Task Force on Shale Gas

Third Report

Assessing the Impact of Shale Gas on Climate Change

Letter from The Panel

Thank you for your continued interest in the Task Force on Shale Gas as we continue to examine the key issues surrounding the creation of a shale gas industry in the United Kingdom. This is our third report, of a planned four, and it looks specifically at climate change impacts that have been associated with shale gas.

We would like to thank our esteemed advisors, whose counsel and guidance continues to be invaluable.

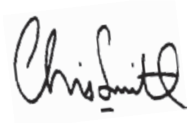
The publication of our second report, which looked at the local environmental and health impacts associated with shale gas exploration and production, received widespread interest and created significant conversation and debate. While not everyone will agree with our conclusions and recommendations, it is the panel's view that our reports provide a useful addition to the debate over shale gas and we have always aimed to make them accessible and understandable to an informed public.

Everyone has a right to make their own personal decision on the issue of shale gas on the basis of trusted and factual information. The guiding principle of the Task Force remains to provide that information.

As with each of our previous two reports, the Panel is indebted to the many businesses, academics, individuals and associations who have given up their time to meet with the Task Force. We very much hope that they recognise the immense value that they have provided to the Task Force's work. All recommendations and conclusions, of course, are the Task Force's alone.

We remain open and transparent around our funding, the people and organisations that we meet, the information and academic literature that we have reviewed and consulted and the timetable that we are working to.

All of this information, as well as our first and second reports and supporting documentation, is available on our website – www.taskforceonshalegas.uk – along with relevant contact details. We remain keen to hear from anyone who can assist our work.



Lord Chris Smith
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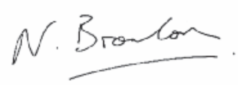

Professor Nigel Brandon
Panel Member

Acknowledgements

We would like to thank all the people and organisations who have contributed information and their perspectives to this report through the submission of evidence to the Task Force by email or through the website.

In addition, we would like to thank all the people and organisations that we have worked with and spoken to on our UK site visits. Our particular thanks go to Dr Andrew Miller, Professor Tim Wheeler DL, Paul Vernon, Garfield Southall, Professor Joseph Howe and Charlie Woodcock.

Our thanks also go to representatives of local communities in Lancashire and Sussex villages, including Marcus Adams, Dr Petra Billings, Cllr Ian Campbell, Denise Campbell, Keith Charman, Mike Damms, Pat Davies, Jean Diggens, Simon Diggens, John N. Diggens, Gayzer Frackman, Rob Green, John Hodson, Neil Jack, Cllr Mike King, Gary Lovatt, Christina Maude, Babs Murphy, Laurence Rankin, Gordon Smith, Martin Spurrier, Dr Jill Sutcliffe, Michelle Taylor, Eric Vaughan, Elizabeth Warner, Charles Metcalfe, Kathryn McWhirter, Professor Laurence Dunne, Louisa Delpy, Helen Savage, Juliette Harris, Dr Rosalind Merrick, Robert Greer and Ed Pack.

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Finally, we particularly wish to thank our advisors, Michael Holgate, Stephen Tindale, James Taylor, Professor Sarah O'Hara, and Dr Robert Ward for giving their perspectives on this report as it was developing. Responsibility for its contents, however, remains entirely with the Task Force Panel.

Introduction

The Task Force on Shale Gas was launched in September 2014 to provide an impartial, transparent and evidence-based assessment of the potential benefits and risks of shale gas extraction to the United Kingdom.

The Task Force's funding comes from businesses involved in the shale gas industry. However the Task Force operates independently from its funders and the funders have no influence over its research, recommendations or publications.

The Task Force recognises that the issue of shale gas extraction and its potential benefits and risks to the UK has become a polarising topic in the UK. As such, it is difficult to find a platform for reasoned debate about shale gas extraction.

