVELOPMENTS IN DETAIL

It is easy to underestimate the contribution that indigenous supplies of oil and gas have made to the UK economy and environment, and similarly to underappreciate the contribution of shale gas (and oil) to the US economy and environment. At the same time, other UK energy developments, including onshore wind and nuclear, provide lessons for the development of a UK shale gas industry.

UK oil and gas

- **Production** exceeded early forecasts by a large margin. In 1974, the Department of Energy projected that North Sea oil production would peak in 1981 at around 115 million tonnes. Actual oil production peaked in 1999 at 137 million tonnes, while gas production peaked in 2000 at 3,826 bcf.
- **Hydraulic fracturing**, albeit at differing intensities, has been used extensively both offshore and onshore. The development of new offshore gas fields, including Cygnus, Ensign and Clipper South, will include the use of hydraulic fracturing to improve flow rates. Over the last 30 years, more than 2,000 wells have been drilled onshore in the UK, of which around 200 have been hydraulically fractured to enhance recovery. Hydraulic fracturing was also carried out in the early 1980s as part of a geothermal energy research project in Cornwall.
- **Energy security** received a large boost. Between 1981 and 2005, the UK produced more oil than it consumed. Between 1970 and 2007, UK production was able to meet at least 75% of a growing and then roughly constant level of natural gas consumption.
- The UK's **balance of payments** was boosted by nearly £40 billion in 2011, with the supply chain adding another £6 billion in exports of goods and services.
- The **environmental** contribution of UK gas production was also significant. In 1965, before North Sea gas production began, coal accounted for 60% of the UK's primary energy consumption and natural gas less than 1%. In 2011, coal's share had fallen to 16%, and the share of natural gas had risen to 36%, reducing carbon emissions and improving air quality.
- North Sea **tax revenues** have been considerable, accounting for more than 5% of total government receipts for much of the 1980s and averaging £6.7 billion a year (2011-12 prices) since the first tax revenues were received in 1968-69. In 2011, the wider supply chain is estimated to have contributed a further £6 billion in corporation and payroll taxes.

- **Tax rates** on oil and gas production total 62% for fields developed after 1993 and 81% for fields developed before 1993, with field allowances reducing the rates for certain types of development. Capital investment has been quite sensitive to tax changes, underlying the importance of a stable tax regime.
- The oil and gas industry supports 440,000 **jobs** across the UK. Within the offshore industry itself, **average wages** stand at £64,000, well over twice the national average.
- In 2011, capital **investment** and operating expenditure reached £17 billion.
- **Aberdeen City and Shire**, the centre for offshore operations, has the second highest Gross Value Added per head of any region in the UK, after Inner London. The oil and gas industry, its wider supply chain, and induced activity support around 60% of the total employment in the region, while a third of the top 50 Scottish-based companies are located there.
- **Partnerships** are crucial to maintaining the health of the industry, with a number originating from the Oil and Gas Task Force report in 1999. For example, PILOT is focused on improving the competitiveness of offshore operations in the UK; OPITO is responsible for skills; Project Pathfinder provides real-time information on upcoming projects for the supply chain; and the Fiscal Forum encourages constructive discussion on tax issues between the industry and the Treasury. The Oil and Gas Industrial Strategy has recently been published.
- UK oil and gas production has supported the **petrochemical and other heavy industry** in the UK, both through providing petrochemical feedstocks and through supplying reliable, secure and competitively-priced energy. According to a recent report by the TUC, energy intensive industries paid £12 billion in corporate taxes and employed 160,000 people directly in 2008, with a further 640,000 employed in the supply chain.

US shale gas

- Dry shale gas **production** rose dramatically, from 749 bcf in 2005 to 8,135 bcf in 2012, accounting for around a third of total US natural gas production and exceeding official forecasts made just a few years ago. Shale gas production is forecast to rise to over 16,000 bcf by 2040, accounting for around half of total natural gas production.
- The most significant **shale gas plays** in the US are the Marcellus (Pennsylvania and West Virginia), Haynesville (Louisiana and Texas), Barnett (Texas), Fayetteville (Arkansas) and Eagle Ford (Texas).
- The largest shale gas producing **states** are Texas, Louisiana, Pennsylvania and Arkansas. In 2011, Texas and Louisiana each produced more shale gas than the UK's total production of natural gas, while Pennsylvania was catching up fast.
- **Energy security** has also been boosted. In 2007, US net gas imports peaked at 3,785 bcf; by 2012, net imports had fallen 55% to 1,717 bcf; and by 2020, the US is expected to become a net exporter of natural gas. This reduction in gas imports took everyone by surprise – in 2000, official forecasts predicted that US net gas imports would rise to 4,640 bcf in 2012.
- The US **balance of payments** has been assisted. In 2005, net gas imports had risen to almost \$30 billion. By 2012, net imports were costing less than \$4 billion, with lower import prices also helping to reduce the bill.
- The **direct economic contribution** of US shale gas production is very large indeed. In 2012, it accounted for more than 600,000 jobs, paid more than \$40 billion in wages, generated \$80 billion in value added and paid almost \$20 billion in federal, state and local taxes.

- The jobs are generally **well paid**, with average wages of \$117,000 for direct jobs and an overall average of \$71,000 for direct, indirect and induced jobs.
- In 2012, capital **investment** reached \$32 billion.
- In **Pennsylvania**, unconventional gas activity is estimated to have supported 79,000 jobs, contributed \$11.6 billion in value added and paid \$1.1 billion in state and local taxes in 2012.
- States with no shale gas production have also benefitted, for example by supplying machine tools or providing financial and legal services. According to IHS, more than 22,000 jobs are supported in **New York State** from unconventional gas activity.
- The **wider economic benefits** of US shale gas are also considerable. Since 2009, US natural gas prices have remained considerably lower than those in Europe and Asia. Production of important petrochemical feedstocks such as ethane and propane increased by 38% between 2008 and 2012, after many years of flat production. Ethylene, a crucial raw material for the manufacture of goods as diverse as food packaging, PVC window frames, tyres and adhesives, is now cheaper to produce in the US than almost anywhere else in the world.
- Major investments in **ethylene crackers** are being made, with ethylene production capacity set to increase by 33% according to PwC. A number of these investments are being made in the North East of the US, as well as in the traditional petrochemical hubs of Texas and Louisiana.
- As a result, PwC and Citi have estimated that at least 1 million new **manufacturing jobs** could be created over the next decade. **German** companies, including BASF, are making large investments in the US.
- The **environmental contribution** of shale gas has also been significant. Between 2005 and 2010, US CO₂ emissions fell by 403 million tonnes, greater than the 318 million tonne fall in the EU over the same period. Between 2005 and 2012, electricity generation from coal fell by 25%, while electricity generation from natural gas rose by 62% and from renewables by 38%. In Pennsylvania, air pollution has fallen quite dramatically, as shale gas production allowed coal-fired plants to be replaced by natural gas.
- **Renewables** development has taken place alongside shale gas production. Between 2005 and 2011, electricity generation from wind increased by 435% in the 15 shale gas producing states, and these states now account for 55% of US wind generation.
- Natural gas is increasingly used as a **transport fuel**, helping to reduce carbon emissions and improve air quality still further. Natural gas now powers 19% of public transport buses, and the fuelling infrastructure necessary to allow natural gas to be used in long-distance trucks is also being developed. The Chief Executive of FedEx has predicted that up to 30% of US long-distance trucking will be fuelled by compressed or liquefied natural gas over the next 10 years.
- US net **coal exports** more than quadrupled between 2005 and 2011, but to put the blame on shale gas is also to put the blame on wind and other renewables, as these have also helped to displace coal in the US.
- Shale gas development has led to **innovation** in water treatment. In this area, the number of unique patents filed in the last six years is as large as the number filed in the previous 25 years.
- State-wide **partnerships** have played an important role to develop skills and a supply chain and encourage the use of natural gas in public transport vehicles. And in Pennsylvania, the Center for Sustainable Shale Development has brought together environmental groups, including the Environmental Defense Fund, and the industry to set higher environmental standards for drilling operations.

Onshore wind and nuclear in brief

- The **onshore wind** industry has developed a Community Benefits Protocol for projects in England, establishing a minimum community benefit payment per megawatt of installed capacity and a process for identifying the relevant community. In Scotland, the Scottish Government Register of Community Benefits from Renewables provides transparent data on the funds provided to local communities hosting onshore wind and other renewable developments.
- In order to reduce **grid connection** delays, the Connect and Manage regime has, since 2010, allowed renewable projects to connect to the transmission system in advance of wider transmission reinforcement work.
- **Nuclear** skills training is extensive, with the official directory listing 23 universities, 14 further education colleges and 12 employer-nominated providers offering nuclear-related courses. Should a new nuclear power station at Hinkley Point C go ahead, at least 5,000 Somerset residents are expected to be employed during the construction phase. According to evidence given to the Energy and Climate Change Select Committee, people living close to nuclear power stations are generally more positive about nuclear energy than the national average.

Key lessons

A number of **lessons** can be learned from these developments:

1. Developments take **time** to achieve scale.
2. Production often **exceeds** early estimates.
3. The **economic benefits** of domestic production can be extremely large.
4. Domestic energy production should be thought about as part of a **wider economic development**.
5. Domestic natural gas production can lead to large **environmental** gains, in particular by replacing coal.
6. **Infrastructure** and **equipment** will be built over time by the private sector.
7. **Skills** can be developed over time, but **outside expertise** will be needed initially.
8. A **stable tax regime** is essential.
9. **Partnerships** are vital to attract investment, provide skills and develop the supply chain.
10. **Supportive local authorities** are also critical to gaining planning consent and attracting investment.
11. The **concerns of local communities** are important and need to be addressed.
12. **Transparency** can do a lot to reassure people that development is being carried out appropriately.
13. Determining responsibility and measures to be taken **if something goes wrong** also helps to provide reassurance.
14. **Finance** is important, both for local authorities and local communities.
15. The development context in the UK and US is **different**.

4. SHALE GAS POTENTIAL

A shale gas industry in the UK could replace a portion of gas imports; generate tax revenues; create jobs in parts of the country that need them most, including in wider manufacturing businesses; and help to reduce carbon emissions and improve air quality. Quantities of shale gas in place are significant, and further exploration will be needed to discover what proportion is recoverable.

Overview of shale gas benefits

- Shale gas could have three main **economic benefits**:
 1. UK shale gas could **replace a portion of gas imports**, improving energy security and the balance of payments.
 2. UK shale gas could represent a **new source of tax revenues** to replace in part falling receipts from Fuel Duty and the North Sea.
 3. Shale gas production could create **well-paid jobs** in parts of the country that need them most and support the wider manufacturing industry, helping to rebalance the UK's economy.
- UK shale gas could also have three main **environmental benefits**:
 1. According to the Committee on Climate Change, if production is well regulated, shale gas can have **lower emissions** than imported LNG. A recent report for the European Commission also reached the same conclusion.
 2. To the extent that UK shale gas supports the production of chemicals and other goods **in the UK** rather than overseas, emissions will be lower, as UK industry is more energy-efficient than in most countries.
 3. Natural gas has great potential as a **transport fuel**, particularly for HGVs and buses. Using Compressed Natural Gas in place of diesel could reduce CO₂ emissions and improve air quality.
- UK shale gas production could potentially have a benign impact on the level and volatility of wholesale prices, but in our view, it is **too early to tell**. The case for shale does not rest on any impact on prices – the six benefits listed above are sufficient.

UK shale gas resources

- Estimates of UK **shale gas in place** are significant. In 2011, the US Energy Information Administration estimated that the UK has 97 trillion cubic feet (tcf) of gas in place, while at the time of writing, the combined estimates of the exploration companies (in their licence areas) add up to 309 tcf of gas in place.
- In oral evidence given to the Energy and Climate Change Select Committee, Nigel Smith of the **British Geological Survey** stated that Cuadrilla's resource estimate of 200 tcf is "more reliable" than the original figure published by the British Geological Survey of 5.3 tcf.
- More important is the size of the **recoverable resources**, which is limited by factors such as technology and economics. The US Energy Information Administration estimated a technically recoverable resource of 20 tcf in the UK. Based on a recovery rate of 10%, the combined gas in place estimates of the exploration companies would equate to a recoverable resource of 30.9 tcf. This is nearly two thirds of the UK's potentially recoverable conventional gas resources.

- The British Geological Survey will shortly be releasing an updated estimate of the quantity of gas in place, which is expected to be substantially higher than previous estimates. NuTech Energy Alliance are carrying out detailed petrophysical analysis of legacy data from several hundred existing wells that drilled through shale rock in the UK, which should increase understanding of the geology and shale gas potential in various UK basins. And the **14th onshore licensing round** will encourage further exploration, allowing better estimates of the UK's recoverable resources to be made.

Advantages

- Although conditions for shale gas production are generally more favourable in the US, the **UK** does have several advantages. Around a third of road miles are unpaved in the US, compared to almost none in the UK; the UK's gas transmission network is closer to potential shale gas development areas than in many parts of the US; the UK's water and sewage networks are more developed; and wholesale gas prices are far higher in the UK.
- **Lancashire** is probably better placed to take advantage of shale gas production than Aberdeen was in the 1960s with respect to offshore production. The National Transmission System for gas has spare capacity and runs through Lancashire; road, rail, air and port infrastructure is excellent; a large industrial sector is located close by; and Lancashire boasts excellent high-end manufacturing.
- Lancashire could become a **centre of expertise** for European shale gas development, as Aberdeen is for offshore production. And Lancashire is far from the only region of the UK that could benefit.

What could shale gas production potentially look like?

- If further exploration confirms early indications that the UK's geology is favourable to shale gas production, it is worth examining what a **potential shale gas production** phase could look like, to get a sense of the possible magnitudes. [Note that this section details a potential production phase.](#)
- The IoD's previous report provided estimates of the overall number of jobs that could be created from a potential shale gas production phase in the UK. We are now in a position to update our previous estimates with a far more detailed model. **Section 4.4** in the main body of the report presents a detailed list of the **assumptions** made in our scenarios, which we do not repeat in this Executive Summary.
- A **single 10-well pad of 10 laterals** could represent an investment of £142 million over its lifetime and support 406 jobs at peak. It could produce 31.6 bcf of gas and, at peak, supply enough gas to power 260,000 homes, although production will decline relatively quickly. It could also use 136,000 m³ of water and see between 2,856 and 7,890 truck movements over 20 years, depending on whether the water comes from a mains connection or is trucked in. Assuming truck movements are concentrated in the early years of drilling activity, this averages out at 3.9-10.8 per day over two years.
- A **single 10-well pad of 40 laterals**, which could be feasible in a thick shale such as the Bowland, could represent an investment of £514 million, supporting 1,104 jobs at peak. It could produce 126.2 bcf and, at peak, power 747,000 homes. It could use 544,000 m³ of water and see 11,155-31,288 truck movements over 20 years, depending on whether the water comes from a mains connection or is trucked in. Assuming truck movements are concentrated in the early years of drilling activity, this averages out at 6.1-17.1 per day over five years.
- It is worth putting the number of **truck movements** into context. British dairy farmers produce 11 million m³ of milk each year. Milk tankers vary in size, but assuming a tanker capacity of 30 m³, 366,667 milk tanker journeys would be needed each year in rural locations to transport milk from the farms where it is produced.

- Gas and wind can work well together, but in order to appreciate the land footprint of shale gas development, it is worth providing a brief **comparison with onshore wind**. A shale gas pad could take up two hectares, and provide enough gas to generate 4,930 GWh (10-lateral pad) or 19,706 GWh (40-lateral pad) of electricity over its lifetime. Scout Moor wind farm in Lancashire has 26 turbines and covers 545 hectares. Assuming it continues to generate the same level of electricity as it has for its first few years of operation, it could be expected to generate 3,719 GWh over its lifetime.
- If a potential shale gas production phase could reach scale, then the potential benefits could be very large indeed. A multi-year development of **100 shale gas pads** of 40 laterals each could see peak production of 853 bcf a year in the low scenario, 1,121 bcf in the central scenario and 1,389 bcf in the high scenario. Capex and opex could peak at £3.7 billion a year, supporting 74,000 jobs in total (direct, indirect and induced - around twice as many as our previous estimate). Water use could peak at 5.4 million m³ per year, with a peak of 50 rigs drilling and fracturing 400 laterals a year, and flowback water could reach 1.6 million m³ per year. In the central scenario, gas import dependency could be reduced from 76% to 37% in 2030, and the cost of net gas imports in 2030 could fall from £15.6 billion to £7.5 billion (2012 prices).
- If each of these 40-lateral pads takes up two hectares of **land** on the surface, then 100 pads would need 200 hectares, equal to two square kilometres. The pads would of course be scattered, and additional land would be needed for gathering stations, compressors, water treatment plants etc, but, overall, shale gas development would not need vast tracts of land.
- **Other respected organisations** have also made estimates of potential shale gas production, which in many respects are similar to the IoD's. The Energy Contract Company (ECC) has set out three production scenarios, with production in 2029-30 reaching 621 bcf in the low scenario, 1,158 bcf in the central scenario and 1,726 bcf in the high scenario. Bloomberg New Energy Finance (NEF) has set out projections for UK shale gas production at peak of 730 bcf a year in the low scenario and 1,460 bcf a year in the high scenario.
- The ECC believes that shale gas production could be **commercially viable** (15% IRR) at gas prices of between 42 and 51 pence per therm, lower than the current level of wholesale gas prices. Bloomberg NEF concludes that the wholesale price of gas will need to be at least 45 pence per therm for production to be commercially viable (15% after-tax IRR).

5. BARRIERS

Talking about hypothetical recoverable resources and what shale gas development could potentially look like is one thing; actually ensuring that shale gas is produced is another. There are a number of barriers to shale gas development in the UK, many of which were not significant issues in the US, and they will need to be overcome. If they are not, shale gas production may struggle to get off the ground.

Overview of barriers

- The first potential barrier to the development of shale gas is **geology**. Early indications suggest that the UK's geology is favourable to shale gas production, but until further exploration and appraisal is carried out, our picture of the UK's geology will remain incomplete.
- The other barriers listed below can be grouped into **five broad categories**. Some are far more significant than others. The significant barriers tend towards raising the cost and slowing the pace of UK shale gas development.

Infrastructure, resources and equipment

- The UK already has an extensive **gas transmission and distribution** system that has spare capacity and has managed changes in flows in recent years, for example from the new LNG terminal in Milford Haven. *Not a barrier.*
- The UK's **transport infrastructure**, including around Lancashire, is excellent, with good roads, rail lines, airports and ports. *Not a barrier.*
- The UK's **water resources** are not unlimited, but around 11,000 million m³ of water is abstracted from non-tidal sources each year. Water use for shale gas could reach 5.4 million m³ a year, around 0.05% of the total. According to the Environment Agency's 2007 classifications (the most recent at the time of writing), water stress for the utilities serving the North of England is classified as low. *Not a barrier.*
- In February 2013, there were 1,708 **drilling rigs** operating onshore in the US, compared to just 82 in Europe. But Europe has had little demand for land rigs up to now, and there is no reason to believe the private sector cannot supply them. *Minor barrier.*
- **Midstream infrastructure**, including gathering pipelines and processing plants, will need to be constructed, but there is no reason to believe that the private sector cannot accomplish this. Planning permission will be needed. *Minor barrier.*
- The UK's **water treatment infrastructure** is extensive, although new plants are likely to be needed in areas of shale gas production. The UK produces 3,650 million m³ of sewage each year. Shale gas production could lead to 1.6 million m³ of flowback water per year, around 0.05% of total sewage production. *Minor barrier.*
- Obtaining a **grid connection** can take around 3 ½ years, which could slow down the pace of shale gas development. Lengthy grid connection times have also affected renewable energy developments. *Moderate barrier.*

Skills and supply chain

- The UK has an extensive offshore but not **onshore drilling services industry**. Less competition will be likely to mean more expensive drilling operations than in the US, although wholesale gas prices are also higher. Shale gas represents an opportunity to develop an onshore drilling services industry in the UK, similar to the offshore services industry, with the potential to export. *Minor barrier.*
- Despite high wages, finding the right **skills** is a major challenge offshore, and the offshore workforce is ageing. A recent survey found that 68% of offshore contractors and 75% of operators experience problems in recruiting suitable employees in particular occupations. Although many of the jobs required onshore are not highly skilled, recruiting suitably-qualified personnel will be a challenge for an emerging UK shale gas industry. *Moderate barrier.*

Finance

- The **tax regime** for shale gas production will need to strike the right balance between generating significant revenue for the Treasury and encouraging production. The existing regime, with a total tax rate of 62% and a Shale Gas Field Allowance providing some offset, would appear to be reasonable, provided the details are appropriate. *Not a barrier.*
- In the UK, **mineral rights** for gas are held by the state, not the landowner. But state ownership of mineral rights has not prevented 2,000 onshore wells from being drilled. Landowners will still receive payments for the use of their land and the National Union of Farmers, representing in most cases the relevant landowners in the UK, is not opposed to shale gas development. *Minor barrier.*

- **Local authority financial benefits**, or the lack of them, are more serious. The UK's tax system is one of the most centralised in the world. It provides a poor incentive for local authorities to encourage development, since the resulting tax revenues tend to flow to the Treasury. The newly-introduced business rates retention scheme will help, but with the baseline being reset every seven years, is not in its current form ideal for shale gas development, which does not pay business rates until production begins. *Moderate barrier.*
- **Community benefits** are also important, especially since landowners do not own the mineral rights for gas. Community support is not just about finance, but ensuring that local people, as well as local authorities, benefit financially from development is a critical part of ensuring that production goes ahead, as the onshore wind industry has discovered. *Moderate barrier.*

Regulation

- It will be important to ensure that **liability for abandoned wells** is vested in an appropriate body. The UK Coal Authority provides an example in the coal industry, and new nuclear power plants have to make financial provision for future decommissioning. *Not a barrier.*
- Wells drilled horizontally may pass underneath the property of other landowners, with claims for **trespass** presenting a risk. *Minor barrier.*
- More exploration is needed to assess the size and quality of the UK's shale gas resources. The **14th onshore licensing round** will open up new areas to exploration and allow new operators the chance to bid, but has been delayed by several years. The consultation period for the new Strategic Environmental Impact Assessment for the 14th round is now over, but at the time of writing, it is not clear exactly when the Government's response will be issued and the 14th round will take place. *Moderate barrier.*
- The **planning and permitting regime** is complex, with approvals from four agencies and two public consultations needed to drill and fracture an exploration well. There is also some uncertainty about when an Environmental Impact Assessment is needed. Each agency issues its own guidance for shale gas operations – in the course of our research we were unable to find a single guidance document setting out the entire permitting and planning process. *Major barrier.*

Reputation

- The UK is around 7.5 times more **densely populated** than the US, and Lancashire is nearly four times more densely populated than Pennsylvania. But 80% of the UK population live on less than 7% of the land, leaving large areas of sparse population. In certain parts of the US, shale gas development takes place in suburban areas. The UK's high population density has not prevented developments such as out-of-town supermarkets and 3,741 onshore wind turbines. And 100 shale gas pads of two hectares each would cover two square kilometres in total, scattered in different areas. *Minor barrier.*
- As mentioned in the "About the report" section, this report does not examine the safety of hydraulic fracturing as we do not propose to repeat the work of expert bodies such as the Royal Society. But, in our view, shale gas operations are currently facing a **confidence hurdle**, with successful drilling and fracturing needed to improve public confidence, and public confidence needed to facilitate development. *Moderate barrier.*
- The shale gas industry needs to have a **social licence to operate**. Public attitudes to shale gas in the UK are improving, as University of Nottingham surveys have shown, and around 50% of residents of Blackpool, Fylde and West Lancashire support continued exploration for shale gas in the region. But significant worries still remain, with 60% associating shale gas with earthquakes. US attitudes tend to be very favourable, with one recent survey finding that 83% of those who have leased their land for shale gas development in "mature" shale gas plays (in Texas, Louisiana and Arkansas) would do so again. *Moderate barrier.*

6. RECOMMENDATIONS

Shale gas development in the UK will be a two-stage process. Exploration must continue so that the size of the recoverable resource can be better determined. If exploration and appraisal is successful, production at scale can then be facilitated. Both stages will require partnerships to overcome the key barriers. And the more that shale gas can be seen as part of a wider economic development programme, the easier it will be to build and maintain those partnerships.

Overcoming the exploration hurdle

Recommendation 1: Provide guidance to clarify the planning process for exploration wells. Technical planning guidance will be issued, probably in July 2013, to provide clarity around planning for shale gas during the exploration phase. In our view, the guidance should clarify three points in particular. First, that an Environmental Impact Assessment is not needed for an application to drill a vertical or lateral well if the development is under the Schedule 2 threshold, but is needed for an application to hydraulically fracture. Second, that the sub-surface operations should be approved by the national bodies – DECC, the Environment Agency and the Health and Safety Executive – with the Mineral Planning Authority concentrating on the surface operations once approval for the sub-surface operations has been given. Third, the boundaries of the site.

Recommendation 2: Launch the 14th licensing round as quickly as possible. The last onshore licensing round took place in February 2008 – more than five years ago. The 14th licensing round should be launched as quickly as possible to facilitate further exploration and appraisal of the UK's shale gas resources.

Developing a shale gas industry

Recommendation 3: Put in place a financial framework that benefits communities and encourages wider economic development. There are three aspects. First, the Treasury tax regime, with a 30% rate of Corporation Tax, a 32% Supplementary Charge and a new Shale Gas Field Allowance. This looks appropriate, provided the details are right. Second, a mechanism will need to be found to ensure that local authorities benefit financially from development. The 100% business rates retention proposed by the Energy and Climate Change Select Committee is one option, provided that the baseline is not reset every seven years, and the revenue could be hypothecated to fund economic development projects. Third, a community benefits scheme should be set up. The onshore wind industry provides a good example of a community benefits protocol, but any mechanism needs to have real community ownership. And given the high tax rates paid by the industry, any extra payments made should be offset against the taxes paid to the Treasury.

Recommendation 4: Ensure that the planning and permitting regime facilitates production. More detailed guidance will be provided by the end of 2013 on the planning and permitting regime. There are several aspects. First, a National Policy Statement (NPS) should be drawn up for onshore oil and gas extraction. NPSs already exist for fossil fuel, nuclear and renewable generation, as well as transmission and storage infrastructure, so an NPS for extraction would be a logical step. Second, an NPS need not be used to replace the role of the local Mineral Planning Authority, but the sub-surface operations should be approved by the national bodies, as per our recommendation for the exploration phase. Third, planning and permitting must cover all potential activities on a pad, rather than covering each well, otherwise the regime would be akin to needing a separate planning application for each turbine in a wind farm. Fourth, operators should have the option to apply for planning and permitting approval for several pads at the same time. Fifth, fees should be set at an appropriate level to ensure sufficient qualified staff to process applications efficiently and undertake regular inspections, particularly to ensure well-integrity.

Recommendation 5: Make operations transparent. First, each pad needs to be accompanied by full disclosure of the chemicals used in the fracturing fluid, as set out in the guidelines issued by the UK Onshore Operators Group, as well as other operational data including truck movements and water use. Second, a fund needs to be set up with liability for abandoned wells. Third, a register should be set up to provide transparent data on the community benefits provided for each development, similar to the Scottish Government Register of Community Benefits from Renewables.

Recommendation 6: Provide skills and supply chain opportunities. First, the Government should work with the industry to develop a skills action plan, as recommended by the Energy and Climate Change Select Committee. For offshore production, OPITO is the focal point for skills, and a similar body could be useful for the shale gas industry, should production begin in earnest. A directory of universities and other providers offering relevant courses, as is produced for the nuclear industry, would also be useful. Second, Project Pathfinder provides real-time data on upcoming offshore projects for the supply chain, and a similar tool should be developed for UK shale gas projects, enabling the supply chain to plan ahead. The industry should also use local suppliers where possible and commercial.

Recommendation 7: Provide government leadership. First, the new Office of Unconventional Gas and Oil (OUGO) should have clear lines of accountability to a single Minister responsible for the office, as recommended by the Energy and Climate Change Select Committee. Second, OUGO should draw together the various planning and permitting guidance into a single document, setting out the entire process of gaining consent for exploration activities and production activities. It should also include expected timescales. Third, OUGO should take the lead on proposing measures to reduce the time it takes to obtain a grid connection. Fourth, one of the lessons from North Sea development is that skilled people from overseas may be needed initially, and the Government must ensure that the visa regime is accommodating. Fifth, OUGO should bring together the key government and industry stakeholders in a similar body to PILOT, which provided strong leadership and partnerships for the offshore industry at a critical time. These five measures are necessary, but may not be sufficient. Ultimately, the regulatory framework could potentially be streamlined, without losing any environmental safeguards.

Recommendation 8: Develop an online shale gas portal. A number of our recommendations include the need for transparency around matters such as drilling operations, community benefits and supply chain opportunities. Rather than provide the information on multiple websites, it could be useful to set up a single shale gas portal, providing full details of the impacts and benefits of development.

Introduction

The debate around shale gas and other unconventional hydrocarbon resources in the UK has too often been polarised between a “game-changing” narrative and two contradictory opposing arguments: that shale gas production will be too limited to make much of a difference; and that shale gas exploration and production will cause immense environmental damage, slow down decarbonisation and prevent the growth of renewable energy.

This report aims to present what we believe to be the real picture. In our view, the UK’s shale gas resources, if developed in an environmentally and socially responsible way, have the potential to reduce gas imports, generate tax revenues and create jobs in parts of the country that need them most. Shale gas development need not come at the expense of decarbonisation and renewable energy objectives; indeed, it could contribute towards meeting those objectives.

It is one thing, though, to talk about potential benefits, and another to ensure that they are realised in practice. So this report looks in some detail at how a shale gas industry could develop, and how the main barriers to its establishment and growth could be overcome.

This report is structured into six parts:

Chapter 1 looks at the context surrounding potential shale gas development. It notes that gas demand is likely to remain at today’s levels for the next 20 years, and that declining North Sea production will mean an increasing reliance on imports. It also points out that tax revenues from the North Sea and from Fuel Duty are likely to fall over time, and that regional divides in jobs and income per head show few signs of closing.

Chapter 2 examines the history of Aberdeen’s role in the development of North Sea oil and gas; the development of Wytch Farm, Western Europe’s largest onshore oil field; and how the US developed the technology to allow a shale gas industry to be established. It also examines the economic history of Lancashire, concluding that the county is well-placed to become a centre of shale gas expertise, continuing a long-standing tradition of innovation and development.



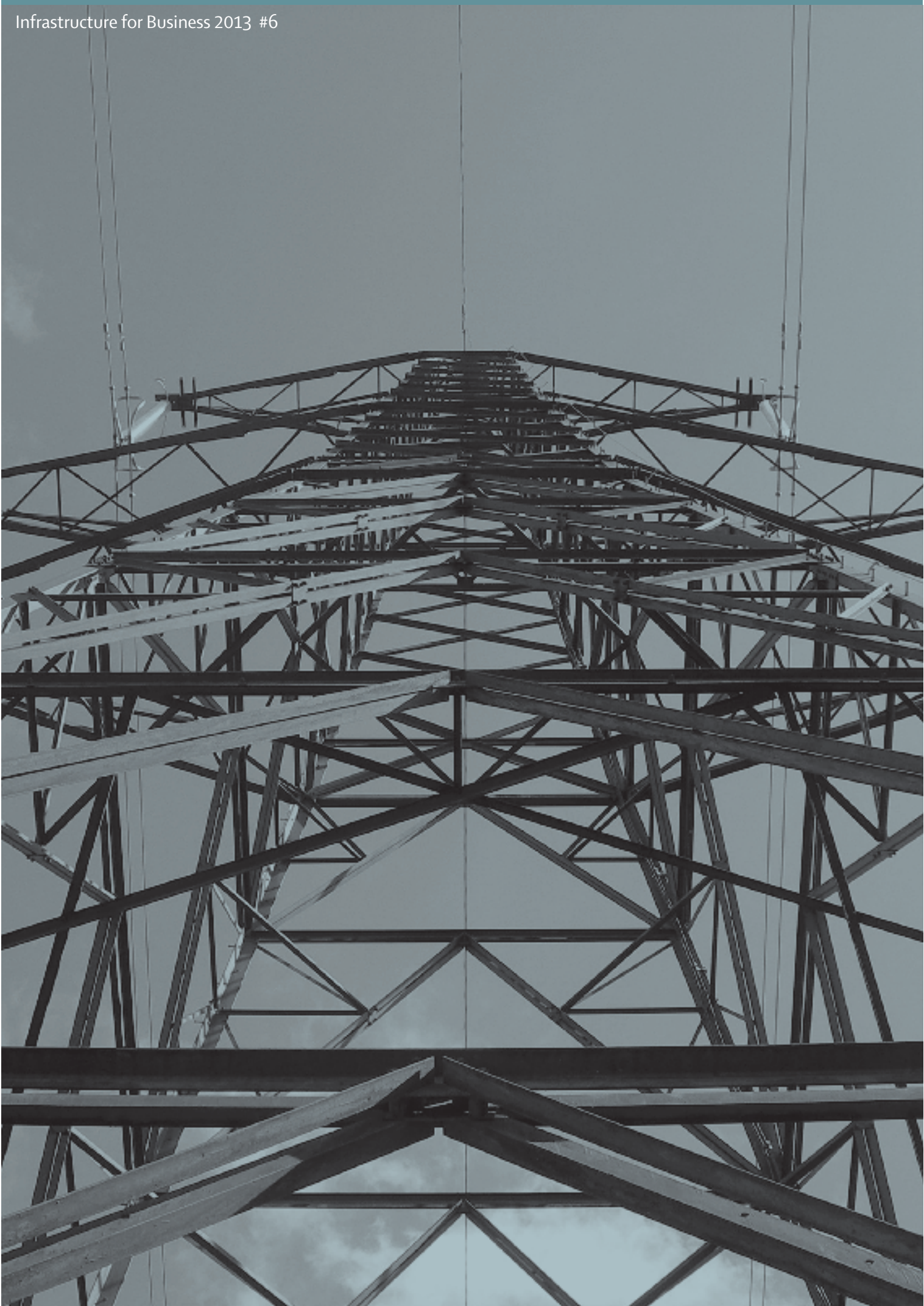
Chapter 3 examines the energy developments described in Chapter 2 in more detail, providing a wealth of data on production, economic contribution, environmental contribution and innovation. It also takes a brief look at other UK energy developments, including onshore wind and nuclear, and considers the lessons that can be learned.

Chapter 4 investigates the potential of a UK shale gas industry, focusing on Lancashire as an example. It explains the benefits that shale gas could bring, including to energy intensive industries, and notes that Lancashire has many advantages as a possible location. It describes how shale gas production could potentially develop, using three scenarios, and the economic benefits that it could bring.

Chapter 5 examines the barriers to the development of shale gas, pointing out that there is a real risk that the potential benefits will not be realised. It concludes that the principal barriers are not related to infrastructure or equipment, but to planning, permitting and sharing of the financial benefits.

Chapter 6 makes recommendations to ensure the industry can develop in a way that benefits local people. It concludes that the first step is to give planning consent swiftly to a number of exploration wells, so that the size of the recoverable resource can be better determined. It then makes recommendations on planning, finance, skills, supply chain, transparency and government leadership, concluding that it would be best to think about shale gas development not in isolation, but as a key part of a broader economic development programme.

It is worth emphasising that, in order to be focused, this report concentrates on the potential of shale gas. Other unconventional hydrocarbon resources in the UK, including unconventional oil and coal-bed methane, also have considerable potential, and they will be examined in future publications.



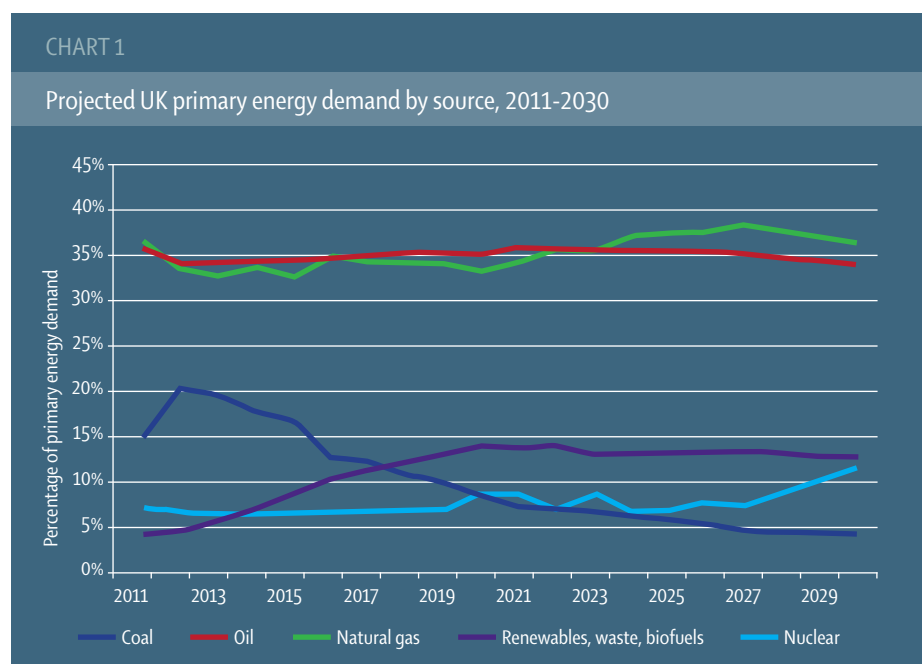
1. Context

The UK faces three problems that are particularly relevant to shale gas: an energy problem, a tax problem and a jobs problem.

1.1 ENERGY

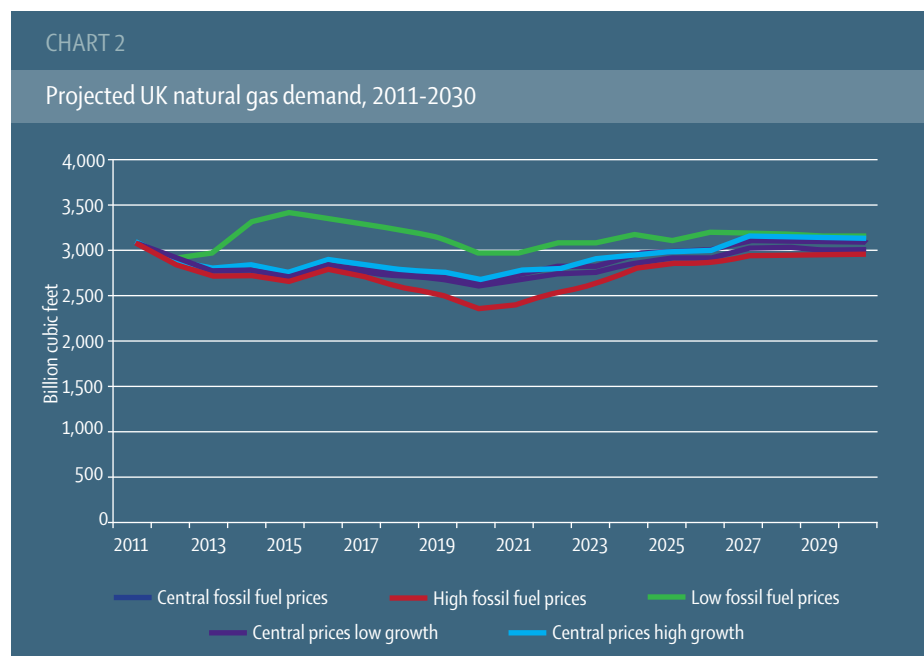
Media coverage of energy issues tends to concentrate on the power sector, but electricity production only accounts for around a third of the UK's gas demand. What really matters is the primary energy used throughout the economy – for heating, transport and industry as well as electricity.

Over the next two decades, overall primary energy demand in the UK is expected to remain roughly stable. In 2011, gas accounted for 37% of the UK's primary energy demand, a figure which, similar to oil, is expected to remain roughly constant over the next 20 years. Over the same period, coal's share is projected to fall from 15% to 4%, while the share of renewables is expected to rise from 4% to 13% and nuclear from 6% to 11%. These energy demand projections are consistent with DECC's central forecasts for greenhouse gas emissions, which project the net UK carbon account to fall, relative to 1990 levels, by 37% by 2020 and 45% by 2025.⁹



Source: Department of Energy and Climate Change, *Updated Energy and Emissions Projections – October 2012*, Annex H – Central Scenario <https://www.gov.uk/government/publications/2012-energy-and-emissions-projections>

In absolute rather than relative terms, the forecasts show that natural gas demand is expected to fall from 3,055 billion cubic feet (bcf) in 2011 to 2,621 bcf in 2020, before rising to 3,049 bcf by 2030. Far from a “dash for gas”, natural gas demand is expected to remain at roughly today’s levels over the next two decades. The level of fossil fuel prices and rates of economic growth are not expected to have a major impact on demand, as Chart 2 shows.



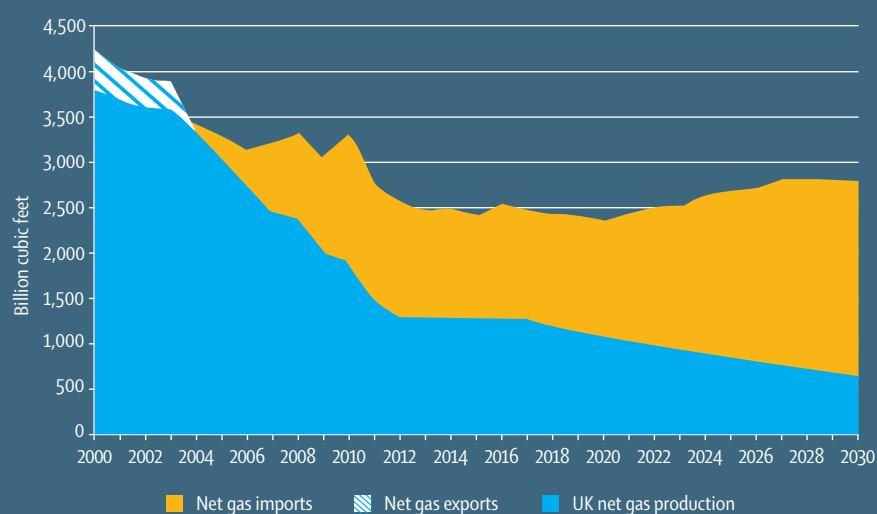
Source: Department of Energy and Climate Change, *Updated Energy and Emissions Projections – October 2012*, Annex H
<https://www.gov.uk/government/publications/2012-energy-and-emissions-projections>

The problem the UK has is that indigenous production is likely to account for a decreasing share of demand for natural gas. Net gas production (i.e. excluding oil and gas producers’ own use) from the UK Continental Shelf peaked in 2000 at 3,823 bcf. By 2011, production had fallen by around 60% to 1,516 bcf. By 2030, production is expected to fall by more than 50% of 2011 levels, to just 668 bcf.

This means that imports are set to account for a rising share of gas demand. In 2000, the UK was exporting gas equivalent to 14% of UK gas demand. By 2011, net imports had risen to 45% of demand and by 2030, net imports are expected to increase to 76% of demand. Currently, Norway and Qatar supply the majority of the UK’s imported gas.

CHART 3

UK net gas production and net gas imports, 2000-2030

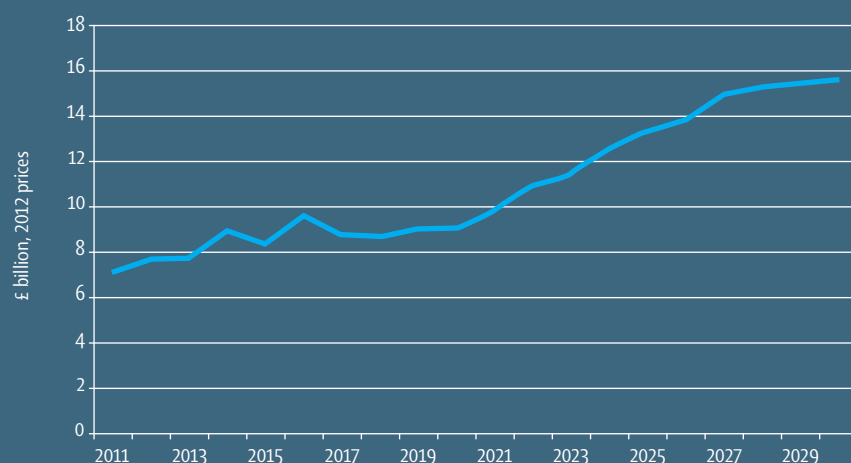


Source: Department of Energy and Climate Change, Production projections, extracted 15 March 2013 <https://www.gov.uk/oil-and-gas-uk-field-data>. NB: Figures given in billion cubic metres are converted to billion cubic feet.

This represents a large import bill. Multiplying net gas import volumes by DECC's central wholesale gas price projections gives an estimated cost of imports of £7.2 billion in 2011, which more than doubles to £15.6 billion (in 2012 prices) in 2030.

CHART 4

Estimated cost of projected net gas imports, 2011-2030



Source for prices: Department of Energy and Climate Change, *Fossil Fuel Price Projections, October 2012, Central Scenario* https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/65698/6658-decc-fossil-fuel-price-projections.pdf. Source for net imports: Department of Energy and Climate Change, Production projections, extracted 15 March 2013 <https://www.gov.uk/oil-and-gas-uk-field-data>. NB: prices given in 2012 pence per therm; net imports given in billion cubic metres converted to therms

The reality, of course, may be quite different from the official forecasts presented above:

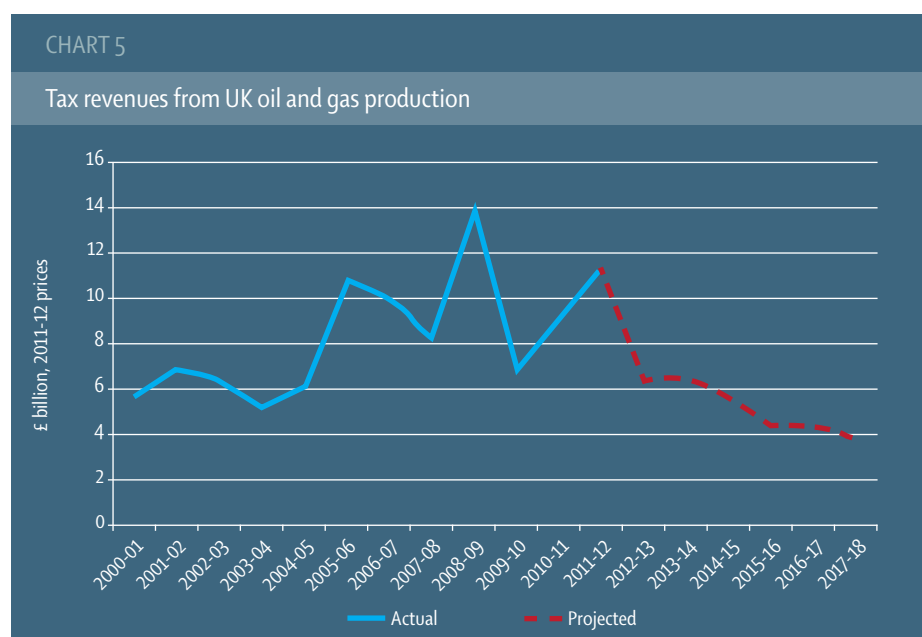
- On the positive side, the latest investment and production forecasts from Oil & Gas UK¹⁰ give reasons to be less pessimistic about the prospects for the North Sea – these forecasts will be explored in Chapter 3. Offshore gas production is still likely to fall over time, but it may fall more slowly, and may even increase for a few years, halting the rise in imports and giving the UK a bit of breathing space to establish onshore production at scale.
- On the negative side, gas demand could increase rather than remain roughly flat, increasing the demand for imports. And this could more than offset a more benign North Sea picture. There are a number of possible factors that could lead to a rise in gas demand: the new nuclear programme failing to achieve scale; energy efficiency measures falling short of aspirations; a slower-than-forecast rise in renewable generation; and a failure of coal-CCS to work commercially.

This matters because, without sufficient supplies of gas, coal is the default option. While coal's share of primary energy is projected to fall as coal-fired power stations are closed as a result of the Large Combustion Plant Directive and Industrial Emissions Directive, it has remained stubbornly high over recent years. Coal consumption is not expected to fall below its 2008 level until 2014.¹¹ In 2011, coal generated more than a third of the UK's electricity¹², and nearly two thirds of coal demand was met by imports.¹³

1.2 TAX

Declining indigenous oil and gas production (the North Sea oil story is broadly similar to the gas story described above) will inevitably mean a reduction in the taxes received from the North Sea. At the same time, car and truck engines continue to become cleaner and more efficient, a very welcome development but one that has already led to a reduction in Fuel Duty revenues. As fuel economy continues to improve, as conventional hybrid vehicles continue to grow in number, and as plug-in-hybrid and electric vehicles start to make inroads, Fuel Duty revenues will continue to fall.

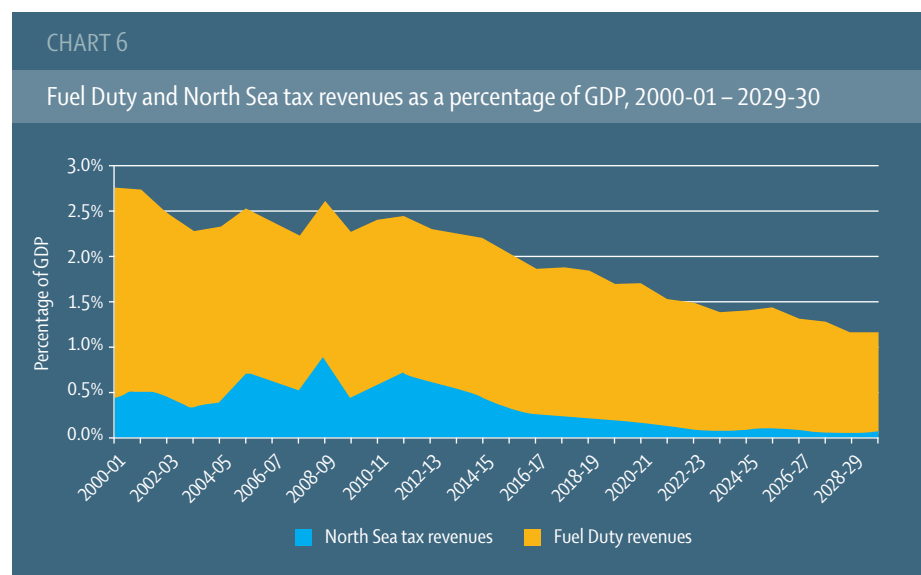
Since 2000, North Sea tax revenue has increased in real terms, largely due to higher tax rates and a higher oil price, but revenues are set to decline rapidly over the next five years, and to continue to decline thereafter.



Source for 2000-01 – 2011-12: HM Revenue and Customs, Table 11.11 (includes Petroleum Revenue Tax, Ring Fence Corporation Tax and Supplementary Charge) <http://hmr.gov.uk/statistics/prt.htm>. Source for 2012-13 – 2017-18: Office for Budget Responsibility, *Economic and Fiscal Outlook*, March 2013, Table 4.7 <http://budgetresponsibility.independent.gov.uk/economic-and-fiscal-outlook-march-2013/>. NB: Figures converted to 2011-12 prices using HM Treasury, GDP Deflators, December 2012 http://www.hm-treasury.gov.uk/data_gdp_fig.htm

Fuel duty revenues have been falling in real terms for a number of years, from £37 billion in 2000-01 (in 2011-12 prices) to £27 billion in 2011-12. Revenues are projected to stabilise over the next five years, but to continue falling thereafter.

As a share of GDP, North Sea taxes are projected to fall from 0.74% in 2011-12 to 0.2% in 2020-21 and 0.07% in 2029-30. Over the same period, Fuel Duty revenues are projected to fall from 1.7% of GDP in 2011-12 to 1.5% in 2020-21 and 1.1% in 2029-30.



Sources for North Sea: Office for Budget Responsibility, *Fiscal Sustainability Report*, July 2012, data for Chart 4.1 <http://budgetresponsibility.independent.gov.uk/fiscal-sustainability-report-july-2012/>; HM Revenue and Customs, Table 11.11 <http://hmrc.gov.uk/statistics/prt.htm>; HM Treasury, GDP Deflators and Money GDP, December 2012 http://www.hm-treasury.gov.uk/data_gdp_fig.htm. Source for Fuel Duty: Office for Budget Responsibility, *Fiscal Sustainability Report*, July 2011, data for Chart 4.4 <http://budgetresponsibility.independent.gov.uk/fiscal-sustainability-report-july-2011/>

Overall, a tax gap of around 1.25% of GDP is expected to open up over the next two decades from lower North Sea and Fuel Duty revenues. Indeed, as the Office for Budget Responsibility has stated, non-demographic trends affecting oil and gas revenues, transport taxes, environmental taxes and tobacco duties “could lower the tax to GDP ratio for these revenue streams by up to 2 percentage points over the next 20 years”.¹⁴

1.3 JOBS

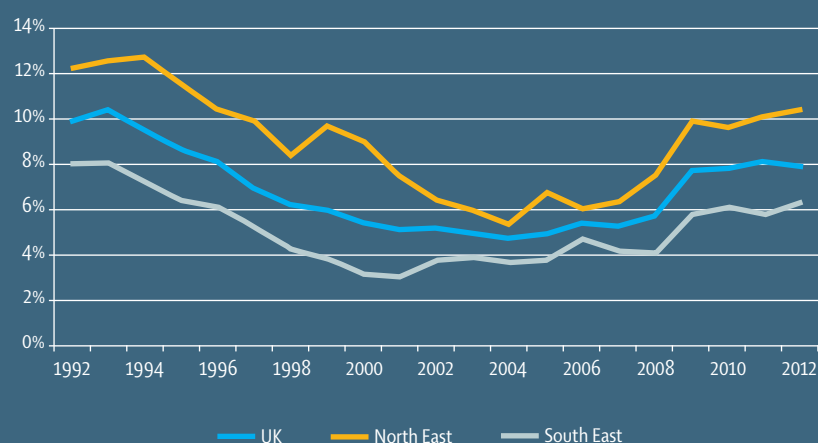
One of the surprising, and welcome, aspects of the recession over the last few years has been the extent to which employment in the private sector has held up (although more than a million people are now working part time because they can’t find a full time job¹⁵). But the UK’s jobs problem is less a cyclical and more a structural one in certain parts of the country.

Over the last 30 years, the number of jobs overall has increased by 5.8 million, but 3.1 million manufacturing jobs have been lost. The manufacturing sector now employs less than half the number of people it did in 1981,¹⁶ and this is not solely down to improved efficiency. Many of the new jobs have been created in lower value-added service sectors, and the loss of manufacturing positions has been a contributory factor in the persistently high unemployment and inactivity rates seen in certain regions and local areas of the UK.

Over the last 20 years, the UK unemployment rate has averaged 6.9%. In the North East, the region with the highest unemployment, the rate has averaged 9%. By contrast, in the South East, the unemployment rate has averaged just 5.1% over the same period.

CHART 7

Unemployment rate, percentage of all aged over 16

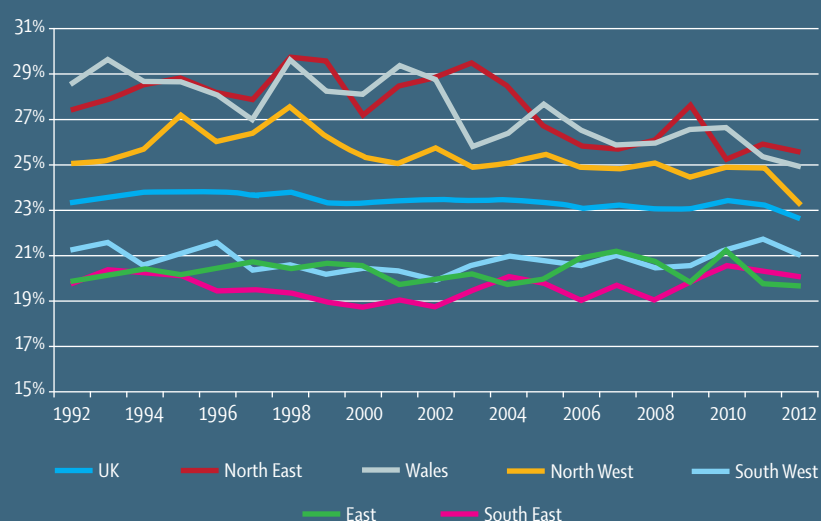


Source: Office for National Statistics, Labour Market Statistics time series data, 20 February 2013 <http://www.ons.gov.uk/ons/datasets-and-tables/data-selector.html?dataset=lms>

Economic inactivity rates are of course far higher than unemployment rates. Over the last 20 years, the UK inactivity rate has averaged 23% of the working-age population. In the North East, Wales and North West regions, inactivity rates have averaged over 25%, while in the South East, East and South West regions, inactivity rates have averaged less than 21%. These differences are sizeable. A 2 percentage point reduction in the inactivity rate in the North West, for example, would equate to around 91,000 more people economically active in the region.¹⁷

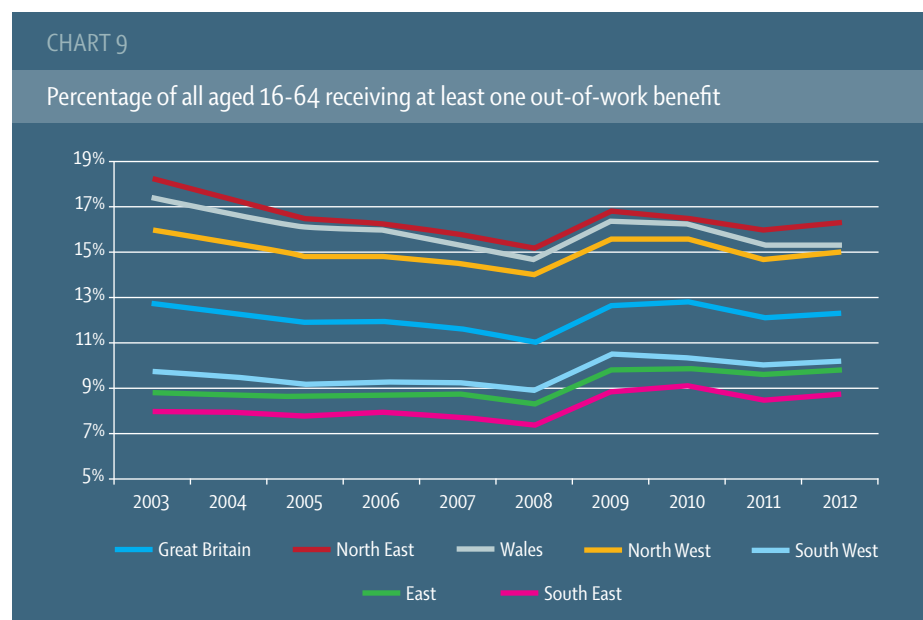
CHART 8

Economic inactivity rate, percentage of all aged 16-64



Source: Office for National Statistics, Labour Market Statistics time series data, 20 February 2013 <http://www.ons.gov.uk/ons/datasets-and-tables/data-selector.html?dataset=lms>

Out-of-work benefit claimant rates show a similar pattern. Over the last decade, the proportion of working-age people receiving at least one out-of-work benefit has averaged 12.1% in Great Britain, but 15% or more in the North East, Wales and the North West, compared with less than 10% in the South East, East and South West regions.



Source: Office for National Statistics, NOMIS Official Labour Market Statistics, Benefit claimants – working age client group, extracted on 26 February 2013 <http://www.nomisweb.co.uk/>

The proportion of out-of-work benefit claimants has been particularly high in certain local authorities. Over the last decade, the percentage of working-age people receiving at least one out-of-work benefit has averaged 20% or more in 12 local authority areas, and 18% or more in 25 local authority areas, as Table 1 shows. A number of these local authorities, including Blackpool and Knowsley, are located within commuting distance of Lancashire's shale gas resources.

TABLE 1

Percentage of all aged 16-64 receiving at least one out-of-work benefit, average for 2003-2012

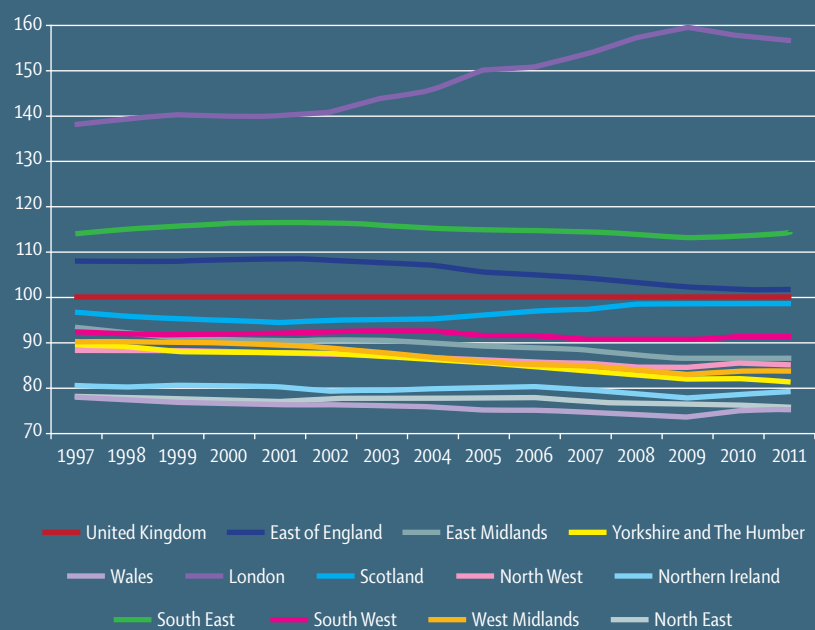
Merthyr Tydfil	24.5%
Blaenau Gwent	24.1%
Knowsley	23.1%
Glasgow City	22.5%
Liverpool	22.4%
Hartlepool	20.8%
Neath Port Talbot	20.8%
Inverclyde	20.8%
Rhondda, Cynon, Taff	20.5%
Middlesbrough	20.5%
Caerphilly	20.0%
Blackpool	20.0%
West Dunbartonshire	19.7%
Hackney	19.6%
South Tyneside	18.9%
Manchester	18.8%
Dundee City	18.8%
Stoke-on-Trent	18.7%
North Ayrshire	18.5%
North Lanarkshire	18.3%
Halton	18.3%
Kingston upon Hull	18.2%
Wolverhampton	18.1%
Burnley	18.1%
Birmingham	18.0%

Source: Office for National Statistics, NOMIS Official Labour Market Statistics, Benefit claimants – working age client group, extracted on 22 February 2013 <http://www.nomisweb.co.uk/>

At the same time, the regional divide in per capita Gross Value Added (GVA) has shown no signs of closing, with London now twice as rich as the North East, and the South East one third richer than the North West. As Chart 10 shows, per capita GVA in most regions has remained roughly constant as a share of the UK average over the last 15 years, with the notable exception of London, which has powered ahead.

CHART 10

Per capita GVA indices, 1997-2011 (UK = 100)



Source: Office for National Statistics, Regional Gross Value Added (Income Approach), December 2012, Table 1.5 (Residence-based GVA) <http://www.ons.gov.uk/ons/rel/regional-accounts/regional-gross-value-added--income-approach-/december-2012/stb-regional-gva-2011.html>



2. Historical narratives

The positive news is that the experience of developing a new hydrocarbon resource is not new to the UK. In the 1960s and 1970s, Aberdeen welcomed the development of a new offshore oil and gas industry, which guaranteed Britain's energy security for several decades, while Western Europe's biggest onshore oil field – Wytch Farm – is located in the middle of a number of environmentally sensitive sites. The US also provides an example of a successful shale gas (and oil) industry that has transformed the country's economic prospects. And Lancashire is well placed to become a centre of shale gas expertise, continuing a long-standing tradition of innovation and development.

This chapter is written by Dan Lewis.

2.1 LANCASHIRE

Can Lancashire become a regional, national, European or even a global centre of shale gas exploitation and expertise?

At first reflection, a knee-jerk response might be a resounding no. Naysayers might argue that because there is no oil and gas industry there, it could not scale quickly, if at all. A more measured secondary response might be to anticipate at least a severe challenge. Everything takes time and circumstances can always change. Yet both of these answers would ignore a whole swathe of postwar hydrocarbon development that has succeeded against the odds, at speed and in extreme, remote and empty environments. Deserts and deep oceans are a far more hostile operating environment than Lancashire farmland. And however obstructive and patience-defying Britain's mish-mash of planning laws are, there is never any question of a risk of the expropriation of company assets or of workers' lives being in danger from an authoritarian and/or unstable political regime or a lack of safety regulations.

It really would be an error to underestimate how mobile, disruptively dynamic and can-do the oil and gas industry can be over a short period of time when a significant resource becomes available. And with estimated gas in place of up to 200 trillion cubic feet (tcf) in the Bowland Shale alone, one side of the equation has clearly been fulfilled. And perhaps more than that, it would be a mistake to ignore Lancashire's pivotal position over the last few centuries in tradeable commodities, the industrial revolution, and its continuing role in a high-tech economy.

A brief history of Lancashire

Lancashire, whose name originates from the Roman city of Lancaster, has played a critical part in British history and its economy for most of the last 1,000 years. A young county by English standards, it was established in 1182. Lancashire famously constituted one side (as Lancaster and York) of one of England's earlier civil wars in the 15th century – known as The Wars of the Roses. Victory in this dynastic struggle led to the establishment of the House of Tudor under Henry VII. The Tudors were a Lancastrian family of Welsh origin and ruled England and Wales for 117 years until the passing of Elizabeth I in 1603.

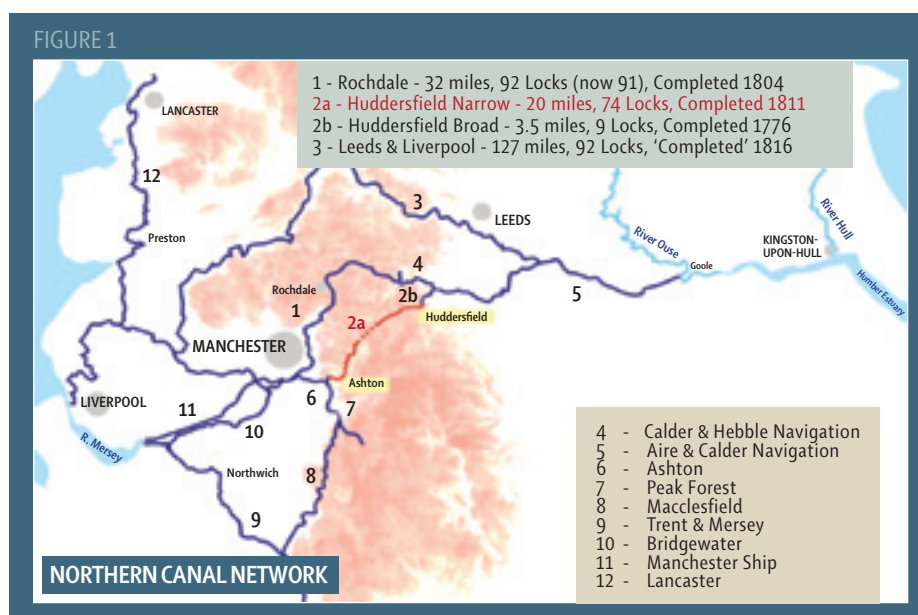
Lancashire then was politically important long before the Industrial Revolution. In a monarchical centrally-run state, with a family from that part of the world, it could only be so. Yet the same was also true economically. In the late medieval English economy, wool was far more critical than North Sea oil and gas is to the UK today. And wool was a major commodity of Lancashire. It is a testament to the power of the wool trade – and the huge export earnings that it brought in – that the House of Lords still has a woosack for the Lord Speaker to sit on, as originally ordered in the 14th Century by Edward III so that he would always be aware of the cornerstone of the economy.

Britain of course did not grow cotton. It was imported via the port of Liverpool, initially from Turkey and the Middle East and much later, in the 19th Century, in huge volumes from the Southern States of the United States until interrupted by the American Civil War in 1861. That Lancashire had such a major port as Liverpool on its doorstep would prove critical to many later developments too.

The other commodity that Lancashire had in abundance was coal. Dating from the carboniferous period 300 million years ago, mining of Lancashire's coal is believed – but not proven – to have started under the Romans or possibly by the Celtic tribe who preceded them, the Brigantes. The advantage of Lancashire's coal seams were that they were near the surface and in places even had outcrops, making them easy to mine or dig up with limited manual technology. After the Romans, there was not much need for coal with abundant wood and turf on the surface. And for a long time, Britain's population was much smaller, more rural and less energy intensive than in Roman times – 3.5 million people in Roman Britain in 200 AD but perhaps 2 million or less in 1066 at the time of the Norman invasion. Thereafter, the first recorded coal mining was in 1521, when Lord Derby granted a lease of mines in Whiston.

In the Elizabethan period, a new market was established for exporting Lancashire coal to Ireland from Liverpool. Shipments rose from approximately 300 tons a year between 1563 and 1599 to more than 4,000 before the outbreak of the Civil War in 1642. At peak in 1907, there were 94,300 miners operating 320 collieries in Lancashire producing 26 million tons of coal per year. Then a long decline ensued with the last mine closing in 1993.¹⁸

Growing wealth led to a major infrastructure gain for Lancashire – the canals – specifically, the one to Liverpool. Initially, canals were built for the carriage of limestone to build new two story homes and to lime-wash walls so workers could see well enough in daylight. However, it was then discovered that the most valuable commodity to transport would be coal.¹⁹ The first commercial canal, the Bridgewater, was built by the then Duke of Bridgewater in the 1760s to move coal from his mine in Lancashire to industry in Manchester. It was later extended from Manchester to the Mersey basin, opening up the port of Liverpool. The value of the canals was that horses could pull 20 times the weight on a barge than they could by cart on a road – this dramatically lowered the cost of exporting coal and opened up new markets.



Source: Huddersfield Canal Society

In the late 19th Century, the canals started to lose their competitive edge in cargo-carrying to another infrastructure gain, the steam railways. The East Lancashire Railway opened up not just a faster national and international connection for the import and export of raw materials and freight, but critically people.²⁰

Yet when the Industrial Revolution was born in Lancashire from 1750, it was only ultimately possible because of the skilled and entrepreneurial workforce it had in place. These people were not just working in the wool trade, but within the infrastructure of the Port of Liverpool, amongst the resources of the coal industry and in many other related activities. The main initial focus of the Industrial Revolution in Lancashire was the shift in cotton fabrication from home cottages to factories. This was thanks to the inventions of Richard Arkwright (born in Preston, Lancs.) that enabled mass production of cotton with the combination of new machinery, raw cotton and power from water mills.

Another Lancashire-based entrepreneur was Joseph Dunn, who enabled work outside of daylight through the importing and distribution of coal gas through the Preston Gaslight Company. Thanks to his efforts, Preston became the first town after London in the UK to be fully lit by coal gas. Lancashire's cotton mill industry peaked in 1860 with 2,650 mills and 440,000 people working in them. The fast flowing water of Lancashire powered the mills and the soft water was ideal for washing the cotton.

Canals and railways were not the only examples of Lancashire's leading position in transport infrastructure. Lancashire was home to the first intercity highway from Liverpool to Manchester, opened in 1934.²¹ Britain's first motorway, the Preston By-Pass section of the M6, was opened in 1958. Today, Lancashire's road network is well-served with motorways running North to South (M6) and from West to East (M55, M61, M65 and M62).²²

Equally, as befitting the leading aerospace cluster across the UK, Blackpool International Airport can lay claim to a rich history and number of firsts. One of Britain's oldest airports, it holds a claim to fame as the venue for the first air show in the UK in 1909. Civilian flights were launched in 1927 to the Isle of Man. And during the Second World War, Vickers erected a factory next to the runway and built 3,841 Wellington bombers. Measured in passenger journeys per year, Blackpool airport peaked in 2007 with 558,000 then suffered a major setback with the withdrawal of Ryanair. Of note is that Blackpool also provides a growing offshore service to oil rigs in the Irish Sea with Bond Offshore Helicopters. Today, Blackpool Airport has huge capacity for expansion as a regional player, with room for up to 2 million passengers per year,²³ but in 2012 only had 235,000.²⁴ And Blackpool itself still achieves an annual visitor tally of 12 million when all other transport links are included, making it one of the most visited UK destinations.²⁵

There have been some notable high-technology successes in the postwar period:

- Firstly, Lancashire is home to a cluster of nuclear activity of national significance. Springfield Fuels, now a subsidiary of Westinghouse-Toshiba, operates the UK's largest nuclear fuel manufacturing plant, at Springfields near Preston. Lancashire is the European headquarters of Westinghouse-Toshiba, a world-leader in nuclear reactor technologies. And nuclear reactors are still in operation at Heysham – if the new nuclear programme gets underway, Heysham will be one of the eight national sites retained for this purpose.
- Secondly, Lancashire is a significant centre of advanced engineering and manufacturing activity, with an estimated 90,000 people working in the sector.²⁶ British Aerospace, or BAE Systems as it is now known, is currently Lancashire's biggest private sector employer. In the late 1950s, one of its predecessor companies, English Electric in Warton, was responsible for building the wings, tailplane and engine cowlings of the radical Tactical Strike and Reconnaissance aircraft or TSR2, before its further development and production was cancelled by the government in 1957.²⁷ Since then, BAE Warton has assembled Typhoon jets and today is set to produce significant parts of the forthcoming F-35 Joint Strike Fighter – the world's largest defence procurement programme. Together with its other centre at Samlesbury, BAE employs around 12,000 people in the county, and in total, has around £19 billion of exports on its order books.²⁸

- Thirdly, Lancashire is also home to major international industrial companies, including Rolls-Royce and Leyland Trucks.

Viewed from a historical long-run, a shift to exploit the Bowland Shale in Lancashire is not a radical departure out of keeping with the region. Instead, it should be considered as a historical continuation of 1,000 years of often first or early mover advantage in nascent industries. The county is absolutely no stranger to the exploitation of natural resources, technological progress and business acumen. So what are the lessons that Lancashire could learn from other parts of the world that were suddenly endowed with hydrocarbon resources?

2.2 ABERDEEN

Today, Aberdeen can justly claim to be the energy capital of Europe and even vies with Houston to be the leading energy capital of the world. The discovery and successful exploitation of North Sea oil and gas from the 1960s was not only a game-changer without many parallels. It also happened in memorable history within these shores. And whilst today's political class has been all too reticent in their praise of the offshore oil and gas industry, they have not held back in making the most of the huge tax receipts, skilled jobs and regional economic growth that have developed off the back of it.

The numbers are quite staggering. Further details are given in Chapter 3, but a snapshot of the economic contribution of the UK oil and gas industry is provided below:

- £40 billion contribution to the balance of payments, with the supply chain adding another £6 billion in exports of goods and services;
- 25% of total corporation taxes;
- 440,000 jobs.

Moreover, it would be a mistake to believe that jobs from North Sea oil and gas have only been created in Scotland. Many oil and gas companies engaged in the North Sea have headquarters in London or within easy reach of the M25 and either Heathrow or Gatwick. Some 55% of jobs are actually located outside of Scotland, with a full 21% being in the South-East.

For all that, it is the local impact that has been most impressive. Aberdeen now has 18 of Scotland's Top 50 companies. And with just 9% of Scotland's population, it is responsible for 26% of its national turnover.

On arriving in Aberdeen by air, the first impression is how many helicopters there are. Aberdeen is the world's busiest heliport, making 37,000 flights a year carrying 480,000 passengers to and from North Sea oil rigs. The next most immediate impression to the visitor as they leave the airport by road is the traffic. It is heavy with new and nearly new cars and reaching the city from the airport takes around an hour in congested, crawling and sometimes narrow roads. It is hoped that the traffic problems will be overcome with the much-delayed construction of the 28 mile Aberdeen bypass or the "Aberdeen Western Peripheral Route", to be finished in 2018.²⁹

Of course, oil and gas production cannot last forever but even here there is good news. Despite oil and gas production peaking in the North Sea over a decade ago, Aberdeen's oil and gas industry actually succeeded in decoupling from declining North Sea production and building a growing export industry with expertise in subsea engineering, service port industries and other supply chain technologies. In 2013, over 40,000 direct and indirect new jobs will be created in the oil and gas sector. The challenge today for Aberdeen is finding people to fill the jobs.

A brief history of Aberdeen's role in North Sea development

For Aberdeen though, it was not ever thus. In the early 1960s, Aberdeen did not have a great deal going for it. The city had a fishing sector and some fish processing, which was very junior to other Scottish fishing ports to the north like Peterhead and Fraserburgh, and Lerwick in the Shetland Islands. Worse, the Scottish fishing industry as a whole was hit by a triple whammy of declining bottom-dwelling demersal fish stocks (i.e. cod, whiting, haddock), newly restrictive fishing rights under the Common Fisheries Policy with Common Market membership from 1973 and the sharing of those dwindling fish stocks with foreign registered vessels. In the UK, the peak landing in tonnage for the fishing industry, of which around 60% or more typically were sourced from Scotland, occurred in 1970.

Aberdeen's other historic industry, granite quarrying, had gone into decline much earlier. For 200 years from the 18th Century, granite from Aberdeenshire's granite quarries had been used for a number of historic buildings and structures across the UK, including the Forth Bridge and the Terrace of the Houses of Parliament. But after 6 million tons had been extracted from the biggest quarry at Rubislaw, leaving one of Europe's largest man-made holes, the site was closed permanently in 1971.

Aberdeen's other sector, shipbuilding, was also facing a prolonged period of decline. Since 1811, it could lay claim to building nearly 3,000 ships.³⁰ The last shipyard however, Hall, Russell & Co. Ltd., closed in 1992.

TABLE 2

Rise and Fall of Aberdeen shipbuilders – 1811-1992

Shipyard	Years in existence
Hall, Russell & Co. Ltd	1864-1992
Alexander Hall and Company	1811-1958
John Lewis & Sons Ltd.	1907-1976
Duthie Shipyards	1817-1907
Walter Hood & Co.	1839-1881

Source: Aberdeen Built Ships Project Website <http://www.aberdeenships.com/>

With fishing going, shipbuilding disappearing and granite gone, it was not obvious where the next source of private sector employment for Aberdeen would come from. Aberdeen City Council's enthusiasm for oil and gas has to be understood in this context.

So just when did a potential opportunity for oil and gas come about for Aberdeen?

Contrary to widely received opinion, it was a surprisingly long time between the discovery of North Sea oil and gas and the first arrival of oil flowing to Scotland's coastline by pipeline. The North Sea's potential was first realised in 1959 with the discovery of the Groningen gas field off the coast of the Netherlands which is still the largest gas field in Europe. It was known by geologists at the time that the Netherlands sedimentary basin went much further out into the North Sea and that augured well for future discoveries. Groningen was the spark that launched a chain of events that ended in oil in Aberdeen. But it took time and arguably, longer than it should have done.

Echoing somewhat the slow take-up of shale gas in the UK, it was a full five years until the regulatory and licensing process was in place for exploration to start. Until the passage of the Continental Shelf Act in 1964, there were no regulations governing hydrocarbon exploitation outside of territorial waters. And there were endless discussions and debates over how to organise a licensing round, how much ownership the state should take of the resource and which nations were entitled to which parts. Resolution did not come quickly. Discovery – at scale – did not come immediately either. The game-changing large field discoveries were essentially the Forties field in 1970 and Brent in 1971.

FIGURE 2

Timeline: 16 Years – from Groningen to oil's arrival in Aberdeen

1959 – Discovery of Groningen gas field
1961 – Shell seeks and fails to get exploration licence from Ministry of Power
1961 – Shell commences seismic exploration off British coast
1963 – Groningen gas production starts
1964 – April: Passing of Continental Shelf Act
1964 – May: Round 1 of Licensing launched for 86,000 square miles of North Sea
1964 – September: Licences awarded
1965 – Launch of Second Round
1965 – First gas discovery by BP
1966 – First oil discovery by Burmah Oil
1967 – First well drilled in the North Sea
1969 – Launch of Third Round
1969 – First Commercial Oil Discovery by Amoco in Central North Sea
1970 – BP discovers Forties field
1971 – Brent field discovered in East Shetland Basin by Shell
1971 – Launch of Fourth Round including relinquished acreage from Rounds 1 and 2
1975 – First oil pipeline from the Forties field in North Sea opened by the Queen at Dyce

Source: Alex Kemp, *The Official History of North Sea Oil and Gas: Vol. I: The Growing Dominance of the State*, 2011

Nonetheless, very early on, not everyone in Scotland was enthused, or felt that they would sufficiently benefit from the North Sea. That's why the 1970s was also a period when the Scottish National Party reached new polling highs which again would not have been possible without the prospect of increased ownership of North Sea oil and gas for Scotland. Their political slogan for that period was: "It's Scotland's oil". Their campaign found resonance with a number of Scots, securing seven seats in the House of Commons. More seriously, a terrorist group also emerged, The Army of the Provisional Government. Also known as The Tartan Army, they attacked four different oil pipelines in the early 1970s.

The relatively long period of time between Groningen and oil arriving in Aberdeen in 1975 was a decisive period for the city. Throughout the 1960s, policymakers in Scotland and London were already thinking about what a North Sea oil and gas industry would look like and where it could be. At the more local level, Aberdeen City Councillors appear to have identified this as an opportunity that they had to have. It may be that they did not have much of a choice. As has been explained earlier, Aberdeen did not have an otherwise great future ahead of it. And as it became clear where the oil and gas was located, Dundee would have been the more obvious location for the offshore service centre as it was nearest the biggest fields. Moreover, Edinburgh could lay claim to an army of professionals to lay the groundwork for the new industry.

Yet in actual fact, Aberdeen had some key advantages over Dundee and Edinburgh. Perhaps the primary advantage that put it ahead of Dundee was that it had a good length 2,000 metre runway made of asphalt whereas until the 1970s, Dundee only had a short 900 metre grass runway which itself was only opened in 1963. Clearly, offshore oil and gas rigs would have to be reached by air and good connections needed to exist with other parts of the UK and beyond. So this alone ruled out Dundee without a major upgrade to the airport.

Meanwhile, Edinburgh, the capital city of Scotland, itself was near enough to the major fields in the North Sea. But this was a city that already had a lot going for it in terms of wealth and a wide range of leading sectors: finance, insurance, banking, tourism, and a major university, to name but a few. The prevailing view of Edinburgh was that they really didn't need an oil and gas sector on top of what they already had.

But by far the biggest reason why Aberdeen succeeded was because they wanted and actively courted the oil and gas sector. Spearheading this effort was the North East Scotland Development Authority (NESDA) which was set up by the five North East Scotland planning authorities in 1971.³¹ NESDA rolled out the red carpet for the oil and gas industry and they came. NESDA also produced a series of papers – alas lost in time – that tracked progress.³²

This support was also important when it came to improving Aberdeen Harbour, which was almost completely rebuilt from the 1960s.³³ Legally, the Harbour is one of Britain's oldest businesses. The first written record of Aberdeen Harbour dates back to 1136 when the Scottish King gave the Bishops of Aberdeen permission to levy a tithe on ships trading at the port.

The improvements from the 1960s onwards were highly significant to the oil and gas industry, which needed very large ships to come and be serviced shore-side. The navigation channel was deepened, additional deep water berthing was constructed, more powerful tugs were procured, a new roll-on roll-off terminal was built and by 1984, a number of oil bases had been built.

Aberdeen's success, though, was not just a story of serendipity and local government and planning foresight. A critical component was the human capital dimension, in the shape of around 5,000 skilled North American oil workers who were the first to work on the early rigs in the 1970s. Building skills and human capital takes time in a new industry in a new area and it could not have been done without a lot of outside help.

Aberdeen then stands out as an example to modern day Lancashire. It too was faced with decline and its best days were seemingly behind it. But the city, in the shape of its planners and political leaders, did see fit to embrace the opportunity that North Sea oil and gas gave them. They were also very fortunate to have a comparatively large window of time, perhaps about 10 years, to see the opportunity coming and to do something about it. And they have never looked back. Today, Aberdeen's biggest problems are traffic and trying to find skilled people for a large number of unfilled job vacancies.

2.3 WYTCH FARM

Wytch Farm in Dorset, not just the UK's but Western Europe's biggest onshore oil field, is the oil field most Britons have never heard of. At peak production in 1997, it was producing 110,000 barrels per day (bpd) which today has fallen to 16,000 bpd.³⁴ It is a huge surprise to most people to realise that the nodding donkeys of oil wells don't just exist in Texas surrounded by people in cowboy hats, but in a picturesque part of England too.

Discovered in 1974, it was initially developed jointly by BP and the state-owned British Gas Corporation and since the 1990s, it has become a showcase in technology, minimized environmental impact and good relations with the local community and council. In 1995, it won The Queen's Award for Environmental Achievement.

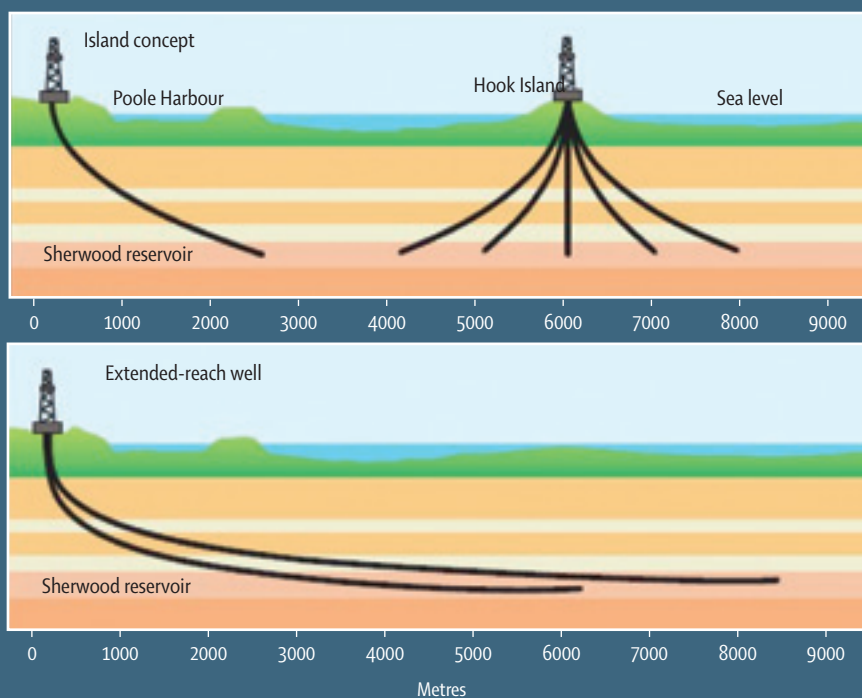
The technological achievement

Wytch Farm consists of three separate oilfields that lie under Poole Harbour and Poole Bay called Bridport, Sherwood and Frome. The Wytch farm facility sits on the coastline and is largely hidden from public view by a coniferous forest. In the 1990s, it was realised that to extend and raise production, drilling would have to go much further out. There were two options;

1. Create an artificial island offshore and place drilling equipment there for direction wells.
2. Drill further horizontally, known as "extended-reach drilling".

FIGURE 3

Two proposed solutions for Wytch Farm: artificial island or extended reach



Source: Oilfield Review http://www.slb.com/~media/Files/resources/oilfield_review/ors97/win97/ex_drilling.pdf

When it was realised that the second choice was not only possible, but development costs would be less than half and it would be ready three years earlier, the extended-reach well solution was chosen. However, the really impressive technological feat behind this was that the world record for extended-reach drilling was broken by reaching a horizontal distance of 10.1 km on the M-11 well. This alone brought onstream an additional 20,000 bpd.³⁵ Along with some other record-breaking laterals, the surface impact of obtaining additional resources was virtually negligible and is instructive for what a number of long-distance laterals from just one pad in Lancashire could look like.

The environmental measures

BP took the trouble to consult widely in the 1980s about developing Wytch Farm.³⁶ For the amount of oil it has produced, Wytch Farm is perhaps one of the lowest visual impact oil wells in the world. For a number of reasons it had to be. It is located in:³⁷

- A designated Area of Outstanding Natural Beauty;
- Amongst Sites of Special Scientific Interest;
- On a World Heritage Coastline;
- Amongst Ramsar sites (designated wetlands);
- On National Trust Land;
- On National Nature Reserves.

So if anything was to go wrong, it would have been an extremely expensive clean-up along with a public relations disaster for BP. A wide array of environmental abatement measures were used in order to minimise the impact of the development – a number at the instigation of Dorset County Council (DCC). These included:

- Designing the surface site to blend into the environment;
- Painting equipment in earth-tone colours to minimise the visual impact;
- Pointing all lighting downward;
- Installing a noise-control package on the drilling rig;
- Setting up regular atmospheric monitoring and lichen observation on nearby trees;
- Regular monitoring of groundwater with a specially installed borehole.

And should anything still go wrong, BP has to have worked with DCC in advance to draw up contingency plans to deal with any unexpected pollution risks. This planning is updated from time to time to reflect changes in regulations, policy and legislation and experience-based learning from any incidents. The latest version was published in December 2010 by the Bournemouth, Dorset & Poole Local Resilience Forum outlining the actions, roles and responsibilities of the different parties.

There are lessons that can be learned from Wytch Farm for Lancashire shale gas. In many ways, gas is inherently much safer than oil – the risks of environmental catastrophe from leaking crude oil are much greater than from the escape of lighter than air methane. And Wytch Farm shows that adopting comprehensive safety measures, reducing the visual environmental impact and engaging with the local community goes a long way to assuaging local doubts about development. Today there is no real tangible opposition to Wytch Farm, which was not the case in the 1980s.

At the same time, there was also no real idea of how much oil Wytch Farm could produce or what it would be worth. When the British Gas Corporation was forced to dispose of Wytch Farm in the 1980s, trying to estimate how many bpd it could produce and what the resource might be was very difficult. The figures ranged very widely. So policymakers should not be too onerous or prescriptive when trying to set the terms of investment on private companies taking a risk with their capital.

2.4 THE US

Even in the US, for most energy analysts, shale gas has only been on the radar for just a few years. The history though is much longer and more complex than widely assumed. It was in fact a decades-long ramp-up of experimentation, critical innovations and at times, patient entrepreneurial risk-taking, useful state support and pan-industry privately-funded research and development.

Technological progress over the long term

The first shale gas was fractured in 1821 from a shallow shale gas well in Fredonia, New York State, drilled by William Aaron Hart.³⁸ In an echo of Joseph Dunn's Preston Gaslight Company, who a decade earlier used coal gas for lighting, Hart used the shale gas for up to 150 streetlights in Fredonia.³⁹ In 1864, near the end of the Civil War, a further development of shale resources (oil rather than gas) came from experimentation using gunpowder and then nitroglycerin to open up fractures in rocks for oil. Colonel Roberts, the pioneer of this technology, patented a method known as "shooting" to enhance oil recovery from shale. This comprised of a torpedo-like metal encased explosive which was lowered into a well and ignited by a weight dropped onto a percussion cap.⁴⁰ This was obviously dangerous work.

The interest in shale rock exploration for gas or oil, however, did not last. There were simply far easier ways to obtain natural gas and oil. And at that point in the 19th Century, with the demand for kerosene for lighting, oil was then still far more valuable than gas, although there was not a huge market for oil either. As the US entered the 20th Century, this started to change and the demand for hydrocarbons to fuel industry and transport increased dramatically.

Hydraulic fracturing made its first US appearance in the 1940s, believed to be at either the Hugoton field of Kansas in 1946 or Oklahoma in 1949 and has since been used on over 1 million oil and gas producing wells.⁴¹ Hydraulic fracturing was first used for the exploitation of "tight natural gas" from limestone or sandstone. Critically, this was far easier to do than shale rock, requiring much less water, sand, lubricants and pressure and little precision in locating the pockets of gas beforehand. It was well-known that the much larger shale rock formations contained a lot of gas but for decades no one knew how to get it out in quantity, and less still at a commercially viable rate.

The problem yet to be solved was that while shale rock was known to contain a lot of pores that contained oil and gas, as a non-permeable rock, there were very few connections between the pores which would allow the oil and gas to flow. Technology would need to progress substantially to break and keep open connections between those pores, but it would take high risk investment from deep pockets.

Microseismic imaging – real-time monitoring and mapping of hydraulic fracture operations using surface, near surface and downhole digital arrays – had also yet to be invented. The same was true of directional drilling and diamond-studded drill bits. Interestingly, a number of the research breakthroughs necessary for shale gas exploitation were funded or part-funded by agencies of the federal government. In its infancy, the shale gas industry was also supported by production tax credits not unlike those received by the renewable industry today, although nothing like on the same scale.

An influential paper by the Breakthrough Institute catalogued the extent of government involvement. It found that, in the beginning: *"Engineers had neither the technology nor the knowledge base to cost effectively map shale expanses, drill horizontally in the formation, initiate fractures that were productive and predictable, and recover the gas resources locked in the formations."*⁴²

The first government-funded efforts in the late 1960s were from the Atomic Energy Commission. To release the shale gas from the rock, they detonated two atomic devices underground – in New Mexico in 1967 and in Grand Valley in Colorado in 1969.⁴³ Compared to modern nuclear weapons, they were small at 29 and 43 kilotons, but both were twice the size of the bombs that destroyed Hiroshima (15 kilotons) and Nagasaki (20 kilotons). Whilst these detonations worked in releasing the gas, the method was shelved due to environmental concerns about radioactive tritium elements contaminating the gas.⁴⁴ This was clearly a taxpayer-funded failure.

In the 1970s, a degree of success was to come with Massive Hydraulic Fracturing (MHF), which was supported by the then newly-created Department of Energy. It still proved to be more expensive than commercially available gas, but the value of MHF was that it allowed oil and gas companies to keep learning about the geology and how to extract the gas and gain valuable feedback.

From 1980-2002, oil and gas companies were also entitled to a production tax credit for marginal wells, known as Section 29, which was initially worth \$0.50 per 1,000 cubic feet of shale gas and \$3 per barrel of oil.⁴⁵ But it is interesting that shale gas production did not take off until the expiry of this subsidy. The end of Section 29 coincided with Mitchell Energy selling out to Devon Energy for \$3.5 billion, matching Mitchell's skill in hydraulic fracturing and Texan plays with Devon's horizontal drilling expertise. This deal may have only happened because the unintended consequence of subsidies is that they create a fixed and predictable income stream with existing technology. When the subsidy is gone, a new incentive appears to innovate and bring costs down which may only come with a bigger investor.

Drill bits continued to improve as well thanks to the use of polycrystalline diamond studs pioneered by a partnership between General Electric and the Energy Research and Development Association. Drilling performance on a lateral well is measured in feet per hour (fph). In early shale gas plays, the typical fph progress was 10. That has now increased to 65 fph, and the latest model from Smith Bits released last year, the Spear PDC, reaches 79 fph. Every improvement in drilling technology mattered because faster drilling meant a faster return on investment.

Horizontal wells are another area that enjoyed some federal support. The Department of Energy helped finance a number of experimental horizontal gas wells in the 1970s and 1980s. In 1976, two engineers from the Morgantown Energy Research Center, a precursor to the current National Energy Technology Laboratory, patented a directional shale drilling technique that enabled operators to reach further out horizontally in shale deposits.

Against this technological research backdrop was a strategic push to exploit new gas reserves, initiated by the Department of Energy in 1976. Known as the Eastern Gas Shales Project, the aim was to explore, catalogue and then find a way to exploit the gas from the Devonian (now known as the Marcellus) and Mississippian organic-rich black shales within the Appalachian, Illinois, and Michigan basins in the Eastern United States.⁴⁶

To some extent, however, the Breakthrough Institute overplays the role of government in the discovery and exploitation of shale gas. All the government support, tight and focussed as it was, would have counted for nothing if the gas industry and entrepreneurs were not prepared to use and combine the results.

By the 1970s, America's natural gas industry knew that it was in trouble. It was losing out in private and public sector capital investment to oil, coal and to some extent nuclear power. From 1958 until the mid-1970s, natural gas was second only to oil in US energy consumption. But by the mid-1980s, coal had overtaken gas. The gas industry was fighting to make gas appear to be a fuel of the future and losing. Indeed, some believe, a dash for gas might have occurred sooner if it was not for coal interests at play politically when coal rebounded and overtook gas.⁴⁷

Moreover, gas was not yet a fuel of electricity and the idea of transporting it on large tankers as liquefied natural gas (LNG) was far beyond the horizon. Hubbert, the inventor of the Peak Oil and Gas Theory, had in 1958 predicted that peak US gas production would come in 1970 and he was only slightly wrong when it came in 1973. At the time, it was a small consolation that the 1973 peak came at a higher level of production than he anticipated. And this in itself was not surpassed until 2011.

The Gas Research Institute (GRI), launched in 1978, was a key response to the seeming crisis of the US gas industry as well as an enabling mechanism for entrepreneurs and researchers to come together. The GRI was funded not by the public sector but by a levy on interstate gas pipelines to finance research on behalf of its core members involved in the production, pipelining and local distribution of natural gas. Perhaps because it was a privately-funded organisation, it was a very lean operation and stands out as an example to government agencies on how to deliver cost-effective research and development. According to a paper published in 1993:⁴⁸

"GRI itself had no laboratories. It contracts out all R&D efforts. Thus GRI's primary product is good decisions: to fund the right projects, to terminate the projects not meeting goals, to choose the right performing organisations and to pick the best path to commercial success."

Using a decision-making system called Project Appraisal Methodology, the GRI claims it achieved a benefit cost ratio of 7 to 1 with an annual budget of \$200 million. It was this kind of undirected and robust or even stochastic approach to research⁴⁹ that led to the funding of the number one shale gas entrepreneur, George Mitchell of Mitchell Energy. The GRI subsidised his first horizontal shale gas well in the Barnett Shale in 1981. What Mitchell did was to take the knowledge acquired from the Eastern Gas Shales Project and bring that to Texas.

Overall, the long-term development of the technologies required for commercial shale gas production stands as a good example of a useful partnership between the public and private sectors.

State level examples

Whilst technological progress at the national level was crucial, the US has a highly devolved system of government. In the last decade, the history of US shale gas exploitation has been the cracking of one major shale gas play after another. The most significant were:

- The Barnett Shale – first well drilled in 1999 in Texas;
- The Fayetteville Shale – first well drilled in 2004 in Arkansas;
- The Haynesville Shale – first wells drilled in 2008 in Texas and Louisiana;
- The Marcellus Shale – first well drilled in 2004 in Pennsylvania.

The rest of this section briefly examines three key states:

- Texas, which has succeeded at huge scale with the Barnett and Eagle Ford plays;
- Pennsylvania, which has also succeeded in different ways with the Marcellus play;
- New York, where shale gas production might or might not occur.

Firstly, Texas is synonymous with America's oil and gas industry. In Houston, it has the world's energy capital with over 5,000 energy related companies providing a number of critical supply chain contributions. The state is also huge with a total acreage of 172 million, around three times the size of the UK. Of all the US states it is the candidate you would pick most likely to succeed with shale gas. It also has a long-established history of regulating oil and gas wells which is done by the surprisingly named Railroad Commission of Texas (RRC). One of the oldest regulatory bodies in the US, dating back to 1891, the role of the RRC is to issue permits for oil and gas wells, monitor well drilling, completion, production and plugging operations.

With a long history of oil and gas production, a stable and predictable regulatory environment and one of the largest known shale resources in the country, everything was in place for an entrepreneur like George Mitchell to spend up to 18 years experimenting with how to make extraction work. It's interesting to note that, despite the presence of major oil and gas companies in Houston, it was the so-called smaller players who seized the opportunity first and ran with it.

The overriding lesson from Texas for the UK is that, world-class resources aside, regulatory expertise and stability are critical to attract long-term investors and premier division companies and their supply chains.