The mission of the Task Force is to create that platform, to provide reasoned and evidence-based conclusions and recommendations to both industry and Government about the potential of shale gas extraction in the UK, to inform the general public and to promote reasonable discussion about these findings.

To make this possible we decided to deal in detail with clusters of issues over a series of reports, enabling us to publish our conclusions at the earliest possible time.

Our first report, published in March, examined the existing planning and regulatory system for shale gas and the public consultation process. We made a series of recommendations that we believe would address reasonable concerns raised by the public around potential shale gas extraction. This report also contains what is hopefully a useful guide to the current political context around shale gas in the UK and an introductory guide to what shale gas exploration and extraction in the UK would consist of and how this would differ from much publicised shale gas operations in the United States. This report is available in full on our website.

Our second report, published in July, looked at the impacts of shale gas associated with the local environment. Specifically it looked at seismic activity, at potential impacts on air and water and on public health impacts. The Task Force made a series of recommendations that we believe would provide a framework under which it would be possible to minimise the risk associated with shale gas to acceptable levels.

This is our third report, in which we examine and assess evidence related to climate change.

Our fourth and concluding report will examine the economics of a shale gas industry in the UK – including community benefits and compensation.

The conclusions drawn by the Task Force in each report, and the resulting recommendations, reflect the views of the Panel only. They do not necessarily reflect the views of any of the organisations we have met or advisors we have consulted. They are drawn by the Panel from a combination of academic review, personal meetings, interviews and site visits.

Climate change - Our starting point

In our second report, the Task Force examined the immediate, local environmental impacts of a potential shale gas industry in the UK. Specifically we looked at seismic impacts and issues related to water and air, as well as reviewing the evidence surrounding the impact on public health.

From the outset of our work, however, we have also been clear that the viability of even a localised shale gas industry must be tested against its global impacts – i.e. its potential climate change impact. Specifically in this report we are interested in understanding how the development of a shale gas industry in the United Kingdom (UK) would affect the UK's overall impact on climate change.

In order to make a reasonable assessment of this and to allow for useful and credible recommendations, the Task Force on Shale Gas has asked a number of simple questions and then looked at the academic literature surrounding each in great detail and drawn relevant conclusions.

Put simply we have asked:

- What are our current energy needs and what is the 'direction of travel' i.e. what are the implications of our climate commitment emissions targets?
- The UK will, of course, require a mix of energy sources. As the nation moves towards its short and medium term climate goals, is there a need for gas within this mix? How does gas as an energy source compare to other sources of energy, for example coal or renewable energy sources?
- What are the different sources and types of gas available to meet UK energy needs and what are the pros and cons of using each from a climate change perspective?

By looking at these questions and reviewing the academic literature associated with each we have been able to make evidence-based recommendations on the role of shale gas in the UK's future energy mix from the point of view of climate change impact.

Current UK climate policy

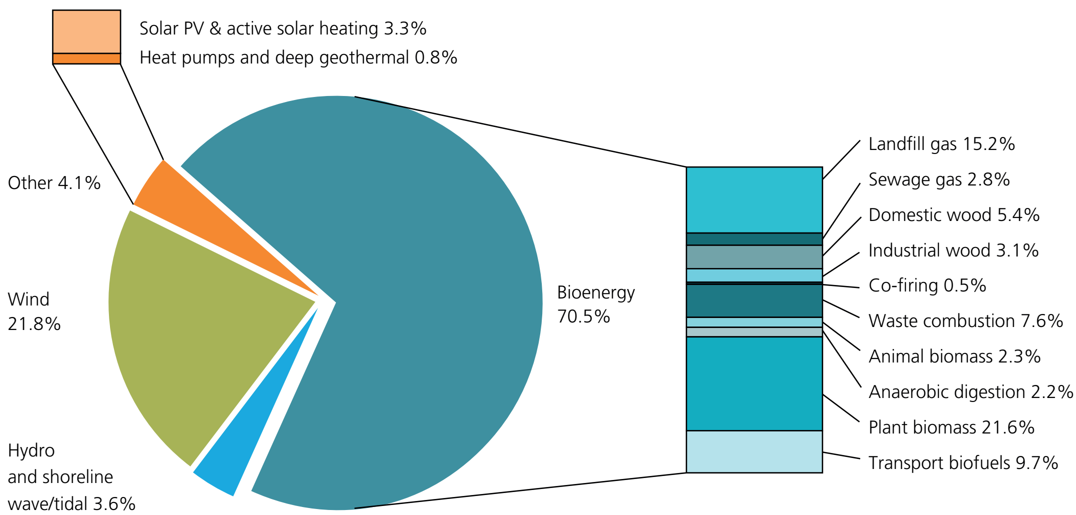
The UK's policy on climate change is set out in two Acts of Parliament; the Climate Change Act 2008 and the Energy Act 2013.