Secondly, Pennsylvania was the first state to discover oil, with Edwin Drake's discovery in 1859 launching the first oil boom. The oil and gas industry, however, never settled there.

TABLE 3

Wells permitted and completed in Pennsylvania from 1800-2010

Period	Number of wells	Average per year
1800-1900	18,406	184
1901-1926	23,047	921
1927-1952	8,538	341
1953-1978	22,568	903
1979-2005	14,627	563
2006-2010	14,625	3,656

Table 3 only details the wells that are known about. Arguably, it's because the oil boom started in Pennsylvania that the state has so many abandoned and unlocated wells (known as orphans) – by one estimate, 200,000.⁵⁰ These were drilled before regulations, which typically prescribed that all wells had to be publicly mapped and plugged on completion, existed. The number of orphans for Texas – at 7,869⁵¹ – is a mere fraction of Pennsylvania's because the oil boom came to Texas later and mostly post the creation of a regulatory environment.

Following the initial boom, the rate of known wells permitted and completed was in decline relative to the rest of the US and has only picked up dramatically in the last few years. Since 2007, the rate of increase in Pennsylvania's natural gas production has been nothing short of remarkable, as shown in Chapter 3.

Pennsylvania is also worth studying for its creation in 2011 of the Impact Fee Law or Act 13. This led to the creation of a local levy for each well drilled, with 60% of the revenue going to areas impacted by drilling and 40% to the Marcellus Legacy Fund for state wide community infrastructure and environmental projects. What Act 13 did was to create a financial incentive and community gain from local drilling activity. The cost of each impact fee is related to the price of natural gas and the type of well. In 2012, with \$45,000 per well and \$9,000 per smaller vertical well, the impact fee brought in \$198 million.⁵²

What should be noted is that this new bounty has been used for social projects too, like building America's equivalent of "affordable housing". The Pennsylvania Housing Finance Agency, for example, received \$5 million to help ease housing shortages in the worst affected areas.⁵³

The key lesson from Pennsylvania for the UK is that for shale gas to succeed, it helps a lot to have local fiscal gain and tangible local community benefits, in addition to landowner royalties.

Thirdly, according to the Energy Information Administration estimates, New York State has 40.5 trillion cubic feet of unproved technically recoverable shale gas resources, 8% of the national total. It has also had a moratorium on high pressure hydraulic fracturing since 2008, recently extended two more years to March 2015 by the New York Assembly.

New York State, should it choose to, could exploit not only the Marcellus but the Utica shale formations. Yet today, according to Con Edison, the state utility gas distributor, nearly all gas comes from outside of the state, in pipeline journeys that last five days, from the gas fields of Texas, Louisiana, the Gulf of Mexico and even Canada.⁵⁴

The irony is that New York could have had a shale gas boom at the same time or even a little bit earlier than Pennsylvania. In the early 2000s, there was a landrush by energy companies to upstate New York to lease acres for exploration and production. Hundreds of millions of dollars were handed over to landowners in leasing fees. Yet just as the companies were about to begin work in summer 2009, the war of public opinion had been lost to a concerted campaign led by environmentalists and celebrities at the very local level.

The leading environmental issue for New Yorkers opposed to shale gas exploitation is potential contamination of the water supply, which is almost entirely unfiltered. Unusually, New York requires no pumping stations to move water from the reservoirs to the city - 95% of the water is moved by gravity from the Catskill and Delaware Watersheds. A celebrated regulatory programme in the 1990s against non-point source pollution from newly industrialised farmland in the Catskills, culminating in the 1996 Watershed Agreement, did much to clean it up. Today, most New Yorkers tend to believe they have the best drinking water in the world which is arguably why they are overtly sensitive to any risk of impurity, no matter how small.

But perhaps the greatest threat to activity is regulatory uncertainty. In New York State, local governments are able to ban or impose a moratorium on hydraulic fracturing within their borders. At present, there are 55 bans and 105 moratoriums at the local or municipal level against hydraulic fracturing, in addition to the state-wide moratorium on high-volume hydraulic fracturing.

As the leases were on a “take it or lose it” three-year basis, huge amounts of money were lost by the energy companies, with one, Norse Energy USA, filing for bankruptcy in December 2012 after having leased 133,000 acres that it could no longer exploit.⁵⁵

The lesson of New York State is that it is not enough to have a valuable resource. Years of delay will ensue at great cost if there is no regulatory certainty and the public has not been convinced of the economic benefits over the perceived threat of environmental damage. Most of New York State’s population is urban and wealthy, concentrated in New York City. The benefits would have mostly flowed to upstate New York, which is poorer and has far fewer people.

Although lower natural gas prices and a manufacturing resurgence have led to enormous national benefits, as highlighted in Chapter 3, the US constitutes anything but a uniform story in shale gas activity.



3. Energy developments in detail

It is easy to underestimate the contribution that indigenous supplies of oil and gas have made to the UK economy and environment, and similarly to underappreciate the contribution of shale gas (and oil) to the US economy and environment. At the same time, other UK energy developments, including onshore wind and nuclear, provide lessons for the development of a UK shale gas industry.

3.1 UK OIL AND GAS

Following the 1964 Continental Shelf Act, which made “provision as to the exploration and exploitation of the continental shelf”⁵⁶, the UK’s offshore oil and gas industry has grown to become a critical part of the economy. For several decades, offshore production has created a significant number of jobs, made a major contribution to tax revenues and ensured that the UK has secure supplies of energy. UK oil and gas resources have also been used as vital feedstocks for the country’s petrochemical industry. While production has been declining over the past decade, the North Sea will continue to supply large quantities of oil and gas for many years to come.

The UK’s onshore production has been small relative to offshore, but it has been carried out in many parts of the country for decades. The experience of previous onshore development is very relevant to the development of shale gas.

This section focuses on both gas and oil production.

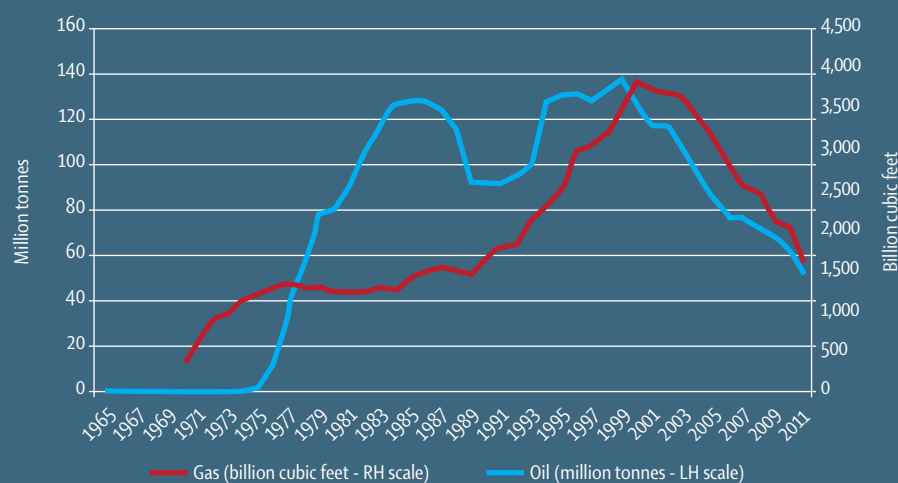
Overall production

Following the spike in oil prices in the early 1970s, UK oil production grew rapidly throughout the 1970s and early 1980s. In 1985, oil production peaked at 128 million tonnes, before falling to 91 million tonnes in 1991 following the Piper Alpha disaster. Production then rose, reaching a new peak of 137 million tonnes in 1999, before falling to 52 million tonnes in 2011.

Gas production grew steadily throughout the 1970s and 1980s, passing 1,500 billion cubic feet (bcf) by 1990. Production then expanded rapidly throughout the 1990s, reaching a peak of 3,826 bcf in 2000. Over the last decade, production has declined, falling to 1,597 bcf in 2011.

CHART 11

UK oil production, 1965-2011, and UK gas production, 1970-2011



Source: BP, *Statistical Review of World Energy*, June 2012 <http://www.bp.com/sectionbodycopy.do?categoryId=7500&contentId=7068481>. NB: Oil production includes Natural Gas Liquids; gas production excludes gas flared or recycled. Gas production figures presented in billion cubic metres are converted to billion cubic feet

Offshore production (around 99% of the total) has also lasted far longer than was originally forecast. In 1974, just before offshore production began, the Department of Energy projected that oil production would peak in 1981 at around 115 million tonnes, before declining to less than 40 million tonnes in 1990. Actual production in 1981 was lower than forecast – at around 90 million tonnes – but oil production didn't peak until 1999 – 18 years later than originally predicted, and at a significantly higher level.

CHART 12

1974 offshore oil production projection and actual UK oil production

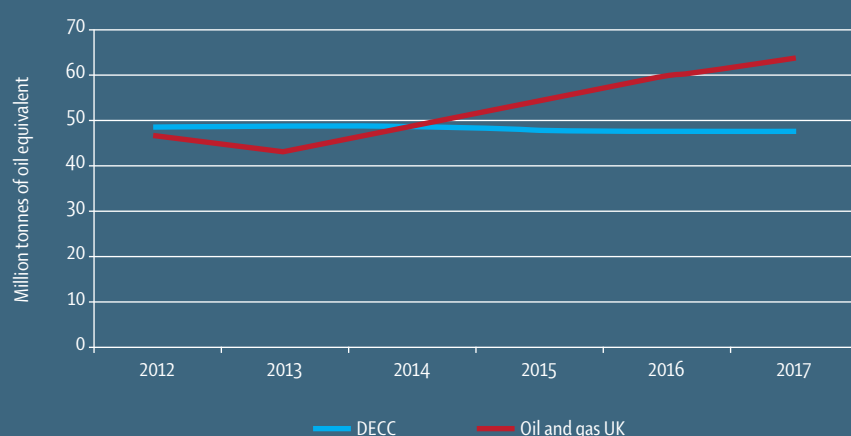


Sources: Department of Energy, *Production and reserves of oil and gas in the United Kingdom*, May 1974, p.13; BP, *Statistical Review of World Energy*, June 2012 <http://www.bp.com/sectionbodycopy.do?categoryId=7500&contentId=7068481>

If the early forecasts of oil and gas production turned out to be large underestimates, the current official forecasts for production declines may also prove to be too pessimistic. Oil & Gas UK projections, based on the current rise in investment, which is likely to lead to production after a time lag, show both oil and gas production rising over the next few years. Oil and gas production may resume their decline, but if the Oil & Gas UK forecasts turn out to be correct, they do give the UK a little more breathing space. Charts 13 and 14 compare the DECC and Oil & Gas UK forecasts.

CHART 13

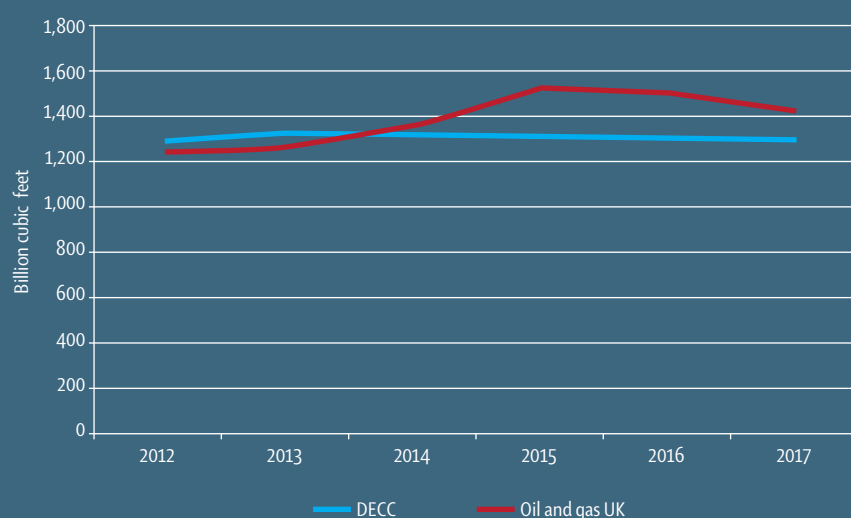
UK oil and natural gas liquids production projections, DECC and Oil & Gas UK compared, 2012-2017



Sources: Department of Energy and Climate Change, Production projections, extracted 15 March 2013 <https://www.gov.uk/oil-and-gas-uk-field-data>; Oil & Gas UK, Activity Survey 2013, data for Section 8 – Production <http://www.oilandgasuk.co.uk/cmsfiles/modules/publications/pdfs/EC037.pdf>. NB: Oil & Gas UK figures given in million barrels of oil equivalent per day are converted to million tonnes of oil equivalent.

CHART 14

UK natural gas production projections, DECC and Oil & Gas UK compared, 2012-2017



Sources: Department of Energy and Climate Change, Production projections, extracted 15 March 2013 <https://www.gov.uk/oil-and-gas-uk-field-data>; Oil & Gas UK, Activity Survey 2013, data for Section 8 – Production <http://www.oilandgasuk.co.uk/cmsfiles/modules/publications/pdfs/EC037.pdf>. NB: Oil & Gas UK figures given in million barrels of oil equivalent per day are converted to billion cubic feet. DECC gas figures given in billion cubic metres are converted to billion cubic feet.

One of the reasons for continued optimism about the North Sea is hydraulic fracturing, which is helping to ensure that new fields are economic to develop:

- The Cygnus gas field, located 150km off the coast of Lincolnshire, is the largest to be discovered within the Southern Gas Basin for 25 years. Gross proven and probable reserves are estimated to be 635 bcf, and at peak production, the field will supply around 1.5 million homes.⁵⁷ The development of the field involves the drilling of 10 production wells, three of which may require hydraulic fracturing to improve flow rates.⁵⁸
- The Ensign gas field lies around 80km off the Norfolk coast. The Ensign field will be developed via three production wells: two platform wells and one subsea. Peak gas production is anticipated to exceed 80 million cubic feet per day. The Ensign field sands have low permeability and hydraulic fracturing techniques will be employed to improve recoverability.⁵⁹
- The Clipper South field also lies in the Southern North Sea. The field is expected to produce for approximately 15 years, peaking at a rate of around 92 million cubic feet per day. The field will be developed by five producing horizontal wells with multiple hydraulic fractures in each well.⁶⁰

Onshore production

Within these production totals, offshore production accounts for around 99%. But onshore production should not be discounted. The UK has a long history of onshore oil and gas development, and extensive experience of hydraulic fracturing onshore. It is worth noting, however, that the hydraulic fracturing process itself can vary greatly in its use of water, sand, lubricants and pressure, with hydraulic fracturing being more intensively used in the production of shale gas:

- Onshore oil production has totalled 69 million tonnes up to and including 2011,⁶¹ while onshore gas production has totalled 164 bcf.⁶²
- Over the last 30 years, more than 2,000 wells have been drilled onshore in the UK. Of these, around 200 (10%) have been hydraulically fractured to enhance recovery.⁶³
- As Chapter 2 detailed, Wytch Farm in Dorset is by far the largest onshore oil and gas field in the UK, and is also Western Europe's largest onshore field. Up to and including 2011, it had produced 81 bcf of gas, almost half of the onshore total, and 59 million tonnes of oil, around 85% of the onshore total.⁶⁴
- As the Royal Society noted, the combination of hydraulic fracturing and horizontal drilling allowed the development of Wytch Farm in 1979. Wytch Farm was discovered by British Gas in the 1970s and operated by BP since 1984. Over 200 wells have been drilled on the site. As the Royal Society report stated: *"Drilling vertically onshore then horizontally out to sea has proved more cost-effective than building offshore platforms, allowing oil to be produced beneath the Sandbanks estate, Bournemouth, from oil reservoirs 10km away".*⁶⁵
- The Elswick gas field in Lancashire (4.5km from Cuadrilla's Preese Hall well) was hydraulically fractured in 1996, and has been producing gas ever since. In the 1990s, several wells were also fractured in the UK to extract coal bed methane.⁶⁶

It is also worth noting that hydraulic fracturing can be used to produce geothermal energy in rocks with poor natural permeability:⁶⁷

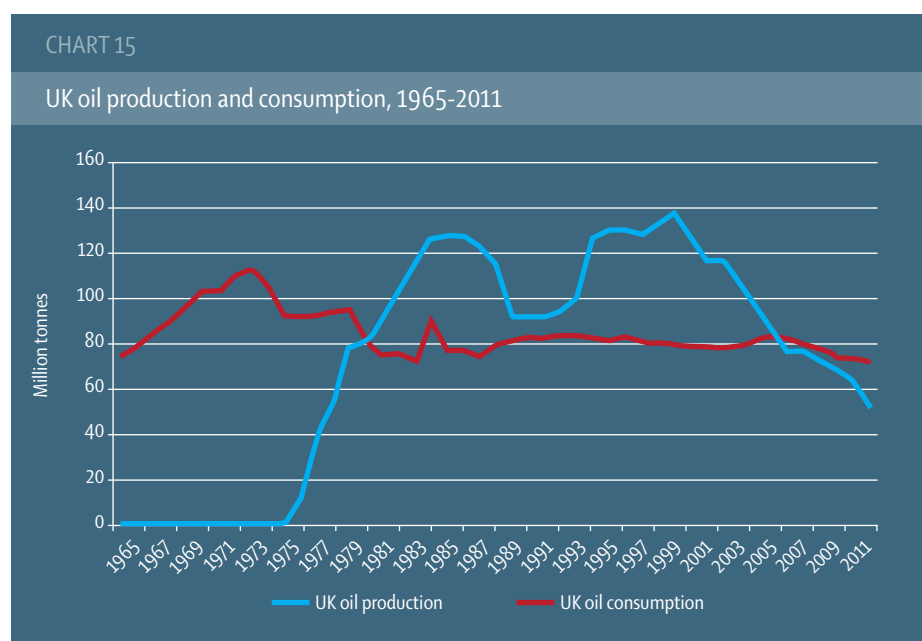
- In the early 1980s, hydraulic fracturing was carried out in Cornwall as part of a major geothermal energy research project carried out by the Camborne School of Mines for the then Department of Energy and European Economic Community. As the Camborne information note on the project explained:

*"A massive hydraulic fracturing operation, the largest ever undertaken in Europe, was undertaken on 4 July 1985. The job lasted for a period of eight hours and the average flow rate was 200 l/s (75 bbl/min) with a peak flow rate of 264 l/s (98 bbl/min). A conventional fracturing fluid was used and a total of 5,500 m³ of gel were injected, followed by a displacement of 200 m³ of water."*⁶⁸

- Also in Cornwall, EGS Energy and the Eden Project are partnering to develop the UK's first deep geothermal power plant.⁶⁹ This development will involve hydraulic fracturing to allow hot water to be circulated and produced at sufficiently high rates.⁷⁰

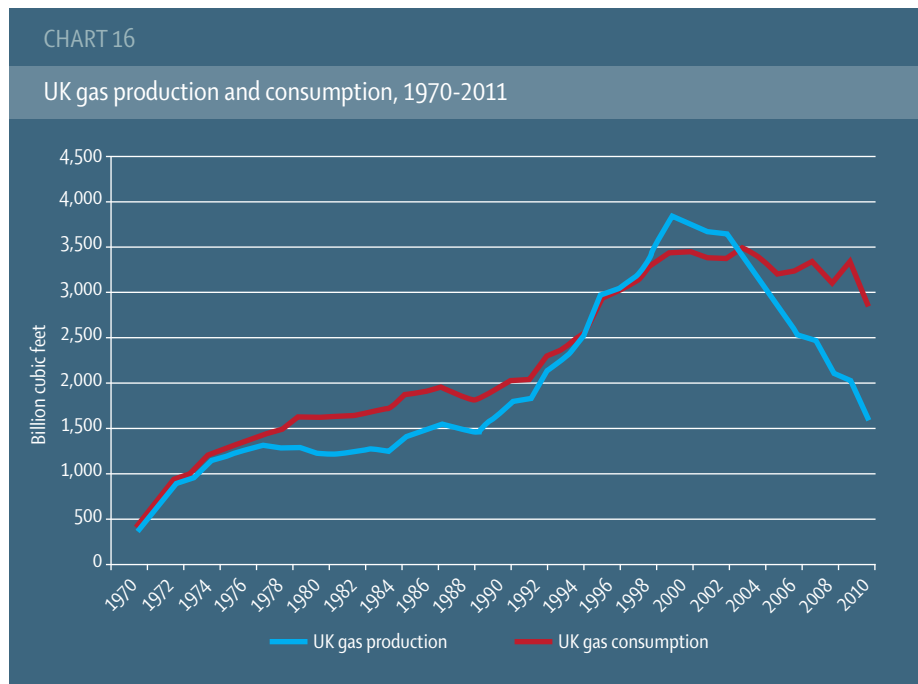
Energy security and environmental contribution

Oil and gas production has been central to the UK's energy security. Between 1981 and 2005, the UK produced more oil than it consumed. Over this period, indigenous production was more than able to meet a relatively constant demand for oil, of around 80 million tonnes a year.



Source: BP, *Statistical Review of World Energy*, June 2012 <http://www.bp.com/sectionbodycopy.do?categoryId=7500&contentId=7068481>. NB: Oil production includes Natural Gas Liquids; oil consumption includes inland demand plus international aviation, marine bunkers, refinery fuel and loss, and consumption of fuel ethanol and biodiesel

The gas story is slightly different from the oil story in that natural gas consumption rose with production, before falling slightly in the last decade. Between 1970 and 2007, UK production was able to meet at least 75% of a growing and then roughly constant level of consumption. Between 1995 and 2003, the UK more than met its natural gas demand from indigenous production.



Source: BP, *Statistical Review of World Energy*, June 2012 <http://www.bp.com/sectionbodycopy.do?categoryId=7500&contentId=7068481>. NB: Gas production excludes gas flared or recycled. Gas production and consumption figures presented in billion cubic metres are converted to billion cubic feet

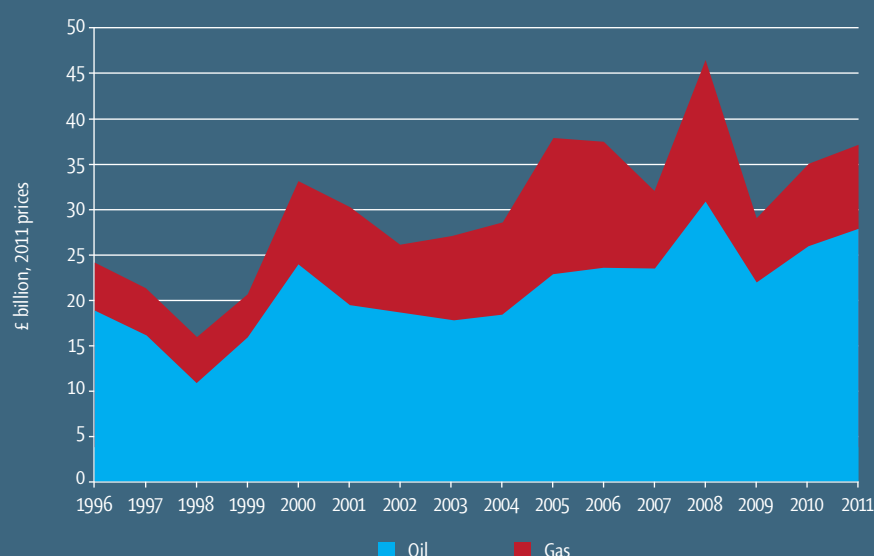
As Charts 15 and 16 show, for about 25 years between the late 1970s and the mid-2000s, the UK did not have a problem with the supply security of two vital forms of energy.

And although the UK is now importing substantial quantities of oil and gas, UK production boosted the country's balance of payments by nearly £40 billion in 2011, with the supply chain adding another £6 billion in exports of goods and services.⁷¹

Chart 17 shows the value of oil and gas produced in the UK over the last 15 years, and hence the contribution to the balance of payments (i.e. oil and gas either exported, or not imported).

CHART 17

Value of UK oil and gas production, 1996-2011

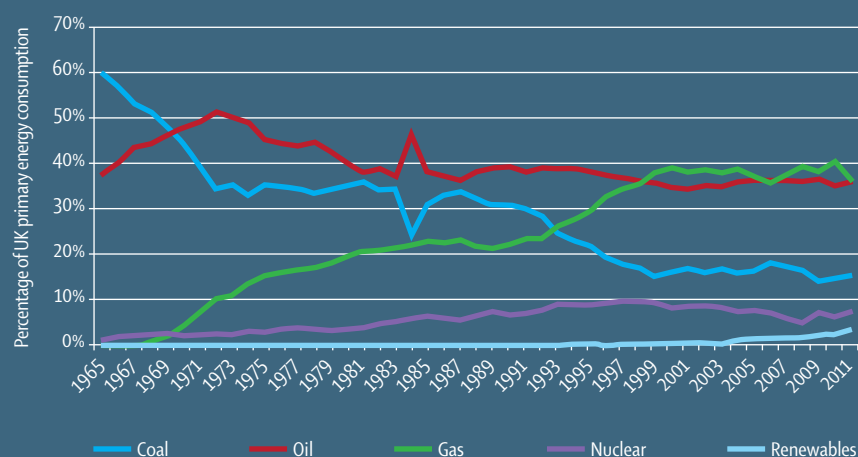


Sources: BP, *Statistical Review of World Energy*, June 2012 <http://www.bp.com/sectionbodycopy.do?categoryId=7500&contentId=7068481>; Bank of England, historical exchange rates <http://www.bankofengland.co.uk/boeapps/iadb/index.asp?Travel=NixIRx&levels=1&XNotes=Y&C=DME&GOXtop.x=47&GOXtop.y=10&XNotes2=Y&Nodes=X3790X3791X3873X33940X33620&SectionRequired=1&HideNums=-1&ExtraInfo=true#BM>. NB: Oil and gas production multiplied by average annual prices expressed in 2011 \$; converted to £ using annual average spot exchange rates.

North Sea gas production also facilitated a decline in UK coal consumption, by providing a secure alternative energy source. Over the last several decades, gas has replaced coal as the UK's most important energy source, leading to improved air quality and lower CO₂ emissions. In 1965, coal accounted for 60% of the UK's primary energy consumption and natural gas accounted for less than 1%.⁷² In 2011, coal's share had fallen to 16%, and the share of gas had risen to 36%. Nuclear and renewables have also played a role in lessening the UK's dependence on coal, albeit a much smaller one.

CHART 18

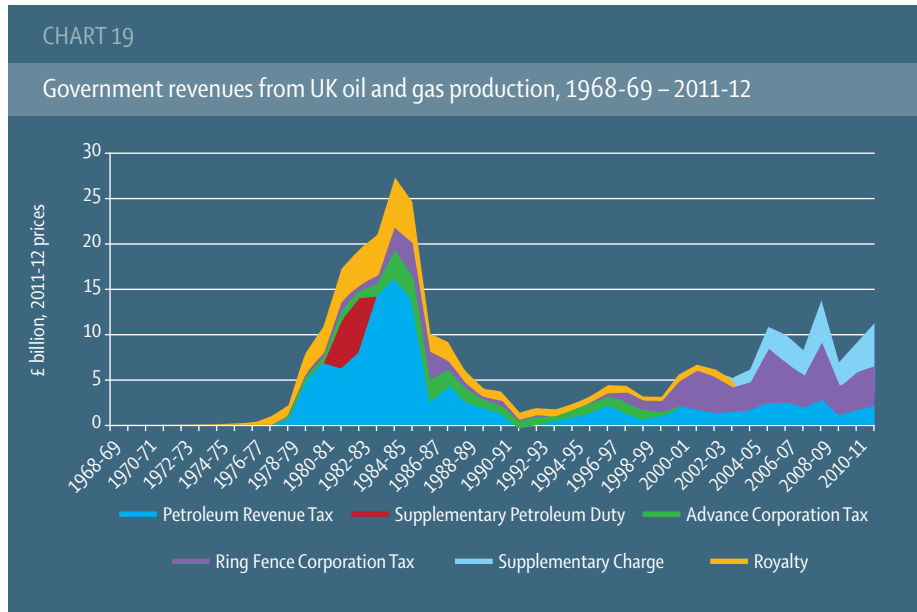
UK primary energy consumption, 1965-2011



Source: BP, *Statistical Review of World Energy*, June 2012 <http://www.bp.com/sectionbodycopy.do?categoryId=7500&contentId=7068481>. NB: Consumption figures converted to comparable units.

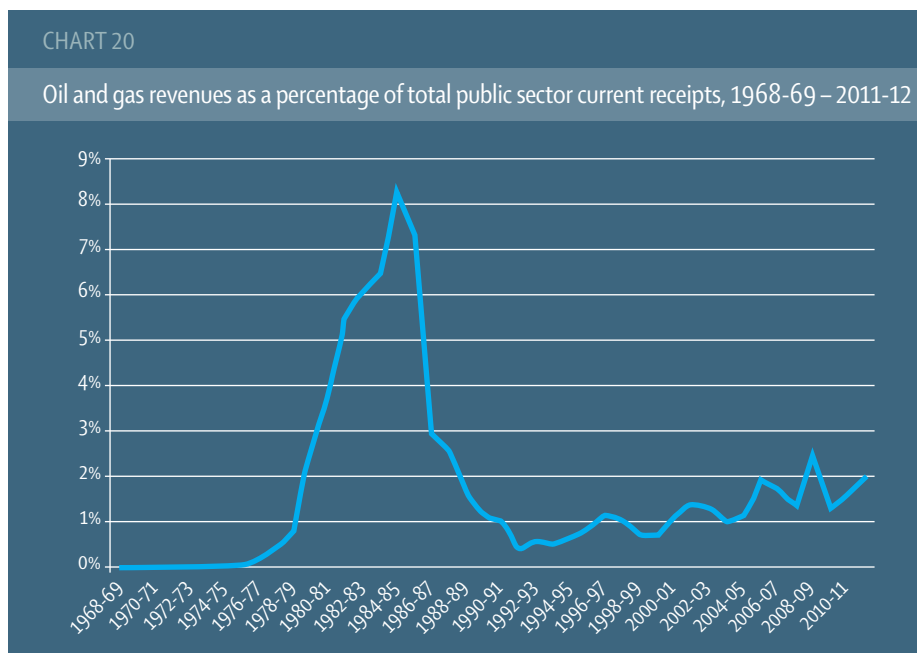
Direct economic contribution

UK oil and gas production has made a major contribution to tax revenues over several decades. Since the first tax revenues were received in 1968-69, the sector has contributed a total of £294 billion (2011-12 prices), averaging £6.7 billion a year. As Chart 19 shows, although revenues have fluctuated considerably, the contribution in most years has been substantial.



Source: HM Revenue and Customs, Table 11.11 <http://www.hmrc.gov.uk/statistics/prt.htm>. NB: In line with HMRC methodology, excludes Gas Levy. Figures converted to 2011-12 prices using HM Treasury, GDP Deflators, December 2012 http://www.hm-treasury.gov.uk/data_gdp_fig.htm

On average, oil and gas revenues have accounted for 1.7% of total government receipts, but for much of the 1980s, oil and gas accounted for more than 5% of total government receipts.



Sources: HM Revenue and Customs, Table 11.11 <http://www.hmrc.gov.uk/statistics/prt.htm>; HM Treasury, Public Sector Finances Databank, February 2012, Table C1 http://www.hm-treasury.gov.uk/psf_statistics.htm

These figures, however, only cover a portion of the taxes from oil and gas development. They do not include VAT paid by companies, nor Income Tax and National Insurance Contributions paid by employees, for example. The actual contribution of oil and gas production to tax revenues is therefore far greater.

The supply chain is also a significant sector in its own right, with 1,100 companies achieving combined revenues of £27 billion in 2011.⁷³ And taxes paid by the supply chain add to the overall tax revenue figure. The wider supply chain is estimated to have contributed a further £6 billion in corporation and payroll taxes in 2011.⁷⁴

The oil and gas industry is also one of the country's largest employers, supporting around 440,000 jobs across the UK. Scotland is home to 45% of the employment total, with London and the South East accounting for 21%.⁷⁵ And according to Oil and Gas People, a recruitment firm specialising in the energy sector, between 40,000 and 50,000 new jobs could be created in the North Sea over the next year as investment picks up again.⁷⁶

TABLE 4

UK oil and gas industry jobs, 2011

	Number of jobs
Direct	32,000
Wider supply chain	207,000
Induced by the economic activity of employees	100,000
Exporting goods and services	100,000
TOTAL	439,000

Source: Oil & Gas UK, *Economic Report 2012* http://www.oilandgasuk.co.uk/2012economic_report.cfm

The jobs are generally very well-paid, with skills shortages pushing up salaries still further:

- According to the Office for National Statistics, mean gross earnings for extraction of crude petroleum and natural gas stand at £79,566 per annum, second only to fund management activities.⁷⁷
- Across the oil and gas industry, average wages offshore stand at £64,000, well over twice the national average.⁷⁸
- According to a recent survey by Oil and Gas People, average wages are set to rise by 15% to £73,600 over the next year.⁷⁹
- Examples of high-wage occupations include:⁸⁰
 - Drilling superintendents - £105,000 a year;
 - Offshore installation managers - £95,000 a year;
 - Drilling supervisors – up to £85,000;
 - Drillers - £52,000.

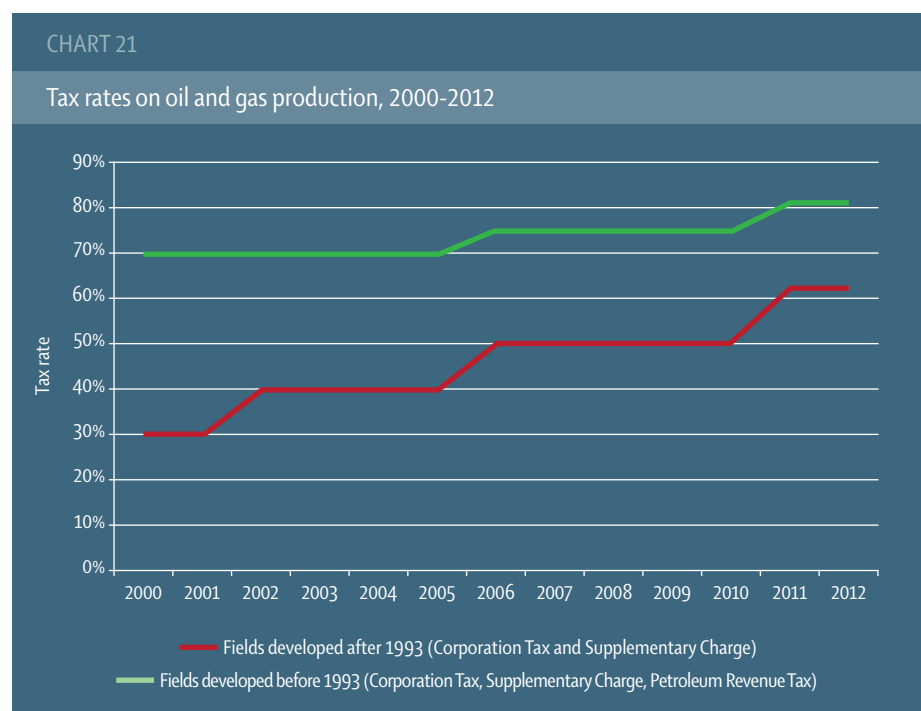
Investment and taxes

A key element is investment, which tends to precede production by several years. In 2011, total capex and opex reached £17 billion, and since investment in the North Sea began, the industry has spent £486 billion (2011 prices), including:

- £310 billion on exploration drilling and field developments;
- £176 billion on production operations.⁸¹

Although many factors affect investment, it has proved to be quite sensitive to tax changes. Too often, governments have succumbed to the temptation to interfere with the stability of the tax system. This can lead to falls in investment, which usually has a knock-on impact on production after a time lag.

Over the last decade, the oil and gas tax regime has been modified almost every year, with the general trend being higher tax rates combined with more generous allowances for certain types of investment. Tax rates have been increased three times – in 2002, 2006 and 2011. Chart 21 shows the overall tax rates paid by the oil and gas industry and how these have increased in recent years.



Source: Oil & Gas UK

Table 5 details the main changes to the tax regime over the last decade.

Year introduced	Tax change	Announcement
2002	Introduction of 10% Supplementary Charge on ring fence profits	Budget 2002
2002	Introduction of 100% first-year allowance for expenditure incurred on almost all ring fence capital expenditure	Budget 2002
2002	Introduction of a 24% allowance for long-life assets	Budget 2002
2003	Abolition of Royalty for all fields	Pre Budget Report 2002
2003	Tariff receipts for new fields and certain new assets exempted from Petroleum Revenue Tax (PRT)	Budget 2003

TABLE 5

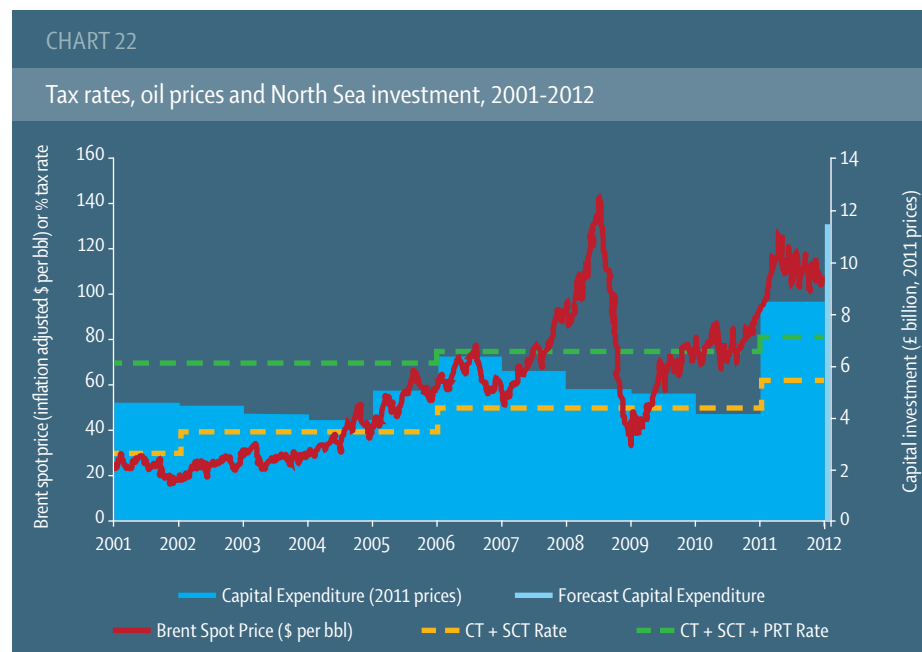
Main changes to tax regime for oil and gas production, 2002-2013 cont...

Year introduced	Tax change	Announcement
2004	Introduction of the Exploration Expenditure Supplement (EES)	Budget 2004
2006	Increase in Supplementary Charge from 10% to 20%	Pre Budget Report 2005
2006	Introduction of Ring Fence Expenditure Supplement (RFES), which extended and replaced the EES	Pre Budget Report 2005
2008	100% first year allowances for new expenditure on long-life assets and mid-life decommissioning	Budget 2008
2008	Provide for companies to claim post-cessation costs of decommissioning fields for tax purposes until such time as the decommissioning has been properly completed	Budget 2008
2008	Allow companies to carry back decommissioning costs to 17 April 2002, for the purposes of ring fence Corporation Tax and Supplementary Charge	Budget 2008
2009	Introduction of a New Field Allowance for small fields and challenging high pressure high temperature and heavy oil fields	Budget 2009
2009	Removal of chargeable gains from licence swaps and making gains exempt where disposal proceeds from ring fence assets are reinvested within the UKCS	Budget 2009
2010	Extension of the Field Allowance to remote deep water gas fields, as are found in West of Shetland	New Fields Order 2010
2011	Increase in Supplementary Charge from 20% to 32%	Budget 2011
2011	Widening of tax base of Supplementary Charge to include ring fence chargeable gains	December 2011
2012	Restriction of rate of tax relief for decommissioning to 20% for Supplementary Charge purposes. This change was stated to be in order to prevent the increase in the Supplementary Charge rate to 32% providing an incentive to decommission fields earlier than would otherwise have been the case	Budget 2011
2012	Increase in RFES from 6% to 10%	July 2011
2012	Small Field Allowance increased and extended to larger fields	Budget 2012
2012	Introduction of Field Allowance for new large deep water developments (West of Shetland oil)	Budget 2012
2012	Introduction of Field Allowance for new shallow water gas field developments	July 2012
2012	Introduction of new Brown Field Allowance to unlock marginal investment in existing fields	September 2012
2013	Government given statutory authority to sign contracts with companies operating in the UK and UK Continental Shelf, to provide assurance on the relief they will receive when decommissioning assets	Budget 2012 (confirmed in Budget 2013)

Sources: Oil & Gas UK, UK oil and gas tax regime <http://www.oilandgasuk.co.uk/taxation.cfm>; HM Treasury, Budget 2012 http://www.hm-treasury.gov.uk/budget2012_documents.htm; HM Treasury, Budget 2013 http://www.hm-treasury.gov.uk/budget2013_documents.htm

As Chart 22 shows, after the introduction of the Supplementary Charge in 2002, and again after its increase in 2006, investment fell. This occurred despite rises in the oil price.

Investment rose in 2011 despite the increase to the Supplementary Charge, although the figures in that year are skewed somewhat by a small number of very large projects that companies had committed to before the tax changes. Investment was, however, safeguarded as a result of the Government's commitment, following Budget 2011, to work with the industry to widen the scope of field allowances and provide certainty on decommissioning tax relief. In September 2011, the Fiscal Forum was established by the Treasury to provide constructive discussion on tax issues with the industry, with the first meeting taking place in January 2012.⁸²



Source: Oil & Gas UK

As Oil & Gas UK has pointed out, the tax increases announced in Budget 2011 were highly damaging to the industry, with four main impacts:

- "(i) Investments in the UK Continental Shelf (UKCS) became less attractive, losing up to 24% of their value. This impact was seen most markedly in commercially marginal projects which then struggled to attract investment, including a number of potential big new field developments as well as new investments in existing fields;
- "(ii) Field allowances intended to promote investment in more marginal fields were seen to be less effective;
- "(iii) The value of new exploration in the UKCS was impaired;
- "(iv) The UK was perceived by overseas investors to be a less certain destination for investment, leading to an increase in risk premiums."⁸³

Oil & Gas UK's quarterly index showed that operators' business confidence fell after Budget 2011 by 25 points on a 100 point scale.⁸⁴

The new and extended field allowances announced after Budget 2011, however, have had a very beneficial impact, and have been critical to safeguarding investment. Field allowances provide relief from the Supplementary Charge for the first five years after the field enters production, acting as a partial hedge against lower oil prices or the underperformance of the investment. New fields which secure the allowance continue to pay Corporation Tax of 30% and rapidly start to pay the Supplementary Charge of 32% as the profitability of the investment increases.

The field allowances have not only safeguarded investment already planned, but facilitated a large rise in investment overall. The new Brown Field Allowance, introduced in September 2012, has already led to companies announcing new investments of more than £2 billion, which will extend the productive life of a number of fields. Overall, investment in 2012 rose to £11.4 billion, the highest for more than 30 years, and investment in 2013 is projected to increase to £13 billion.⁸⁵ And, as was shown earlier, production is expected to pick up from 2014.

Infrastructure

Chapter 2 explained how Aberdeen's airport was a key advantage for the city in the 1960s, and how improvements to Aberdeen Harbour were carried out to facilitate the growth of the industry. But much of the infrastructure and equipment needed for the production, processing and transportation of North Sea oil and gas had to be built or acquired from scratch. Rigs, oil pipelines, terminals, the National Transmission System for gas, and other pieces of infrastructure all had to be planned, designed and constructed.

The number of rigs is a good example. As Table 6 shows, the rig count increased rapidly in the mid-1960s, before stabilising and then increasing again in the early 1970s.

Year	Mobile rigs employed	Exploration/appraisal wells started	Development wells started
1964	1	1	0
1965	7	10	0
1966	12	28	3
1967	13	58	13
1968	13	38	36
1969	13	52	27
1970	12	24	28
1971	13	28	34
1972	19	43	35

Source: Department of Trade and Industry, *Production and reserves of oil and gas on the United Kingdom Continental Shelf*, 1973, p.9

As will be shown in subsequent chapters of this report, some of the infrastructure that resulted from North Sea development could be useful for the development of shale gas.

In Aberdeen itself, as the UK Government recently pointed out, North Sea development *“happened in spite of, not because of, its infrastructure. From a small airport through to traffic congestion and limited housing stock, Aberdeen has struggled to keep up with the demands of the thriving oil and gas sector.”*⁸⁶

Although the situation is improving, in certain places infrastructure is still sorely lacking. Aberdeen's badly-needed western bypass was first conceived shortly after the Second World War, but was rejected for lack of funds. The idea was revived again the 1980s, saw preliminary studies being carried out in the 1990s and the Scottish Executive becoming a project partner in 2003. Years of legal delays followed, with an appeal right up to the Supreme Court, which was rejected in October 2012. The bypass is now going ahead, and is expected to open in 2018, but the delays have seen the project's costs increase to £650 million.⁸⁷

Partnerships

As Chapter 2 showed, the UK's oil and gas industry was not created by accident. And a number of partnerships are important to maintaining the industry's strength today. These include the following.

Oil and Gas Task Force. In response to falling oil prices and worries about a high cost base of activity on the UKCS, the Oil and Gas Task Force was set up as a temporary body in 1998 "to draw up short, medium and long term objectives and actions for Government and the industry to achieve together". The Task Force was chaired by John Battle, former Minister for Energy and Industry, and included senior representatives from oil companies, suppliers, unions and key government departments.

The Task Force's report, published in 1999, set out a vision for 2010:⁸⁸

"The UK oil and gas industry and Government working in partnership to deliver quicker, smarter and sustainable energy solutions for the new century. A vital UK Continental Shelf is maintained as the UK is universally recognised as a world centre for the global business."

The report set out a number of practical objectives to meet that vision:⁸⁹

- Investment sustained at £3 billion per annum from UKCS activity;
- Production at three million barrels of oil equivalent per day;
- Prolonged self-sufficiency in oil and gas;
- A 50% increase in exports in oil and gas supplies products;
- £1 billion additional value from new businesses;
- Supporting up to 100,000 more jobs than there otherwise would have been.

The report also made a number of recommendations, including:⁹⁰

- A new organisation to promote best practice throughout the supply chain;
- A strategic group to focus training activity and to maximise commitment to skills;
- More flexible and streamlined UKCS regulation;
- A website providing a single 'front door' for jobs and training;
- Tax changes, including amending the position of CGT rollover relief.

PILOT. The successor to the Oil and Gas Task Force, PILOT is chaired by the Secretary of State for Energy and Climate Change and includes industry representatives as well as representatives from relevant government departments. DECC's Oil and Gas Industry Development team provides the secretariat. PILOT continued in similar vein to the Task Force, focusing on the delivery of actions to improve the competitiveness of the UKCS and meet the 2010 vision. It is now looking at a new roadmap for the future of the UKCS.

Many of the PILOT projects have evolved into the key organisations fundamental to the UKCS today. The Industry Technology Facilitator was initiated by one of the strategic groups looking to improve the flow of new technology to the market, while LOGIC (Leading Oil and Gas Industry Competitiveness) was created by PILOT to stimulate supply chain collaboration and improve competitiveness. Initiatives such as Vantage POB, Masterdeed, IMHH and standard contracts were brought together under LOGIC.⁹¹

PILOT has had a number of successes, including:⁹²

- New players – a diverse range of new players entered the basin, which has led to the development of more small fields and technology.
- Fallow initiative – this has stimulated activity by placing still prospective acreage into the hands of companies that want to develop it.
- Access to infrastructure – companies are able to negotiate with pipeline owners, etc, for access. This has helped enable subsea tiebacks to infrastructure hubs, although there are still ongoing challenges in this area.
- Stewardship – initiative to critically analyse the potential of each producing asset.
- Technology development – working to foster innovation and facilitating the development and implementation of new technologies. This led to the establishment of the Industry Technology Facilitator.
- Skills – the industry workforce has increased by 100% throughout the life of PILOT, and oil and gas academy OPITO was established following work in PILOT.
- Exports – there has been a higher level of exports from the industry than anticipated and the subsea industry is renowned across the world.
- Investment – levels of investment in the basin exceeded expectations, including rising capital investment in the current economic climate.

OPITO. The oil and gas industry's focal point for skills, learning and workforce development, OPITO works with employers and trade unions to manage the industry's training and safety programmes. OPITO provides a link between employers and training providers to ensure that skills development meets the specific needs of the industry. It also sets training standards and approves providers that deliver training in accordance with these standards.⁹³

Project Pathfinder. Project Pathfinder is an online tool to provide real-time information on upcoming projects, including new field developments and decommissioning work, to the supply chain. It includes the location, type of development, timing, and contact details within the companies, covering 95% of the UK operators. It was developed as a direct result of requests from supply chain companies for early information on emerging projects to enable them to plan ahead and be in the best position to bid for contracts.⁹⁴

Oil & Gas UK. Oil & Gas UK was set up in 2007 as the offshore industry's leading trade association. It has over 300 members, including production, exploration and supply chain companies. Member companies are based across the UK, with several from outside the UK.⁹⁵ Oil & Gas UK has three main objectives:⁹⁶

- Maximise recovery of oil and gas reserves from the UKCS;
- Ensure a sustainable long term future for the UK supply chain;
- Raise the positive profile and reputation of the industry, highlighting the contribution it makes.

Oil & Gas UK also has a number of forums, which member companies can join, looking at various aspects of offshore oil and gas production, including aviation safety, decommissioning, well lifecycle practices, health and safety and fiscal issues.⁹⁷

Fiscal Forum. Highlighted earlier in this chapter, the Fiscal Forum was set up in September 2011, following the tax rises announced in Budget 2011. The aim of the Fiscal Forum is to encourage constructive discussion between the industry and government on tax issues.⁹⁸ It has facilitated the introduction and extension of field allowances which have partially offset the impact of the increase to the Supplementary Charge.