Administrations in Scotland, Wales and Northern Ireland also have a responsibility to contribute to the UK's climate change policy through devolved policy areas[1]. For instance Scotland has its own Climate Change Act, produced in 2009, which committed Scotland to reducing emissions by 42% by 2020 relative to year 1990 and then yearly reductions between 2020 and 2050[2]. Northern Ireland's Environment Minister is in the process of producing a Climate Change Act while the Welsh Government has been advised on potential climate change legislation that could be put in place[3].

The Climate Change Act 2008 established a framework to develop an economically credible emissions reduction path and includes a target of reducing greenhouse gas (GHG) emissions by at least 80% by 2050 compared to emission levels in 1990. For this 2050 target to be met, the UK's electricity generation must become fully decarbonised (we use this term as a short hand for the removal of all greenhouse gases)[4]. As of July 2015, greenhouse gas emissions were 36% below 1990 levels. This progress has been delivered through a variety of means including reduced power sector and industry emissions, in part from investments in low-carbon technologies and energy efficiency, and a switch from coal to gas, and in part due to the economic downturn[5].

Fig.1. 2013 renewable energy sources in the UK

(From Department of Energy and Climate Change, 2014c).



Total renewables used = 11,201 thousand tonnes of oil equivalent (ktoe)

The Climate Change Act also contains legislation that requires the Government to put legally binding carbon budgets in place in order to ensure that the 2050 target is met. In the UK, carbon budgets place restrictions on the volume of GHGs that can be emitted over five years[6]. This means that if more GHGs are produced in one sector that must be compensated for in another.

In addition, the Climate Change Act established the independent Committee on Climate Change (CCC) to advise the government on how to achieve emissions targets (via carbon budgets) and to report to Parliament on progress made in reducing GHGs. The CCC has recently been given a new duty to advise the government on whether the exploitation of shale gas (and other onshore petroleum resources) is compatible with meeting carbon budgets[7].

The Government published The Carbon Plan[8] to outline the approach needed to ensure that carbon budgets are met. The Carbon Plan highlights that, if the UK is to meet its 2050 goal of cutting emissions by 80%, there must be significant changes in the way energy is produced in the UK. Electricity production will need to undergo decarbonisation through the development of renewable and nuclear energy sources. The successful implementation of Carbon Capture and Storage (CCS) is also considered to be key to meeting long-term GHG emission targets[9].

In addition to UK-specific legislation, as a member of the European Union (EU), the UK participates in EU action to tackle climate change. This includes meeting targets set out in EU legislation on emissions, energy efficiency and renewable energy.

Furthermore, the UK is a signatory to the international treaty set out by the United Nations Framework Convention on Climate Change (UNFCCC), the Kyoto Protocol.

It is clear, then, that significant changes will be required in the short and medium-term to the UK's energy generation and consumption if challenging targets, set to combat the impacts of climate change, are to be met.

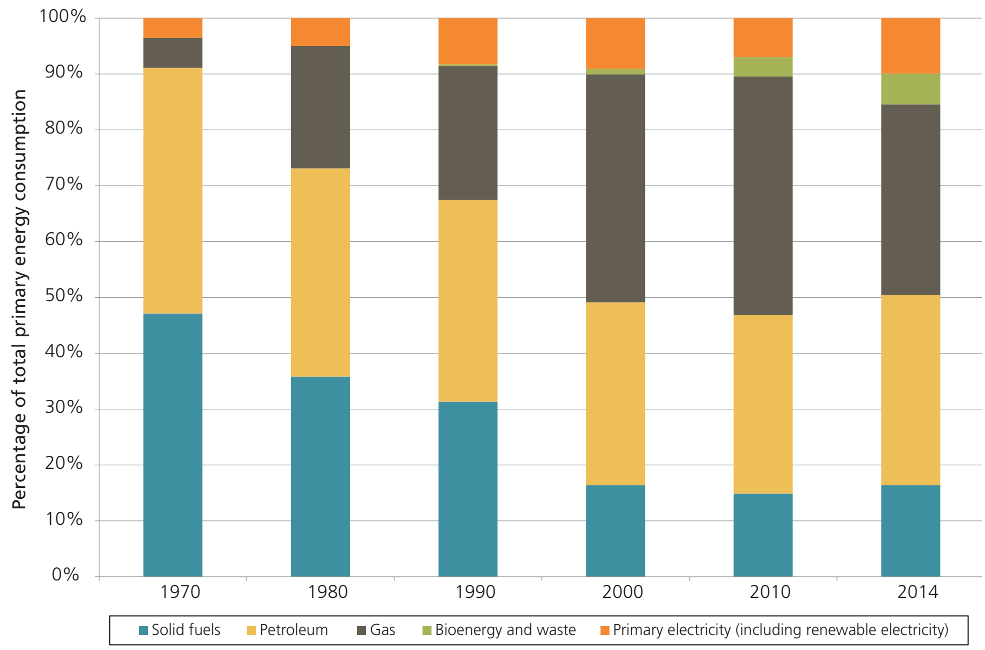
In order best to envisage what impact a UK shale gas industry will have on UK GHG emissions, it is necessary to understand what role gas will play in the UK. To do this we can examine the role played by gas in the UK's current energy mix and then review a range of scenarios from global, government and other organisations as to how they envisage that energy mix changing in the coming decades.

> "The Climate Change Act 2008 established a framework to develop an economically credible emissions reduction path and includes a target of reducing greenhouse gas (GHG) emissions by at least 80% by 2050."

Gas in the current UK energy mix

In order to assess fully the potential climate impact of the introduction of shale into the UK's energy mix, we first must examine the UK's current energy mix. In 2014, total UK overall energy consumption in primary energy terms (i.e. fuels obtained directly from natural resources – coal, oil and gas) was 193.4Mtoe. Mtoe or million tonnes of oil equivalent is a common unit of measurement which enables different fuels to be compared and aggregated. A tonne of oil equivalent (toe) is a unit representing energy generated by burning one metric tonne (1000 kilograms or 7.4 barrels of oil), equivalent to the energy obtained from 1270 cubic metres of natural gas or 1.4 metric tonnes of coal. This is the lowest since before 1970.

Fig.2. Total primary energy consumption by fuel, UK, 1970 to 2014



This graph shows the amount of five types of fuel used directly for consumption prior to any loss of energy via conversion or transformation process.
Source: DECC- https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/449102/ECUK_Chapter_1_-_Overall_factsheet.pdf.

Since 1970, the overall final fuel mix in the UK has significantly changed from solid fuels; diminishing from 45.0 Mtoe to only 2.6 Mtoe in 2014, largely replaced by gas which grew from 14.4 Mtoe in 1970 to 40.2 Mtoe in 2014.

Data from January to March 2015, reveals that 25% of the UK's electricity is produced from gas – natural gas makes up 24.2% of this 25%. The remaining 75% of electricity is produced by coal (31.3%), nuclear (19.1%), renewables (22.3%), oil and other sources (2.3%) respectively[10].