Aberdeen City Council. The City Council continues to provide a supporting role in many ways, from publishing briefing papers highlighting the importance of the energy sector to the region,⁹⁹ to helping local companies to export.¹⁰⁰ Aberdeen City and Shire Economic Future (ACSEF) was set up in 2001 as a joint partnership between Aberdeen City Council, Aberdeenshire Council and Scottish Enterprise. *Energetica* is a new ACSEF project, designed to position Aberdeen City and Shire as a global energy hub. It aims to create a concentration of energy technology companies, housing and leisure facilities along a 30-mile corridor from Aberdeen to Peterhead.

Aberdeen universities. Although skills providers in the sector are widely dispersed, having two local universities certainly helps:

- The University of Aberdeen offers a wide range of undergraduate and post-graduate energy-related degrees, including subsea engineering, energy law, integrated petroleum geoscience and energy economics and finance.¹⁰¹
- Robert Gordon University also offers a wide range of undergraduate and post-graduate degrees, including an MSc in drilling and well engineering,¹⁰² and an MBA in oil and gas management.¹⁰³ The University's "Energy Centre" was designed to provide a focal point for the development and deployment of accredited learning material related to the oil and gas and renewable industries.¹⁰⁴

Oil and Gas Industrial Strategy and the Oil and Gas Industry Council. In March 2013, the offshore oil and gas industry and the Government agreed an updated industrial strategy for the sector, with three key aims:

- *"To maximise the economic production of the UK's offshore oil and gas resources;*
- *"To sustain and promote the growth of the UK industry's supply chain, in both domestic and international markets;*
- *"To promote purposeful collaboration across industry and between industry and government."*¹⁰⁵

A list of actions was agreed to ensure that the aims of the strategy are met, and a new body, the *Oil and Gas Industry Council*, was set up to ensure that the actions (with the exception of the fiscal regime) are delivered in practice. This strategy follows on from the Scottish Government's Oil and Gas Strategy of May 2012.¹⁰⁶ Actions were agreed in the following areas:¹⁰⁷

- Safety;
- UK supply chain;
- PILOT;
- Access to finance;
- Technology;
- Skills;
- Awareness of the industry;

- Engaging with other industries;
- Decommissioning;
- Fiscal Regime.

Aberdeen City and Shire – key statistics

Aberdeen is the centre of the UK's offshore oil and gas industry, and the energy sector has had a major impact on the area's economy.

In 2011, Gross Value Added (GVA) per head in Aberdeen City and Shire was £32,113, the second highest region in the UK after Inner London.¹⁰⁸

At the European level, the most recent Eurostat figures show that Gross Domestic Product (GDP) per head in Aberdeen City and Shire was the 15th highest out of the 277 regions in the European Union for which data was available.

TABLE 7

GDP per head in European regions, 2009

Region NUTS (Level 2)	GDP per head in purchasing power in standard (PPS), 2009 (EU27=100)	Rank, 2009
Inner London	332	1
Luxembourg	266	2
Région de Bruxelles-Capitale	223	3
Hamburg	188	4
Bratislavský kraj	178	5
Île de France	177	6
Praha	175	7
Stockholm	172	8
Groningen	170	9
Åland	164	10
Wien	161	11
Oberbayern	160	12
Bremen	160	13
Darmstadt	158	14
Aberdeen City and Shire	158	15

Source: Eurostat, *GDP and household accounts at regional level*, source data http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/GDP_and_household_accounts_at_regional_level#Database

NB: Region given as "North Eastern Scotland" is identical to Aberdeen City and Shire

It is estimated that there are over 1,000 companies in Aberdeen City and Shire that operate wholly or predominantly in the energy sector. The spectrum of companies ranges from exploration and production multinationals to smaller enterprises that support the sector, including in engineering, consultancy, legal and financial services, human resources, catering and IT.¹⁰⁹

A third of the top 50 Scottish-based companies are located in Aberdeen City and Shire, and almost all of these are in the energy sector. Table 8 presents the data for 2010.

TABLE 8

Aberdeen City and Shire companies in the largest 50 Scottish companies

Company	Activity	Rank - Scotland
Total Upstream UK (Scotland)	Oil and gas exploration	5
Chevron North Sea	Oil and gas exploration	9
FirstGroup	Passenger transport services	10
Petro-Canada UK	Oil and gas exploration	14
John Wood Group	Energy related services	15
CNR International (UK)	Oil and gas exploration	18
Apache North Sea	Oil and gas exploration	19
Talisman Energy (UK)	Oil and gas exploration	20
Expro International Group	Oil well management	26
Maersk Oil North Sea UK	Oil and gas exploration	28
Abbot Group	Drilling, offshore engineering	30
Dana Petroleum	Oil and gas exploration	31
Venture Production	Oil and gas production	33
Technip UK	Offshore engineering, construction	34
Halliburton Manufacturing and Services	Offshore services and equipment	38
Stewart Milne Group	Construction and development	42
Aberdeen Asset Management	Fund management services	47

Source: Aberdeen City Council, *The Importance of the Energy Sector to Aberdeen City and Shire*, Briefing paper 2010/02, May 2010, Figure 3 <http://www.aberdeencity.gov.uk/nmsruntime/saveasdialog.asp?IID=30832&slD=3365>

The oil and gas industry, its wider supply chain, and induced activity support 137,300 jobs in Aberdeen City and Shire (defined by Parliamentary constituency) – around 60% of the total employment in the region. Of these jobs, 23,500 are directly in the industry.

TABLE 9

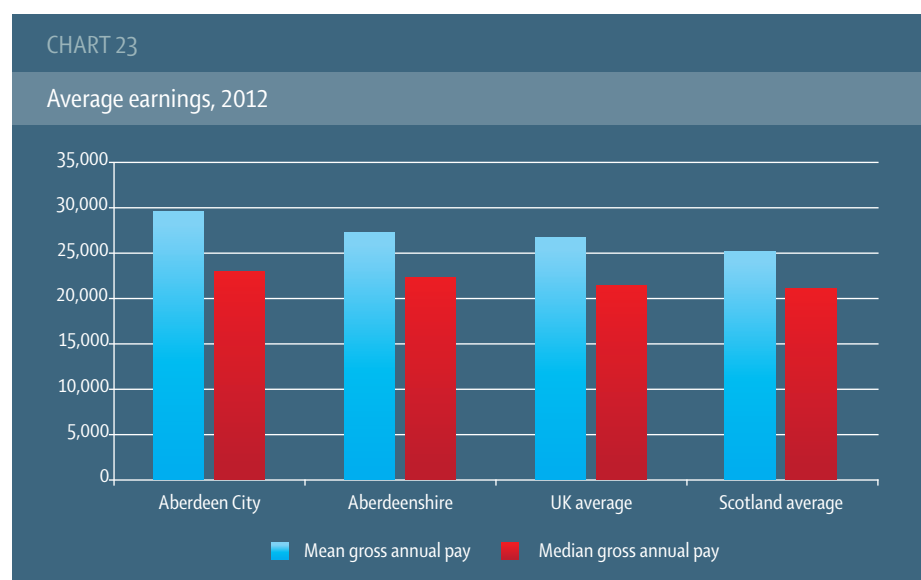
Oil and gas employment in Aberdeen City and Shire

	Number of jobs	Percentage of total employment in Aberdeen City and Shire
Direct employment	23,500	10%
Direct and supply chain employment	105,500	46%
Direct, supply chain and induced employment	137,300	60%

Source: Aberdeen City Council, *The Importance of the Energy Sector to Aberdeen City and Shire*, Briefing paper 2010/02, May 2010, Figure 5 <http://www.aberdeencity.gov.uk/nmsruntime/saveasdialog.asp?IID=30832&slD=3365>. NB: Aberdeen City and Shire defined as Parliamentary constituencies Aberdeen North, Aberdeen South, Banff and Buchan, and West Aberdeenshire and Kincardine

Unemployment and inactivity is at a very low level relative to the rest of Scotland and the UK. Aberdeen City and Shire currently has the eleventh lowest unemployment rate and the ninth lowest inactivity rate in the UK.¹¹⁰

Wages and salaries are at a premium, with both median and mean earnings for residents of Aberdeen City and Shire comfortably above the UK and Scotland average, as Chart 23 shows. This is not surprising – as was highlighted earlier in this chapter, mean gross earnings for extraction of crude petroleum and natural gas stand at £79,566 per annum, second only to fund management activities,¹¹¹ and across the oil and gas industry, average wages stand at £64,000, well over twice the national average.¹¹²



Source: Office for National Statistics, *Annual Survey of Hours and Earnings*, 2012, Place of Residence by Local Authority, Table 8.7a (Annual pay – Gross) <http://www.ons.gov.uk/ons/publications/re-reference-tables.html?edition=tcn%3A77-280149>

The success of the oil and gas industry in Aberdeen has also led to wider developments benefitting the construction and retail sectors in the region:¹¹³

- In 2008-09, several new company headquarters and campuses were opened or announced:
 - Halliburton opened new headquarters in Dyce, housing 500 staff;
 - BP opened its new £60 million headquarters in Dyce;
 - Technip expanded into a second site at Westhill;
 - Subsea7 opened a new £30 million campus at Westhill to accommodate 850 staff;
 - Acergy relocated staff to its new 17 acre campus in Westhill;
 - Aker Offshore Partners confirmed a lease at new premises in Aberdeen to accommodate 300 staff;
 - GDF Suez committed to opening a £6 million exploration and production hub in Aberdeen.
- Aberdeen Harbour contributes almost £400 million to the economy of the region, helping to sustain almost 11,000 full-time equivalent jobs.
- Over the past decade, Aberdeen has seen several large city centre retail developments. According to Experian, Aberdeen was the 20th highest ranking retail centre out of 1,800 in the UK in 2008.

Wider economic contribution

The benefits of UK oil and gas production are not limited to those highlighted above. Oil and gas are vital feedstocks for the petrochemical industry. The chemicals that are made are used in numerous industries, including agriculture, pharmaceuticals and the manufacturing of goods that can be used to improve energy efficiency.

In fact, it would be hard to enter any room and not be surrounded by the products of hydrocarbon-based chemicals, from the paint on the walls to the PVC windows to the plastic iPhone cover. Similarly, any non-organic food on your plate will have been produced with the aid of hydrocarbon-based fertilisers. Light industry and services rely on heavy industry, and heavy industry relies on oil and gas, among other feedstocks, and considerable quantities of electricity and heat.

In the UK, some heavy industry has moved overseas, but much still remains, forming one of the most important sectors of the British economy. In 2008, according to a recent report by the TUC, energy-intensive industries:¹¹⁴

- Had a combined turnover of £95 billion, 20% of the UK manufacturing total;
- Employed 160,000 people directly, with a further 640,000 employed in the supply chain;
- Paid £12 billion in corporate taxes and levies, 47% of all manufacturing taxes;
- Purchased £69 billion of goods, materials and services, a fifth of the UK manufacturing total;
- Generated £77,000 Gross Value Added per employee (excluding the petroleum sector, which is much higher still), considerably more than the UK average of £46,000.

As the TUC report concluded:

*"Iron and steelmaking, cement and lime manufacture, chemicals, ceramics, glass, non-ferrous metals (such as aluminium, zinc and lead), pulp and paper, coke and refined petroleum product industries form the bedrock of UK manufacturing. They are the core of the real economy. These industries produce primary inputs for much of what we manufacture and consume in some of the most advanced plants of their kind globally. They contribute hugely to the social and economic fabric of the country. And they are the key to our green and sustainable future, providing products that include steel for wind turbines, glass for double glazing and fibres for loft insulation."*¹¹⁵

Heavy industry is based in many areas of the UK. A good example is the North East, home to a large industrial sector on Teesside – producing chemicals, steel, pharmaceuticals and plastics.¹¹⁶

- In 2010, turnover in this sector was £85 billion, 9% of the entire North East economy, and 27,600 people were employed directly.
- In 2012, net exports of chemicals and related products in the North East totalled £2.7 billion.

Heavy industry is no longer about smokestacks, but has a critical role to play in reducing carbon emissions. Energy-intensive industries manufacture goods that can be used to improve energy-efficiency and provide the raw materials and products needed to manufacture, install, and maintain renewable energy technologies such as wind and solar. For example, a representative 3 MW onshore wind turbine will require 309 tonnes of steel and 1,206 tonnes of concrete, amongst other materials.¹¹⁷

Globally, the chemical industry has improved its energy efficiency considerably, and is facilitating CO₂ reductions in other parts of the economy, by producing the products needed for insulation, energy efficient lighting and increased agricultural yields.¹¹⁸

- Between 1990 and 2005, chemical production in the EU rose by 60%, while total energy consumption was stable. Over this period, the chemical industry cut its energy intensity by 3.6% per year. Since 1974, the US chemical industry has reduced energy consumed per unit of output by nearly half.
- In 2005, global CO₂ emissions linked to the chemical industry amounted to about 3.3 gigatonnes of CO₂ equivalent (GtCO₂e), of which 2.1 GtCO₂e were a result of the production of chemicals from feedstock and fuels delivered to the chemical industry, while 1.2 GtCO₂e arose during the extraction phase of the feedstock and fuel material, and during the disposal phase of the end products.
- By providing products and technologies to other industries, the chemical industry has facilitated gross savings of 6.9–8.5 GtCO₂e, meaning that for each tonne of CO₂ equivalent emitted by the chemical industry itself, 2.1–2.6 tonnes have been saved elsewhere. The net CO₂e emission abatement enabled by the chemical industry's products across the economy amounted to 3.6 to 5.2 GtCO₂e.
- The biggest savings have been made through:
 - Key chemical insulation materials for buildings – including expanded polystyrene (EPS), extruded polystyrene (XPS), and polyurethane (PU) – leading to a net emission saving of 2.4 GtCO₂e;
 - Agrochemicals, which increase crop yields and so reduce the amount of land needed to be converted to agricultural use, leading to a net saving of 1.6 GtCO₂e;
 - Materials for the production of Compact Fluorescent Lamps, leading to a net saving of 0.7 GtCO₂e.

In the long term, the chemical industry may be able to make greater use of renewable feedstocks, including syngas derived from waste and biomass. For the present and immediate future, however, hydrocarbon-based feedstocks will remain predominant, which is why the North Sea has been so important to Britain's heavy industry.

Oil and natural gas contain hydrocarbon molecules that are split apart during processing and then recombined into useful chemistry products.¹¹⁹

- Natural gas is separated to produce methane, which is shipped to consumers via pipelines, and Natural Gas Liquids (NGLs), including ethane, propane and butane, which are used as petrochemical feedstocks.
- Oil is refined to produce a variety of petroleum products, including naphtha and gas oil, which are the primary heavy liquid feedstocks for the petrochemical industry.
- Naphtha, gas oil, ethane, propane and butane are then processed in large vessels, or "crackers", which are heated and pressurised to crack the hydrocarbon molecule chains into smaller ones.
- These smaller hydrocarbons are then used as the building blocks of an enormous variety of products. A good example is ethylene, which is produced from ethane, propane, or naphtha. Ethylene is probably the most important basic chemical product.

Figure 4 illustrates the ethylene supply chain from ethane feedstock through petrochemical intermediates and final end use products.

FIGURE 4

Simplified ethylene flow chart

Ethane	Ethylene	Low density Polyethylene (LDPE) and Linear Low Density Polyethylene (LLDPE)			Food packaging, film, bin bags, nappies, toys, housewares
		High Density Polyethylene (HDPE)			Housewares, crates, drums, bottles, food containers
		Ethylene Dichloride	Vinyl Chloride	PVC	Window frames, swimming pool liners, pipes
		Ethylene Oxide	Ethylene Glycol		Automotive anti-freeze
			Ethylene Glycol	Fibres	Clothing, carpets
				Polyester Resin	Bottles
		Ethylbenzene	Styrene	Polystyrene Resins	Models, cups
				Styrene Acrylonitrile Resins	Instrument lenses, housewares
				Styrene Butadiene Rubber	Tyres, footwear, sealants
				Styrene Butadiene Latex	Carpet backing, paper
		Linear Alcohols			Detergent
		Vinyl Acetate			Adhesives, coatings, textiles, paper, finishing, flooring

Source: American Chemistry Council, *Shale Gas and New Petrochemicals Investment: Benefits for the Economy, Jobs, and US Manufacturing*, March 2011, Figure 1 <http://www.americanchemistry.com/ACC-Shale-Report>

Written evidence given by Ineos to the Energy and Climate Change Select Committee highlights the importance of North Sea supplies, and the coming risks:

"Since the 1970s North Sea oil and gas has provided the petrochemical industry with advantaged ethane and liquefied petroleum gases (propane and butane) feedstocks that have seen a successful petrochemical manufacturing industry grow based on a competitive olefins (ethylene and propylene) market."

"This has been able to support downstream derivative manufacturing even though such products may be disadvantaged by distribution costs. UK derivatives today are exposed to global competition from low cost regions such as United States and Middle East. The UK derivative portfolio (polyethylene, polypropylene, polyethylene vinyl chloride (PVC), ethanol, ethyl acetate (ETAC) and vinyl acetate monomer (VAM) in particular) cannot compete with low cost product unless the upstream feeds are competitive. Therefore, if feed costs into UK olefins manufacturing were to level with the rest of Europe, these derivatives would be outcompeted not only by their US and Middle East competitors, but also lose out against mainland European competitors who would then have similar costs but more differentiated derivatives and lower freight costs to serve the market.

"Production forecasts for these advantaged petrochemical feedstocks from the North Sea show a marked decline at the end of this decade. Without a replacement advantaged feedstock the inevitable decline in UK olefins manufacturing industry, and therefore the associated downstream derivatives, is likely to follow."¹²⁰

Indeed, Ineos has recently signed supply and infrastructure agreements that will secure a significant volume of ethane feedstock from the US for use in the company's European crackers, including the Grangemouth cracker in Scotland. It is expected that, when complete, the project will transport approximately 70,000 barrels per day of ethane and propane sourced from the Marcellus Shale.¹²¹ As Tom Crotty, the CEO of Ineos Olefins & Polymers Europe, said:

"For the chemical raw-material use, the import of ethane from US shale gas extraction is more than economic. After all the liquefaction and re-gasification costs, we can land it far cheaper than we can buy it locally."¹²²

It has been fashionable in some circles for several decades to talk of a post-industrial age. In reality, this would merely mean heavy industry shifting to another part of the world, which would be likely to lead to more emissions globally, given that UK industry is highly efficient. Indeed, according to the Committee on Climate Change, increasing imports have actually increased the UK's overall carbon footprint:

"The UK's carbon footprint has increased by around 10% since 1993, as growth in imported emissions more than offset the 19% reduction in production emissions. As a result, the UK is now one of the world's largest net importers of emissions, with a carbon footprint that is around 80% larger than its production emissions."¹²³

Unfortunately, higher electricity prices and less secure feedstocks do present significant risks to the UK's energy intensive sector. Although the global economic crisis will have been a major factor, between 2008 and 2011, there has been a 7% decline in employment across all energy-intensive industries, and a 9% reduction in turnover.¹²⁴

The TUC report provided further explanation:

"Both industry and trade union stakeholders contacted within the context of this study talked about a tipping point, where investment in new plants is made unattractive by energy prices and industrial policy, and existing plants become uneconomic. They also talked about whole industry sub-sectors being undermined through loss of critical mass and associated specialist resources and infrastructure."¹²⁵

The closure of the Dow ethylene oxide plant in Teesside in 2009 provides a good example.¹²⁶

- The closure of the plant itself resulted in 75 job losses.
- Croda International, reliant on ethylene oxide supply from the Dow plant, was also forced to close, with the loss of 125 jobs.

- Other derivative operations are now dependent on ethylene oxide shipped from Europe, although ethylene oxide is hazardous and not transported long distances if possible, so this is unlikely to be a long-term solution.
- Sabic, which owns the ethylene cracker, and other businesses that shared processes and utilities supplies with the Dow plant, were also impacted.

The Ineos plant in Runcorn is another good example. It has the second largest “cell room”, where chlorine is extracted from brine, in Europe. Caustic soda is also produced in the process. The plant is a heavy user of electricity and therefore depends on a competitive price of electricity.

Both chlorine and caustic soda have numerous uses. If the plant were to close, many more industries would also close. Rather than import the basic chemicals, many of the downstream businesses would migrate to countries where they were still domestically produced for reasons of reliability of supply and transport costs.¹²⁷

Ineos commissioned a study of the impacts on the wider economy if the plant was to close, concluding that up to 133,000 jobs would be lost. The study dates from 2001, but its findings are still relevant today.

TABLE 10

Potential impacts of closure of the Ineos Runcorn plant

	Industries/ companies	Directly dependent job losses	Job losses in wider economy	Total job losses
Core impact	Ineos	3,000	6,000	9,000
Immediate impact – downstream industries	PVC, soaps, detergents, sewage treatment	7,000	13,000	20,000
Intermediate – related industries damaged	Pharmaceuticals, food processing, toiletries	23,000	43,000	66,000
Long term – disadvantaged industries	Consumer goods and services	13,000	25,000	38,000
TOTAL		46,000	87,000	133,000

Source: LECG Limited, *Report to Ineos Chlor Limited: The evaluation of options for the chlor-alkali plant at Runcorn*, September 2001 – cited in Ruth Lea and Jeremy Nicholson, *British energy policy and the threat to manufacturing industry*, Civitas, April 2010 <http://www.civitas.org.uk/pdf/EnergyPolicyApril2010.pdf>

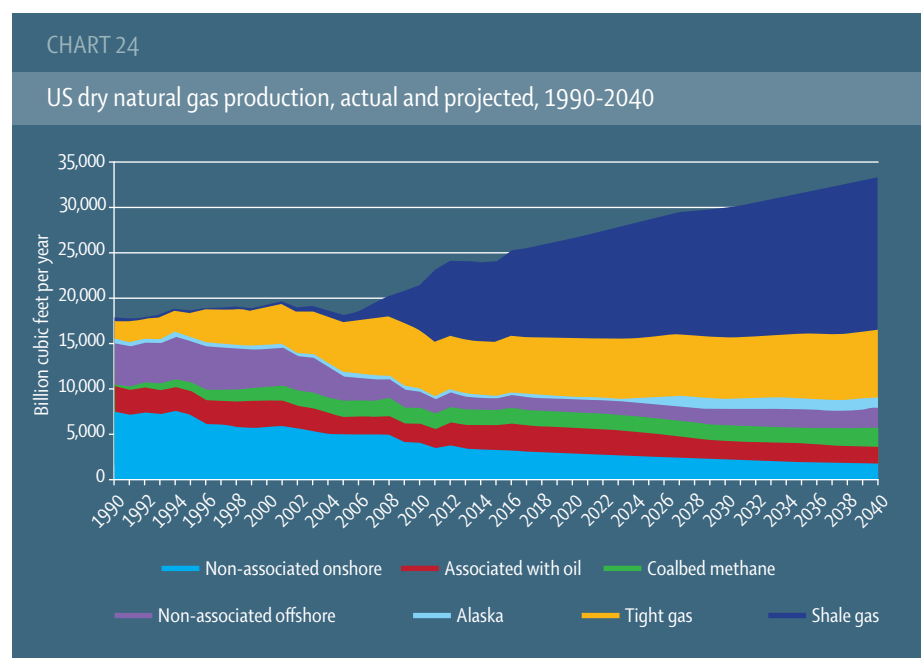
3.2 US SHALE GAS

The development of unconventional gas resources in the US is part of a broader home-grown energy revolution, which has also encompassed unconventional oil and renewable energy developments. This revolution has already helped to cut energy prices, reduce imports, create jobs, bring back manufacturing, lower CO₂ emissions and improve air quality.

This section focuses primarily on the shale gas part of the story, although the other parts are also very important.

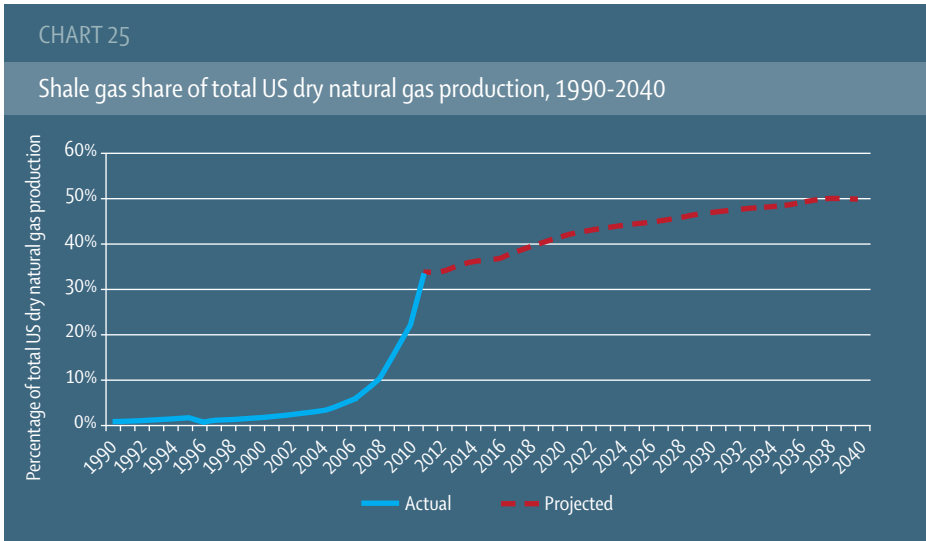
Shale gas production

Natural gas production in the US remained relatively stable between 1990 and 2005. Then shale gas production began in earnest, growing from 749 billion cubic feet (bcf) in 2005 to 8,135 bcf in 2012. Although conventional natural gas production fell over the same period, overall natural gas production rose from 18,051 bcf in 2005 to 23,914 bcf in 2012, a rise of 32%.



Source: US Energy Information Administration, *Annual Energy Outlook 2013 Early Release Overview*, data for Figure 3 "US Dry Natural Gas Production" (Reference Case) http://www.eia.gov/energy_in_brief/article/about_shale_gas.cfm

As Chart 24 shows, this growth is expected to continue, with shale gas production doubling from its 2012 level to 16,704 bcf by 2040. By this time, shale gas is expected to account for around half of all US natural gas production, up from around a third today.



Although future projections should be treated with some caution, there is no denying the rapid build-up of production over the last decade, which has consistently turned out higher than forecast, as Chart 26 shows.

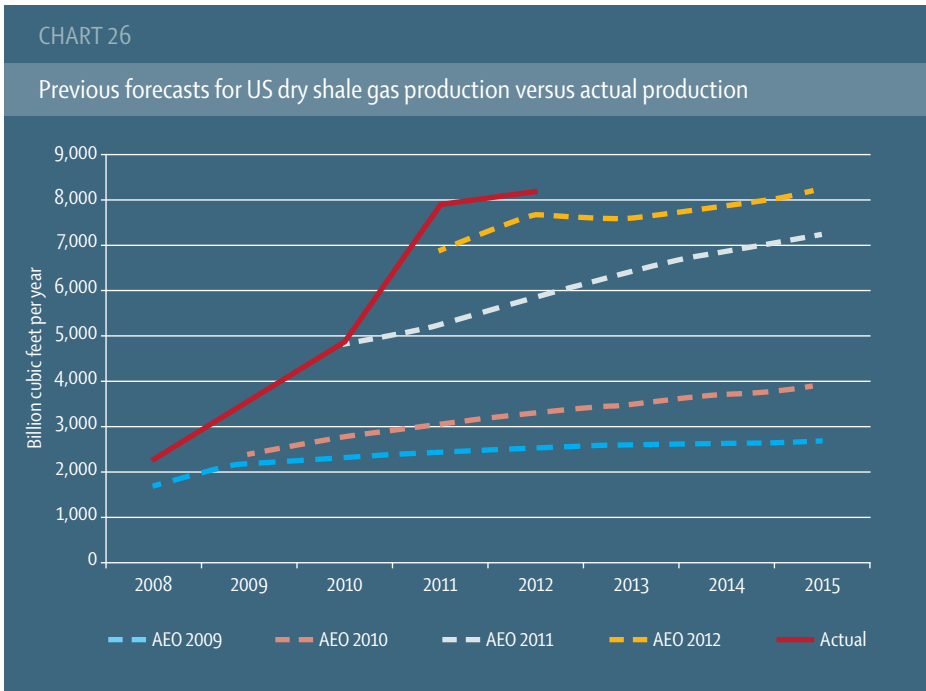
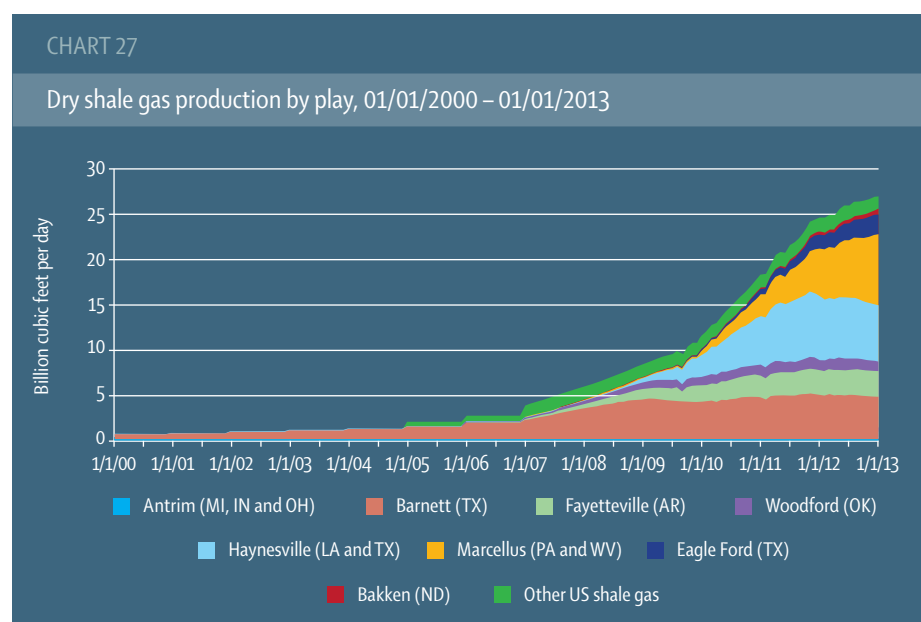


Table 11 details the most significant shale gas plays in the US. Together, these currently account for around 95% of total US shale gas production.

Play	States	Production on 1 January 2013 (billion cubic feet per day)
Marcellus	Pennsylvania, West Virginia	7.81
Haynesville	Louisiana, Texas	6.20
Barnett	Texas	4.56
Fayetteville	Arkansas	2.83
Eagle Ford	Texas	2.21
Woodford	Oklahoma	1.07
Bakken	North Dakota	0.58
Antrim	Michigan, Indiana, Ohio	0.27
Other US	-	1.37
TOTAL		26.91

Source: US Energy Information Administration, data for shale gas production by play http://www.eia.gov/energy_in_brief/article/about_shale_gas.cfm. NB: Figures may not sum to total due to rounding

Chart 27 details production by play since 2000. While the Antrim and Barnett plays were the first to be developed, the most phenomenal growth over the last few years has been seen in the Marcellus play – at the start of 2007, Marcellus production was just 0.02 bcf per day; just six years later, production had boomed to 7.81 bcf per day.



Source: US Energy Information Administration, data for dry shale gas production by play http://www.eia.gov/energy_in_brief/article/about_shale_gas.cfm

Production data from shale gas wells is also available by state, from 2007 to 2011.¹²⁸ As Table 12 shows, the biggest producing states in 2011 were Texas, Louisiana, Pennsylvania and Arkansas, which together accounted for 84% of the US total.

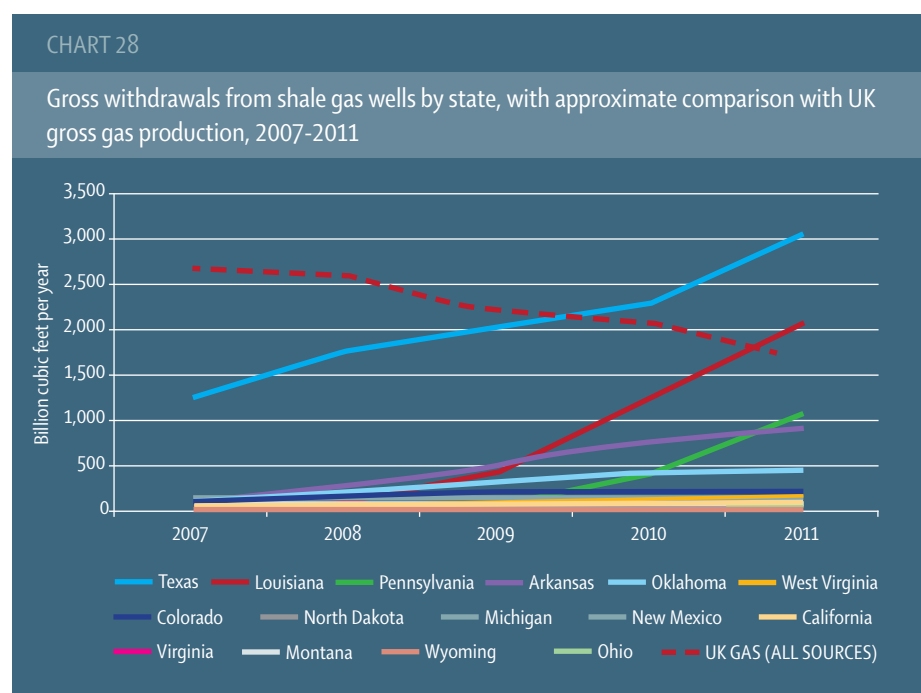
TABLE 12

US shale gas producing states

State	Gross withdrawals from shale gas wells in 2011 (billion cubic feet)	Percentage of US total
Texas	3,066	36.1%
Louisiana	2,088	24.6%
Pennsylvania	1,068	12.6%
Arkansas	935	11.0%
Oklahoma	449	5.3%
West Virginia	227	2.7%
Colorado	211	2.5%
North Dakota	115	1.4%
Michigan	114	1.3%
California	94	1.1%
New Mexico	93	1.1%
Virginia	19	0.2%
Montana	13	0.2%
Wyoming	5	0.1%
Ohio	3	0.1%
TOTAL	8,501	100.0%

Source: US Energy Information Administration, Natural Gas Gross Withdrawals and Production, "Gross withdrawals from shale gas wells" http://www.eia.gov/dnav/ng/ng_prod_sum_dcu_NUS_a.htm. NB: Figures may not sum to total due to rounding

As Chart 28 illustrates, Texas was for a long time the predominant shale gas producing state. Production has also grown steadily in Arkansas, and very rapidly since 2009 in Louisiana and Pennsylvania.



Sources: US Energy Information Administration, Natural Gas Gross Withdrawals and Production, "Gross withdrawals from shale gas wells" http://www.eia.gov/dnav/ng/ng_prod_sum_dc_u_NUS_a.htm; Department of Energy and Climate Change, DUKES 2012, data for Figure F.2, "Gross gas production", July 2012 <https://www.gov.uk/government/publications/natural-gas-chapter-4-digest-of-united-kingdom-energy-statistics-dukes>. NB: For the UK, figures are given in million cubic metres and are converted to billion cubic feet in this chart. The UK and US numbers are not compiled on exactly the same basis, and therefore the comparison in this chart should be used as an approximate guide only.

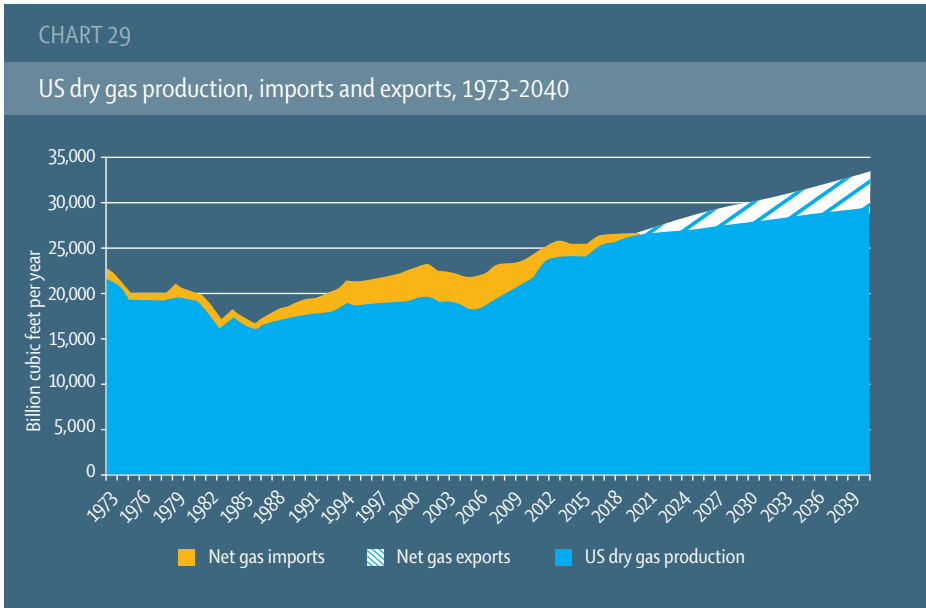
Chart 28 also makes an approximate comparison with the UK. Gross natural gas production in the UK, which includes dry gas, associated gas and oil and gas producers' own use, was 1,681 bcf in 2011. Shale gas production alone in both Texas and Louisiana is higher than the UK's entire gas production from all sources, while Pennsylvania is catching up fast.

Energy security contribution

Unlike the UK, imports account for a relatively small proportion of US gas demand. But over the last 40 years, the US has consistently been a net importer of gas.

That position is changing rapidly. In 2007, net imports peaked at 3,785 bcf. By 2012, net imports had fallen to 1,717 bcf, a reduction of 55%. By 2020, the US is expected to become a net exporter of gas.

This reduction in gas imports took almost everyone by surprise. In 2000, the Energy Information Administration forecast that net imports would rise to 4,640 bcf in 2012 and 5,140 in 2020.¹²⁹ LNG import terminals were constructed and have now either been abandoned or are being refitted for export.



Source for 1973-2011: US Energy Information Administration, Natural gas dry production, imports and exports http://www.eia.gov/dnav/ng/ng_sum_lsum_dcu_nus_a.htm. Source for 2012-2040: US Energy Information Administration, *Annual Energy Outlook 2013* Early Release Overview, Table 13 "Natural Gas Supply, Disposition and Prices" (Reference Case) http://www.eia.gov/forecasts/aeo/er/tables_ref.cfm

Lower net gas imports have helped to improve the US balance of payments. In 2005, net imports had risen to almost \$30 billion (nominal prices). By 2012, the cost of net gas imports had fallen to less than \$4 billion. Lower average import and export prices have also helped to cut the bill, but volumes are still important.



Source: IoD calculations based on data from US Energy Information Administration, Natural gas imports, exports, import prices and export prices http://www.eia.gov/dnav/ng/ng_sum_lsum_dcu_nus_a.htm

Direct economic contribution

Since the publication of the IoD's previous shale gas report in September 2012¹³⁰, detailed numbers have been released showing the impressive contribution that shale gas production has already made to the US economy.¹³¹ Economic impacts of upstream shale gas activity can be separated into three categories:¹³²

- **Direct.** "Activities required to explore, produce, transport, and deliver products to downstream elements or activities that provide critical on-site equipment and services."

- **Indirect.** “Activities in outside industries that supply materials and services to the developers of unconventional gas and to their tier of suppliers.”
- **Induced.** “The economic effects from workers spending their wages and salaries on consumer goods and household items.”

As Table 13 shows, in 2012, upstream shale gas activity accounted for more than 600,000 jobs, paid more than \$40 billion in wages and salaries and generated \$80 billion of value added. The jobs created are well paying – with average salaries of \$71,000 overall and \$117,000 for direct jobs.

	Number of workers	Labour income (\$ billion)	Value added (\$ billion)	Labour income per employee
Direct	126,709	14.9	32.4	117,000
Indirect	186,398	13.6	23.1	73,000
Induced	292,277	14.3	25.4	49,000
TOTAL	605,384	42.8	80.9	71,000

Source: IHS, *America's New Energy Future: The Unconventional Oil and Gas Revolution and the US Economy, Volume 1: National Economic Contributions*, October 2012, Appendix B <http://www.ihs.com/info/ecc/a/americas-new-energy-future.aspx>. NB: Figures may not sum to totals due to rounding

Shale gas production also generated significant tax revenues, at both federal and state levels. In 2012, upstream shale gas activity contributed almost \$20 billion in federal, state and local taxes.

	\$ billion
Federal Taxes	9.9
Personal Taxes	7.6
Corporate Taxes	2.3
State and Local Taxes	9.8
Personal Taxes	1.2
Corporate Taxes	6.4
Severance Taxes	1.5
Ad Valorem Taxes	0.6
Federal Royalty Payments	0.1
TOTAL GOVERNMENT REVENUE	19.8

Source: IHS, *America's New Energy Future: The Unconventional Oil and Gas Revolution and the US Economy, Volume 1: National Economic Contributions*, October 2012, Appendix B <http://www.ihs.com/info/ecc/a/americas-new-energy-future.aspx>. NB: Figures may not sum to totals due to rounding

These economic benefits are set to increase substantially as production continues to rise. By 2020, shale gas production is forecast to account for nearly 1.1 million jobs, pay nearly \$80 billion (2012 prices) in wages and salaries, generate \$150 billion (2012 prices) in value added and pay nearly \$40 billion (2012 prices) in federal, state and local taxes. After 2020, the benefits are forecast to be even larger. Table 15 sets out the projections through to 2035.

TABLE 15

Contribution of upstream shale gas activity to the economy and government revenue, 2012-2035

\$ billion, 2012 prices	2012	2015	2020	2025	2030	2035
Number of workers						
Direct	126,709	170,389	222,082	267,475	274,339	285,022
Indirect	186,398	260,398	336,540	404,569	414,408	429,878
Induced	292,277	418,069	537,418	647,572	665,568	689,610
Total	605,384	848,856	1,096,040	1,319,616	1,354,315	1,404,510
Value added						
Direct	32.4	49.4	62.7	75.8	78.4	81.0
Indirect	23.1	32.9	42.4	51.0	52.3	54.2
Induced	25.4	36.3	46.6	56.2	57.8	59.8
Total	80.9	118.6	151.7	183.0	188.4	195.0
Labour income						
Direct	14.9	21.7	27.7	33.5	34.5	35.7
Indirect	13.6	19.1	24.6	29.6	30.3	31.5
Induced	14.3	20.5	26.3	31.7	32.6	33.8
Total	42.8	61.2	78.7	94.8	97.5	101.0
Contribution to government revenue						
Federal Taxes	9.9	14.3	18.3	22.1	22.7	23.6
State and Local Taxes	9.8	15.0	19.5	23.8	24.4	25.1
Federal Royalty Payments	0.1	0.2	0.3	0.4	0.4	0.4
Total	19.8	29.5	38.2	46.3	47.6	49.1

Source: IHS, *America's New Energy Future: The Unconventional Oil and Gas Revolution and the US Economy, Volume 1: National Economic Contributions*, October 2012, Appendix B <http://www.ihs.com/info/ecc/a/americas-new-energy-future.aspx>. NB: Figures may not sum to totals due to rounding.

This economic activity has been driven by high levels of investment and well-completions. In 2012, total upstream capital expenditure for shale gas exceeded \$30 billion, as Table 16 shows, while more than 5,000 shale gas wells were completed.¹³³

TABLE 16	
Shale gas upstream capital expenditure, 2012	
	\$ billion
Drilling capital expenditure	9.6
Drilling	6.4
Support services	3.2
Completion capital expenditure	19.3
Hydraulic fracturing	15.5
Other	3.9
Facilities capital expenditure	1.7
Material	1.0
Fabrication	0.4
Project management	0.1
Other	0.2
Gathering system capital expenditure	1.8
Total upstream capital expenditure	32.4

Source: IHS, *America's New Energy Future: The Unconventional Oil and Gas Revolution and the US Economy, Volume 1: National Economic Contributions*, October 2012, Appendix A <http://www.ihs.com/info/ecc/a/americas-new-energy-future.aspx>. NB: Figures may not sum to totals due to rounding.

Table 17 provides a useful summary of the major industries benefitting from the development of unconventional gas (and oil) in the US:¹³⁴

- Direct industries include drilling, extraction, equipment and services used on the production sites.
- The significant capital expenditure also benefits the manufacturing and construction industries, as well as industries such as financial and insurance services.
- Induced effects result when employees in the unconventional oil and gas sector and supply chain spend their incomes on consumer goods, ranging from food and clothing to medical services.
- State revenues are also used to fund infrastructure improvements, such as roads and water treatment facilities, and expansion in education and training provision to address skills needs.

As the IHS report points out:

*"For non-producing states, the significant capital expenditures required for upstream oil and gas development are having an appreciable effect on the demand for capital goods, such as construction machinery typically manufactured in the upper Midwest states, such as Illinois and Michigan, and non-capital goods, such as financial and insurance services from New York."*¹³⁵

TABLE 17

Major industries benefitting from unconventional gas and oil production

Direct	Indirect	Induced
Chemical Manufacturing	Administrative and Support Services	Accommodation
Computer and Electronic Product Manufacturing	Construction	Administrative and Support Services
Construction	Fabricated Metal Product Manufacturing	Amusement, Gambling and Recreation Industries
Fabricated Metal Product Manufacturing	Financial and Insurance Services	Educational Services
Machinery Manufacturing	Machinery Manufacturing	Food and Beverage Stores
Mining (except Oil and Gas)	Management of Companies and Enterprises	Food Services and Drinking Places
Nonmetallic Mineral Product Manufacturing	Primary Metal Manufacturing	General Merchandise Stores
Oil and Gas Extraction	Professional, Scientific and Technical Services	Hospitals
Primary Metal Manufacturing	Real Estate	Nursing and Residential Care Facilities
Professional, Scientific and Technical Services	Truck Transportation	Professional, Scientific and Technical Services
Support Activities for Mining	Wholesalers	Real Estate
Truck Transportation		Wholesalers
Utilities		

Source: IHS, *America's New Energy Future: The Unconventional Oil and Gas Revolution and the US Economy, Volume 2: State Economic Contributions*, December 2012 <http://www.ihs.com/info/ecc/a/americas-new-energy-future.aspx>

One of the most interesting aspects of the US shale boom has been that some non-producing states have also gained substantially, mainly from the indirect and induced benefits of drilling activity. Table 18 details the 10 states with the highest number of jobs and the largest value added from unconventional gas production. These lists include New York State, which continues to impose a moratorium on hydraulic fracturing. Note that the data used below includes tight gas production as well as shale gas production (which adds around 50% to the overall jobs, tax revenue and value added totals), and so is not directly comparable with the data provided in the tables above. Table 19 details the largest 10 contributions to state and local taxes.

TABLE 18

Economic contributions of unconventional gas activity, top 10 states, 2012

\$ billion	Direct	Indirect	Induced	Total
Number of workers				
Texas	56,594	72,819	107,013	236,425
Pennsylvania	25,130	23,803	30,361	79,294
Louisiana	22,532	21,627	24,571	68,730
Colorado	19,462	16,189	24,208	59,859
Utah	9,348	15,838	23,740	48,926
California	3,237	16,577	28,244	48,057
Oklahoma	12,776	11,033	14,843	38,652
Arkansas	10,275	6,666	9,487	26,428
New York	82	6,659	15,497	22,238
Illinois	2,313	6,733	12,036	21,083
Value added				
Texas	18.9	10.1	9.0	37.9
Pennsylvania	6.0	3.1	2.6	11.6
Colorado	5.9	2.0	2.0	9.9
Louisiana	5.6	2.3	1.7	9.6
Oklahoma	3.2	1.2	1.0	5.5
California	0.4	2.1	2.8	5.4
Utah	2.1	1.4	1.6	5.1
Arkansas	2.0	0.6	0.6	3.2
Wyoming	2.3	0.4	0.3	3.0
New York	0.0	0.9	1.6	2.6

Source: IHS, *America's New Energy Future: The Unconventional Oil and Gas Revolution and the US Economy, Volume 2: State Economic Contributions*, December 2012, Appendix A <http://www.ihs.com/info/ecc/a/americas-new-energy-future.aspx>. NB: Figures may not sum to totals due to rounding.

TABLE 19

Contribution to state and local tax revenue of unconventional gas activity, top 10 states, 2012

	\$ billion
Texas	4.2
Colorado	1.3
Louisiana	1.1
Pennsylvania	1.1
Utah	1.0
Oklahoma	0.9
California	0.8
Wyoming	0.6
New York	0.5
Arkansas	0.5

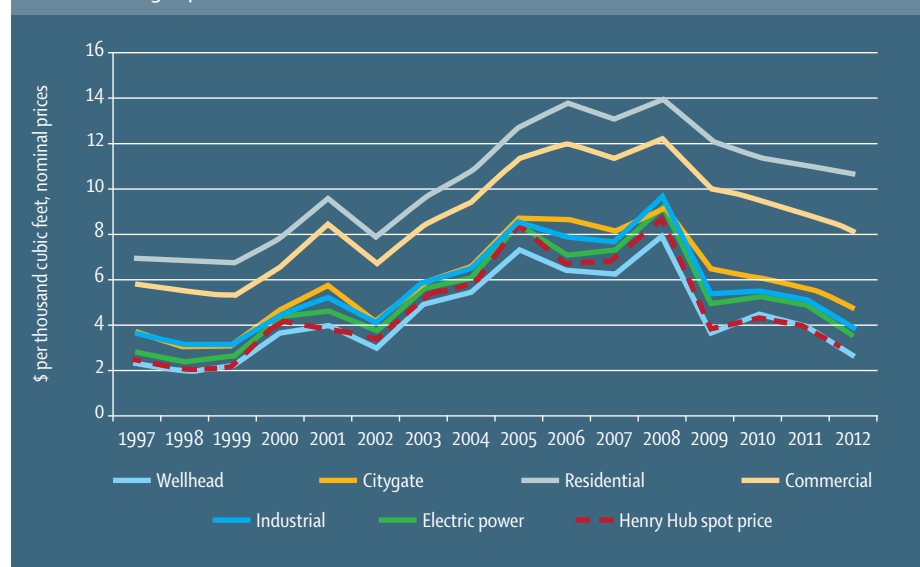
Source: IHS, *America's New Energy Future: The Unconventional Oil and Gas Revolution and the US Economy, Volume 2: State Economic Contributions*, December 2012, Appendix A <http://www.ihs.com/info/ecc/a/americas-new-energy-future.aspx>

Wider economic contribution

Shale gas production has had a beneficial impact on natural gas prices. Annual average wellhead prices rose very substantially after 2000, but have now returned to close to the previous low levels, with knock-on price benefits for industry, residential and commercial customers, and electricity generation. Although prices have started to tick up again over the last few months, they are expected to remain subdued, before increasing in the longer term. The Henry Hub spot price, for example, is not predicted to rise above \$5 until 2021.¹³⁶

CHART 31

US natural gas prices, 1997-2012

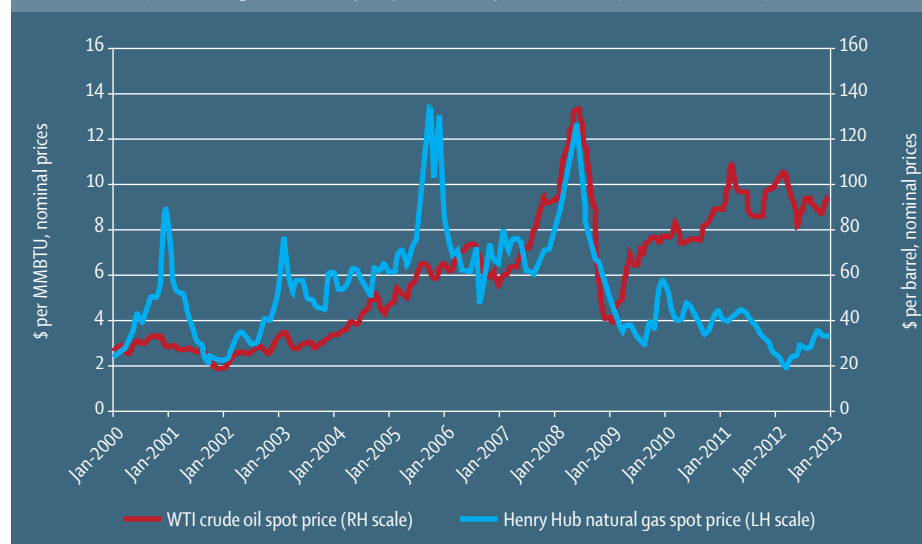


Source: US Energy Information Administration, Natural gas wellhead price, citygate price, residential price, commercial price, industrial price, electric power price, Henry Hub price http://www.eia.gov/dnav/ng/ng_sum_lsum_dcu_nus_a.htm. NB: For ease of comparison, Henry Hub price converted from \$ per million British Thermal Units to \$ per thousand cubic feet

In the last few years, US natural gas prices have also decoupled from oil prices, encouraging a shift to gas as a transport fuel.

CHART 32

US monthly natural gas and oil spot prices compared, January 2000 – January 2013



Source: US Energy Information Administration, Henry Hub Gulf Coast Natural Gas Spot Price http://www.eia.gov/dnav/ng/ng_pri_fut_s1_m.htm and Cushing, OK WTI Spot Price http://www.eia.gov/dnav/pet/pet_pri_spt_s1_m.htm

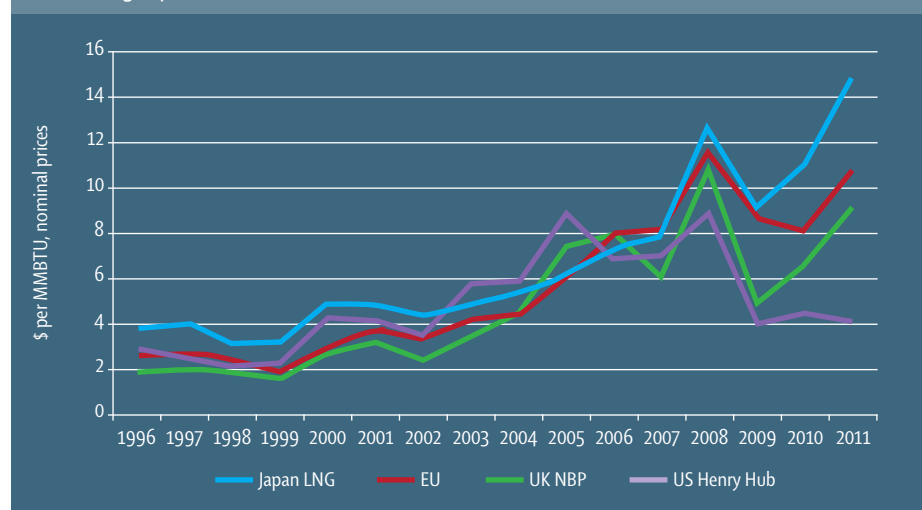
As was explained earlier in this chapter, oil and natural gas are vital feedstocks to the petrochemical industry. The chemicals produced are then used to manufacture a wide range of products. Cheap, abundant domestic natural gas could lead to a re-shoring of production to the US, and indeed, already is to some extent.

Two elements are key:

- Firstly, US natural gas prices are amongst the lowest in the world. As Chart 33 shows, since 2009, US natural gas prices have remained considerably lower than those found in other regions.

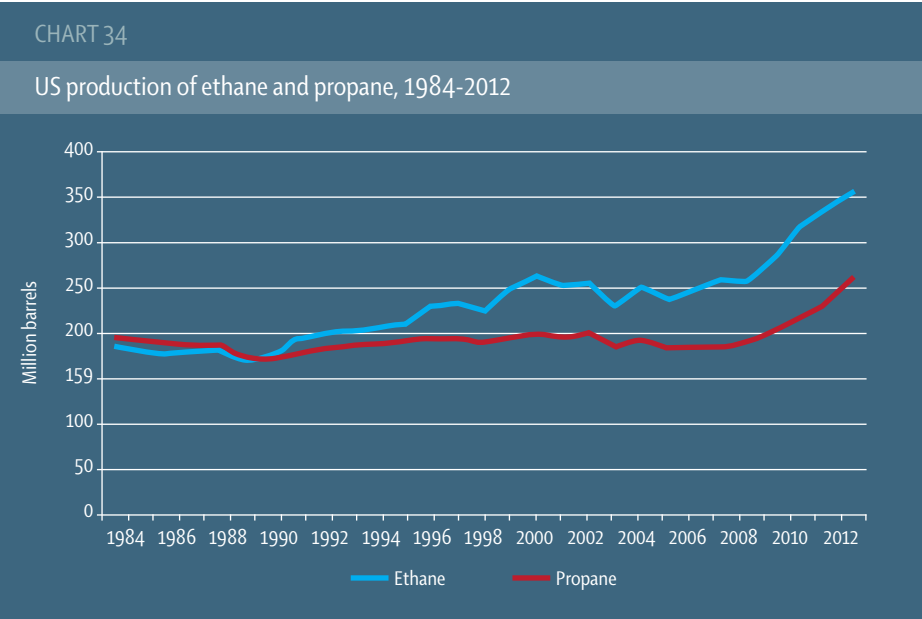
CHART 33

Natural gas prices, 1996-2011



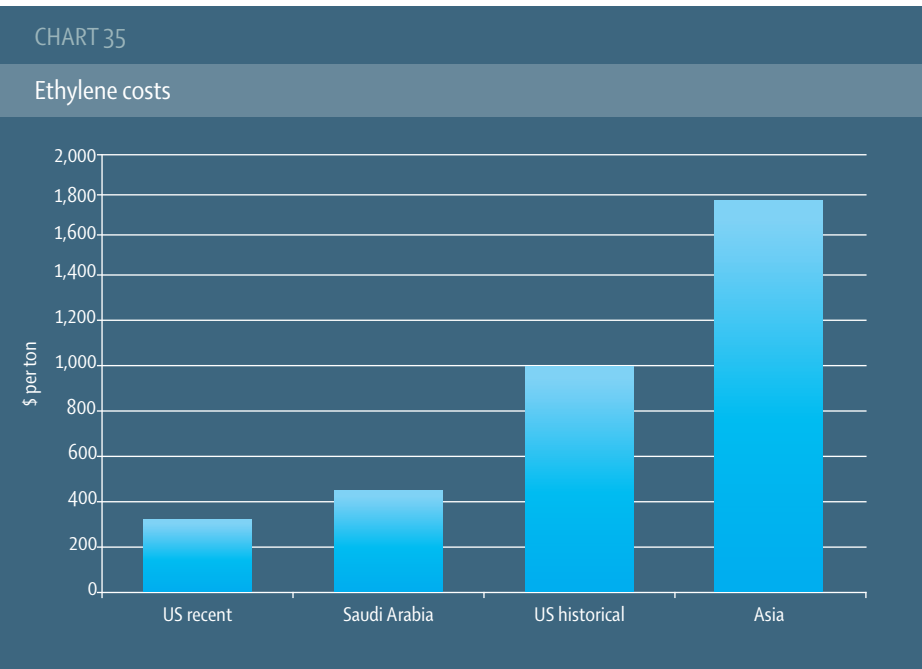
Source: BP, *Statistical Review of World Energy*, June 2012 <http://www.bp.com/sectionbodycopy.do?categoryId=7500&contentId=7068481>

- Secondly, before natural gas can be transported and sold, its impurities must be extracted. The by-products of this extraction process (Natural Gas Liquids, or NGLs) include ethane, butane and propane, which, as was shown earlier in this chapter, are valuable raw materials in the petrochemical industry. A number of US shale plays, including parts of the Eagle Ford and Marcellus, are rich in NGLs.¹³⁷ According to PwC, NGL production in the US is expected to increase by more than 40% over the next five years,¹³⁸ and indeed, production of ethane and propane has already increased by 38% between 2008 and 2012, breaking a long run trend of relatively flat production, as Chart 34 shows.



Source: US Energy Information Administration, Natural Gas Plant Field Production http://www.eia.gov/dnav/pet/pet_pnp_gp_dc_nus_mbbbl_a.htm

Ethylene is probably the most important basic chemical product. As Chart 35 shows, dramatic falls in natural gas prices in the US have opened up a large advantage in production costs relative to the Middle East, using ethane as a feedstock. In Europe and to a lesser extent Asia, the majority of ethylene is produced from naptha, leading to still higher costs.



Source: PricewaterhouseCoopers, *Shale gas: Reshaping the US chemicals industry*, October 2012, Figure 2 http://www.pwc.com/en_US/industrial-products/publications/assets/pwc-shale-gas-chemicals-industry-potential.pdf. NB: assumes 2.5% ethylene margin.

Higher supply and lower prices, not surprisingly, are leading to a large increase in production. PwC has estimated that the US chemicals industry has invested \$15 billion in ethylene production, increasing capacity by 33%.¹³⁹

According to ICIS, a market intelligence specialist for the global chemical, energy and fertilizer industries, there are currently seven worldscale (capacity of 1-1.5 million tonnes per year) crackers planned in the US, along with seven planned expansions of existing facilities. The companies proceeding with plans to build new crackers include Dow Chemical, ExxonMobil Chemical, Chevron Phillips Chemical, Formosa Plastics, Sasol, Shell Chemicals and Occidental Chemical/Mexichem. The total planned ethylene capacity additions amount to nearly 10 million tonnes per year, around 37% of existing US capacity.

Six of the seven new crackers are located in the existing petrochemical industry hubs in Texas and Louisiana, and are scheduled to come online in 2016-17. The other cracker will be built in Pennsylvania, in the heart of the Marcellus shale region, and is set to come online in 2019-20.¹⁴⁰

For petrochemicals and fertilizer producers, feedstock or energy inputs account for up to 90% of total production costs. Lower natural gas prices for both industrial use and electricity generation, and higher supply and a fall in production costs for feedstocks such as ethylene, could benefit the entire value chain:¹⁴¹

- The investments made by the chemical industry alone will create a need for speciality steels, reactors, separation columns, pipes, compressors, pumps, valves, fittings, control systems, storage tanks and other chemical processing equipment. Engineering and construction services will also be needed.
- Lower production costs and higher supply should lead to a decline in chemicals pricing, reducing costs for US manufacturers. Producers of products with a high ethylene content, such as downstream speciality chemical manufacturers, packaging manufacturers and plastic bottle manufacturers, could have a big advantage.
- Production of plastics, performance materials and advanced materials is starting to return to the US. At the same time, the manufacturing of electronic devices and their components, including touch-sensitive screens, is also returning.

Germany is the manufacturing powerhouse of Europe, but many German companies are expanding their operations in the US. For example:

- German chemicals giant BASF has announced plans for wide-ranging expansion in the US. Since 2009, BASF has invested more than \$5.7 billion in North America.¹⁴²
- Reifenhäuser Maschinenfabrik, a major manufacturer of extrusion equipment, is expanding in the US this year to take advantage of the growth prospects in the North American polyethylene market, in large part because of shale gas. The company expects to see considerable growth in food packaging manufacturing in the US.¹⁴³

The economic impacts could be enormous. Last year, Citi estimated that 1.1 million jobs could be created in the manufacturing sector by 2020 as a result of increases in oil and gas production,¹⁴⁴ while a PwC report estimated that 1 million new manufacturing jobs could be created by 2025 through more affordable energy and demand for products used to extract shale gas.¹⁴⁵

As Henk-Jan Rikkerink, head of research for equities at Fidelity Worldwide Investment, recently summed-up:

"The energy sector will benefit most directly, with the refining industry benefiting from cheap feedstock (an example being Valero Energy), and service companies taking advantage of higher activity levels (for example, Halliburton).

"Beyond the energy sector, the main beneficiaries will be chemical companies. US petrochemical groups that use natural gas liquids as feedstock have moved much lower on the global cost curve and are expected to benefit not only from lower raw material costs but also from improved operating rates.

"Indeed, half a dozen large petrochemical plants are expected to be built on the US Gulf Coast by the end of the decade. Eastman Chemical is one example of a company that should get a significant boost from cheaper domestic gas supplies. US nitrogen fertiliser companies are also expected to benefit from lower material costs.

"The impact of shale is likely to have implications beyond the energy and chemical sectors. The depth of the analysis at Fidelity extends to identifying the third and fourth-order beneficiaries of reduced energy costs, higher capital spending and infrastructure expansion in the industrial sector. For example, the growth in chemical plants will benefit flow control and automation contractors (such as Spectris)."¹⁴⁶

Environmental contribution

Shale gas is benefitting the environment in two ways – by contributing to CO₂ reductions through the displacement of coal, and by contributing to improved air quality through the displacement of both coal and oil.

First, US CO₂ emissions are falling:

- Between 2005 and 2010, CO₂ emissions from fuel combustion fell by 403 million tonnes. This represents the largest fall in volume terms of any country in the world and more than 25% larger than the 318 million tonne fall in the European Union.¹⁴⁷
- In percentage terms, US emissions fell by 7% over the same period. This represents the 30th largest fall out of 142 countries, and is similar to the 8% fall in the European Union.¹⁴⁸
- In terms of individual sectors, US CO₂ emissions from gas rose by 93 million tonnes over this period. But this was more than offset by a fall of 183 million tonnes from coal and 316 million tonnes from oil.

TABLE 20

US CO₂ emissions by sector, 2005 and 2010

Million tonnes	2005	2010	Change 2005-2010	Percentage change 2005-2010
Coal	2,124	1,941	-183	-9%
Oil	2,433	2,117	-316	-13%
Gas	1,190	1,282	+93	+8%
Total	5,772	5,369	-403	-7%

Source: International Energy Agency, CO₂ Emissions from Fuel Combustion – Highlights, 2012 (Sectoral Approach) <http://www.iea.org/publications/freepublications/publication/name,32870,en.html>. NB: Figures may not sum due to rounding

Second, there are a number of reasons for this fall in emissions, including the recession, improving fuel economy, and the displacement of coal by gas and renewables in electricity generation. One myth, however, that needs to be corrected is that shale gas has come at the expense of renewables. In fact, shale gas and renewables have grown together, and in many cases this joint growth has occurred in the same state:

- Between 2005 and 2012, electricity generation from coal fell by 25%. Over the same period, electricity generation from natural gas rose by 62% and from renewables by 38%, while nuclear generation remained roughly flat.

TABLE 21

US electricity generation by main sources, 2005 and 2012

TWh	2005	2012	Change 2005-2012	Percentage change 2005-2012
Coal	2,013	1,517	-496	-25%
Natural gas	761	1,231	+470	+62%
Nuclear	782	769	-13	-2%
Renewables (including hydro and biomass)	358	495	+138	+38%
Other (including oil)	142	42	-100	-70%
Total (all sources)	4,055	4,054	-1	0%

Source: US Energy Information Administration, *Electric Power Monthly*, February 2013, Table 1.1 "Net Generation by Energy Source" http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_1_1. NB: Figures may not sum to totals due to rounding

- Wind has accounted for 89% of the growth in renewable electricity generation over this period,¹⁴⁹ and has grown rapidly in 12 of the 15 shale gas producing states, with only Louisiana, Arkansas and Virginia generating no electricity from wind. Overall, between 2005 and 2011 (latest year available for state data), electricity generation from wind grew by 435% in shale gas producing states, and in 2011, wind generation in these states accounted for 55% of the US total. Texas, the largest shale gas producing state, also dominates electricity production from wind.

TABLE 22

Electricity generation from wind in shale gas producing states

TWh	2005	2011	Change 2005-2011
Texas	4.2	30.5	+26.3
Louisiana	0.0	0.0	+0.0
Pennsylvania	0.3	1.8	+1.5
Arkansas	0.0	0.0	+0.0
Oklahoma	0.8	5.6	+4.8
West Virginia	0.2	1.1	+0.9
Colorado	0.8	5.2	+4.4
North Dakota	0.2	5.2	+5.0
Michigan	0.0	0.5	+0.5
New Mexico	0.8	2.1	+1.3
California	4.3	7.8	+3.5
Virginia	0.0	0.0	+0.0
Montana	0.0	1.3	+1.3
Wyoming	0.7	4.6	+3.9
Ohio	0.0	0.2	+0.2
Shale gas producing states – total	12.3	65.9	53.6
US Total	17.8	120.2	102.4
Shale gas producing states – percentage of US total	69%	55%	52%

Source: US Energy Information Administration, Electricity generation – detailed state data, "Net Generation by State by Type of Producer by Energy Source" <http://www.eia.gov/electricity/data/state/>. NB: Figures may not sum to totals due to rounding

- Although levels of renewable support vary greatly by state, the US overall is ranked third on Ernst and Young's renewables attractiveness index.¹⁵⁰ Shale gas has not prevented the US government, at state and federal levels, from supporting the deployment of renewables – through, for example, the Production Tax Credit and Renewable Portfolio Standards.

Third, shale gas operations do produce small levels of air pollutants, particularly at the compressor stations. But the net impact of developing shale gas and using domestic natural gas in place of coal has been extremely positive in states such as Pennsylvania:

- According to the Pennsylvania Department of Environmental Protection (DEP), emissions of air pollutants have decreased substantially since 2008, while shale gas operations only account for a small proportion of the total. Table 23 provides the details.

TABLE 23

Air pollution in Pennsylvania, 2008 and 2011 compared

Tons per year	2008 total	2011 total	2011 of which unconventional natural gas	Change 2008-2011	Percentage Change 2008-2011
Carbon monoxide (CO)	94,409	85,990	6,852 (8%)	-8,419	-9%
Nitrogen oxide (NO _x)	235,485	192,275	16,542 (9%)	-43,210	-18%
Particulate matter (PM ₁₀)	30,719	22,588	577 (3%)	-8,131	-26%
Sulphur dioxide (SO _x)	864,789	353,480	122 (0%)	-511,309	-59%
Volatile organic compounds (VOC)	24,671	20,363	2,820 (14%)	-4,308	-17%

Source: Pennsylvania Department of Environmental Protection, *DEP Releases Air Emissions Data from Natural Gas Operations*, 12 February 2013 <http://www.depweb.state.pa.us/portal/server.pt/community/air/6000>

As the Pennsylvania DEP Secretary, Mike Krancer, concluded: “The data show that emissions from drilling represent a small fraction of air pollution in the state, which has gone down considerably since shale gas development began in earnest several years ago... It is worth noting that annual sulphur dioxide emissions are down more than half a million tons per year from where they were in 2008. This is a direct result of air quality regulations and the increased use of natural gas in the power generation sector.”¹⁵¹

Fourth, natural gas has great potential as a vehicle fuel:

- Compressed Natural Gas vehicles are substantially cleaner than gasoline vehicles on a well-to-wheel basis, as shown in Table 24,¹⁵² and of course, emit almost no air pollutants from the tailpipe.

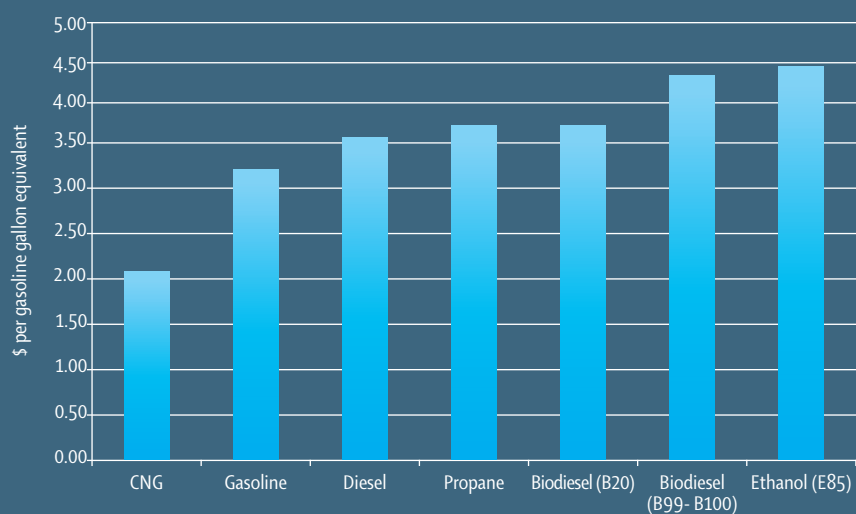
TABLE 24		
Well-to-wheel air pollution reduction from CNG vehicles, relative to conventional gasoline vehicles		
Percentage reduction	Passenger cars	Heavy duty vehicles
Greenhouse gases	20%-30%	11%-23%
Volatile Organic Compounds (VOC)	72%	72%
Nitrogen Oxide (NOx)	12%-19%	0%-4%
Weighted toxics (including Benzene, 1-3 butadiene, diesel PM, PM10, Formaldehyde)	38%-95%	1%-6%
Other impacts (including spills)	Over 90%	Over 90%

Source: TIAX LLC, *Full Fuel Cycle Assessment: Well-to-wheels energy inputs, emissions, and water impacts*, report prepared for California Energy Commission, June 2007, Tables 3-11 and 3-13 <http://www.energy.ca.gov/2007publications/CEC-600-2007-004/CEC-600-2007-004-F.PDF>

- On an energy-equivalent basis, CNG is at least a third cheaper than gasoline, diesel or ethanol, as shown in Chart 36, while methanol also represents an exciting possibility.¹⁵³ Indeed, the heads of the three major Detroit car manufacturers have testified in Congress that they would be willing to make “flex-fuel” vehicles – cars that can run on petrol, ethanol, methanol or any mixture of those fuels – constitute up to 50% of their output.¹⁵⁴ Flex-fuel cars, of course, can be filled up at any type of filling station – maximising convenience for consumers.

CHART 36

Overall Average Fuel Prices on Energy Equivalent Basis, January 2013

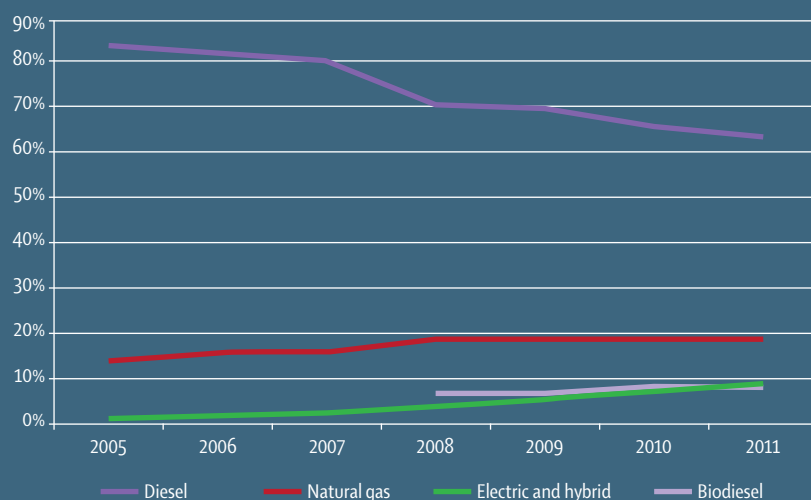


Source: US Department of Energy, *Clean Cities: Alternative Fuel Price Report*, January 2013, Table 2 http://www.afdc.energy.gov/uploads/publication/alternative_fuel_price_report_jan_2013.pdf

- Over recent years, the amount of natural gas used in vehicles has steadily increased, from 23 bcf in 2005 to 33 bcf in 2012¹⁵⁵ – although this remains relatively low. Natural gas currently powers around 112,000 vehicles in the US,¹⁵⁶ and there are 566 CNG filling stations across the country.¹⁵⁷
- Natural gas is powering an increasing proportion of public transport buses, together with electric, hybrid and biodiesel technologies. Natural gas now powers 19% of buses, and since 2005, the proportion of conventional diesel buses has fallen from 84% to 64%.

CHART 37

Proportion of public transport buses powered by diesel and alternative fuels



Source: American Public Transportation Association, 2012 *Public Transportation Fact Book*, Appendix A: Historical Tables, Table 27 <http://www.apta.com/resources/statistics/Documents/Forms/AllItems.aspx?RootFolder=%2fresources%2fstistics%2fDocuments%2ffactBook&FolderCTID=0x0120006BE9AB89F00BAE4583BADAD635F81BA6>

- Private companies are also looking to convert part of their fleets to natural gas. The Chairman and Chief Executive of FedEx recently said that the company was looking to move a portion of its 90,000 vehicles from diesel to natural gas, complementing a shift to electric and hybrid engines in its smaller vehicles. He also predicted that up to 30% of US long-distance trucking will be fuelled by compressed or liquefied natural gas over the next 10 years, as the cost of the trucks declines and fuelling stations become more common.¹⁵⁸
- Companies are also looking to build the fuelling infrastructure necessary to allow natural gas to break into the long-distance trucking industry, in addition to municipal and airport use. Clean Energy Fuels (CEF), one of the largest providers of natural gas fuel for transportation in North America, is building "America's Natural Gas Highways" – a project of 150 LNG fuelling stations by 2013 targeted at the heavy-duty fleet. As the CEO of CEF, Andrew Littlefair, said:

*"Before the shale gas boom, we used to promote natural gas vehicles on an air-quality basis. That all resonated well. But now, all of the sudden, we can also say: not only are they 23% less emitting, but you can have cheaper service in your cities because natural gas saves \$1.50 per gallon on these refuse trucks.... Markets for airports and refuse trucks are each around a 2 billion gallon per year market. By contrast, America's goods transport truck market is a 30 billion gallon per year market."*¹⁵⁹

Finally, as has been seen, gas and renewables have helped to reduce the share of coal in the energy mix. Not surprisingly, net exports of US coal have increased, from 20 million short tons in 2005 to 94 million short tons in 2011. Within that total, net coal exports to Europe increased from 18 to 54 million short tons over the same period.¹⁶⁰

A number of commentators have argued that US shale gas has to some extent merely displaced emissions overseas.¹⁶¹ But as was seen in Table 21, both natural gas and renewables have increased their share of the US electricity mix at the expense of coal. At the same time, US Environmental Protection Agency air quality regulations are becoming more stringent,¹⁶² which is likely to lead to the closure of some older coal-fired power stations. So to argue that US shale gas displaces emissions overseas is also to argue that US wind and other renewables, and tighter air quality rules, similarly displace emissions overseas.

In reality, any lower carbon development or environmental regulation that reduces the use of coal in one country increases the amount of coal available to export to other countries. But that's no argument against expanding natural gas, renewable and nuclear generation, or tightening up air quality standards. The challenge is for other countries to follow the US lead.

Pennsylvania – key statistics

Shale gas production in Pennsylvania has been transformative:

- Shale gas production has increased in Pennsylvania from virtually zero in 2007 to 1,068 bcf in 2011 – nearly two thirds of the UK's entire natural gas production. Table 25 provides the production data. Note that the US and UK measures are slightly different, and so the comparison is approximate only.

TABLE 25

Gross withdrawals from shale gas wells in Pennsylvania, with approximate comparison with UK gross gas production, 2007-2011

Billion cubic feet	2007	2008	2009	2010	2011
Pennsylvania shale gas	-	10	89	399	1,068
UK gas (all sources)	2,677	2,594	2,204	2,108	1,681

Sources: US Energy Information Administration, Natural Gas Gross Withdrawals and Production, "Gross withdrawals from shale gas wells" http://www.eia.gov/dnav/ng/ng_prod_sum_dc_u_NUS_a.htm; Department of Energy and Climate Change, DUKES 2012, data for Figure F.2, "Gross gas production", July 2012 <https://www.gov.uk/government/publications/natural-gas-chapter-4-digest-of-united-kingdom-energy-statistics-dukes>. NB: For the UK, figures are given in million cubic metres and are converted to billion cubic feet in this table. The UK and US numbers are not compiled on exactly the same basis, and therefore the comparison in this table should be used as an approximate guide only.

- In 2012, unconventional gas production in Pennsylvania generated almost 80,000 jobs, \$11.6 billion value added and over \$1 billion in state and local taxes. Tables 26 and 27 set out the economic contribution.

TABLE 26

Economic contribution of unconventional gas activity, Pennsylvania, 2012

\$ billion	Direct	Indirect	Induced	Total
Number of workers	25,130	23,803	30,361	79,294
Value added	6.0	3.1	2.6	11.6

Source: IHS, *America's New Energy Future: The Unconventional Oil and Gas Revolution and the US Economy, Volume 2: State Economic Contributions*, December 2012, Appendix A <http://www.ihs.com/info/ecc/a/americas-new-energy-future.aspx>. NB: Figures may not sum to totals due to rounding.

TABLE 27

Government revenues from upstream shale gas activity, Pennsylvania, 2012

	\$ million
Federal Taxes	1,386
Personal Taxes	1,027
Corporate Taxes	352
Federal Royalty Payments	7
State and Local Taxes	1,050
Personal Taxes	250
Corporate Taxes	787
State Royalty Payments	13
TOTAL GOVERNMENT REVENUE	2,436

Source: IHS, *America's New Energy Future: The Unconventional Oil and Gas Revolution and the US Economy, Volume 2: State Economic Contributions*, December 2012, Appendix A <http://www.ihs.com/info/ecc/a/americas-new-energy-future.aspx>

- In addition, Pennsylvania charges drillers an “impact fee”, which changes from year to year based on natural gas prices and the consumer price index. It is currently set at \$45,000 per well, with smaller, shallow wells paying a lower fee of \$9,000. 60% of the revenue is paid directly to counties and municipalities hosting wells, with the remaining 40% going to state agencies.¹⁶³ In 2011 – the first year of operation – the impact fee raised \$204 million.¹⁶⁴ In 2012, with falling natural gas prices, the impact fee raised \$198 million.¹⁶⁵
- The wider economic benefits could also be immense. As the American Chemistry Council put it two years ago: “Portions of [the Marcellus] formation are rich in NGLs but at a distance from the Gulf Coast where much of the existing petrochemical industry exists. Significant development of infrastructure (pipelines, ethane recovery, etc.) would be needed and could also include investment in petrochemical and derivatives capacity. Thus, areas in western Pennsylvania, New York and/or West Virginia could become the next US petrochemical hub.”¹⁶⁶

Innovation

Much has been written about advances in the horizontal drilling and hydraulic fracturing process over the last few years. But hydraulic fracturing has also spurred innovation in other related areas, not least water treatment, which has seen a large increase in patent activity following the surge in shale gas (and oil) production.

According to CambridgeIP, a company specialising in global patent research, nearly 700 patents relating to water treatment for the hydraulic fracturing process have been filed up to and including early 2011. These are broken down into three categories: preparation of fracking fluid, treatment of produced water, and recycling of produced water.

TABLE 28

Hydraulic fracturing water treatment – number of patents

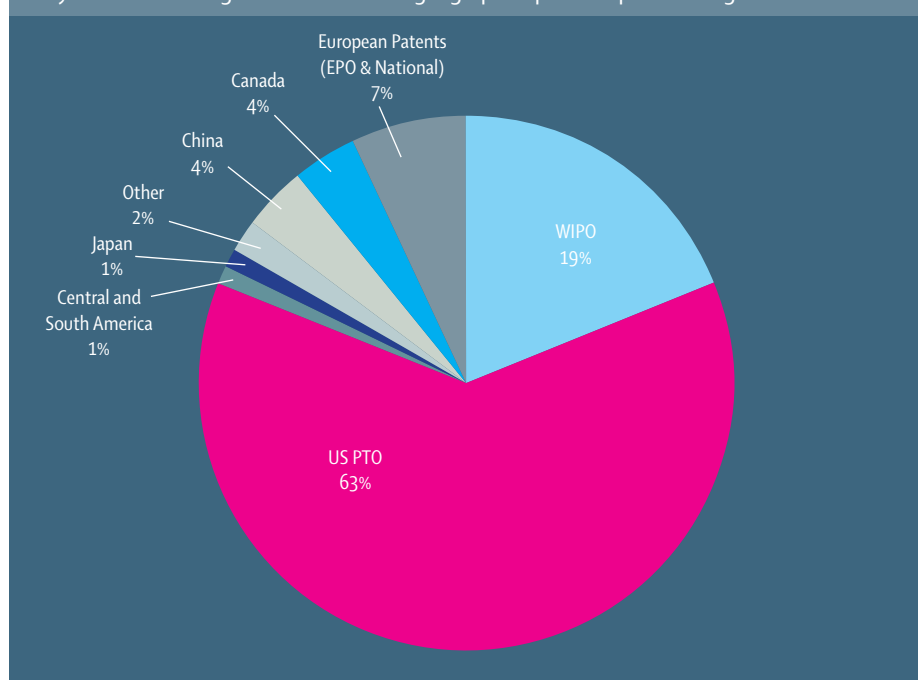
Area	Number of patents
Preparation of fracking fluid	345
Treatment of produced water	271
Recycling of produced water	76
TOTAL	692

Source: CambridgeIP, 2013

Not surprisingly, the US dominates the scene, with nearly two thirds of patents filed, while Canada is also an important destination. As shale gas exploration increases internationally, a wider geographic coverage of patents is likely. Already, 19% of patents in this area have been filed through the World Intellectual Property Organisation (WIPO).

CHART 38

Hydraulic fracturing water treatment – geographic spread of patent filings



Source: CambridgeIP, 2013

The companies most active in this area are the oil and gas companies themselves (Shell, Exxon Mobil etc) and the larger service providers (Halliburton, Baker Hughes etc). Patents have also been filed by the likes of Dow Chemicals and Synoil Fuils, illustrating the importance of chemical and fluids specialists in the innovation process. Individual inventors have also made a sizeable contribution.

TABLE 29

Hydraulic fracturing water treatment – largest patent filers

	Company	Number of patents
1	Halliburton	107
2	Shell Oil Company	52
3	Baker Hughes Inc.	27
4	United Energy Corporation	24
5	Schlumberger	21

Source: CambridgeIP, 2013

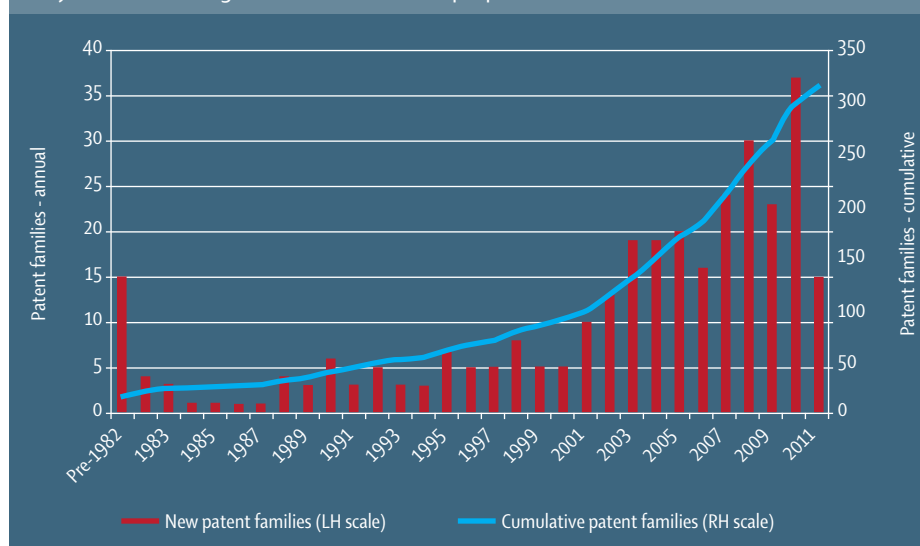
According to Quentin Tannock, Chairman of CambridgeIP:

“The increase in shale gas production has seen a corresponding increase in the number of patented water treatment inventions around the world. We observe as many unique patents filed in the six years between 2005 and 2011 as in the previous 25 years. The number of unique patents is a different measure to the number of patents, as patents filed multiple times in different jurisdictions are only counted once.

“There has also been an increase in the proportion of SME patent owners as this patent space heats up. Large companies account for around half of patents filed – a share that has stayed relatively constant, while in the last five years SMEs have accounted for 36% of patents filed, an increase from 12% before 2007. Another interesting feature of the patent space, perhaps attributable to the shale gas industry, is a growth in the number and maturity of patented off-grid water treatment innovations.”

CHART 39

Hydraulic fracturing water treatment – unique patents, 1980-2011



Source: CambridgeIP, 2013. NB: Patents filed in the last 18 months may not be published yet and can therefore be under-represented.

The IoD is grateful to CambridgeIP (<http://www.cambridgeip.com/>) for supplying the data and analysis in this innovation section of the report, although it should not be taken necessarily to imply endorsement of the wider report on the part of CambridgeIP.

Infrastructure and partnerships

Unlike the North Sea in the early years, US shale development was able to take advantage of high levels of onshore conventional and tight gas production, as well as several decades of experience developing the horizontal drilling and hydraulic fracturing processes. A large onshore drilling services industry already existed to service shale gas wells, and indeed, declining conventional production meant that spare capacity became available.

In other respects, however, significant infrastructure development has taken place over the last decade. For example, the gas pipeline network has needed significant extra capacity since the shale boom began in earnest. Between 1997 and 2006, annual capacity additions to the pipeline network ranged between 5 and 11 billion cubic feet a day. Between 2007 and 2011, annual capacity additions were 15 billion cubic feet a day or more – in 2008, almost 45 billion cubic feet a day was added to pipeline capacity.¹⁶⁷

State-wide partnerships have also proved to be important, as the following three examples illustrate. Firstly, Colorado:¹⁶⁸

- Colorado has had a renewable energy standard since 2004, and the Clean Air, Clean Jobs Act 2010 gave the clean energy sector further impetus. The state's two investor-owned utilities are in the process of converting 900 megawatts from coal-fired to gas-fired electricity over the next several years.
- The state has a long history of conventional oil and gas development and a skilled workforce, and benefits from being located close to natural gas basins throughout the central US. The Governor's Office of Policy and Research views unconventional resources as a growing industry for the state.
- The unconventional oil and gas industry has established partnerships with local universities and colleges. Exxon Mobil and General Electric have worked with the Colorado School of Mines to develop a program on unconventional oil and gas regulatory practices, and the Engines and Energy Conversion Laboratory at Colorado State University is designing and testing natural gas engines.
- The Colorado Energy Office seeks to increase the use of CNG in the state's transportation fleet and has an agreement with the Colorado Municipal League to support CNG vehicle purchases. Subsequently, retailers have announced plans to open several new natural gas fuelling stations in partnership with producers, local governments and the Regional Air Quality Council.

Secondly, Ohio:¹⁶⁹

- In 2011, Governor John Kasich and JobsOhio, an economic development organisation, assembled key stakeholders, including the Ohio Chamber of Commerce, to determine the best approach for linking unconventional oil and gas development to economic growth initiatives. Although shale development is still in its early days in Ohio, initiatives are underway in three areas.
- *Skills:* Additional training is being developed for truckers, welding, mechanical engineering and oil field safety and orientation, so that operators do not have to hire out of state.
- *Supply chain:* Workshops hosted by chambers of commerce and economic development groups, with support from the Ohio Oil & Gas Association and the Ohio Shale Coalition, are held regularly to introduce potential suppliers to the standards, culture and operating practices of the unconventional oil and natural gas industry. These workshops detail strategies companies can use to win contracts and what developers seek in their potential suppliers.
- *Innovation:* Ohio universities are working with the industry to research topics such as new materials and environmental protection measures.

Thirdly, Pennsylvania:

- In Pennsylvania, the Center for Sustainable Shale Development (CSSD) has brought together organisations such as the Environmental Defense Fund and the Pennsylvania Environmental Council with the production companies to set performance standards and provide third-party accreditation.¹⁷⁰ The formation of the CSSD has been met with some opposition, but although it is still early days, it should help to increase oversight and set higher environmental standards for drilling operations. Most importantly, it is an example of environmental groups and industry working together – an all-too-rare occurrence.

3.3 ONSHORE WIND AND NUCLEAR IN BRIEF

Other UK energy developments also provide important lessons for an emerging shale gas industry, not least onshore wind and nuclear. This section does not go into detail, but concentrates on a few important points.

Onshore wind

Onshore wind has grown rapidly over the last decade. In 2000, only a few hundred megawatts of installed capacity existed in the UK. By 2005, capacity had increased to around 1 GW. By summer 2012, onshore wind capacity had grown to 5 GW, with a further 1.8 GW under construction.¹⁷¹ There are now 3,741 onshore turbines.¹⁷²

Despite considerable levels of government support, both political and financial, onshore wind has not had everything its own way. Planning and delays to grid connections have in some cases proved to be significant barriers, leading to a number of measures being put in place to facilitate the development of onshore wind and other renewables:

- Onshore wind farms of 50 MW or above are now designated as “nationally significant infrastructure”, which means that planning decisions are made by Ministers rather than local authorities, with planning expertise for these larger projects concentrated in the Major Infrastructure Planning Unit (MIPU).¹⁷³
- Following the Local Government Finance Act 2012, all business rate income from new renewable projects will be retained by the local planning authority, rather than just a share of the business rate income, as will be the case generally.
- RenewableUK, the trade body for onshore wind, has agreed a Community Benefits Protocol, which was launched in February 2011. The criteria have been agreed by all participating onshore RenewableUK members and apply to all projects of 5 MW and above in England. The Protocol states that “a community benefit scheme will receive support equivalent to a minimum value of at least £1,000 per megawatt of installed capacity per annum and will be index-linked with the RPI for the lifetime of the project.” The Protocol also sets out how the relevant communities will be identified and stipulates that early and transparent consultation must take place.¹⁷⁴
- In Scotland, the Scottish Government Register of Community Benefits from Renewables provides transparent data on the funds provided to local communities hosting onshore wind and other renewable developments. The database is searchable by project, and details the amount paid, the types of projects that the money will be spent on, and how the local community is defined.¹⁷⁵
- In order to reduce grid connection delays, since August 2010, the “Connect and Manage” regime has meant that generation projects are allowed to connect to the transmission system in advance of the completion of the wider transmission reinforcement work. As the DECC website puts it, this “is enabling new generation to connect to the network more quickly thereby removing a key barrier to new renewables”.¹⁷⁶

Together with a trend of submitting smaller projects, the measures have had some success. With respect to onshore wind planning:¹⁷⁷

- UK approval rates for projects above 50 MW subject to a Ministerial decision reached 91% in 2011-12;
- Approval rates at the local authority level in England rose from 45% of projects in 2010-11 to 58% in 2011-12;
- In Scotland, perhaps partly because of a less dense population, local authority approval rates are higher, but they have also risen, from 65% of projects in 2010-11 to 70% in 2011-12;
- Across the UK average decision times across for projects above 50 MW determined by Ministers fell from 52 months in 2010-11 to 42 months in 2011-12;
- Across the UK, average decision times at local authority level fell from 15.5 months to 14 months.

Nuclear

Although nuclear is probably the cheapest and most reliable major low-carbon energy source after large-scale hydro, the new nuclear programme in the UK is yet to break ground, as negotiations over the strike price and the security of long-term contracts continue. The nuclear industry, however, employs around 50,000 people¹⁷⁸ directly to manage the existing power stations and decommissioning operations, and has built up an excellent network of training provision. And a huge amount of work has been done to ensure that, should new nuclear go ahead, local communities will benefit, as they have from existing sites:

- Educational provision has improved greatly over the past decade. In 2002, with new nuclear power stations looking unlikely, a report commissioned by the Health and Safety Executive concluded that “if nuclear education were a patient in a hospital it would be in intensive care”. The report suggested that immediate action was needed if nuclear education was not to disappear entirely. In 2004, a grouping called the Nuclear Technology Education Consortium (NTEC) was formed, which brought together around 10 universities to deliver postgraduate courses. NTEC demonstrated that students were once again becoming extremely interested in doing nuclear science and engineering courses. As a result, a range of new undergraduate and graduate programmes based in individual universities have been established, including at the Universities of Lancaster, Manchester and Leeds and at Imperial College London. The Engineering and Physical Sciences Research Council (EPSRC) has also been increasing its support for nuclear research and in particular for PhD students.¹⁷⁹ Today, the *UK Nuclear Education, Skills and Training Directory* lists 23 universities, 14 further education colleges and 12 employer-nominated providers offering nuclear-related courses.¹⁸⁰
- Nuclear power stations of 50 MW or above in specified locations are also designated as “nationally significant infrastructure”, meaning that planning approvals are decided by Ministers.¹⁸¹ Once a reactor is given “Generic Design Assessment” approval, the planning process is governed by a strict timetable, which has helped to speed up planning applications. EDF was recently granted planning permission for the Hinkley Point C development, the first consent for a new nuclear power station since 1995.¹⁸²

- EDF has undertaken a considerable amount of work to ensure minimal disruption during the construction of Hinkley Point C and maximum opportunities for local people. Should the development go ahead, which at the time of writing is still uncertain, at least 5,000 Somerset residents are expected to be employed during the construction phase.¹⁸³ EDF has also invested £2 million in the Construction Skills Centre and Energy Skills Centre at Bridgewater College, to help ensure that local young people can gain the skills needed for jobs constructing the power plant, and £1 million in an Enterprise Centre in West Somerset, to help local businesses prepare for supply chain opportunities.¹⁸⁴
- Overall, support for new nuclear power stations stands at 42%, up from 20% in 2001, while opposition stands at 20%, down from more than 50% in 2001. Just over a third (35%) have a favourable impression of the nuclear industry, compared to 18% with an unfavourable impression.¹⁸⁵ These are not spectacular polling numbers, but they are not disastrous either. And according to evidence given to the Energy and Climate Change Select Committee, people who live close to nuclear power stations – within a 10-15 mile radius – are generally more positive than the national polls, although opinion can also be more polarised.¹⁸⁶

3.4 KEY LESSONS

A number of lessons can be learned from the developments highlighted both in this chapter and in Chapter 2. The list below summarises the main ones, although is by no means exhaustive.

1. The first lesson is that developments take **time**. In the UK, North Sea gas production began 10 years, and oil production 16 years, after the Groningen discovery. It also took a considerable period of time for nuclear and onshore wind to reach scale in the UK. In the US, although shale gas production has taken off over the last decade, it was preceded by several decades of research and development of the horizontal drilling and hydraulic fracturing techniques, some of which was funded by government. Once developments start to achieve scale, however, production can increase very rapidly.
2. Energy developments do take time to scale, but an equally important lesson is that reserves and production often **exceed** early estimates, and by quite some margin, as exploration work continues and production technology improves. In 1974, when oil first began to flow from the North Sea, the Department of Energy forecast that production would peak in 1981 at around 115 million tonnes a year. In actual fact, it peaked in 1999 – 18 years later – at 137 million tonnes a year. In the US, shale gas production has exceeded official forecasts, even those made less than two years ago.
3. The **economic benefits** of domestic oil and gas production can be extremely large indeed – well-paid jobs, significant tax revenue, a contribution to the balance of payments and the development of a local supply chain, with the spending of employees feeding through to the wider economy. Although in some countries, natural resources have been more of a curse than a blessing, as a stronger exchange rate and high returns in the extractive industries negatively affect the development of other sectors of the economy, in large and well-diversified economies such as the UK and US, domestic oil and gas development can provide an important boost.
4. Domestic energy production should be thought about as part of a **wider economic development**. This is a crucial lesson. In the UK, domestic oil and gas provided feedstocks to the chemical industry, which in turn benefitted heavy industry in general. In the US, cheap and plentiful domestic natural gas is leading to massive investments in chemical plants and the re-shoring of other manufacturing operations.

5. The next lesson is perhaps not immediately apparent, but domestic natural gas production can lead to large **environmental** gains, as it allows a move away from coal. Over several decades, gas from the North Sea replaced coal as the UK's largest energy source, and shale gas is facilitating a move away from coal in the US. Gas is also the most effective back-up power source for renewables such as wind and solar, and in the US, is increasingly being used as a transport fuel, providing further air quality gains. Finally, natural gas is a vital feedstock for the chemicals needed to manufacture goods that can improve energy efficiency, such as insulation materials and PVC frames for double- or triple-glazed windows. And if the goods are made at home, the environment will also benefit, as UK heavy industry is more energy efficient than in many other countries.

6. If the resource looks promising enough, **infrastructure**, including pipelines and gathering stations, will be built and **equipment**, including drilling rigs, will be made. The private sector is very effective at rapidly expanding production to meet demand.