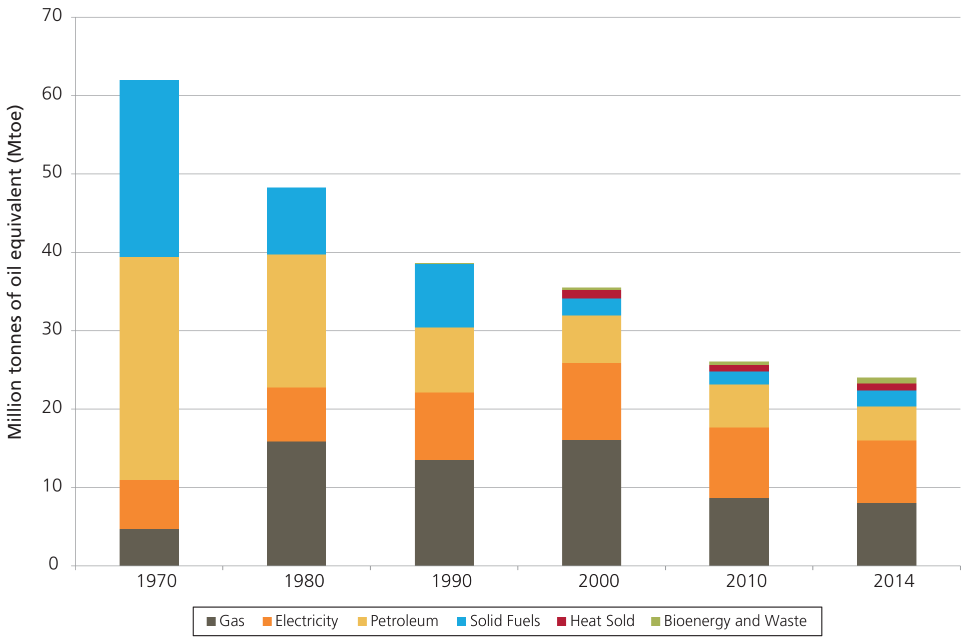
Even more gas is used for heating. Nearly half of the total energy used in the UK is used for heating of one sort or another. Industrial heat use alone accounts for 20% of all UK energy[11].

Gas central heating makes up the majority of household heating in the UK. In 2010, 85% of homes were heated by gas, 9% by electricity, 4% by oil and just over 2% used alternative fuel sources such as solid fuel (e.g. coal or wood) or liquefied petroleum gas[12]. Domestic heating equipment represents a substantial investment by householders and is expected to operate for about 15 years.

Of the total natural gas consumed in the UK in 2011, 52% was used to provide heat for buildings and industry. This compares to 34% burned in power stations to make electricity[13].

Gas is also an essential raw material in a raft of manufacturing industries (e.g. chemicals, fertilisers, hydrogen manufacture, and plastics), accounting for about 10% of all natural gas produced[14]. Fertiliser manufacture, which relies on natural gas, is one of the cornerstones of the global farming industry. And of the feedstock required for the UK chemicals industry, 13%, or 512 thousand toe of gas, was also used in 2012[15].

Fig.3. Industrial final energy consumption by sub-sector, UK (1990 to 2014)