7. **Skills** can be developed locally over time, but initially, **outside expertise** will be needed. The early development of the North Sea depended on skilled workers from the US, and more recent shale gas development in states such as Pennsylvania has relied on considerable expertise from earlier shale gas development in Texas. The UK's nuclear industry provides excellent skills training, and is a good example to look at.

8. In the UK specifically, a **stable tax regime** is essential. Successive governments have failed to heed that basic lesson, and investment in the North Sea has suffered as a result. Recent changes, including providing certainty on decommissioning relief and expanding field allowances, have helped to safeguard investment and production, following damaging tax rises in 2011.

9. **Partnerships** are vital to attracting investment, improving skills, providing opportunities for the supply chain, managing safety and resolving issues that arise. The North Sea benefits from a number of such well-established partnerships – it has an industry body, a skills body, a supply chain programme and a fiscal forum. In the US, partnerships have been developed to set environmental standards for drilling and to harness the economic opportunities from production. In Pennsylvania, the Center for Sustainable Shale Development has brought together organisations such as the Environmental Defense Fund and the Pennsylvania Environmental Council with the production companies to set performance standards and provide third-party accreditation. In Ohio, the Governor and JobsOhio, an economic development organisation, have brought together key stakeholders and begun work on training, supply chain and innovation initiatives.

10. **Supportive local authorities** are also critical, not only to give planning consent, but actively to encourage development and attract investment. Aberdeen City Council wanted to see oil and gas development in Aberdeen, and worked with partners such as the North East Scotland Development Authority to make sure that it happened. And although the decision to grant planning approval to Hinckley Point C ultimately rested with the Energy Secretary, his decision would have been a lot harder if the local county and district councils had been opposed.

11. The **concerns of local communities** matter, and energy companies need to spend time explaining to local people why the development is important, the measures that will be put in place to protect the environment and local quality of life, and the benefits that the local community can expect to receive. Wytch Farm provides a good example, while the nuclear industry has also been quite successful in explaining the benefits of new nuclear development, with people living near nuclear power stations more likely to be in favour of nuclear energy than the general population. And once the onshore wells have been drilled, they tend not to be noticed.

12. **Transparency** can do a lot to reassure people that development is being carried out appropriately. Fracfocus.org provides a register of the chemicals used in over 40,000 well sites across the US.

13. Determining the measures to be taken **if something goes wrong**, and the parties that are responsible, also helps to provide reassurance. At Wytch Farm, BP works with Dorset County Council to draw up contingency plans. The latest version was published in December 2010 by the Bournemouth, Dorset & Poole Local Resilience Forum outlining the actions, roles and responsibilities of the different parties. Understanding legal liability is also important.

14. **Finance** matters. The UK's system of local government finance tends to act against development, as the local authority is unable to keep the revenue gains, although the system is now changing. And local communities can also feel left out. The UK's onshore wind industry has been working hard to address these issues, and has set up a Community Benefits Protocol for projects in England, establishing a minimum community benefit payment. Local authorities are also able to retain up to 100% of business rates from new renewable projects such as onshore wind farms, and in Scotland, the Scottish Government Register of Community Benefits from Renewables provides transparent data on the funds provided to local communities hosting onshore wind and other renewable developments. In the US, although the financial context is very different, the impact fee recently introduced in Pennsylvania is an interesting model. Labelled an "impact fee" to get around Governor Corbett's pledge not to raise taxes, the charge is currently \$45,000 per well and the revenue is split 60:40 between local counties/municipalities and the state government.

15. Finally, the development context in the UK and US is **different**. In the UK, development tends to be slower and more controlled, with a centralised regulatory regime in place beforehand and a strict planning system for onshore development. In the US, development is perhaps less controlled, with a flurry of activity, a lot of learning by experience and a huge degree of flexibility. As the process settles down and matures, a great advantage that the US has is that it seems to be able to retain a high level of flexibility, with both industry and officials able to respond quickly to changes in prices and other conditions. In the US, individual states also have considerable authority over environmental regulations, with hydraulic fracturing either permitted or forbidden at the state level. Oil and gas rights in the US belong to the individual owner of those rights (not always the present landowner), while in the UK, they belong to the state, after being transferred in the Petroleum Act of 1934. Given that shale gas development in the UK is coming after the US, the UK can learn from the US experience, not least from the rapid improvements that have been made to the drilling and fracturing processes, and from the mistakes that have occasionally been made with regard to water disposal.



4. Shale gas potential

A shale gas industry in the UK could replace a portion of gas imports; generate tax revenues; create jobs in parts of the country that need them most, including in wider manufacturing businesses; and help to reduce carbon emissions and improve air quality. Quantities of shale gas in place are significant, and exploration will be needed to discover what proportion is recoverable.

This chapter describes how shale gas production could potentially develop, to give an illustration of the potential of a shale gas industry to benefit the economy. Lancashire has a number of strengths that could allow it to become a centre for UK – and indeed European – shale gas operations, and it is far from the only region of the UK that could benefit.

4.1 OVERVIEW OF SHALE GAS BENEFITS

UK shale gas could have six main benefits – three economic and three environmental.

Potential economic benefits

1. Shale gas could replace a portion of gas imports. Whether UK shale gas production will be sufficient to reverse the rise in imports, or whether it will simply slow the rise in imports, is an open question. The prospect of either, however, should be welcomed, both for balance of payments and energy security reasons.
2. It could represent a new source of tax revenues to replace in part falling receipts from Fuel Duty and the North Sea. Shale production is unlikely to make a meaningful contribution to reducing the present budget deficit but, like the North Sea, it could help to support the public finances for many decades.
3. Shale gas production could create well-paid jobs in parts of the country that need them most, helping to rebalance the UK's economy. Job creation is likely to spread beyond the industry itself and its supply chain, with the chemical sector in particular likely to benefit.

Potential environmental benefits

1. Natural gas from UK shale, provided the production process is well-regulated, should produce fewer lifecycle CO₂ emissions than imported gas, particularly LNG:

- According to the Committee on Climate Change, shale gas can have “lower emissions than imported liquefied natural gas (LNG), if regulatory arrangements are in place to manage methane released during its production. If wider social and environmental issues can also be addressed (e.g. local water supply impacts), UK shale gas may therefore play a useful role substituting for imported gas in meeting demand for heat, and for gas-fired generation to balance the system or in conjunction with CCS.”¹⁸⁷
- According to a recent report prepared for the European Commission, emissions from electricity generated from shale gas are 2-10% lower than electricity generated from conventional pipeline gas located outside of Europe (in Russia and Algeria), and 7-10% lower than electricity generated from LNG imported into Europe.¹⁸⁸

As Chart 2 in Chapter 1 showed, natural gas demand is likely to be relatively flat over the next two decades, which is consistent with DECC's central forecasts for greenhouse gas emissions, which project the net UK carbon account to fall, relative to 1990 levels, by 37% by 2020 and 45% by 2025. Using UK gas rather than imported gas to heat homes, feed industry and support renewables in generating electricity should result in lower CO₂ emissions. And as a recent report by the Pöyry energy consultancy concluded, developing UK shale gas at scale would have no impact on the UK's ability to meet its 2020 renewables target.¹⁸⁹

Looking further ahead, the Government projects that oil and gas will still meet around 70% of the UK's primary energy requirements into the 2040s.¹⁹⁰ The International Energy Agency also predicts that global natural gas demand can rise by 20% by 2035 under a scenario that keeps CO₂ concentrations to 450 parts per million.¹⁹¹

If UK natural gas use does fall in order to meet the UK's 2050 CO₂ target, then UK shale gas could meet a larger proportion of UK demand, and, depending on production volumes, could potentially be exported.

2. To the extent that UK shale gas supports the production of chemicals and other goods in the UK rather than overseas, emissions will be lower, as UK industry is more energy-efficient than in most countries. Gas is also an important feedstock in the production of goods that can be used to improve the country's energy efficiency, such as PVC for double- or triple-glazed windows.

3. Natural gas has great potential as a transport fuel, particularly for buses, HGVs and vans. As Table 24 in Chapter 3 showed, using Compressed Natural Gas (CNG) in place of gasoline could substantially reduce well-to-wheel CO₂ emissions. UK shale gas could be used as a source of CNG for road transport.

Prices

UK shale gas could potentially have an impact on prices in two ways:

- First, on the level or volatility of wholesale (National Balancing Point) prices;
- Second, on prices for petrochemical feedstocks such as ethane.

Wholesale prices: UK wholesale gas prices are projected by DECC to increase from 61.2 pence per therm in 2012 to 77.5 pence per therm in 2016, before levelling out at 71.9 pence per therm in 2018.¹⁹² Shale gas production would have a beneficial impact on wholesale prices if they were to level out at less than 71.9 pence per therm, or if they were to fall below the 2012 level of 61.2 pence per therm. According to the recent Pöyry report cited above, wholesale gas prices would be 2-4% lower than otherwise if UK shale gas production were to proceed at scale.¹⁹³

In our view, it is too early to say whether or not UK shale gas production will have a benign impact on wholesale gas prices, as it has in the US. In our view, conventional and unconventional gas developments overseas will be the major determinant of wholesale gas prices. We agree with the conclusion of the Energy and Climate Change Select Committee: *"It is too early to say whether domestic production of shale gas could result in cheaper gas prices in the UK."*¹⁹⁴

Petrochemical feedstocks: If UK shale gas contains liquids such as ethane and propane, the petrochemical industry could benefit from competitively-priced feedstocks. Again, it is too early to say just how competitive.

As Tom Crotty, the CEO of Ineos Olefins & Polymers Europe, told the Energy and Climate Change Select Committee:

*"We would hope that, at a minimum, it would stop that further [price] rise. I should say, from a chemicals point of view, we must not forget the other aspect of shale gas, which is potentially a key raw material for the chemicals industry, not from its energy content but from its chemical content. That has probably been the most transformational impact of it on the US chemical industry."*¹⁹⁵

Conclusion on prices: Although it is too early to tell whether shale gas production will reduce UK gas prices, the case for shale does not rest on any impact on prices. In our view, the major benefits of UK shale gas will be the six listed above.

As the Energy and Climate Change Select Committee concluded:

*"It would be wrong for the Government to base policy decisions at this stage on the assumption that gas prices will fall (it is possible that they will rise) in the future. However, if large quantities [of shale gas] are found they will either bring down prices in the UK, or generate substantial tax revenues, or both – and will certainly reduce imports with benefits to our balance of payments and energy security. For all these reasons the Government should encourage exploration to establish whether significant recoverable reserves exist."*¹⁹⁶

4.2 UK SHALE GAS RESOURCES

As the Royal Society has pointed out, shale gas is not a completely new development in the UK:

*"The first UK well to encounter shale gas was drilled in 1875. Its significance at the time went unnoticed as abundant conventional reservoirs made shale gas extraction uneconomic. It was not until the mid-1980s that research began into the potential for gas production from UK shales. In 2003, the Petroleum Revenue Act was repealed, exempting shale gas production from the Petroleum Revenue Tax. In 2008, 97 Petroleum Exploration and Development Licences were awarded for shale gas exploration in the UK during the 13th Round of Onshore Licensing. A 14th licensing round is pending."*¹⁹⁷

Estimates of UK shale gas in place are significant. In 2011, the US Energy Information Administration estimated that the UK has 97 trillion cubic feet (tcf) of gas in place. At the time of writing, the combined estimates of the exploration companies, in their licence areas, add up to 309 tcf of gas in place.

TABLE 30

Estimates of UK shale gas in place

Date	Organisation	Amount (tcf)	Type of resource
April 2011	US Energy Information Administration	97.0	"Risky gas in Place"
June 2011	Eden Energy Ltd	34.2	"Gas Initially in Place"
September 2011	Cuadrilla Resources Ltd	200.0	"Gas in Place"
April 2012	IGas Energy Plc	9.2	"Gas Initially in Place"
May 2012	Dart Energy International	65.6	"Gas Originally in Place"
	Total exploration companies	309.0	NB: Exploration company estimates cover their licence areas only, not the whole of the UK

Sources: US Energy Information Administration, *World Shale Gas Resources: An Initial Assessment of 14 Regions Outside the United States*, April 2011, Table 1-3 <http://www.eia.gov/analysis/studies/worldshalegas/>; Eden Energy Ltd, UK Gas Assets <http://www.edenenergy.com.au/wales.html> (NB: Eden holds a 50% interest – its share of Gas Initially in Place is 17.1 tcf); Cuadrilla Resources Ltd <http://www.cuadrillaresources.com/what-we-do/about-natural-gas/>; IGas Energy Plc, *Operational update*, 2 April 2012 <http://www.igasplc.com/uploads/120402msoperationsupdatefinal.pdf>; Energy-pedia News, 10 May 2012 <http://www.energy-pedia.com/news/united-kingdom/new-150262>

Annual UK gas consumption is around 3 tcf, and so the figures shown in Table 30 are substantial. In oral evidence given to the Energy and Climate Change Select Committee, Nigel Smith of the British Geological Survey stated that Cuadrilla's resource estimate of 200 tcf is "more reliable" than the original figure published by the British Geological Survey of 5.3 tcf.¹⁹⁸

But what really matters is not the size of the overall gas in place estimates but the size of the recoverable resources, which is limited by factors such as technology and economics, and ultimately the size of the reserves – how much gas could actually be produced. Estimates of recoverable resources are more limited. Those that have been made are shown in Table 31.

TABLE 31			
Estimates of UK shale gas recoverable resources			
Date	Organisation	Amount (tcf)	Type of resource
2010	British Geological Survey	5.3	"Reserve potential"
April 2011	US Energy Information Administration	20.0	"Technically Recoverable Resource"
June 2011	Eden Energy Ltd	12.8	"Recoverable Volume" NB: Covers Eden Energy Ltd's licence area only

Sources: British Geological Survey, *The Unconventional Hydrocarbon Resources of Britain's Onshore Basins – Shale Gas*, published by DECC in 2011, p.1 https://www.og.decc.gov.uk/UKpromote/onshore_paper/UK_onshore_shalegas.pdf; US Energy Information Administration, *World Shale Gas Resources: An Initial Assessment of 14 Regions Outside the United States*, April 2011, Table 1-3 <http://www.eia.gov/analysis/studies/worldshalegas/>; Eden Energy Ltd, UK Gas Assets <http://www.edenenergy.com.au/wales.html> (NB: Eden holds a 50% interest – its share of Recoverable Volume is 6.3 tcf);

To put these limited estimates of recoverable resources in context, the UK's remaining potentially recoverable conventional gas resources are 51.8 tcf, of which 17.4 tcf are classified as reserves.¹⁹⁹

No recoverable resource or reserve estimates have yet been made from the much larger gas in place volumes identified by exploration companies such as Cuadrilla. But calculations of recovery rates by the International Energy Agency, the MIT and others allow indicative estimates to be made:

- According to a study by the Centre for Global Energy Studies, shale gas recovery rates have averaged 18% in the US.²⁰⁰
- The International Energy Agency has found that "recovery factors for shale gas and light tight oil are very low, compared to conventional reservoirs: estimates in most cases do not exceed 15% of the original oil and gas in place".²⁰¹
- According to a recent MIT study, "recovery factors" for unconventional gas resources, including tight gas, shale gas and coal bed methane are "typically of the order of 15% to 30% of GIIP [Gas Initially in Place]".²⁰² The findings of the MIT report were also highlighted in a recent European Commission study, which stated: "Recovery rates are much lower than in conventional gas – typically of the order of 15-30% of OGIP [Original Gas in Place]".²⁰³

Table 32 takes the combined gas in place estimates of the exploration companies and applies a number of different recovery rates. At the low end, a recovery rate of 5% of the gas in place estimated by the exploration companies would equate to a recoverable resource of 15.5 tcf of gas – more than five years of total UK consumption. At the high end, a recovery rate of 25% of the gas in place would imply a recoverable resource of 77.3 tcf – over 25 years of total UK consumption.

A recovery rate of 10% may be more realistic as a conservative assumption. This would equate to a recoverable resource of 30.9 tcf based on the findings of the exploration companies – nearly two thirds potentially recoverable conventional gas resources.

TABLE 32					
Potential UK shale gas recoverable resources based on various recovery rates					
	Recovery rate				
	5%	10%	15%	20%	25%
Gas in place (tcf) – total of exploration company estimates	309	309	309	309	309
Recoverable resource (tcf)	15.5	30.9	46.4	61.8	77.3
Years of total UK consumption (3 tcf a year)	5.2	10.3	15.5	20.6	25.8
Percentage of potentially recoverable conventional gas resources	30%	60%	90%	119%	149%

The UK's recoverable resource potential could be higher than that detailed in Table 32, for two reasons:

- The British Geological Survey (BGS) is currently finalising an updated estimate of the quantity of gas in place.
- The 14th onshore licensing round will take place in due course. This will open up more areas for exploration, allowing better estimates to be made of both the quantity of gas in place and the size of the recoverable resource.

These estimates should also be put in the context of conventional gas production, which totalled around 83 tcf between 1965 and 2011.²⁰⁴ Indications are that the UK has a lot of shale gas.

Further exploratory drilling will be essential to make more detailed estimates of the UK's recoverable shale gas resources. In the meantime, detailed petrophysical analysis of data from several hundred existing wells that drilled through shale rock in Midland Valley, Scotland, Northern and Southern England is being carried out by NuTech Energy Alliance. This should also help to increase understanding of the UK's geology and potential for shale gas development.

Definitions

Gas in place

The total volume of natural gas that is underground prior to development.

Recoverable resource

The term is broken down into “technically recoverable resource” – the volume of gas that is technically possible to produce – and “economically recoverable resource” – the volume of gas that is both technically possible to produce and also possible to produce commercially. The latter term is smaller than the former.

Reserve

The volume of gas estimated to have a specified probability of being produced – broken down into “proven”, “probable” and “possible”.²⁰⁵

4.3 ADVANTAGES

The UK has several advantages that could help to ensure that shale gas production occurs at scale. Lancashire is also very well placed to become a centre of expertise for shale gas operations, although it is far from the only region of the UK that could benefit.

UK

There has been a significant amount of recent comment that the UK lacks the conditions that have facilitated rapid growth in US shale gas production. In some respects, this is true, and Chapter 5 describes the barriers to UK production in some detail. But in a few respects, the UK is potentially in a more favourable position than the US:

- Although roads are generally wider than in the UK, minor roads in the US are often unpaved, meaning that heavy trucks will have a greater impact. The US has 4.1 million miles of roads, of which 1.3 million miles are unpaved – nearly a third of the total.²⁰⁶ And few areas of the UK are so remote as to need new roads entirely.
- Shale gas and oil developments in the US are often further away from transmission infrastructure than they would be in the UK. Indeed, in North Dakota, gas processing and pipeline infrastructure is so far away that gas produced from shale oil wells has been routinely flared – between 2010 and 2011, gas vented or flared in North Dakota doubled to 50 bcf, almost a quarter of the US total,²⁰⁷ and according to the US Energy Information Administration, more than a third of all gas produced in North Dakota in the first nine months of 2011 was vented or flared.²⁰⁸ Companies have been able to claim an economic hardship of connecting a well to a natural gas pipeline, which allows them to flare natural gas for one year without paying taxes or royalties, and then to claim an extension. Over the last two years, more than 95% of extension requests were granted, although a new Bill aims to cut the exemption.²⁰⁹ And at the same time, pipeline and processing infrastructure is being built rapidly, which will reduce the quantity of natural gas being flared in the state.
- The mains water and sewerage network is also less developed in the US, which is not surprising given the size of the country. Around 15% of homes rely on private drinking water supplies, such as water from wells,²¹⁰ compared with around 1% in the UK.²¹¹ Similarly, around 20% of households in the US are not connected to a public sewer, depending on facilities such as individual septic systems or small community cluster systems to treat their wastewater.²¹² This means that, compared to the UK, shale gas developments are more likely to need to extract water locally rather than using a mains supply, and will generally have to transport wastewater over longer distances to be treated.
- The Bowland shale in Lancashire is around 1,000 metres thick, compared to thicknesses of 150-200 metres for the main US shale plays, and has a relatively high Total Organic Content (above 2%).²¹³ This could allow horizontal wells to be drilled at different depths from the same wellpad, meaning that a comparable level of production could need fewer sites in the UK than in the US.
- Although drilling costs are likely to be higher initially in the UK – perhaps twice as high – wholesale gas prices are around three times higher than in the US. Bloomberg New Energy Finance estimates that shale gas production in the UK will be economic between \$7 and \$12 per MMBTU, close to the \$8-11 range in which UK spot prices have traded over the past two years.²¹⁴ The profitability of UK shale gas production is likely to be less dependent on shale oil or Natural Gas Liquids (NGLs) production.

Lancashire

One of the interesting aspects of the development of Aberdeen as a centre for North Sea oil and gas, as highlighted in Chapter 2, was that much of the infrastructure and expertise had to be built up from scratch. In some respects, the same will be true in Lancashire, but overall, Lancashire is probably better placed now than Aberdeen was in the 1960s:

- Lancashire has potentially excellent shale gas resources within the county, rather than many miles out to sea.
- The National Transmission System for gas has spare capacity and runs through Lancashire. Several compressor stations already exist. (For more details, see Chapter 5.)
- Road, rail, air and port infrastructure is excellent. (For more details, see Chapter 5.)
- The UK's largest CNG filling station, capable of filling 500 HGVs a day, is located in Crewe, a little to the South of Lancashire.²¹⁵
- There are two universities, the University of Central Lancashire (UCLAN) and the University of Lancaster. The University of Lancaster, one of the UK's leading research-intensive higher education institutions, has considerable energy expertise across a wide range of disciplines.²¹⁶ UCLAN also has considerable energy expertise with a wide range of courses in energy engineering and management.²¹⁷
- As detailed in Chapter 2, Lancashire was the home of the industrial revolution, and has a long history of innovation and development.
- The North West has a large industrial sector, which could benefit from Lancashire shale gas.
- As Chapter 2 detailed, advanced engineering and manufacturing is a key Lancashire strength, with around 90,000 people working in the sector.

If Aberdeen was able to become a European, and indeed global, centre for offshore oil and gas expertise, there is no reason why Lancashire – which in many respects is in a stronger position than Aberdeen was in the 1960s – cannot become a centre of expertise for European shale gas development. Indeed, Lancashire's inherent strengths in advanced engineering and manufacturing, coupled with the opportunities presented by shale gas, could enable the area to regain its role as a national economic powerhouse.

4.4 WHAT COULD SHALE GAS PRODUCTION POTENTIALLY LOOK LIKE?

Assuming that further exploration confirms early indications that the UK's geology is favourable to shale gas production, it is worth examining what production could look like in practice.

The IoD's previous report provided estimates of the overall number of jobs that could be created from a potential shale gas production phase in the UK. We are now in a position to update our previous estimates with a far more detailed model, as is described below.

This section begins with an examination of a single pad and builds up a picture of more widespread development, using three production scenarios. Shale gas production at scale would require hundreds and potentially thousands of horizontal (lateral) wells to be drilled, but the surface impact would be far smaller than these large numbers suggest. UK shale gas development could be highly efficient in its use of land and a single pad could be a major source of investment and employment.

It is worth emphasising that the picture presented in this section is of a potential production phase.

The IoD is grateful to Graham Dean, Director of Reach Coal Seam Gas Limited, for his assistance with the calculations presented in this section. All conclusions and any errors are ours alone.

Assumptions

In presenting any estimates of this nature, a number of assumptions need to be made.

Land use: We assume that both a 10-well pad of 10 laterals and a 10-well pad of 40 laterals would use two hectares of land. We assume that a 40-lateral pad would have the same number of vertical wells as the 10-lateral pad, but would have four laterals from each vertical well. In the US, earlier shale gas pads tended to be single-well, but in areas such as the Marcellus play in Pennsylvania, multi-lateral pads are now the norm. The Bowland shale in Lancashire is around 10 times as thick as the main shale plays in the US, meaning that potentially several laterals could be drilled from each vertical well – indeed, it is possible to envisage pads with more than 40 laterals.

Estimated ultimate recovery (EUR) per lateral: In the US, the average Estimated Ultimate Recovery (EUR) per lateral in a number of shale plays has been calculated at 3.2 bcf over 30 years, as Table 33 shows.

TABLE 33		
Average Estimated Ultimate Recovery (EUR) per lateral, US shale plays		
Shale gas play	Total laterals surveyed	EUR @ 30 years per lateral, bcf
Barnett	731	3.0
Fayetteville	467	1.4
Woodford	305	1.7
Haynesville	275	5.9
Eagle Ford	59	3.8
AVERAGE	-	3.2

Source: Jason Baihly, Raphael Altman, Raj Malpani and Fang Luo, *Shale Gas Production Decline Trend Comparison over Time and Basins*, Schlumberger Paper SPE 135555, 2010 http://www.slb.com/resources/technical_papers/technical_challenges/unconventional_gas/135555.aspx

We also present a low scenario, where the EUR for each lateral is reduced to 2.4 bcf, and a high scenario, where the EUR for each lateral is increased to 4 bcf.

Initial production rate and decline factor: Although further exploration and appraisal will be essential to work out these measures, we assume an initial production rate of 2.6 million cubic feet per day in the central scenario, 2.1 million cubic feet per day in the low scenario and 3.1 million cubic feet per day in the high scenario. We also assume a hyperbolic decline curve factor of 0.8436.

Abandonment: We assume that wells will be abandoned after approximately 20 years of production. By this time, production rates will be so low that cashflow will likely turn negative, and almost all of the lateral's EUR will have been recovered.

Water use per lateral for fracturing: 13,600 cubic metres, the average for the Eagle Ford play in Texas.²¹⁸ It is worth noting that, according to the waste management plan submitted by Cuadrilla for the Anna's Road site in January 2013, water use is unlikely to exceed 10,000 cubic metres per lateral.²¹⁹

Flowback water: We assume that flowback water totals 30%. According to a recent report by Accenture, wastewater (flowback water and produced water) averages 15-25% in the “dry” shales (e.g. Marcellus) and up to 75% in the “wet” shales (e.g. Barnett).²²⁰

Truck movements: Table 34 provides an estimate of the number of truck journeys. The key variable is whether the water needs to be trucked to the site or whether it can be provided via a mains connection.

Activity	Number of truck journeys	Source and explanation
Per pad		
Site access and drill pad construction	40	European Commission higher estimate
Drill rig setup	40	European Commission estimate
Wellpad completion	10	European Commission estimate
Per well		
Drilling water	50	European Commission higher estimate per well
Pipe	50	European Commission higher estimate per well
Casing	10	European Commission higher estimate per well
Drill cuttings	25	European Commission lower estimate per well, but assumed none used for site landscaping. Assumed 1 truck can handle same quantity as for cement i.e. 2.8m ³
Drilling waste water	50	European Commission higher estimate per well
Fracturing fluid – water	453	Eagle Ford Average (IEA), assumes 30 m ³ truck capacity (IEA)
Fracturing fluid – chemicals	2	0.005% of fracturing fluid formed of chemicals – Cuadrilla
Fracturing fluid – flowback water	136	Assumes 30% flowback water
Gas collection – produced water	3	European Commission higher estimate per well
TOTAL	870	Total over 20 years, but heavily concentrated in early years
Total assuming water supplies for drilling and fracturing from mains	367	Assumes trucks not needed to transport water for drilling and fracturing to the site, saving 50 and 453 journeys, respectively, per well

Sources: European Commission, *Impacts of shale gas and shale oil extraction on the environment and on human health*, 2011, Table 4 <http://www.europarl.europa.eu/committees/en/studies/download.html?languageDocument=EN&file=44388>; International Energy Agency, *Golden Rules for a Golden Age of Gas*, 2012, pp.30-31 http://www.worldenergyoutlook.org/media/weowebsite/2012/goldenrules/WEO2012_GoldenRulesReport.pdf; Cuadrilla Resources Ltd <http://www.cuadrillaresources.com/what-we-do/hydraulic-fracturing/fracturing-fluid/>

Drilling timescale: Two months per lateral for drilling and fracturing during the first year, once site preparation work has been completed. In subsequent years, we increase the drilling pace to ten laterals per year. We also assume that production will not start until 2016 or 2017, given the need for further exploration work and the time taken to obtain planning approval.

Capex: We assume drilling costs of £6 million per lateral – around the midpoint of Bloomberg New Energy Finance’s range of \$8 million (around £5 million) to \$11 million (around £7 million).²²¹ We also assume facility costs of £15 million and abandonment costs of £10 million for a 10-well pad of 10 laterals. For a 10-well pad of 40 laterals, we assume facility costs of £30 million and abandonment costs of £40 million. These capex assumptions are common to all scenarios.

Opex: We assume variable operating costs of £0.5 million per bcf and fixed operating costs of 2.5% of cumulative capital expenditure per year.

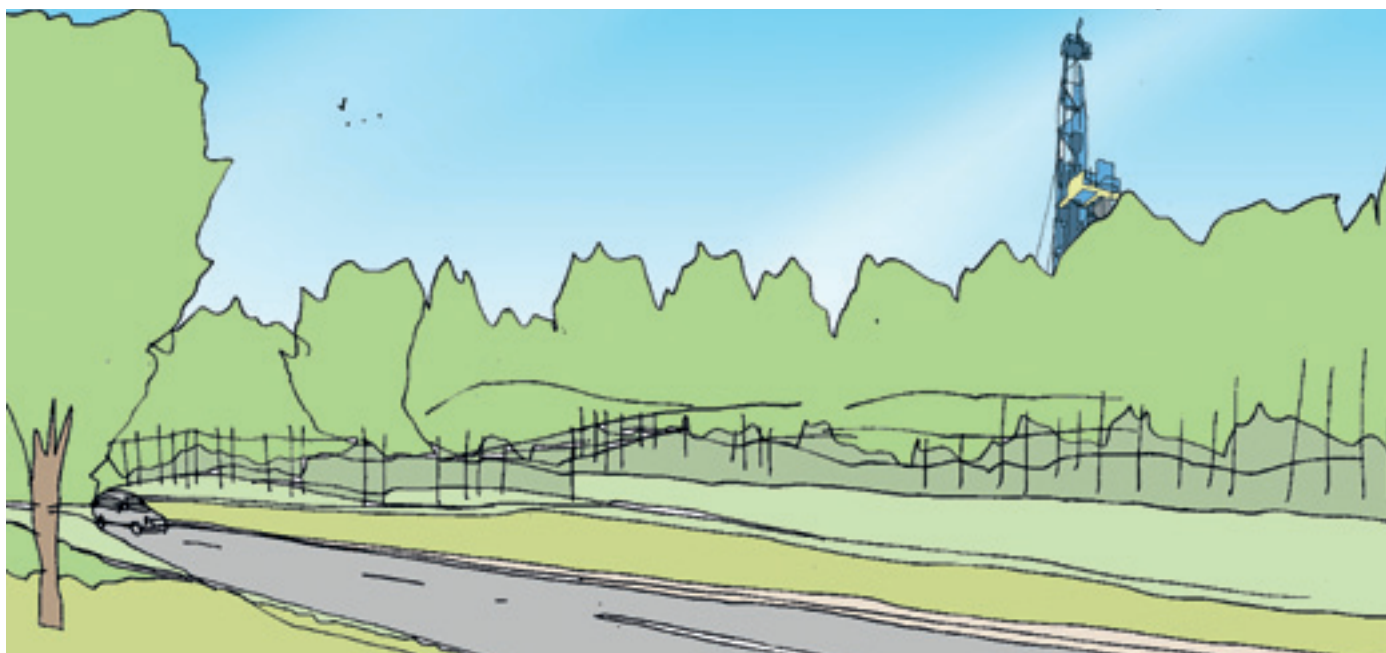
Jobs: We assume that each £1 million of capex and opex leads to the creation of 20 jobs in total (direct, indirect and induced). This is similar to the North Sea, where £17 billion of capex and opex supports 339,000 jobs²²² (direct, indirect and induced, not including the jobs from exporting goods and services) at an average of £50,147 of expenditure per job. It is also similar to the US, where, according to the models developed by IHS, each \$1 million (around £650,000) of capex leads to the creation of 19 jobs in total (direct, indirect and induced).²²³ For each pad, we take a 6-year moving average of capex and opex in order to calculate the number of jobs.

Calorific value of gas: 1,025 BTU per ft³ or 38.2 MJ per m³.

Electricity conversion efficiency: 52% – the average for UK gas-fired generation in 2008.²²⁴

Household energy use: Average of 4,160 KWh electricity and 15,180 KWh gas.²²⁵

Transmission and distribution losses: 7% loss for electricity²²⁶ and 1.6% loss for gas.²²⁷



Artist's impression of a UK drilling rig from a distance. Source: Cuadrilla Resources Ltd

Single pad – 10-well pad of 10 laterals

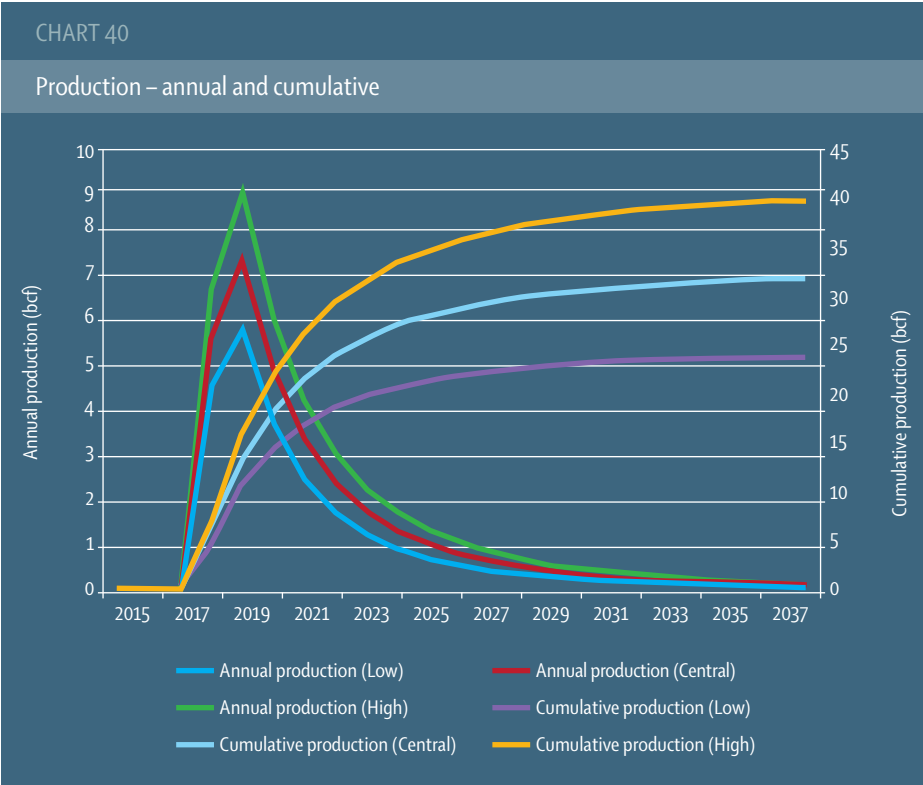
We start by examining the potential characteristics of a 10-well pad of 10 laterals. Table 35 provides the overall numbers.

TABLE 35		
Potential characteristics of a 10-well pad of 10 laterals, central scenario		
	Amount	Comments
Gas production	31.6 bcf	Total over lifespan
Investment	£142 million (constant prices)	Total capex plus opex over lifespan
Jobs	Peak of 406	Total of direct, indirect and induced
Homes	Peak of 260,000 homes powered OR 145,000 homes heated	Assuming losses in generation (for electricity) and transmission / distribution (for both electricity and gas) specified in previous section
Drilling schedule	Year 1 – 6 laterals Year 2 – 4 laterals	Once site preparation work completed
Water used for fracturing	136,000 m ³	Will be heavily concentrated in early years
Flowback water	40,800 m ³	Will be heavily concentrated in early years
Total number of truck movements	2,856 – 7,890	Depending on whether drilling and fracturing water trucked to the site or provided by mains supply. Total over 20 years, but truck movements will be heavily concentrated in early years

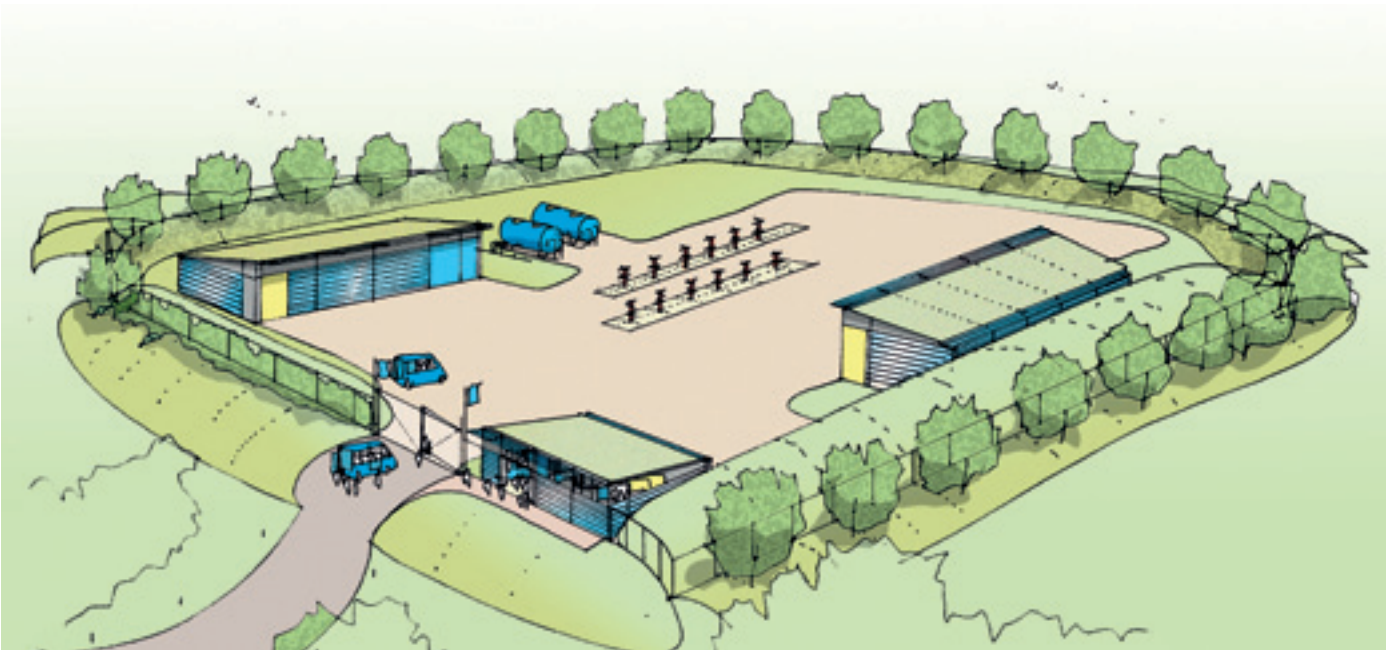
Source: IoD calculations

Over 20 years, truck movements average out at 0.4-1.1 per day. Assuming all the truck movements take place in the two years of drilling, truck movements would average 3.9-10.8 per day.

Charts 40-42 provide the annual picture, assuming that work begins on the pad in 2016. The most important thing to note is that the biggest impacts are in the early years. Production declines relatively rapidly. This means that, in order to maintain a high level of production, shale gas activities will need to move from pad to pad.



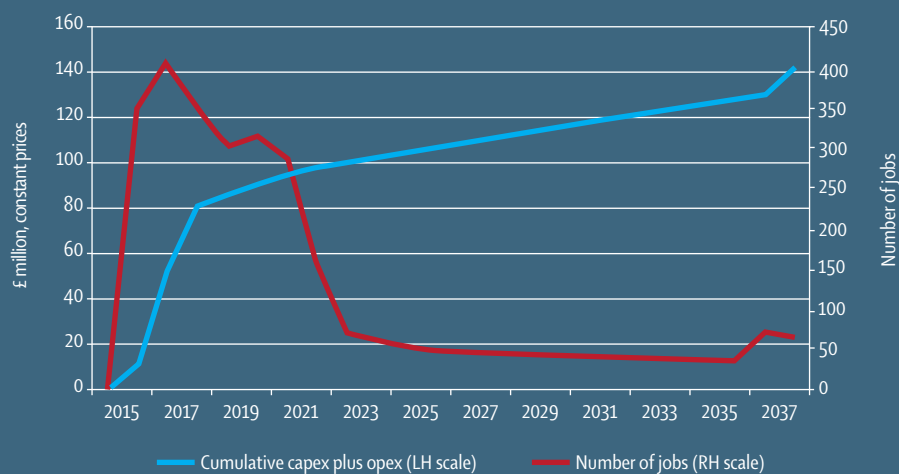
Source: IoD calculations



Artist's impression of a completed 12-well shale gas pad. Source: Cuadrilla Resources Ltd

CHART 41

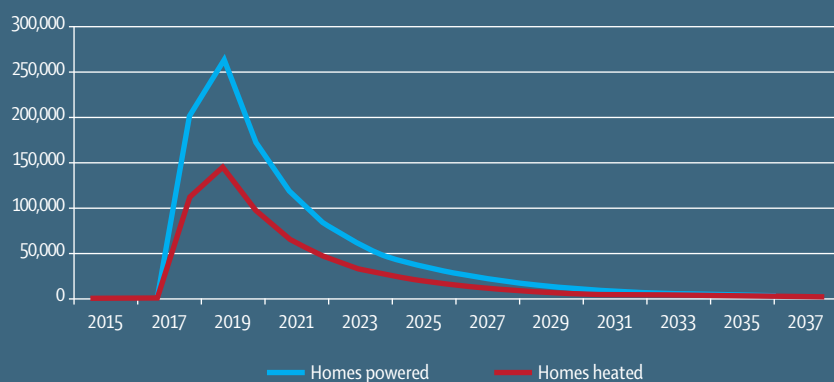
Cumulative investment and jobs – central scenario



Source: IoD calculations

CHART 42

Homes powered OR heated – central scenario



Source: IoD calculations

Single pad – 10-well pad of 40 laterals

A 10-well pad of 40 laterals would represent a much larger development in terms of gas produced, investment, jobs and water use, but not in terms of land. Table 36 provides the overall numbers.

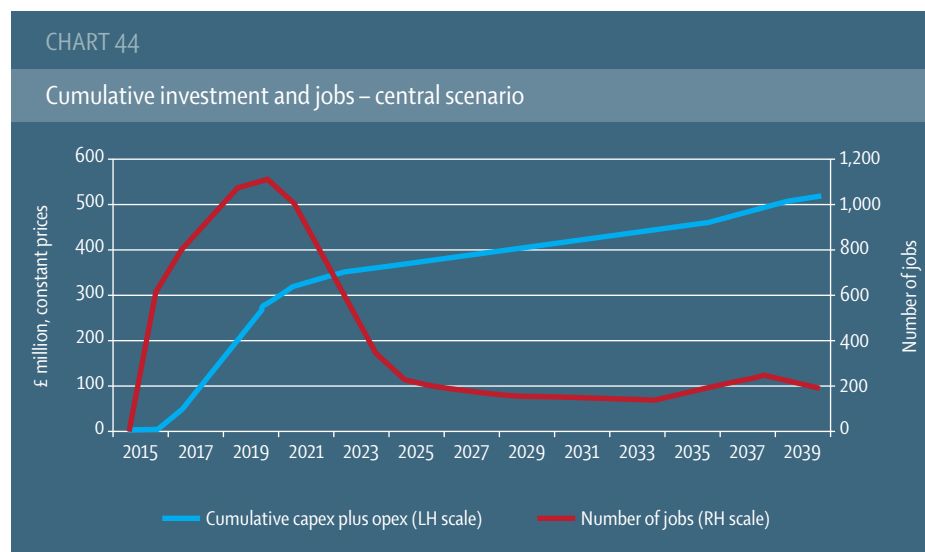
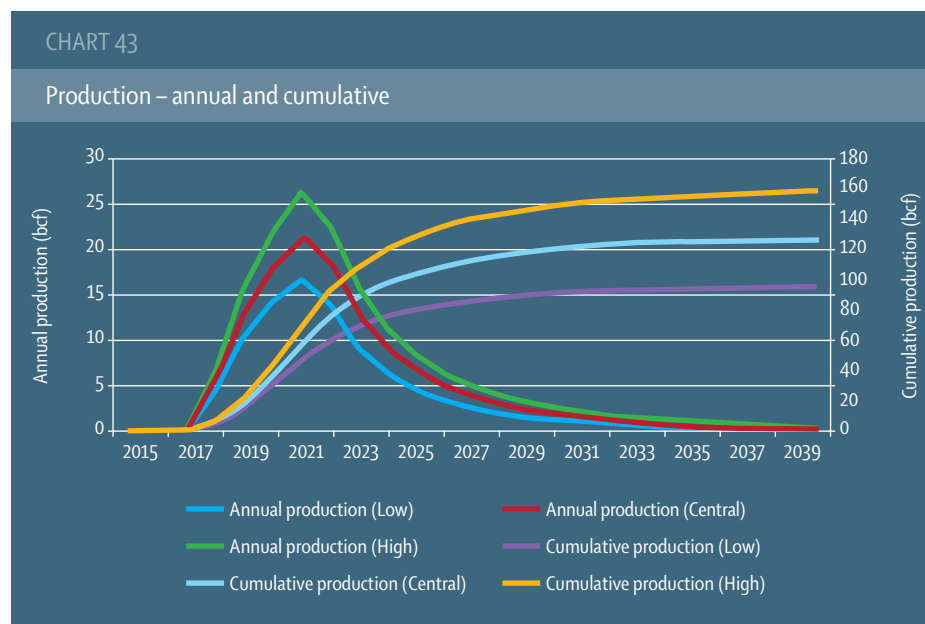
	Amount	Comments
Gas production	126.2 bcf	Total over lifespan
Investment	£514 million (constant prices)	Total capex plus opex over lifespan
Jobs	Peak of 1,104	Total of direct, indirect and induced
Homes	Peak of 747,000 homes powered OR 417,000 homes heated	Assuming losses in generation (for electricity) and transmission / distribution (for both electricity and gas) specified in previous section
Drilling schedule	Year 1 – 6 laterals Year 2 – 10 laterals Year 3 – 10 laterals Year 4 – 10 laterals Year 5 – 4 laterals	Once site preparation work completed
Water used for fracturing	544,000 m ³	Will be heavily concentrated in early years
Flowback water	163,200 m ³	Will be heavily concentrated in early years
Total number of truck movements	11,155 – 31,288	Depending on whether drilling and fracturing water trucked to the site or provided by mains supply. Total over 20 years, but truck movements will be heavily concentrated in early years

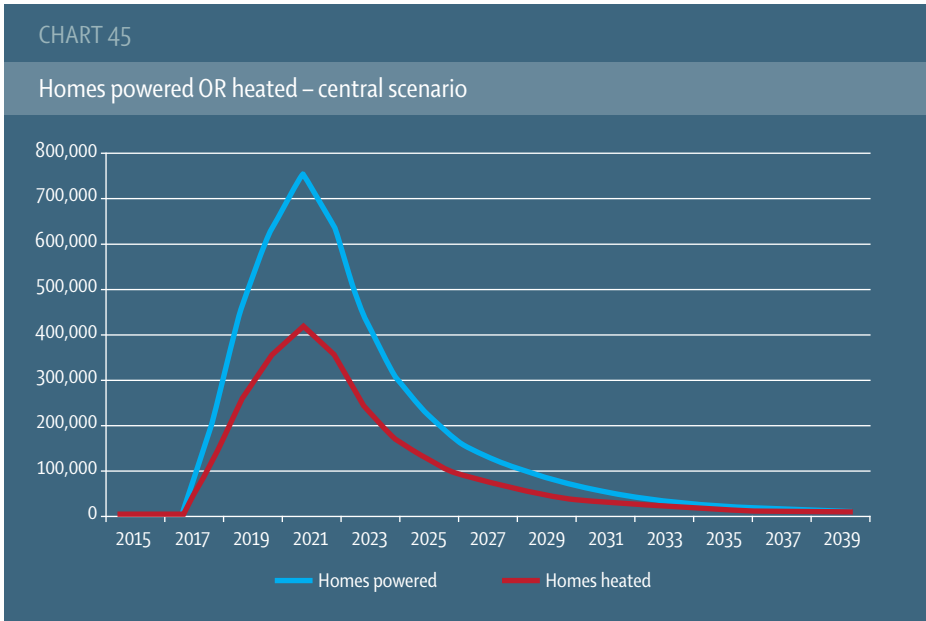
Source: IoD calculations

Over 20 years, truck movements average out at 1.5-4.3 per day. Assuming all the truck movements take place in the five years of drilling, truck movements would average 6.1-17.1 per day.

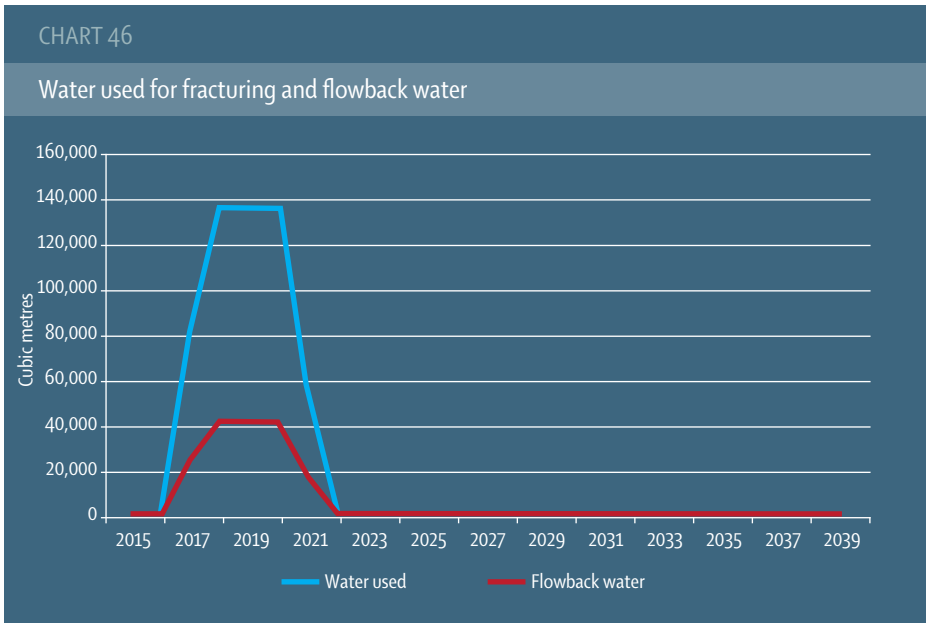
It is worth putting the number of truck movements into context. British dairy farmers produce 11 billion litres (11 million cubic metres) of milk each year.²²⁸ Milk tankers vary in size, but assuming a tanker capacity of 30,000 litres (30 cubic metres) – the same size assumption as was made for water tankers in Table 34 above – 366,667 tanker journeys would be needed each year in rural locations to transport milk from the farms where it is produced.