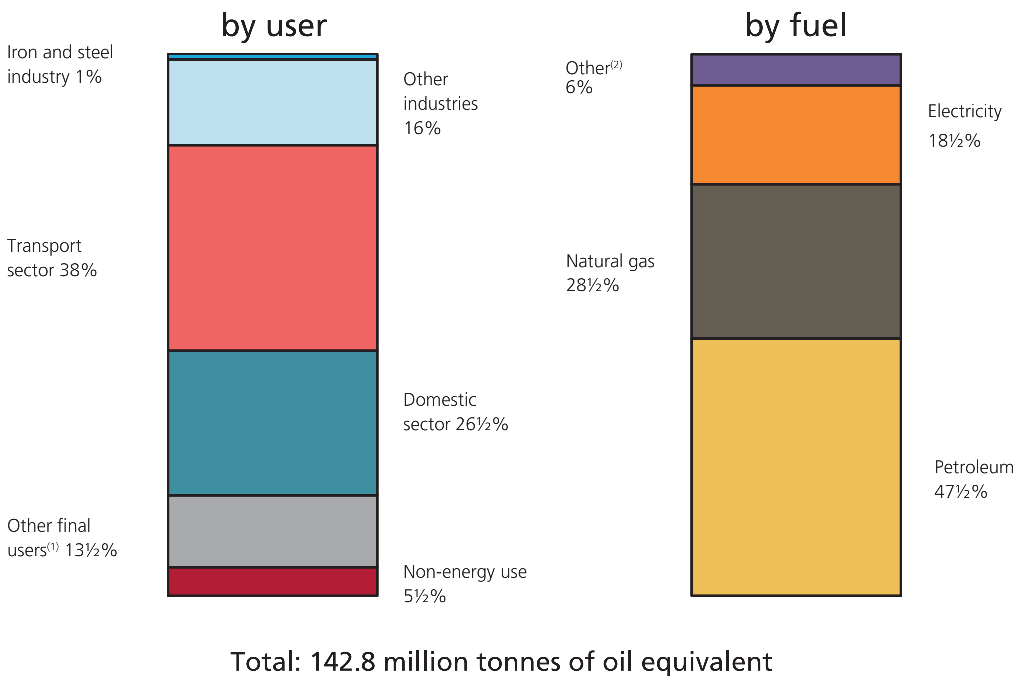
Source: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/449108/ECUK_Chapter_4_-_Industrial_factsheet.pdf

The UK's final overall energy consumption in 2014 was 142.8 Mtoe. Of this the transport and domestic sectors were the two largest consumers (38% and 26.5% respectively). Petroleum liquids and natural gas were the two largest energy sources (47.5% and 28.5% of the total usage respectively). 86% of the petroleum liquids in the UK in 2014 were used by the transport sector and 60% of the gas was used in the domestic sector. In total, in 2014 fossil fuels accounted for 84.5% of the UK's energy supply.

Combined Heat and Power (CHP) is a useful means of reducing emissions by improving energy use efficiency. Heat is a by-product of the generation of electricity. In CHP the waste heat is captured and used for local heating. In 2014, CHP accounted for around 6.0% of the total electricity generated in the UK and around 8.5% of UK gas demand[16].

Fig.4. Graphs displaying the total energy use in the UK in 2014 by end user and by fuel type.

(From Department of Energy and Climate Change, 2015).



(1) Includes services and agricultural sectors.
(2) Includes coal, manufactured fuels, renewables & waste, and heat sold.

Imported energy

The UK imports coal, natural gas, crude oil and petroleum products. For almost a decade, the UK was a net natural gas exporter, and then in 2004 it again became a net importer as gas consumption rose and production declined. Similarly, it became a net importer of petroleum products in 2013[17]. These products come from a number of countries.

Considering UK use of natural gas only, 46% presently comes from the North Sea and the remainder is imported[18]. The UK imports gas from Norway (58% of imports), the Netherlands (16%) and Belgium (7%)[19]. The remaining 20% of imported gas is liquefied natural gas (LNG), mainly imported from Qatar[20].

In 2013 coal imports increased by 10.1% from 2012 levels, to their highest level since 2006. However electricity generation demand for coal fell by 8.8% and coal stock piles increased by 10.9%[21]. Coal is mainly imported from the US (25% of imports), Russia (41% of imports) and Colombia (23% of imports).

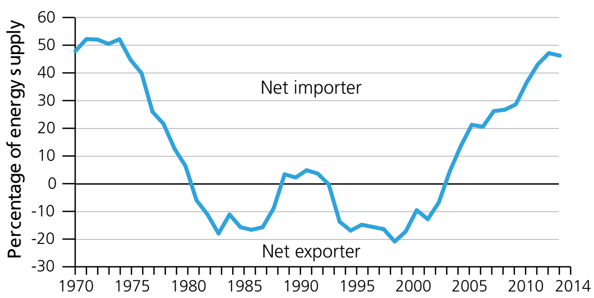
Crude oil is mainly imported from Norway (40% of imports), with other Organisation of Petroleum Exporting Countries (OPEC) accounting for 36% of imports[22]. The fuel for nuclear power stations is imported from Canada and Australia[23].

Since 1999, when UK energy production peaked mainly due to the growth of oil and gas, there has been a sharp rise in fossil fuel imports; over this period imports have more than doubled[24].

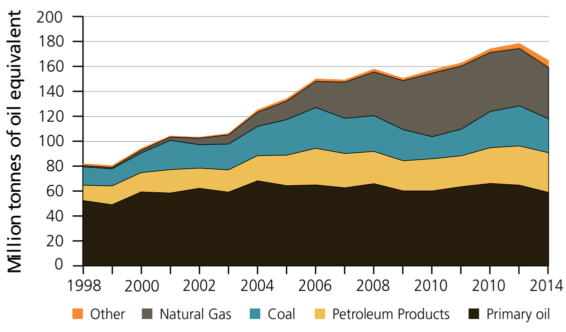
In 2013, the UK recorded the highest level of imported energy since 1974 owing to an ongoing decline in domestic oil and gas production. This meant nearly half of the UK's net energy supply came from imports including coal, manufactured fuels, crude oil, and gas[25].

Fig.5.

Import dependency, 1970 to 2014



Key sources of imports, 1998 to 2014



Source: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/449067/ UK_Energy_in_Brief_2015.pdf)

Renewable energy in the UK energy mix

In order to meet our climate change commitments as a nation, the UK's energy future has to be in renewables and low carbon technologies.

In the context of the debate around shale gas in the UK, it is useful to ask two questions:

- Is it feasible for renewables to meet the UK's short term energy needs?
- Will the introduction of a shale gas industry into the UK improve or worsen the UK's ability to move to a low carbon future?

We recognise that the answer to the second question may be more political than scientific – but if our starting point is that the development of a shale gas industry must enable, rather than inhibit, the transition to a low carbon emissions future then this is something which should be considered. Of course one of the other important factors in the medium term will be the need for a substantial increase in the energy efficiency of homes and buildings across the country.

Renewable energy use in the UK

Overall, renewable sources provided 7.2% of the UK's total primary energy requirements in 2014.

Fig.6. Electricity supply by fuel type in 2012 and 2013.

(From Department of Energy and Climate Change, 2014c).