Charts 43-46 provide the annual picture.





Source: IoD calculations



Source: IoD calculations

Shale gas and onshore wind – surface footprint compared

In our view, gas and wind can work well together, with gas being needed for heating and to provide back-up electricity generation when wind speeds are low, particularly as wind generating capacity increases. Although both forms of energy have different and often complimentary roles, in order to appreciate the surface footprint of potential shale gas development, it is worth providing a brief comparison with onshore wind.

Table 37 sets out the electricity generation potential of a 10-well pad of 10 laterals and a 10-well pad of 40 laterals, using the central production scenario. A 10-lateral pad could generate 4,930 GWh and a 40-lateral pad 19,706 GWh over a lifespan.

TABLE 37			
Electricity produced from one shale gas pad – potential over lifespan			
	10-well pad of 10 laterals	10-well pad of 40 laterals	Comments
Gas produced	31.6 bcf	126.2 bcf	Central production scenario; assumes no condensate produced
Gross electricity generation	9,480 GWh	37,896 GWh	Assumes calorific value of 1,025 BTU per ft ³ or 38.2 MJ per m ³
Net electricity generation	4,930 GWh	19,706 GWh	Assumes conversion efficiency of gas-fired generation of 52%; excludes transmission losses

Source: IoD calculations

This can be compared with the Scout Moor Wind Farm in Lancashire, which comprises 26 wind turbines of 2.5 MW, giving a capacity of 65 MW. Since it began operation in 2008, it has generated an average of 149 GWh per annum out of a maximum of 570 GWh – a load factor of 26%.

TABLE 38				
Electricity generation from Scout Moor wind farm – 2008-09 to 2012-13				
Year	Capacity (MW)	Capacity (GWh)	GWh generated	Capacity Factor
2008-09	65	569.8	78.6	-
2009-10	65	569.8	142.7	25%
2010-11	65	569.8	131.6	23%
2011-12	65	569.8	171.9	30%
2012-13	65	569.8	71.8	-
AVERAGE			148.8	26%

Source: Renewable Energy Foundation, R00200RQEN: Scout Moor Wind Farm <http://www.ref.org.uk/roc-generators/view.php?rid=R00200RQEN&tab=summary&returnurl=http%3A%2F%2Fwww.ref.org.uk%2Froc-generators%2F>. NB: Less than 12 months data for 2008-09 and 2012-13. These years are not included in the average load factor calculation. Figures rounded. Excludes transmission losses.

Wind turbines are designed to have an economic life of 25 years, which multiplied by 148.8 GWh per year gives a total of 3,719 GWh over the lifespan of Scout Moor wind farm

TABLE 39

Electricity generation from Scout Moor wind farm – potential over 25-year lifespan

Average electricity generation per annum	148.8 GWh
Lifespan	25 years
Electricity generation over lifespan	3,719 GWh

Source: IoD calculations. NB: Excludes transmission losses

Table 40 compares the potential shale gas pads with Scout Moor wind farm. It is worth noting that, although the shale gas pads take up a small percentage of the surface area of the wind farm, the land underneath wind turbines can be used for other purposes, and that the gas from a shale pad would need to be fed into a CCGT to generate electricity, taking up additional land.

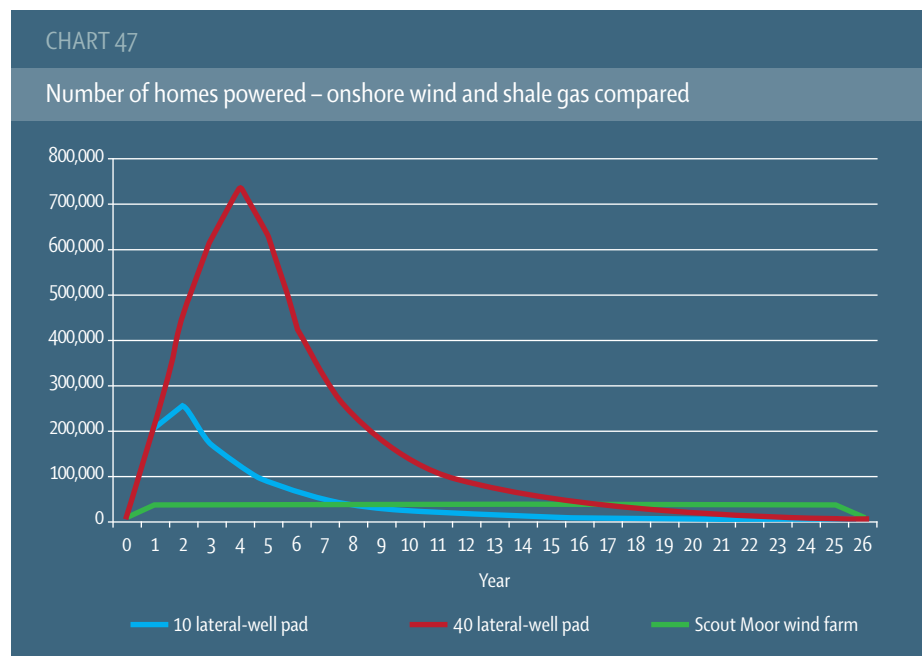
TABLE 40

Potential of shale gas pads and Scout Moor wind farm compared

	10-well pad of 10 laterals	10-well pad of 40 laterals	Scout Moor wind farm
Surface area	2 hectares	2 hectares	545 hectares
Height of drilling rigs / turbines	26 metres	26 metres	60 metres
Number of drilling rigs / turbines	1	1	26
Overall electricity generation	4,930 GWh	19,706 GWh	3,719 GWh

Sources: Scout Moor surface area – Lancashire County Council, External Overview and Scrutiny Committee, minutes from meeting on Thursday 6th January 2005 at 10.00 am at County Hall, Preston <http://www3.lancashire.gov.uk/council/meetings/displayFile.asp?FTYPE=M&FILEID=8454>. Drilling rigs height – Cornell University, Department of City and Regional Planning, *Visual Impacts of Natural Gas Drilling in the Marcellus Shale Region*, 2010 http://cce.cornell.edu/EnergyClimateChange/NaturalGasDev/Documents/City%20and%20Regional%20Planning%20Student%20Papers/CRP5072_Visual%20Impact_Final%20Report.pdf. Scout Moor wind turbine height and numbers – Renewable Energy Foundation, R00200RQEN: Scout Moor Wind Farm <http://www.ref.org.uk/roc-generators/view.php?rid=R00200RQEN&tab=summary&returnurl=http%3A%2F%2Fwww.ref.org.uk%2Froc-generators%2F>

In the early years, assuming that the gas was used solely to generate electricity, the shale gas pads could potentially power a significantly larger number of homes. In the later years, the wind farm would generate more electricity. Chart 47 illustrates.



Source: IoD calculations. NB: Assumes central production scenario for shale gas, and transmission/distribution losses of 7% for both onshore wind and shale gas. Assumes average 26% load factor for Scout Moor wind farm.

Widespread development – 100 10-well pads of 40 laterals

If shale gas production could reach scale, then the economic benefits could be very large indeed. Below we set out a hypothetical nationwide development of 100 10-well pads of 40 laterals. Each 40-lateral pad has the characteristics we described in the previous section, including a drilling schedule of five years, and the overall development is staggered, so that no more than 10 new pads are developed each year.

Table 41 details a potential drilling schedule, assuming that rigs move from pad to pad once the drilling in any one pad has been completed. At peak, 50 rigs would be drilling 400 laterals a year.

	New pads	Laterals drilled (after site preparation work is complete)	Number of rigs
2015			
2016	2		
2017	3	12	2
2018	5	38	5
2019	10	80	10
2020	10	160	20
2021	10	248	30
2022	10	322	38
2023	10	380	45
2024	10	400	50
2025	10	400	50
2026	10	400	50
2027	10	400	50
2028		400	50
2029		340	40
2030		240	30
2031		140	20
2032		40	10

Charts 48-53 set out the potential scenarios for production, investment, jobs, homes powered or heated, water used for fracturing and flowback water. The investment and jobs estimates are presented for the central scenario, as they do not differ greatly in the low and high scenarios. Also worth noting is that the gas imports charts only run to 2030, as official estimates of net gas imports and gas prices are not made beyond that date.

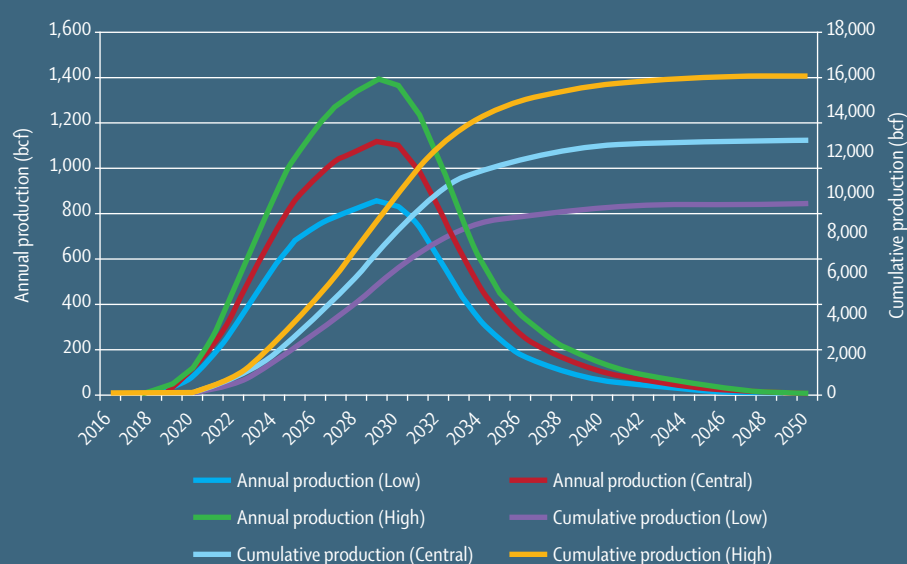
The results can be summarised as follows:

- **Gas production:** Peak production of 853 bcf per annum in the low scenario, 1,121 bcf in the central scenario and 1,389 bcf in the high scenario.
- **Investment:** Capex and opex peaking at £3.7 billion in constant prices.
- **Jobs:** Peaking at 74,000 jobs in total (direct, indirect and induced - around twice as high as our previous estimate).
- **Homes:** Powering the equivalent of 30-48 million homes at peak, OR heating the equivalent of 17-27 million homes at peak.
- **Water:** Water used for fracturing peaking at 5.4 million cubic metres per annum and flowback water peaking at 1.6 million cubic metres per annum.

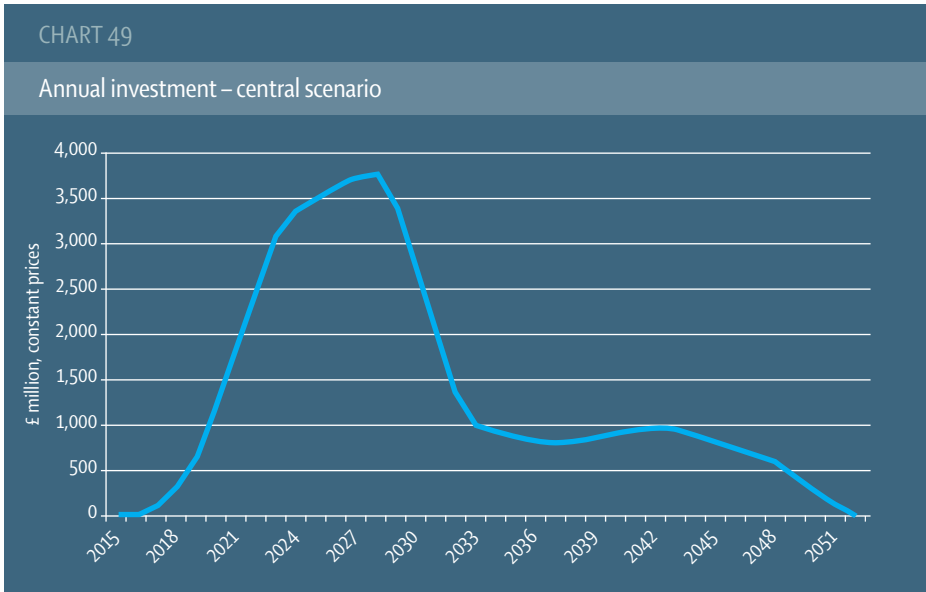
- Imports:** As shown in Chapter 1, by 2030, without shale gas, gas import dependency could rise to 76% and the cost of net gas imports could rise to £15.6 billion per annum in 2012 prices. Development of 100 10-well pads of 40 laterals could lower the import bill to £9.5 billion in 2030 in the low scenario, £7.5 billion in the central scenario and £5.6 billion in the high scenario. In 2030, in the low scenario, gas import dependency could be 46%; in the central scenario, 37%; and in the high scenario, gas import dependency could fall to 27%.
- Land use:** If each 10-well pad of 40 laterals takes up two hectares of land on the surface, then 100 pads would need 200 hectares of land. This is equal to two square kilometres. The pads would of course be scattered, and additional land would be needed for gathering stations, compressors, water treatment plants etc, but, overall, shale gas development would not need vast tracts of land.

CHART 48

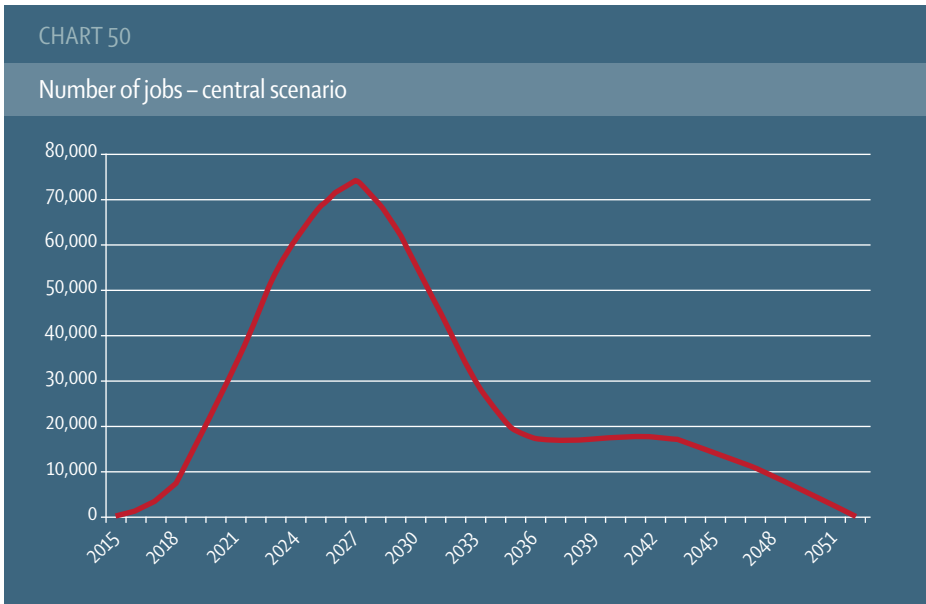
Production – annual and cumulative



Source: IoD calculations



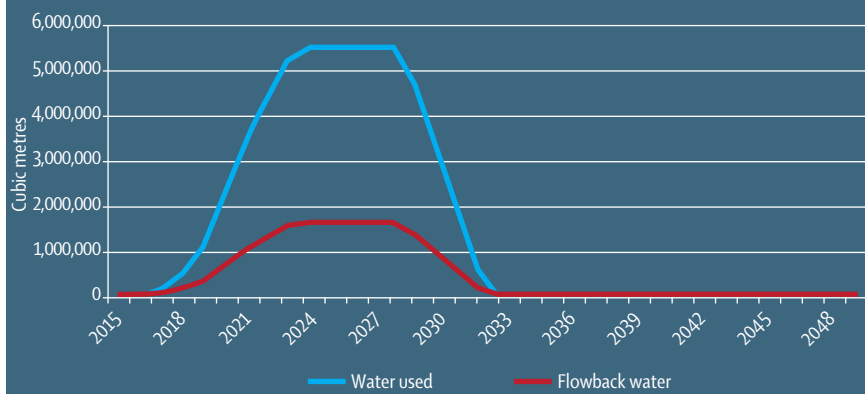
Source: IoD calculations



Source: IoD calculations

CHART 51

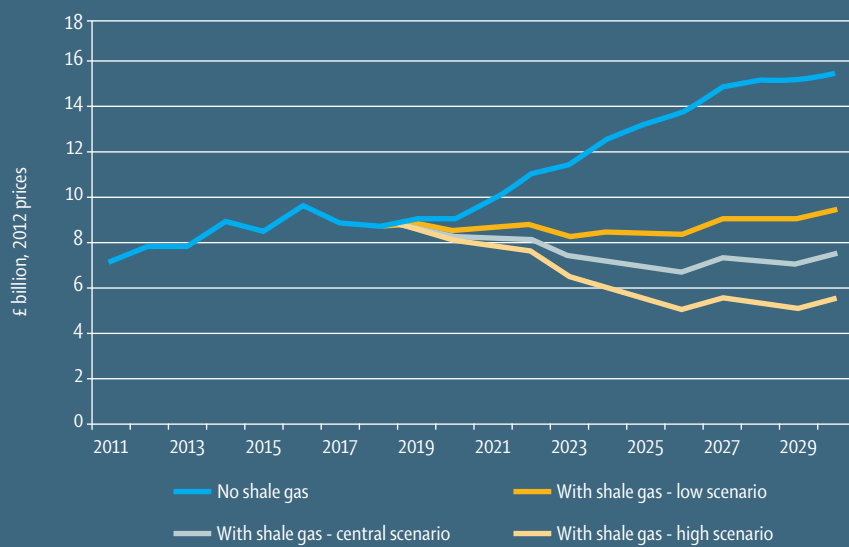
Water used for fracturing and flowback water (all scenarios)



Source: IoD calculations

CHART 52

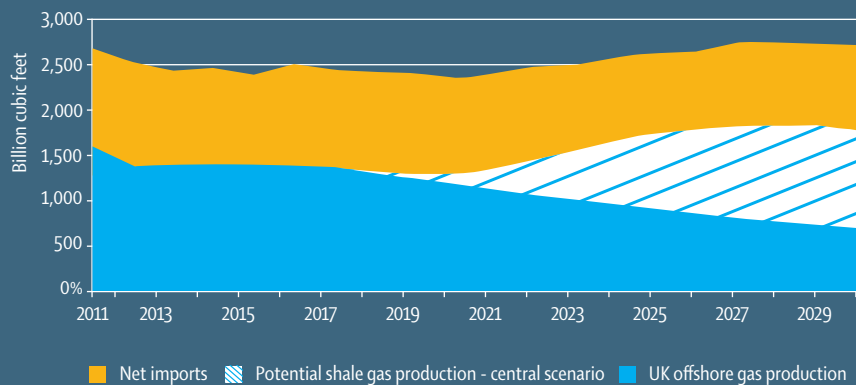
Cost of net gas imports



Source: IoD calculations

CHART 53

UK offshore and shale gas production and net gas imports – central scenario



Sources: IoD calculations

It is worth emphasising again that the development described above is of a potential production phase. Actual production could be smaller or larger than that described. Drilling activity could also potentially go on for longer, meaning that the employment and other economic benefits are felt for many more years.

Interestingly, if gas is to be a bridge fuel to a low carbon energy system, then shale gas could play a useful role, given that production will decline relatively quickly once drilling activity ceases.

Other estimates of potential shale gas production

Other respected organisations have also made estimates of potential shale gas production, which in many respects are similar to the IoD's.

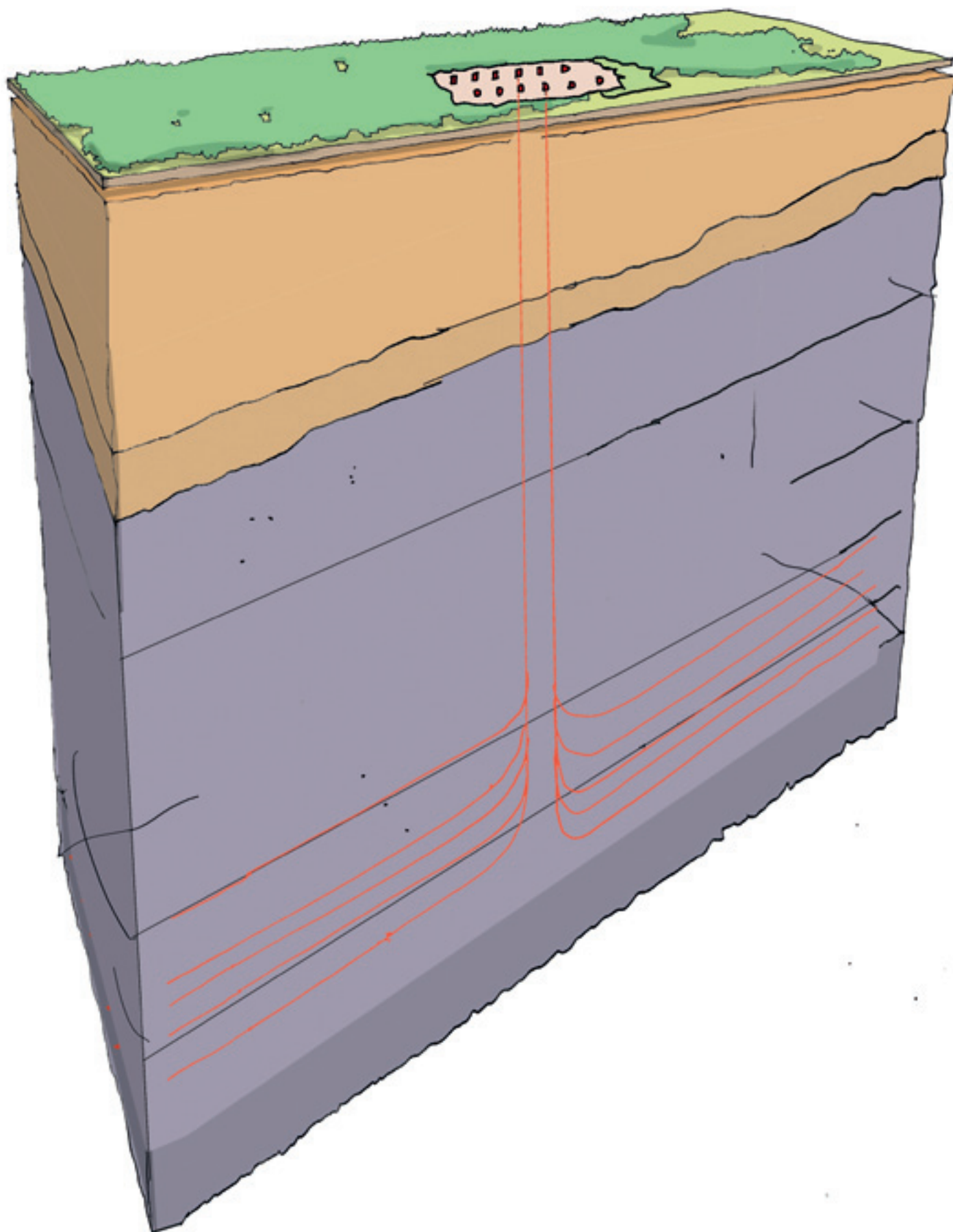
Energy Contract Company.²²⁹ According to the Energy Contract Company (ECC): "Overall, ECC's view is that the Bowland Shale has all of the basic requirements of a good producible resource and that shale gas development in the UK should therefore be viable."

The ECC report sets out three scenarios for shale gas production, beginning in 2016-17. By 2029-30, the ECC projects shale gas production to reach 621 bcf in the low case, 1,158 bcf in the mid case and 1,726 bcf in the high case. The ECC also believes that shale gas production can be economic (15% IRR) at between 42 and 51 pence per therm – lower than the current level of wholesale gas prices.

The ECC report notes, however, that shale gas production risks being delayed by public opposition.

Bloomberg New Energy Finance.²³⁰ Bloomberg New Energy Finance (NEF) projections for UK shale gas production at peak range between around 730 bcf to around 1,460 bcf.

The Bloomberg NEF report pointed out that drilling costs are likely to be far higher in the UK than in the US, and concluded that UK shale gas production would be unlikely to lead to a substantial drop in prices, requiring a wholesale price of at least 45 pence per therm to be commercially viable (15% after-tax IRR).



Artist's impression of two shale gas wells, each with five laterals. Source: Cuadrilla Resources Ltd

Application for an environmental permit – Part A about you

Part A – About you

You will need to fill in this part A if you are applying for a new permit, applying to change an existing permit or want to transfer an existing permit to yourself. Please check that this is the latest version of the form available from our website.

Please read through this form and the guidance notes that came with it. Please write clearly in the answer spaces.

Notes: If you believe including information on a public register would not be in the interests of national security you must tick the box in section 5 of F1 or F2 and enclose a letter telling us that you have told the Secretary of State/Welsh ministers. We will not include the information in the public register unless directed otherwise.

It will take less than one hour to fill in this part of the application form.

Where you see the term 'document reference' on the form, give the document references and send the documents with the application form when you've completed it.

Contents

- 1 About you
- 2 Applications from an individual
- 3 Applications from an organisation of individuals
- 4 Applications from public bodies
- 5 Applications from companies
- 6 Your address
- 7 Contact details
- 8 How to contact us

1 About you

Are you applying as an individual, an organisation of individuals (for example, a partnership), a company (this includes Limited Liability Partnerships) or a public body?

☐ An individual

☐ An organisation of individuals (for example, a partnership)

☐ A public body

☐ A registered company or other corporate body

- ☐ Now go to section 2
- ☐ Now go to section 3
- ☐ Now go to section 4
- ☐ Now go to section 5

2 Applications from an individual

2a Please give us the following details

Name

Title (Mr, Mrs, Miss and so on)

First name

Last name

Date of birth (DD/MM/YYYY)

Now go to section 6

3 Applications from an organisation of individuals

3a Type of organisation

For example, a charity, a partnership, a group of individuals or a club

3b Details of the organisation

If you are an organisation of individuals, please give the details of the main representative below. If relevant, provide details of other members (please include their title Mr, Mrs and so on) on a separate sheet and tell us the document reference you have given this sheet.

Contact name

Title (Mr, Mrs, Miss and so on)

First name

5. Barriers

Talking about hypothetical recoverable resources and what shale gas development could potentially look like is one thing; actually ensuring that shale gas is produced is another. There are a number of barriers to shale gas development in the UK, many of which were not significant issues in the US, and they will need to be overcome. If they are not, shale gas production may struggle to get off the ground.

It is, however, important not to over-emphasise the barriers. Although several are significant, others are much less so.

5.1 OVERVIEW OF BARRIERS

The first potential barrier to the development of shale gas in the UK is geology. Early indications suggest that the UK's geology is highly favourable to shale gas production, but until further exploration and appraisal is carried out, our picture of the UK's geology will remain incomplete.

If the UK's geology is unfavourable to shale gas production, we can stop right here, but assuming that the geology is favourable, the barriers to the establishment and growth of a UK shale gas industry can be grouped into five broad categories. Some are far more significant than others. Table 42 gives an overview.

It is also worth noting that, as mentioned in the "About the report" section, this report does not examine the safety of hydraulic fracturing. Other expert bodies, including the Royal Society, have looked into the safety issues in detail and we do not propose to repeat their work.

TABLE 42

Potential barriers to the establishment and growth of a UK shale gas industry

Area	Barrier	Comments
Infrastructure, resources and equipment		
Existing gas transmission and distribution infrastructure	No	Extensive gas grid with spare capacity
Transport infrastructure	No	UK has good roads and air infrastructure
Water resources	No	Good water resources, especially in the North of England and Scotland
Drilling rigs and other equipment	Minor	Onshore rigs few in number, but because of lack of demand. Private sector can scale up
Midstream infrastructure	Minor	Will need to be constructed
Water treatment infrastructure	Minor	Will need to construct new water treatment plants to reduce truck journeys
Grid connections	Moderate	3 ½ year connection time. Grid connection delays have also affected renewables industry
Skills and supply chain		
Drilling services industry	Minor	Less competition than in US, but because of lack of demand. Opportunity to establish UK as centre of expertise, similar to offshore
Skills	Moderate	Offshore skills shortages already a problem
Finance		
Tax regime for shale gas production	No	HM Treasury consultation ongoing on Shale Gas Field Allowance and extension of Ring Fence Expenditure Supplement from 6 to 10 years
State ownership of mineral rights	Minor	Likely to lead to fewer pads with more laterals per pad i.e. more efficient use of land. Onshore industry has had successful dealings with landowners, who would receive payment for use of their land. National Farmers Union not opposed
Local authority financial benefits	Moderate	UK system of local government finance poorly structured to incentivise development. Some reform underway, but appropriate mechanism will need to be found
Community benefits	Moderate	Appropriate mechanism for community benefits will need to be found

TABLE 42

Potential barriers to the establishment and growth of a UK shale gas industry cont...

Area	Barrier	Comments
Regulation		
Liability for abandoned wells	No	Provided appropriate fund with legal liability is set up
Trespass	Minor	Possible for operators to be exposed to trespass when drilling under neighbouring land, although compensation would be minimal. Legal clarity needed
14th licensing round	Moderate	Need to release more areas for exploration
Planning and permitting	Major	Planning and permitting system will need to be streamlined, with clear guidance and direction from central government
Reputation		
Population density	Minor	UK more densely populated than US, but 80% of population live on less than 7% of land, and shale development doesn't need vast tracts of land
Confidence hurdle	Moderate	Need successful development to gain public confidence and public confidence to encourage development
Social licence to operate	Moderate	Without a social licence to operate, industry will find it more difficult and time-consuming to obtain necessary approvals

Combined, these barriers tend towards raising the cost and slowing the pace of UK shale gas development. The sections below set out the list provided in Table 42 in more detail.

5.2 INFRASTRUCTURE, RESOURCES AND EQUIPMENT

Existing gas transmission and distribution infrastructure

The UK already has an extensive gas transmission and distribution system:²³¹

- There are nine terminals which receive gas produced from the UK Continental Shelf and via pipeline from countries such as the Netherlands and Belgium. Three of these terminals are also equipped to handle LNG shipments. The interconnectors of course are used for the export as well as import of gas.
- There are 23 compressor stations ensuring that the gas is transported at the right pressure.
- The National Transmission System (NTS) – the high pressure part of the pipeline network – is 7,600 km long.

- The NTS supplies gas to UK end consumers from over 175 off-take points. These include large end users, primarily large industrial consumers and power stations, who receive gas directly from the NTS rather than through a distribution network, and the twelve local distribution zones (LDZ) that contain pipes operating at lower pressure which eventually supply the smaller end consumers, including domestic customers.
- The NTS has managed changes in flows in recent years, for example from the new LNG terminal at Milford Haven.

The existing NTS has considerable spare capacity, which could be used without the need for additional investment, as Table 43 shows.

TABLE 43		
National Transmission System – unused capacity		
Sector and exit point	Approximate unused system capability (million cubic metres per day)	Basis of analysis
North – West	0-14	0 – 2011 forecast peak at St Fergus for 2014 of ~ 76 mcm/d 14 – 2010 forecast peak at St Fergus for 2014 of ~ 91 mcm/d
North – East	0-19	0 – 2011 forecast peak at St Fergus for 2014 of ~ 76 mcm/d 19 – 2010 forecast peak at St Fergus for 2014 of ~ 91 mcm/d
Central – West Coast	19	
Central – West Midlands	0-14	0 – Historical flows at Milford Haven of ~ 36 mcm/d; 14 – 2011 forecast peak at Milford Haven for 2014 of ~ 67 mcm/d
Central – East Coast	20-60	20 – Rough flow set at zero; 60 – 2011 forecast peak at Rough for 2014 of ~ 40 mcm/d
Central – East of England	20-60	20 – Rough flow set at zero; 60 – 2011 forecast peak at Rough for 2014 of ~ 40 mcm/d

Source: National Grid, *NTS Exit Capacity Analysis*, March 2011 http://www.nationalgrid.com/NR/rdonlyres/91AFA23C-7155-4FE3-AF0D-A18BCC6C0A46/45962/SpareExitCapacityEXTERNAL_FINAL.pdf. NB: “Unused capacity” defined as “the capability of the NTS, over and above the baseline, that has not been allocated to a User”.

The infrastructure around Lancashire is generally good, with terminals at Barrow to the North and Burton Point to the South West, several compressor stations and 19 million cubic metres per day (0.67 bcf per day) of unused capacity in the NTS (Lancashire sits within the “Central – West Coast” sector in Table 43).

In our view, the existing gas transmission and distribution system does not present a barrier to the production of UK shale gas.

Transport infrastructure

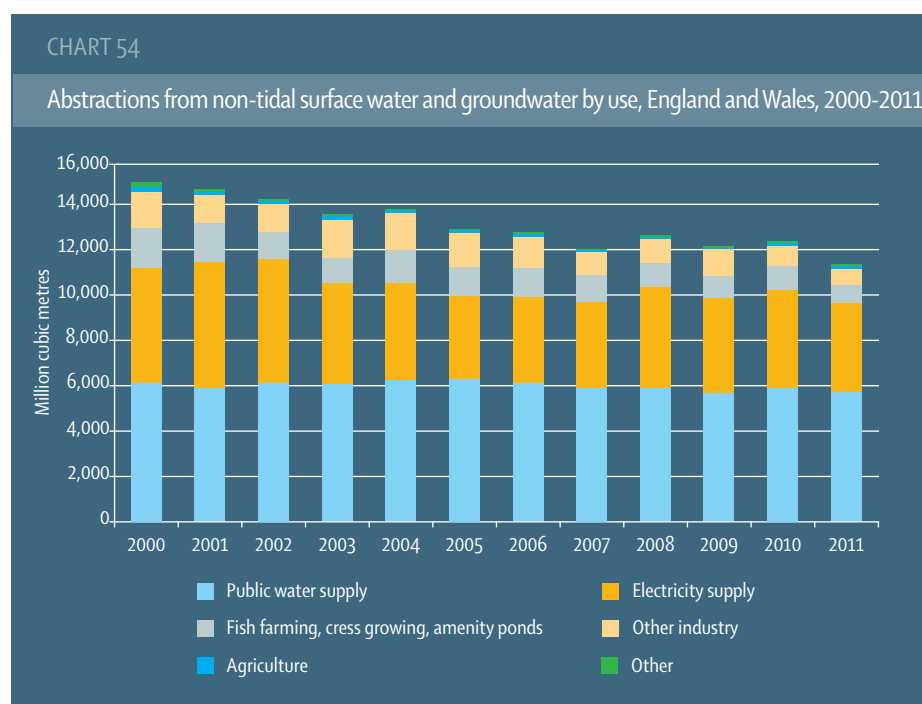
Transport infrastructure in the UK is good:

- New road construction is unlikely to be needed. The UK has an extensive motorway and trunk road network, and unlike in the US, the UK's minor roads are all paved. Although minor roads can be narrow, they are able to accommodate large vehicles, such as milk tankers.
- New air infrastructure is unlikely to be needed. Outside of Heathrow, the UK has spare capacity at all of its airports. For Lancashire, Manchester airport is already a busy international terminal, handling almost 20 million passengers a year in 2012,²³² while Liverpool John Lennon airport now offers direct flights to New York.²³³ Blackpool airport's runway is 1,869 metres long,²³⁴ which is unlikely to be of sufficient length for long-haul flights, but is more than sufficient for short-haul routes that can connect to long-haul destinations via airports such as Dublin and Amsterdam.
- The UK has an extensive passenger and freight rail network. For Lancashire, trains to London run hourly from Preston, taking around 2h 15m.²³⁵
- The UK's port infrastructure is also excellent. A little South of Lancashire, the Port of Liverpool and Manchester Ship Canal handle more than 40 million tonnes of cargo and 15,000 ship movements a year – making the River Mersey Britain's third busiest estuary.²³⁶

In our view, the UK's existing transport infrastructure does not present a barrier to the production of UK shale gas.

Water resources

Excluding tidal waters, the UK uses around 11,000 million cubic metres of water a year, a figure that has been declining steadily from around 15,000 million cubic metres in 2000.



Source: Department for Environment, Food and Rural Affairs, Water Abstraction Statistics, Estimated abstractions from all surface and groundwaters by purpose and source: 2000 – 2011 <http://www.defra.gov.uk/statistics/environment/inland-water/iwfg12-abstrac/>

The Environment Agency is in charge of managing water resources, and in 2009, published a water resources strategy for England and Wales. It noted that water demand is likely to increase in future, as more homes are built, and that drier weather brought about by climate change could lead to more water being used for irrigation at the same time as less water is available.²³⁷ The severe drought of 2011 and early 2012 was a reminder that the UK's water resources are not unlimited.

The picture, however, is very different in various parts of the country. At the time of writing, the Environment Agency is in the process of updating its classification of areas of water stress. According to the 2007 classifications (the most recent), the areas of moderate or serious water stress are in the South and East of England. By contrast, water stress for the utilities serving the North of England is classified as low, including for United Utilities, which serves Lancashire.²³⁸

As was shown in the Chapter 4 scenarios, water use for shale gas production could be significant, exceeding 5 million cubic metres per annum. But this is only around 0.05% of 2011 abstraction of non-tidal surface water and groundwater.

Under the Water Resources Act 1991, an operator is required to seek an abstraction permit from the Environment Agency if more than 20 cubic metres per day of water is to be abstracted from surface or groundwater bodies. If water is instead sourced from a mains supply, the water company will need to ensure it can still meet the conditions of the abstraction permit that it will already be operating under.²³⁹

Given the extent of the UK's water grid, shale gas developers are likely to be able to use mains water supply much of the time. Shale gas production will make new demands on water resources that the relevant water utilities will have to manage, but it will represent a very small proportion of the total, and production is likely to be in parts of the country with low water stress.

As the Royal Society pointed out, alternatives do exist. Seawater is being increasingly used for offshore hydraulic fracturing, and waterless fracturing fluids are being developed, including gels and carbon dioxide and nitrogen gas foams.²⁴⁰ At the same time, recycling of used fracturing fluid is also possible.

In our view, the UK's water resources do not present a barrier to the production of UK shale gas.

Drilling rigs and other equipment

Onshore rigs are far more numerous in the US than in Europe:

- According to oilfield services company Baker Hughes, in February 2013, there were 1,708 land rigs operating in the US, compared to 82 in Europe.²⁴¹
- Offshore, Europe has 53 rigs in operation, and the US has 54.²⁴²
- As Bloomberg New Energy Finance has also pointed out, the vast majority of high-horsepower rigs and pressure pumping systems needed to hydraulically fracture are located in the US.²⁴³

The number of land rigs currently in operation, however, is more a function of demand than supply. Compared to the US, Europe does not have significant onshore oil and gas production, and therefore does not need a large number of land rigs. Nor has it needed, up until now, large quantities of equipment for onshore hydraulic fracturing.

As the potential production scenarios set out in Chapter 4 showed, demand for rigs could rise to around 50. There is no reason to believe that, should UK shale gas production begin in earnest, rigs and associated equipment will not be supplied to meet that demand. Indeed, the UK already boasts world-class manufacturers of equipment used for drilling, including Weir Group PLC, which is headquartered in Glasgow. Weir Group already provides around half the high-pressure pumps used in the US and Canadian shale markets.²⁴⁴ The main issue is likely to be how quickly demand can be met.

In our view, the availability of drilling rigs and other equipment presents no more than a minor barrier to the production of shale gas at scale in the UK, with the private sector able to meet demand.

Midstream infrastructure

The need to lay gathering pipelines and construct processing plants is unlikely to be a significant issue:

- As was explained earlier in this chapter, the UK's gas grid is extensive, and gathering pipelines are unlikely to need to be very long.
- As was explained in Chapter 4, UK shale gas production is likely to need fewer pads than commonly thought, and far fewer than in the US. This means that the number of gathering pipelines will be limited.
- New processing capacity can be built relatively easily, and costs can be met by the industry. New processing plants could be sited close to existing industrial sites – Lancashire, for example, has significant industrial development, and an Enterprise Zone to the East of Blackpool.
- Although fractionators cost money to build, the heavier hydrocarbons, including ethane and propane, have significant value as feedstocks to the chemical industry. As Tom Crotty, the CEO of Ineos Olefins & Polymers Europe, said: "For example, I am not suggesting this is an investment strategy that we have, but our major site in the north-west is in Runcorn, which is not a million miles away from where a lot of development is going on. You could conceivably see us running a fractionator on that site, as an example."²⁴⁵

In our view, the UK's midstream infrastructure presents no more than a minor barrier to the production of UK shale gas.

Water treatment infrastructure

Over 10 billion litres (10 million cubic metres) of sewage are produced every day in England and Wales,²⁴⁶ which adds up 3,650 million cubic metres per year.

As was shown in Chapter 4, the volume of flowback water from shale gas operations could reach around 1.6 million cubic metres per annum, which is around 0.05% of sewage production in England and Wales. Not all sewage, however, is the same, but with a large chemical sector, the UK already has good infrastructure for chemical waste treatment.

Additional wastewater from shale gas operations is likely to have a larger impact in areas with higher production, and new treatment plants with the capacity to handle naturally occurring radioactive material (NORM) will likely be needed. Locating new treatment facilities close to shale gas pads could help to reduce the distance travelled by trucks transporting the wastewater, and may also allow treated wastewater to be reused in new wells, reducing the volume of water that needs to be abstracted.

New water treatment plants would of course represent additional investment and job creation by the private sector.

In our view, the UK's water treatment infrastructure presents no more than a minor barrier to the production of UK shale gas.

Grid connections

Before gas can flow into the National Transmission System (NTS), three distinct processes must be completed, although they can be run in parallel. In total, obtaining a grid connection takes around 3 ½ years. Table 44 sets out the three processes.

TABLE 44

Entry connection processes for gas to flow into the National Transmission System

Process	Timescale	Description
Physical connection	Typically 24-36 months	National Grid will provide a connection to the NTS
Network Entry Agreement	Normally agreed in parallel with the physical connection process	Sets out the technical and operational conditions for the connection
Entry Capacity	Typically 42 months from the date of the Quarterly System Entry Capacity auction (this is longer than the physical connection process, and so needs to be considered at the outset)	For all new entry connections, the Shipper (or potential Shipper) needs to ensure that they have purchased sufficient daily capacity rights to accommodate gas entry flows from the connecting point. The provision of any necessary physical infrastructure including any extension, up-rating or expansion of the NTS is undertaken by National Grid in response to Shippers' demands for entry capacity through the auctions process

Source: National Grid http://www.nationalgrid.com/uk/Gas/Connections/ntsentry/entry_conn_processes/entry_con_process

It is likely that much of the shale gas produced will be fed into the NTS, either to supply homes directly, or to be sent to gas fired power plants to generate electricity. A lengthy process to obtain grid connections could slow down the pace of development.

This problem is not unique to gas:

- Onshore and offshore wind developments have been affected by grid connection delays, although given the remote location of many wind farms, additional grid infrastructure is quite considerable. As highlighted in Chapter 3, since August 2010, the "Connect and Manage" regime has meant that generation projects are allowed to connect to the transmission system in advance of the completion of the wider transmission reinforcement work.
- Delays to grid connections are also cited by RenewableUK, the trade association for wind and marine energy, as one of a number of risks to the development of wave and tidal power.²⁴⁷

The impacts of lengthy grid connection timescales should not, however, be overdone. As Chapter 3 showed, onshore wind capacity has increased from around 1 GW in 2005 to 5 GW in 2012. And it is possible to get a connection to the local gas distribution network as well as the NTS.

In our view, the length of time needed to obtain grid connections could slow down the growth of shale gas production, presenting a moderate barrier to the production of shale gas at scale.

5.3 SKILLS AND SUPPLY CHAIN

Drilling services industry

Although the UK has drilled around 2,000 wells onshore, and, at Wytch Farm, has been at the forefront of advances in horizontal drilling, it does not have an extensive onshore drilling services industry.

As was pointed out earlier in this chapter, the UK does not possess a large number of onshore rigs because demand for them has been low, and the same point can be made with regard to onshore drilling services. If further exploration and appraisal work confirms the presence of a significant resource that is economic to develop, then we can expect an onshore drilling services industry to be established. Although there are significant differences between offshore and onshore development, the UK's offshore expertise is likely to prove useful.

Nevertheless, it will take time to establish a competitive onshore drilling services industry, and this will have some impact on the speed at which UK shale gas can be developed:

- In the course of our research, we have spoken to a number of investors and potential investors who have told us that the lack of an onshore drilling services industry in the UK at present is an issue;
- Less competition will mean higher prices for drilling than in the US, although UK wholesale gas prices are also higher;
- A competitive drilling services industry is less of an issue for the majors, but is important for the smaller entrepreneurial companies who may prefer to outsource much of the drilling and fracturing work.

It is, however, worth remembering that the UK did not have an existing drilling services industry when the North Sea first came into play. The industry had to be developed, and over time grew to become a major employer and exporter, with Aberdeen firmly established as an international centre of offshore expertise.

Similarly, the lack of an onshore drilling services industry is as much an opportunity as it is a challenge. The development of a drilling services industry based in the UK could not only provide jobs on UK shale gas wells, but could, like the offshore industry, also generate significant exports.

As the CEO of Weir Group PLC recently stated:²⁴⁸

"The UK is in a fantastic position to take advantage of [shale gas], given the infrastructure that already exists off the back of our North Sea, to take a leading role in the development of this industry across Europe. We have the skills, we have the capability; it makes a lot of sense from a job creation and tax revenues point of view. We should get out there and prove the technology in a UK context, and use that as a platform to become a European hub as shale reserves are developed across both Western and Eastern Europe."

Overall, in our view, the lack of an onshore drilling services industry presents a minor barrier to the development of UK shale gas at scale.

Skills

Meeting the need for skilled workers will be a priority for an emerging shale gas industry. The UK's well-established offshore oil and gas industry struggles to meet skills requirements, despite the partnerships set up to provide training and the high wages paid in the sector:

- According to the Government's oil and gas industrial strategy:

*"High levels of activity and global competition have resulted in skills shortages; the availability of skilled workers is seen as one of the biggest challenges the industry faces. The supply/demand mismatch is impacting project schedules and driving up costs; a major threat to the overall competitiveness of the sector Current demand for experienced engineers and geoscientists in the UK (and globally) outstrips supply. The industry expects it will require an additional 15,000 staff over the next 4-5 years across a range of disciplines, including design engineers (all disciplines), subsea and drilling."*²⁴⁹

- A recent Ernst & Young / Oil & Gas UK survey of 150 members of the offshore supply chain found that 53% of respondents view sourcing suitably qualified personnel as the main factor limiting growth in their organisation.²⁵⁰
- The latest twice-yearly oil and gas survey carried out by the University of Strathclyde for the Aberdeen and Grampian Chamber of Commerce found that 68% of contractors and 75% of operators experienced problems in recruiting suitable employees in particular occupations.²⁵¹ The report noted:

"Amongst operators the recruitment difficulties included: geo science professionals; senior engineers; reservoir, development, process, Sub Sea and mechanical engineers; a gap in those in the 35-49 year age range with 8-15 years' experience; and an over reliance on the contractor labour pool. Contractors again reported a broader range of difficulties in recruiting suitable staff."

- A major problem is age. Almost half of the UK oil and gas extraction industry workforce is aged 45 or over, with just over a quarter aged 34 or younger.²⁵²

Skills shortages are not unique to offshore oil and gas. The UK has a broader challenge to improve science, technology, engineering and maths (STEM) skills, and a lack of skilled candidates is also affecting many IoD members. A recent survey of 1,100 IoD members found that 23% were experiencing "skills shortage vacancies" – vacancies proving hard to fill because of a lack of skilled applicants.²⁵³ The Government has recognised the problem, and its recent drive to improve access to each of the STEM subjects at school and improve the image of engineering should help, but more will need to be done.

Although it will be a challenge to recruit the most highly skilled people for shale gas production, working onshore should prove to be more attractive, as it does not pose the same lifestyle issues as working on remote offshore rigs for several weeks at a time. And although the specialist skills are in high demand, other parts of the supply chain will not need such highly skilled people.

Table 45 provides a list (not exhaustive) of the main occupations needed for unconventional oil and gas extraction in the US, together with hourly wages. It is a useful guide for the types of jobs that will be needed for UK shale gas production, and shows that, while there are a large number of skilled occupations, other occupations are semi-skilled or unskilled.

TABLE 45

Oil and gas occupations and hourly wages in the US

Occupation	Average hourly wage
Management, business and financial	
General and operations managers	\$63.03
Construction managers	\$45.42
Engineering managers	\$64.74
Cost estimators	\$32.12
Accountants and auditors	\$34.83
Professional and related	
Architects	\$37.79
Surveyors	\$27.44
Civil engineers	\$40.18
Electrical engineers	\$43.98
Mechanical engineers	\$39.42
Petroleum engineers	\$67.55
Engineers, all other	\$47.99
Architectural and civil drafters	\$24.00
Civil engineering technicians	\$23.22
Surveying and mapping technicians	\$19.98
Geoscientists	\$63.61
Geological and petroleum technicians	\$27.65
Sales and related	
Sales representatives, wholesale and manufacturing	\$31.85
Office and administrative support	
First line supervisors/managers of office and administrative support workers	\$27.62
Bookkeeping, accounting and auditing clerks	\$17.56
Secretaries and administrative assistants	\$18.60
Office clerks, general	\$14.95

TABLE 45

Oil and gas occupations and hourly wages in the US cont...

Occupation	Average hourly wage
Skilled blue collar	
First line supervisors/managers of construction trades and extraction workers	\$32.63
Carpenters	\$23.29
Cement masons and concrete finishers	\$19.33
Paving, surfacing and tamping equipment operators	\$18.97
Operating engineers and other construction equipment operators	\$21.70
Electricians	\$27.49
Plumbers, pipefitters and steamfitters	\$26.99
Derrick operators, rotary drill operators and service unit operators, oil and gas	\$23.28
Mobile heavy equipment mechanics	\$22.22
Industrial machinery mechanics	\$24.36
Maintenance and repair workers, general	\$19.96
Petroleum pump system operators, refinery operators and gaugers	\$26.83
Crane and tower operators	\$24.55
Pump operators and wellhead pumpers	\$21.59
Semi-skilled blue collar	
Roustabouts, oil and gas	\$16.72
Helpers – extraction workers and other extraction workers	\$17.62
Welders, cutters, solderers and brazers	\$19.08
Inspectors, testers, sorters, samplers and weighers	\$19.39
Truck drivers, heavy and tractor-trailer	\$18.37
Excavating and loading machine and dragline operators	\$19.25
Unskilled blue collar	
Construction labourers	\$16.54
Fence erectors	\$15.25
Labourers and freight, stock and material movers	\$13.62

Source: IHS, America's New Energy Future: The Unconventional Oil and Gas Revolution and the US Economy, Volume 1: National Economic Contributions, October 2012 <http://www.ihs.com/info/ecc/a/americas-new-energy-future.aspx>

A key industry that will benefit, and where there is currently considerable spare capacity in the UK, is the construction industry. Other jobs not mentioned in Table 45 would include, for example, security guards, financial services professionals and public relations staff. In these examples, the UK does not have a shortage of suitably qualified people.

As mentioned in Chapter 2, one lesson to be learned from previous developments, including the development of the North Sea, is that skilled people from outside may be needed initially.

In our view, ensuring sufficient numbers of skilled personnel will be a challenge for an emerging UK shale gas industry, and is likely to present a moderate barrier to the production of shale gas at scale in Britain.

5.4 FINANCE

Tax regime for shale gas production

Ensuring that the tax regime for shale gas strikes the right balance between generating significant revenue for the Treasury and encouraging production will be crucial. The wrong tax regime could present a major barrier to the development of a shale gas industry, but there are two reasons why we don't believe that the tax regime will in practice present a barrier:

- Firstly, an excessively burdensome tax regime would be counterproductive from the Treasury's point of view. If the industry does not develop, little revenue will be generated, no matter how high the tax rate.
- Secondly, the Treasury has learned lessons from recent changes to the tax regime for oil and gas production, as detailed in Chapter 3. The increase to the Supplementary Charge in 2011 has been partially offset by more generous field allowances; the new Fiscal Forum ensures that a productive dialogue is maintained between the Treasury and the North Sea industry; and certainty is being provided on decommissioning relief. Partly as a result, investment in the North Sea is increasing rapidly.

Shale gas production is likely to remain within the existing oil and gas tax regime, with appropriate modifications, which would seem to be the most sensible arrangement. The existing tax rate for new developments is 62%, composed of a 30% rate of Corporation Tax and a Supplementary Charge of 32%. Various field allowances reduce the Supplementary Charge payable on certain types of development. At no point does the tax regime subsidise production.

For shale gas, Budget 2013 set out a new Shale Gas Field Allowance and an extension to the Ring Fence Expenditure Supplement from six to 10 years for shale gas projects. A consultation will shortly be announced to ensure that the details of these measures are appropriate, with implementation likely to be in the 2014 Finance Act.²⁵⁴

In our view, provided that the details of the measures announced in Budget 2013 are appropriate, the tax regime for shale gas will not present a barrier to the growth of a UK shale gas industry and should ensure that the Treasury receives significant tax revenue.

State ownership of mineral rights

In the UK, the state owns the rights to the following minerals – oil, gas, coal, gold and silver. The ownership of oil and gas rights within the land area of Great Britain was transferred to the state by the Petroleum Act of 1934. The Continental Shelf Act 1964 applied the provisions of the 1934 Act to the UK Continental Shelf.²⁵⁵

In the US, the situation is very different, with oil and gas rights in private hands. In theory, this should mean that the environment for development is more conducive in the US, with landowners receiving royalty payments for the oil and gas produced as well as lease payments for the use of their land. Given that shale gas development tends to involve drilling horizontally, landowners with wells thousands of feet below their land will also benefit from royalty payments, even if the wellpad is sited away from their land.

In practice, while private ownership of mineral rights is more conducive to development, it is not always entirely straightforward. Several problems can arise, although it is important not to exaggerate their significance:

- Firstly, the owner of the sub-surface mineral rights for a particular piece of land may not be the same person as the owner of the surface rights. The rules differ in the various states. In Texas, for example, land ownership includes two distinct sets of rights, or "estates," the surface estate and the mineral estate. In many areas of Texas, it is common for the mineral estate and the surface estate to be owned by different parties:

- Most significantly, *“Texas law holds that the mineral estate is dominant. This means that the owner of the mineral estate has the right to freely use the surface estate to the extent reasonably necessary for the exploration, development, and production of the oil and gas under the property. This right to freely use the surface estate for the benefit of the mineral estate may be exercised by a company or individual that has taken a mineral lease from the actual owner of the mineral estate.”*²⁵⁶
- This legal division has led to problems, with some home-buyers purchasing the surface estate only and then being given an unwelcome surprise when drilling takes place on their property. In this example, home-owners have little power to prevent development and do not benefit from royalty payments. Of course, purchasing the surface estate only is cheaper than purchasing both the surface estate and the mineral estate, but it is not an ideal state of affairs.
- Secondly, in the early years of shale gas development in states such as Pennsylvania (as recently as 2006), leases were sold cheap (as low as \$25 per acre) and royalty payments were agreed at a small proportion of the value of the gas produced (the legal minimum in Pennsylvania was 12.5%, and many early deals did not exceed that percentage). Initially, landowners did not appreciate just how valuable their mineral resources actually were, and companies were in no hurry to tell them. Over time, lease payments rose rapidly (to thousands of dollars an acre) and royalties also increased (to 20% and more) as drilling activity intensified and landowners realised that better deals could be obtained. Landowners who signed early could justifiably feel a little hard done by.²⁵⁷
- Thirdly, private ownership of the oil and gas rights can lead to “wasteful drilling”, with each landowner wanting to benefit financially from an oil or gas well on their property and consequently a scattering of onshore development. The desire to prevent the “wasteful drilling” seen in the US was a cited reason (though far from the only reason) for transferring ownership of onshore oil and gas rights in the UK to the state in 1934.²⁵⁸

In practice, state ownership of mineral rights in the UK is not likely to be as large a barrier as commonly thought:

- State ownership of oil and gas rights has not prevented approximately 2,000 wells from being drilled onshore in the UK over the last 30 years, as highlighted in Chapter 3. Nor has it prevented extensive coal mining in many areas of the country.
- Landowners will still receive payments for the use of their land for drilling activities.
- The shale gas exploration and production companies that we have spoken to in the course of our research have told us that while landowners will want to ensure that a good price is agreed, they are generally willing to allow development. While some individual landowners will be opposed to shale gas production, landowners in general are not seen as a major roadblock.
- In practice, the landowners are likely to be farmers. The National Farmers Union is not opposed to shale gas development, stating that “the NFU recognises that unconventional fossil fuel reserves like shale gas may contribute to the diversity of UK energy sources in the future”.²⁵⁹
- Mineral rights ownership in the UK is likely to mean more compact development at fewer sites than in the US. And as explained in Chapter 4, the thickness of the UK’s shale resources could potentially allow more wells to be drilled from a single pad than in the US.

In our view, state ownership of mineral rights presents a minor barrier to the production of shale gas at scale in the UK.

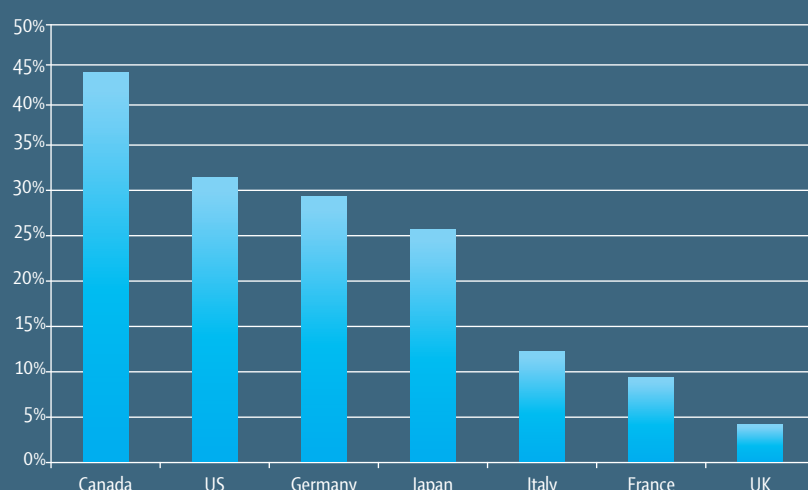
Local authority financial benefits

The UK has the most centralised tax system of any major economy. Just 4% of tax revenue is set locally, which essentially comprises council tax. Even this tax is subject to capping from Whitehall. Revenue from other local taxes, such as business rates, is received by the Treasury and then recycled back to local authorities in the form of grants, with richer local authorities tending to receive less.

In France and Italy, other unitary states, local tax revenue comprises around 10% of total revenue, while in federal countries such as the US, Germany and Japan, state and local taxes comprise around 25-30%. In Canada, provincial and local tax revenue exceeds 40% of total tax revenue.

CHART 55

State, provincial and local tax revenue as a percentage of total tax revenue, 2001



Source: OECD, *Fiscal Relations Across Government Levels*, 2003, Table 1 <http://www.oecd.org/eco/public-finance/33638994.pdf>

This state of affairs is not conducive to development, since the planning authorities that will permit the development are generally at the local authority level, and the authorities that will benefit financially from the development are at the national level. Fundamentally, incentives are not aligned. Although measures such as Section 106 agreements have helped, local authorities are in the unenviable position of being fully exposed to the downsides of development, including local opposition, while having far more limited exposure to the upsides.

Aberdeen City Council provides an illustration of the problem. Despite Aberdeen being the centre for offshore oil and gas, with many of Scotland's largest companies located there, and despite Aberdeen City and Shire being the second richest region of the UK (see Chapter 3), the City Council recently came close to bankruptcy. In 2008, it was forced to make expenditure cuts of £50 million, almost double the amount forecast,²⁶⁰ and at one point the City Council had just £900,000 in its reserves.²⁶¹

The Coalition Government has set out a number of measures to improve financial autonomy for local authorities. Amongst other provisions, the Local Government Finance Act 2012, which came into force in April this year, allows councils to retain a proportion of business rates generated in their area, above a baseline. The Government has pledged not to reset the baseline before 2020, giving local authorities seven years to keep additional business rates, before the process starts again. The formula is complicated slightly by the addition of a levy payment to provide a safety net if, for example, a major employer closes in one local authority. Where local authorities are not unitary, there is also a methodology for apportioning revenues to the county and district authorities.²⁶²

The most important aspect of the legislation is that the level of business rates themselves will not change, so the only way that local authorities can increase business rate income is to promote business growth and attract new businesses to their area. By giving local authorities far more exposure to the upsides, the scheme should encourage new development.

The problem with this new system as regards shale gas is that business rates are only payable when production has started, which could be several years after approval is sought for exploration. Given that the baseline is reset every seven years, local authorities will not have much time to benefit from the retention of part of the business rate income from shale developments. (This also affects the nuclear industry, as the construction of a nuclear power plant can take five years or more.)

For renewables, the picture is different. All business rate income from new renewable projects will be retained by the local planning authority, rather than just a share of the business rate income, as will be the case generally. This could potentially be extended to other energy developments.

In our view, the UK's system of local government finance, even following the Local Government Finance Act 2012, acts as a moderate barrier to the production of shale gas at scale.

Community benefits

Local authorities make the majority of planning decisions, but local communities are crucial to the process. And so they should be. Development will affect their area and the views of local people need to be fully taken into account.

The problem is that the downsides of development tend to receive more prominence than the upsides. Development will bring investment and jobs into an area, including many jobs in the wider economy, with local shops, pubs and B&Bs all benefitting. But people can often feel that development is done *to* them, rather than *with* them.

In the US, as well as the economic benefits that oil and gas development brings to an area, landowners receive royalty payments for the oil and gas produced beneath their land. This direct financial benefit is lacking in the UK.

As was explained in Chapter 3, however, other energy industries have managed to overcome the same problem:

- The onshore wind industry has developed a Community Benefits Protocol, with a commitment to pay at least £1,000 per year for the lifetime of the project for each megawatt of installed capacity.
- The nuclear industry has been very successful at demonstrating the benefits of nuclear power plants to local communities – so much so that nuclear power tends to be more popular locally than across the general population.

Ensuring community support is about far more than just finance. But ensuring that local people, as well as local authorities, benefit from shale gas development is a critical part of ensuring that production goes ahead.

In our view, the need to provide community benefits presents a moderate barrier to the growth of shale gas production in the UK, with an appropriate community benefit mechanism needing to be found.

5.5 REGULATION

Liability for abandoned wells

Shale wells will produce gas for several decades before abandonment, and DECC requires operators to submit an abandonment plan and obtain consent before operations to abandon a well are commenced.²⁶³ It will be important to ensure that wells are monitored post-abandonment, and that liability for any well-failure post-abandonment is vested in an appropriate body. Nuclear and coal provide good examples:

- The UK Coal Authority was established in 1994 to undertake specific statutory responsibilities, including dealing with property and historic liability issues, such as treatment of mine water discharges. As its website states: *“The Authority is the public body which deals with public safety risks arising from past coal mining activities. These include mine entry and mine working collapses, gas emissions, mine water emissions and spontaneous combustion of coal.”*²⁶⁴
- New nuclear power plants will have to make financial provision for future decommissioning.

Similar arrangements will need to be made for onshore oil and gas production, with operators contributing to a fund with liability for abandoned wells. The fund should also ensure that abandoned wells are properly monitored.

In our view, provided such arrangements are made, liability for abandoned wells will not present a barrier to the production of UK shale gas.

Trespass

Wells drilled horizontally or diagonally may pass underneath the property of other landowners. In 2008, Mohammed Al Fayed took Star Energy to the High Court. Star Energy had drilled three wells underneath Mr Al Fayed’s Oxted Estate from its Palmers Wood oil field, without informing Mr Al Fayed beforehand.

The High Court awarded Mr Al Fayed 9% of the proceeds from the field since 2000, and the same percentage of future income. Star Energy appealed. The appeal judges then ruled Mr Al Fayed was not entitled to a share of the income, but could be awarded compensation of £1,000 for past and future trespass.

Mr Al Fayed then took his claim to the Supreme Court, and Star Energy appealed over findings they had trespassed. The Supreme Court upheld the finding of trespass, but threw out the rest of Mr Al Fayed’s claim.²⁶⁵

The issue ought to be clear, given that the 1934 Petroleum Act transferred oil and gas rights from the landowner to the state without compensation. But the trespass claim was still upheld. The law firm Reed Smith provided further explanation:²⁶⁶

“Potential exploiters of shale gas will be granted licences by the Government to explore and exploit shale gas reserves but their project planning will need to understand that without proper procedures being followed it is possible for them to be exposed to actionable trespass even where wells are drilled under licence.

“Historically, property owners in England and Wales own the surface of the land and the heavens above and strata below. How far down that ownership extends has been the subject of recent case law (Star Energy v Bocardo in 2010). In the Star Energy case, the Supreme Court ruled that an oil company had trespassed on an owner’s land by drilling from a well head close to the boundary of the two properties diagonally downwards and under the adjoining land. One of the strange features of trespass is that damages are paid to the occupier or owner whether or not they have suffered damage.

"The oil company had not negotiated any consent from the neighbour and they had not applied for the relevant statutory rights to do so. The land owner was therefore entitled to damages. The good news outcome for those extracting oil or gas onshore is that compensation was assessed on the least costly basis. It was assessed as the value that would be paid if the right to drill had been compulsorily acquired. There was a procedure under which the oil company could have made a claim for a statutory right to drill the well but they had not done this. The compensation did not depend on the value that the oil company got from using the wells."

It is beyond our legal expertise to assess the precise implications of this ruling, but in the many conversations we had during the course of our research for this report, the trespass case was mentioned several times, particularly by US investors and operators. Although it appears that compensation would be minor, trespass is an issue that needs clarifying. Defining the boundary of a shale gas pad in the planning guidance could help.

In our view, the uncertainty surrounding trespass presents a minor barrier to the production of shale gas in the UK. Given the legal nature of this issue, this is very much a provisional view.

14th licensing round

At present, more exploration is needed to assess the size and quality of the UK's shale gas resources. The 14th onshore licensing round will open up new areas to exploration and allow new operators the chance to bid, and it is therefore an important next step. If exploration and appraisal is successful, production will follow after a period of time, so the sooner exploration can be widened, the sooner production could start.

The last onshore round (the 13th round) took place in February 2008 – over five years ago,²⁶⁷ and the 14th round has been delayed for several years. DECC had already commenced a Strategic Environmental Assessment (SEA) in 2010, with a view to further onshore licensing, and conducted a public consultation in the latter part of that year. But work stopped following the moratorium on hydraulic fracturing in 2011.²⁶⁸

Following the lifting of the moratorium in December 2012, a new SEA was undertaken for the 14th round, and the consultation period is now over. At the time of writing, however, it is not clear exactly when the Government's response will be issued and when applications will be invited.²⁶⁹ The delay to the 14th round is another factor slowing down the development of shale gas in the UK.

In our view, until the 14th onshore licensing round is held, the absence of a new onshore licensing round presents a moderate barrier to the production of shale gas at scale in the UK.

Planning and permitting

As mentioned in the "About the report" section and earlier in this chapter, this report does not examine the safety of hydraulic fracturing. The IoD supports strong regulation of all aspects of the shale gas exploration and production process. We do not question the need for the industry to obtain the necessary environmental permits, conduct the necessary environmental impact assessments and install the necessary seismic monitoring equipment. Safety will, and must, remain of paramount importance.

It is, however, worth commenting on the application processes. In the immediate future, drilling activities will be focused on exploration rather than production, and so this section focuses on the planning and permitting regime for exploration.

Table 46 details the main regulatory permissions needed for an exploratory well that is both drilled and hydraulically fractured, and the agencies involved.

TABLE 46		
Main regulatory permissions for an exploratory shale gas well, England		
Permission	Comments	Agency
Petroleum exploration and development licence	Gives operators exclusive rights to explore for, and develop, the resource	DECC
Water abstraction licence	Needed if operators want to abstract water directly from surface water or groundwater exceeding 20 cubic metres a day	Environment Agency
Notice to drill	Under the Water Resources Act (1991), operators must notify the Environment Agency of their intention to drill a borehole and detail how they intend to protect water resources	Environment Agency and Health and Safety Executive
Groundwater activity	Unlikely to need a permit under the Environmental Permitting Regulations (2010), but only substances that have been assessed as being non-hazardous pollutants under the Groundwater Daughter Directive may be used in hydraulic fracturing fluids	Environment Agency
Permits for the management and disposal of wastes from drilling the borehole	Will be treated in the same way as those from any similar minerals exploration	Environment Agency
Mining waste permit	Environmental permit needed for managing flow-back fluid and waste gases, which are defined as mining wastes under the Mining Waste Directive. Environment Agency guidance suggests that a bespoke environmental permit will be needed, with a public consultation, as the application is deemed as high public interest	Environment Agency
Permit for naturally occurring radioactive material (NORM)	Environmental permit needed for temporary storage and subsequent treatment and disposal of flow-back fluid. Environment Agency guidance suggests that a bespoke environmental permit will be needed, with a public consultation, as the application is deemed as high public interest. The Environment Agency encourages operators to submit applications for mining waste and NORM together so they can be processed and consulted on at the same time	Environment Agency

TABLE 46

Main regulatory permissions for an exploratory shale gas well, England cont...

Permission	Comments	Agency
Health and Safety approval needed	Approval from the Health and Safety Executive needed to: ensure safe working practices (Health and Safety at Work Act 1974); manage health and safety at the site (Borehole Site and Operations Regulations 1995); ensure well integrity (Offshore Installations and Wells (Design and Construction) Regulations 1996 – also applies to onshore wells)	Health and Safety Executive
Land use planning permission	Needed for surface operations i.e. the construction and operation of individual well-pads. Environmental Impact Assessment, Environmental Risk Assessment and public consultation needed. Environment Agency is a statutory consultee in the planning process	Local Mineral Planning Authority e.g. Lancashire County Council
Final consent	All operations including drilling, hydraulic fracturing, well suspension, well re-entering etc require DECC approval via the WONS (well operations and notifications system). For hydraulic fracturing specifically, the operator needs to: review available information on faults and monitor background seismicity; conduct real time seismic monitoring during operations, subject to a traffic light regime; submit a hydraulic fracturing plan; monitor the growth in height of the fracture away from the borehole	DECC

NB: Other statutory consultees may include Natural England (<http://www.naturalengland.org.uk/>) and Public Health England (<https://www.gov.uk/government/organisations/public-health-england>). Sources: Department of Energy and Climate Change, *Written Ministerial Statement by Edward Davey: Exploration for shale gas*, 13 December 2012 <https://www.gov.uk/government/speeches/written-ministerial-statement-by-edward-davey-exploration-for-shale-gas>; Environment Agency, *Guidance Note: Regulation of exploratory shale gas operations*, November 2012 http://a0768b4a8a31e106d8b0-50dc802554eb38a24458b98ff72d550b.r19.cf3.rackcdn.com/LIT_7284_231c35.pdf; Health and Safety Executive, *The regulation of onshore unconventional oil and gas exploration (shale gas)* <http://www.hse.gov.uk/offshore/unconventional-gas.htm>; Lancashire County Council, *The Role of the County Council in Shale Gas Developments* <http://www.lancashire.gov.uk/corporate/web/?siteid=3063&pageid=40065&e=e>

All of these permissions are necessary, but with four agencies and two public consultations – one for the Environment Agency and one for the Mineral Planning Authority – the process can seem a little cumbersome. Certain agencies are also statutory consultees on both the planning application and each other's permit applications.

Guidance is also a problem. Each agency issues its own guidance for shale gas operations. In the course of our research we were unable to find a single guidance document setting out the entire permitting and planning process. The industry and local authorities in particular would benefit from clear guidance covering the entire process, clarifying which agency is responsible for which aspects of the process.

The situation ought to improve later in the year, with several announcements being made in Budget 2013.²⁷⁰

- The new Office for Unconventional Gas and Oil (UOGO) will provide a focal point for investors. OUGO has also been tasked with bringing forward proposals for a community benefits regime for shale gas developments by summer 2013.²⁷¹
- Technical planning guidance will be provided to improve clarity around planning for shale gas during the exploration phase. This will be developed by the Department for Communities and Local Government. The Review of Government Planning Practice Guidance, carried out in 2012, concluded that guidance needed to be shortened and simplified,²⁷² and our understanding is that planning guidance will be progressively re-written, with guidance for shale gas being provided by July 2013.
- More detailed guidance will be provided by the end of 2013 to ensure that the planning system is properly aligned with the licensing regime and the regulatory regimes.
- The Government will also keep under review whether the largest shale gas projects should have the option to apply to the major infrastructure regime.

These developments are welcome news, but it will be important to ensure that the details are right. Chapter 6 sets out our initial thoughts on how the planning and permitting regimes could be clarified, without losing any of the essential environmental safeguards.

In our view, the planning and permitting regime for shale exploration, as currently constituted, presents a major barrier to the development of shale gas in the UK.

5.6 REPUTATION

Population density

Much has been made of the argument that, because the UK is more densely populated than the US, shale gas development at scale will be far harder to achieve in this country.

It is certainly true that the UK is more densely populated than the US. Table 47 presents population densities for the US overall and the shale gas producing states, and provides a comparison with the UK. Overall, the UK is around 7.5 times more densely populated than the US, and Lancashire is nearly four times more densely populated than Pennsylvania.

TABLE 47

US and UK population densities compared

2010 for US, 2011 for UK	Number of people per square kilometre
US	34
Texas	37
Louisiana	41
Pennsylvania	110
Arkansas	22
Oklahoma	21
West Virginia	30
Colorado	19
North Dakota	4
Michigan	67
New Mexico	7
California	92
Virginia	78
Montana	3
Wyoming	2
Ohio	109
UK	260
England	410
Wales	150
Scotland	70
Lancashire	400

Sources: Office for National Statistics, 2011 Census: Population density, local authorities in the United Kingdom <http://www.ons.gov.uk/ons/publications/re-reference-tables.html?edition=tcn%3A77-294273>; US Census Bureau <http://www.census.gov/compendia/statab/2012/tables/12s0014.pdf>. NB: For ease of comparison, densities converted to people per square kilometre

In practice, however, the difference between the UK and US is likely to be less than Table 47 suggests:

- In some US states, farmland is divided either into sections (1 square mile – 260 hectares) or quarter sections (1 quarter of a square mile – 65 hectares). For the latter, this means that farmhouses will be located every quarter of a mile (just over 400 metres) in each direction. In these areas it will be difficult to locate a shale gas pad more than a few hundred metres from a farmhouse, although some farms will be several quarter sections in size. In areas of farmland in the UK, the distances from farmhouses may be of similar orders of magnitude (although farmland is not laid out in a grid pattern in the UK).

- In both the UK and the US, the urban population is around 80%.²⁷³ UK urban development tends to be very compact. Despite the high overall population density, only 6.8% of the UK's land area is classed as urban. In England, the proportion is 10.6%, in Wales 4.2% and in Scotland just 1.9%.²⁷⁴ In the UK, therefore, 80% of the population live on less than 7% of the land, which means that there are large areas of land located away from built-up areas that would be available for shale gas development.
- The UK's high population density has not prevented other development from taking place, including, for example, motorways, out-of-town supermarkets, industrial sites, power lines and 3,741 onshore wind turbines.
- In certain parts of the US, shale gas development takes place in suburban areas, Fort Worth (Barnett shale) being a good example.

In addition, the land required by shale gas development is not likely to be as large as sometimes thought. As Chapter 4 illustrated, if a pad needs two hectares of land, then two square kilometres would support 100 pads. The pads would of course be scattered, and additional land would be needed for gathering stations, compressors, water treatment plants etc, but, overall, shale gas development does not need vast tracts of land.

In our view, the UK's high overall population density presents no more than a minor barrier to the production of shale gas at scale.

Confidence hurdle

As mentioned in the "About the report" section and earlier in this chapter, this report does not examine the safety of hydraulic fracturing – other expert bodies, including the Royal Society, have examined the process in detail, and we do not propose to repeat their work.

Nevertheless, it is important to mention that, in our view, shale gas operations are currently facing a confidence hurdle. Successful drilling and hydraulic fracturing is needed to improve public confidence, and public confidence is needed to facilitate development.

Until that happens, regulators, politicians and local authorities will understandably take a very cautious approach, which will inevitably slow down the pace of development. We are not suggesting that regulators are wrong to take a cautious approach, but we are noting that it is having the effect of slowing down the timetable for exploration and subsequent production.

In our view, until it is overcome, the confidence hurdle presents a moderate barrier to the production of shale gas at scale.

Social licence to operate

The shale gas industry needs to have a social licence to operate, and it is the responsibility of the industry to make sure that its operations are seen to be acceptable. Without a social licence to operate, the industry will find it more difficult and more time-consuming to obtain the necessary approvals to undertake exploration, and subsequent production, activities.

Public attitudes towards shale gas in the UK are quite open minded, and are improving, although the industry does have some way to go to convince people of the merits of development. In December 2012, following the lifting of the moratorium on hydraulic fracturing, BritainThinks surveyed 500 residents of Blackpool, Fylde and West Lancashire by telephone, with some questions repeated from an earlier survey carried out in October 2012. The key findings included:²⁷⁵

- Half (50%) support continued exploration in the local area to understand the potential for natural gas from shale, up from 44% in the previous survey.
- Job creation (90%) is the most important potential benefit from shale gas, while the potential risk of water pollution (92%) is seen as the most significant downside.
- DECC's decision to lift the moratorium on hydraulic fracturing made 37% feel more supportive and 25% less supportive of continued shale gas exploration in Lancashire.
- Respondents were then briefed on the new controls introduced by DECC, including requirements on exploration companies to conduct a review of seismic risks in the area; to submit a detailed plan showing how any seismic risks are to be addressed; to carry out seismic monitoring before, during and after the hydraulic fracturing process; and to implement a traffic light system to identify any unusual seismic activity requiring reassessment or halting of operations. Nearly two thirds (64%) said that hearing about the controls made them feel more supportive and 15% less supportive.

In March 2013, the University of Nottingham published a report analysing the results of five YouGov surveys of around 3,000 people commissioned by the University in March 2012, April 2012, June 2012, December 2012 and March 2013. It also showed that public attitudes are shifting. The key findings included:²⁷⁶

- In the most recent survey, 60% associated shale gas with earthquakes, a fall from 71% in April 2012.
- In the most recent survey, 36% associated shale gas with water contamination, down from 45% in March 2012. Over the same period, the number of people believing that hydraulic fracturing will not result in water contamination rose from 24% to 29%.
- In the most recent survey, 32% believed that shale gas was a clean energy source, an increase from 25% in March 2012. Over the same period, the proportion believing that shale gas was not a clean energy source fell from 45% to 39%.
- In the most recent survey, 53% said that shale gas is a cheap source of energy, an increase from 40% in March 2012. Just 21% said that shale gas is not a cheap energy source, a fall from 29% in March 2012.

US attitudes towards natural gas and shale gas tend to be very favourable. In November 2011, Deloitte commissioned a survey of 1,694 American adults. The key findings included:²⁷⁷

- “Clean” is the top association with natural gas, with around 6 in 10 making that connection.
- Around 9 in 10 find each of the following statements at least somewhat believable:
 - “Shale gas operations can increase employment in local communities”;
 - “Development of shale gas resources in the US can create many jobs here while reducing dependence on foreign sources of energy”;
 - “New technologies have been introduced that make shale gas extraction safe and environmentally sound when done responsibly”;
 - “Using natural gas from shale resources to generate electricity can significantly reduce our carbon footprint”.
- Of those living in “mature” shale gas plays, including Texas, Louisiana and Arkansas, 28% know at least one person in their area employed in the oil and gas industry, and 62% believe that pay in the shale gas industry is higher than the local average.
- Around three fifths agree that the benefits of shale gas outweigh the risks, compared with around one fifth who think that the risks outweigh the benefits.
- In mature shale gas plays, 71% would advise family and friends to lease their land for shale gas development, and of those who have leased their land, 83% would do it again. Interestingly, in “new” shale gas plays, including Pennsylvania, only 52% would advise family or friends to lease their land, and of those who have leased their own land, only 53% would do so again. This shows that although attitudes are generally positive, in certain areas the industry has to make a greater effort to work alongside local communities.
- Amongst respondents where development is taking place or planned, around a third believe that the industry is very or extremely trustworthy, a figure which rises to 43% for residents of mature plays. Around half believe that the industry is somewhat trustworthy and just 15% believe that the industry is not trustworthy.
- Less than a fifth believe that there is too little regulation of natural gas development.

The challenge for the industry in the UK is to achieve the same positive polling results as the shale industry in the US, particularly in the mature shale plays. The nuclear industry also provides a model to study – as Chapter 3 noted, nuclear power tends to be more popular in areas close to nuclear power stations.

In our view, the need for the shale gas industry to gain a social licence to operate currently presents a moderate barrier to the production of shale gas at scale in the UK.



6. Recommendations

Shale gas development in the UK will be a two-stage process. Exploration must continue so that the size of the recoverable resource can be better determined. If exploration and appraisal is successful, production at scale can then be facilitated. Both stages will require partnerships to overcome the key barriers. And the more that shale gas can be seen as part of a wider economic development programme, the easier it will be to build and maintain those partnerships.

This chapter sets out a number of recommendations to facilitate exploration and subsequent production. Our recommendations are not solely aimed at government – the emerging shale gas industry also needs to play its part.

6.1 OVERCOMING THE EXPLORATION HURDLE

Currently, the biggest priority is to allow exploration to continue. Only with further exploration can better estimates be made of the size of the UK's recoverable shale gas resources.

Out of the barriers identified in Chapter 5, the two most significant as regards exploration are planning and permitting, and the delays to the 14th licensing round. Our first two recommendations are designed to address these two barriers, facilitating further exploration and appraisal work.

1. Provide guidance to clarify the planning process for exploration wells

As Chapter 5 noted, technical planning guidance will be issued, probably in July 2013, to provide clarity around planning for shale gas during the exploration phase. In our view, the guidance should clarify three points in particular. It is important to note that this section does not recommend the removal of environmental protections.

Firstly, guidance should clarify when an Environmental Impact Assessment (EIA) is needed. In our view, an EIA should not be needed for an application to drill a vertical or a lateral well if the size of the development is under the Schedule 2 threshold.²⁷⁸ An EIA should, however, be needed for an application to hydraulically fracture. It should also be needed for an application that covers all three steps – drilling a vertical well, drilling a lateral well and hydraulic fracturing.

Onshore wind provides a useful analogy, with an anemometer often used to measure the wind speed at a particular site before a decision is made to proceed with an application for a wind farm. The anemometer usually requires temporary planning consent. A vertical exploration shale gas well can be thought of in a similar way – data from the vertical well will usually be analysed before a lateral well is drilled and any hydraulic fracturing undertaken.

Secondly, in order to reduce overlap, guidance should clarify which authorities are responsible for which aspects of the process. In our view, the sub-surface operations should be approved by the national bodies – DECC, the Environment Agency and the Health and Safety Executive – with the Mineral Planning Authority concentrating on the surface operations once approval for the sub-surface operations has been received.

Such a split would help to ensure that expertise on the hydraulic fracturing process is concentrated in the national agencies rather than dispersed among a number of local authorities. Two public consultations would still be necessary for an application to drill and hydraulically fracture an exploration well – one for the Environment Agency and a second for the Mineral Planning Authority – but they would be focused on different aspects of the process.

Thirdly, the site boundaries also need defining, given that lateral wells will be drilled deep underground beyond the surface boundary of the site. Guidance on boundaries should also help to ensure that trespass is not invoked.

2. Launch the 14th licensing round as quickly as possible

As Chapter 5 explained, the 14th onshore licensing round will open up new areas to exploration and allow new operators the chance to bid. The last onshore licensing round took place in February 2008 – more than five years ago – and the 14th round has already been delayed for several years. The consultation period for the new Strategic Environmental Impact Assessment for the 14th round is now over, but at the time of writing, it is not clear exactly when the Government's response will be issued. The 14th licensing round should be launched as quickly as possible to facilitate further exploration and appraisal of the UK's shale gas resources.

6.2 DEVELOPING A SHALE GAS INDUSTRY

If exploration and appraisal is successful, a number of steps will need to be taken to develop a shale gas industry in practice. Although the two measures outlined above must take priority, many of the steps detailed below should also be taken swiftly to ensure that production is not delayed, and if production does occur, to ensure that it benefits local communities. All parties must work together to bring about responsible development that benefits local people.

In our view, the main barriers to production, as detailed in Chapter 5, are planning and permitting, local authority and community benefits, skills, grid connection delays, and the need for confidence in the industry and a social licence to operate. Our next six recommendations are designed to address these barriers, ensuring that production can go ahead at scale if exploration is successful.

3. Put in place a financial framework that benefits communities and encourages wider economic development

There are three aspects to an appropriate financial framework: the Treasury tax regime; a mechanism to ensure that local authorities benefit financially from development; and a mechanism to ensure that local communities are also included and feel a sense of ownership. We will make recommendations for each in turn.

Firstly, as Chapter 5 explained, the Treasury tax regime is likely to be composed of a 30% rate of Corporation Tax; a 32% Supplementary Charge; and a new Shale Gas Field Allowance and an extension to the Ring Fence Expenditure Supplement to 10 years, both of which will in some circumstances reduce the Supplementary Charge payable. A consultation will shortly be launched to ensure that the details are appropriate. In our view, such a regime for shale gas production looks sensible.

Secondly, local authorities also need to benefit financially. The Energy and Climate Change Select Committee concluded that one option could be to allow local authorities to retain 100% of business rates from shale gas developments, as per the proposal for renewable energy developments.²⁷⁹ We agree that this could be a sensible option, provided that the baseline is not reset every seven years (see Chapter 5). And, given that the industry is likely to be paying a 62% rate of tax to the Treasury, it would not represent an additional tax for the industry to bear. Other mechanisms, including Pennsylvania's "impact fee", should also be examined as possible alternatives.

If 100% business rates retention was favoured as a mechanism, it would be important to ensure that the right local authorities benefit, in particular the relevant Mineral Planning Authority, which will approve the planning applications. And we would also recommend that the revenue be hypothecated in some way to cover economic development expenditure, ensuring that shale gas production helps to facilitate wider economic growth in the area. Further work will be needed to determine the best option for local authority benefits.

Thirdly, local communities should also benefit from production in their area. As Chapter 5 pointed out, a big problem is that the downsides of development tend to receive more prominence than the upsides. Development will bring investment and jobs into an area, including many jobs in the wider economy, with local shops, pubs and B&Bs all benefitting. But people can often feel that development is done *to* them, rather than *with* them.

Resolving this tension is not easy, and it affects many other developments as well as shale gas. As Chapter 3 described, the onshore wind industry has introduced a community benefits protocol, which commits to pay a minimum amount per megawatt of installed capacity, sets out how the relevant community will be identified, and stipulates that early and transparent consultation must take place. Perhaps partly as a result, approval rates for planning applications are now increasing, although other factors are important, including a trend of submitting smaller projects.

In our view, communities should derive some benefit from hosting nationally important developments. And the shale gas industry needs to be seen as a good neighbour. This is about far more than just finance – our recommendations on transparency and the supply chain (see below) are also crucial.

Perhaps most important is for local communities to feel a sense of ownership, including identifying local priorities and helping to manage any community benefits scheme. There is little sense in imposing a standard regime on all local areas, as local needs and aspirations will differ. Flexibility and consultation will be critical.

We would also recommend that, given the high tax rates paid by the industry, payments made into a community benefits scheme should be offset against the taxes paid to the Treasury.

4. Ensure that the planning and permitting regime facilitates production

As shown in Chapter 4, shale gas production at scale will require multiple laterals drilled from multiple pads, and the planning and permitting regime should not slow down development unduly. More detailed guidance will be provided by the end of 2013 on the planning and permitting regime.

There are several aspects to ensuring that planning facilitates shale gas production. It is important to note that this section does not recommend the removal of environmental protections.

First, a National Policy Statement (NPS) should be issued to make clear that shale gas constitutes nationally significant energy infrastructure. In the energy sector, there are already NPSs for:

- Fossil fuel generating infrastructure;
- Renewable energy infrastructure;
- Gas supply infrastructure and gas and oil pipelines;
- Electricity networks infrastructure;
- Nuclear power generation.²⁸⁰

In practice, these NPSs cover the following types of infrastructure:

- Gas-fired, coal-fired, coal-gasification combined-cycle, oil-fired and biomass co-fired plants of 50 MW and above;²⁸¹
- Biomass and/or waste plants of 50 MW or above;²⁸²
- Offshore wind farms of 100 MW or above;²⁸³
- Onshore wind farms of 50 MW or above;²⁸⁴
- Underground gas storage and LNG facilities with a storage capacity of 42 million cubic metres or above, or a maximum flow rate of 4.5 million cubic metres of gas per day or above;²⁸⁵
- Gas reception facilities with a maximum flow rate of 4.5 million cubic metres of gas per day or above;²⁸⁶
- Gas Transporter Pipelines of more than 800mm in diameter and more than 40 kilometres in length (or likely to have a significant effect on the environment), with design operating pressure of at least 7 bar guage and supplying gas for at least 50,000 potential customers;²⁸⁷
- Cross-country pipelines over 10 miles long which would otherwise require consent under s.1 of the Pipe-lines Act 1962 together with diversions to such pipelines regardless of length;²⁸⁸
- 400kV and 275kV transmission lines, and 132kV-230kV distribution lines, either carried on towers/poles or underground, together with associated infrastructure such as substations and converter stations;²⁸⁹
- Nuclear power stations of 50 MW or above on certain sites.²⁹⁰

In other words, *generation*, *transmission* and *storage* of energy are deemed to be nationally significant infrastructure. The omission from this list is *extraction* of energy. Up until now, oil and gas extraction has been largely offshore, while coal mining has a long history. So an NPS for onshore extraction has not been necessary. But with the prospect of significant shale gas production, together with other unconventional sources such as coal-bed methane and shale oil, an NPS for onshore fossil fuel extraction would be a logical development.

Second, an NPS for onshore fossil fuel extraction need not be used to replace the role of the local Mineral Planning Authority. Indeed, most onshore wind farm applications are still processed by local authorities.²⁹¹ It will be important, however, to clarify which authorities are responsible for which aspects of the process.

In this context, we repeat the recommendation for the exploration phase. The sub-surface operations should be approved by the national bodies – DECC, the Environment Agency and the Health and Safety Executive – with the Mineral Planning Authority concentrating on the surface operations once approval for the sub-surface operations has been received.

The nuclear industry provides a useful way of thinking about the issue, with a Generic Design Assessment issued for the reactor and a planning application to cover the remaining aspects of construction and operation of the plant. Applications for drilling and hydraulic fracturing could also be subject to a “Generic Design Assessment” to ensure that the proper procedures are followed, with the planning application covering aspects such as truck movements, noise levels, site access work and the timing of drilling and fracturing activities.

Third, for a potential production phase, permitting and planning consent must be given to all potential activities on a pad, rather than to each well. Otherwise the process will become far too cumbersome. A useful analogy can be made with wind farms: it would clearly be wasteful if each turbine in a wind farm required separate planning approval. Once exploration and appraisal is completed, the operator should submit a field development plan together with an EIA. Two public consultations would be necessary – one for the Environment Agency and one for the Mineral Planning Authority – but they would be focussed on different aspects of the process.

Fourth, operators should have the option to apply for planning and permitting approval for several pads at the same time. This would lead to synergies, but would also risk a refusal for several pads, rather than just one. Nevertheless, it should be an option.

Fifth, fees for planning and permitting applications should be set at an appropriate level to ensure that there are sufficient qualified personnel to handle applications efficiently and undertake regular inspections, particularly to ensure well-integrity.

5. Make operations transparent

The industry has a duty to ensure that its operations are transparent and meet the highest environmental standards. The industry also needs to be transparent about the financial benefits provided to local communities. There are three key aspects to this.

Firstly, each pad needs to be accompanied by full disclosure of the chemicals used in the fracturing fluid, as set out in the guidelines issued by the UK Onshore Operators Group. In addition, data should be made available on other aspects of the process, such as the quantities of water used, truck movements, and the timing of drilling and fracturing activities.

Secondly, although operators already need to submit an abandonment plan and obtain consent before operations to abandon a well are commenced, communities need to have reassurance that wells will be properly managed post-abandonment. They also need to know who will be responsible. In our view, the best way to manage abandoned wells is for operators to make payments into a fund with liability for abandoned wells. The fund should also ensure that abandoned wells are properly monitored in order to prevent problems from arising in the first place. As Chapter 5 described, the UK Coal Authority provides a similar function with respect to abandoned coal mines, and new nuclear power plants also have to make financial provision for future decommissioning.

Thirdly, as Chapter 3 described, in Scotland, the Scottish Government Register of Community Benefits from Renewables provides transparent data on the funds provided to local communities hosting onshore wind and other renewable developments. The database is searchable by project, and details the amount paid, the types of projects that the money will be spent on, and how the local community is defined. A similar register should be set up for shale gas developments, which would complement the community benefits recommendation made above.

6. Provide skills and supply chain opportunities

Chapter 5 noted that skills shortages are a major issue in the UK's offshore oil and gas sector, while Chapter 3 detailed the numerous partnerships set up to develop skills and the supply chain in both the offshore and nuclear industries. Should shale gas production begin in earnest, it will be important to develop a number of similar partnerships.

Firstly, although skills provision is a major challenge across the UK, an emerging shale gas industry can take a number of steps to help ensure that people gain the necessary skills. The Energy and Climate Change Select Committee concluded:

*"We recommend that Government encourage partnerships such as the one between Cuadrilla and the University of Central Lancashire to ensure the skills required to develop the shale gas industry are available. Government should make an assessment of the need for skills development and should work with industry and the relevant sector skills council to develop a skills action plan for shale gas similar to the Nuclear Supply Chain Action Plan which the Government has recently published."*²⁹²

We agree with this recommendation, and would emphasise the need for government to work with industry. We would also add two points:

- For offshore oil and gas production, OPITO is the focal point for skills, managing the industry's training and safety programmes. It also sets training standards and approves providers that deliver training in accordance with these standards. A similar body could be useful for the shale gas industry, should production begin in earnest.
- As detailed in Chapter 3, the UK Nuclear Education, Skills and Training Directory lists 23 universities, 14 further education colleges and 12 employer-nominated providers offering nuclear-related courses. Over time, a similar directory could be useful for the shale gas industry.

Secondly, a commitment to develop a UK-based supply chain will also be essential. Aberdeen's success is due to the supply chain as much as the exploration and production companies themselves:

- As detailed in Chapter 3, Project Pathfinder provides real-time information on upcoming offshore projects to the supply chain. The online tool includes the location, type of development, timing, and contact details within the companies, covering 95% of the UK operators. A similar tool should be developed for UK shale gas projects, enabling the supply chain to plan ahead.
- Contracting decisions should of course be made for commercial reasons, but a commitment by the industry to use local people and suppliers where possible would help to ensure that local areas benefit from development.

7. Provide government leadership

The Energy and Climate Change Select Committee strongly criticised the Government for slow progress in providing the framework for shale gas development, which is worth quoting at length:

*"It has been two years since we last reported on shale gas. In the meantime progress has been slow, largely because of the 18 month moratorium on drilling. We do not believe that it was necessary to take so long to establish the safety of fracking. Hundreds of thousands of wells have been drilled in the USA providing an unprecedented test bed for this technology. In that respect it is different from other new technologies like nuclear where there are rarely more than one or two examples of new reactor types in operation. Had there been any serious consequences they would have come to light. The length of the moratorium has conveyed the impression that the case for and against proceeding with shale gas exploration is finely balanced when this is simply not the case. Care is required to ensure that the shale gas industry in the UK develops more quickly in the future while doing everything possible to allay unwarranted concerns of local communities. But the lack of progress over the past two years is disappointing. The Government has signalled that it sees a role for conventional and unconventional gas in the UK's future energy mix, but it has been slow to establish the framework within which the shale gas industry will operate."*²⁹³

We agree with the Committee's criticism. Government leadership has been sorely lacking. The establishment of the new Office for Unconventional Gas and Oil (OUGO), however, is an opportunity to provide the leadership that the industry needs. There are several aspects to this.

First, we agree with the Committee's recommendation: *"When the Government provides detail of the objectives, remit and responsibilities of the Office of Unconventional Gas and Oil, it should include clear lines of accountability to a single Minister responsible for the Office."*²⁹⁴

Second, OUGO should draw together the various planning and permitting guidance into a single document, setting out the entire process of gaining consent for exploration activities and production activities. The document should include the roles and responsibilities of the various agencies, expected timescales for obtaining consent, and the duties of operators, including the need to set up a community benefits scheme. The document should be for the use of government agencies, Mineral Planning Authorities and operators.

Third, OUGO should take the lead on proposing measures to reduce the time it takes to obtain a grid connection. As Chapter 5 pointed out, obtaining a connection to the National Transmission System takes around 3 ½ years. This is excessive, especially given that an operator will want to secure planning approval before taking the risk of paying for a grid entry connection.

Fourth, as mentioned in Chapter 3, one lesson to be learned from previous developments, including the development of the North Sea, is that skilled people from overseas may be needed initially. The Government must ensure that the visa regime is accommodating, in this instance particularly for skilled people from North America. OUGO should take the lead in negotiations with the Home Office.

Fifth, as Chapter 3 explained, the Oil and Gas Task Force, which then became PILOT, provided strong leadership and partnerships for the offshore industry at a critical time. OUGO could bring together the key government and industry stakeholders in a similar body to deliver actions to ensure that shale gas production proceeds in a timely manner.

These measures are necessary, but may not be sufficient. Ultimately, the regulatory framework could potentially be streamlined, without losing any environmental safeguards.

8. Develop an online shale gas portal

A number of our recommendations include the need for transparency around matters such as drilling operations, community benefits and supply chain opportunities. Rather than provide the information on multiple websites, it could be useful to set up a single shale gas portal, providing full details of the impacts and benefits of development. The website could include:

- Full operational data, including chemicals used in the fracturing fluid, the quantities of water used, truck movements, the timing of drilling and fracturing activities and noise maps;
- Community fund data for each development;
- Live planning applications;
- The pipeline of upcoming projects for the supply chain;
- A skills directory;
- Job opportunities;
- An annual report, similar to the Economic Report issued annual by Oil & Gas UK for the offshore sector. The report would detail investment, jobs, gas produced and equivalent number of homes powered or heated, Treasury tax payment totals, local authority business rate or fee payment totals and community benefit totals. It would also provide a supply chain map, detailing the areas of the UK benefitting from the activities of the industry.

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Faster, better and cheaper infrastructure helped fuel the rapid growth of the industrial revolution, giving businesses the platform they needed to thrive at home and export to the world. In the last century, Britain continued to develop new forms of travel, leading the way in aviation and building an extensive motorway system.

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