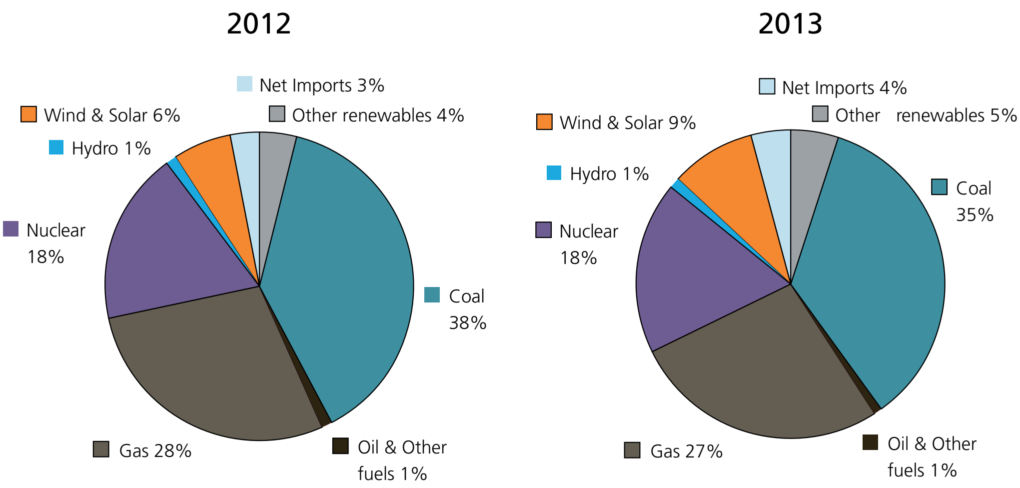


Figure 6 highlights the need to distinguish between renewables as a growth area for electricity generation and renewables as a contributor to the supply of total energy needs in the UK which, as outlined above, encompass far more than simply electricity.

Renewable energy use in the UK grew by 21% between 2012 and 2013. The 2013 contribution to the energy mix provided by renewable energy sources was split as follows: bioenergy, including fuels derived from wood, wood waste, and other by-products from a variety of agricultural processes, (70.5%); wind (21.8%); hydro-electric (3.6%); solar PV and active solar heating (3.3%).

Of the 11.2 million tonnes of oil equivalent (Mtoe) of primary energy use accounted for by renewables, 8.4 Mtoe was used to generate electricity, while only 1.7 Mtoe was used to generate heat, and 1.1 Mtoe was used for road transport. In other words, of 11.2 Mtoe of renewable energy, 75% was used for electricity generation, 10% was used for road transport and the remaining 15% was used for heating[26]. Renewables' share of electricity generation has increased to 22.3% in the first quarter of 2015, helped largely by increased capacity in wind and solar.

Between 2012 and 2013[27] the capacity to generate electricity from renewable energy sources increased by 25%. Specifically, hydroelectric power generation decreased by 10.7% due to reduced rainfall while electricity generated by wind power increased by 42% due to increased capacity[28].

Challenges facing the renewable energy industry

The scenarios below set out how the renewable energy sector might be grown to meet the UK carbon commitments for 2050. The scenarios favour a long term evolutionary approach rather than a short term revolution, as there are number of challenges that need to be overcome as the contribution renewables make to the energy mix increases. These include:

Investment in infrastructure: The national electricity grid arose from putting power stations close to the sources of energy, which were originally coal mines. The grid infrastructure is in need of investment and there is an opportunity for the upgrade to optimise the development of the energy resources of the future, allowing areas with high resource potential both onshore and offshore to be grid connected. However, this investment can only cope with a fraction of the wind, tidal and wave energy that is potentially available[29]. It should also be noted that the visual impact of bigger transmission pylons can be a major public concern. For the future, offshore transmission lines are being considered which have much less visual impact and should be easier to consent. They have the additional potential to provide better connectivity with Scandinavia, so that excess power generated in the UK can be exported to Scandinavian hydro power schemes and re-imported when UK production is low. However, such schemes require massive investment and will take time to implement.

Investment in projects: Investors only have a limited amount of funds available and so need to finish one project and start to receive an income stream to free up capital for further investment. They also need to be re-assured that the projected economics of renewable projects are indeed viable.

Intermittency and infrastructure: Studies have shown that there is a potential constraint on the amount of renewable energy that can be used to meet electricity demand due to the intermittency of power generation e.g. where would we get our electricity from on a windless day? We have seen how smart grids can help meet this challenge. A recent report by Pike Research[30] forecasts that during the period from 2010 to 2020, cumulative European investment in Smart Grid technologies will reach €56.5 billion, with transmission accounting for 37% of the total amount. The report demonstrates that by 2020 almost 240 million smart meters will have been deployed in Europe.

Other options are also available, such as the use of very large capacity redox batteries, Vehicle-to-Grid applications for bridging short term demand, the growth of demand side management from the development and use of smart appliances that only use energy when it is available, and energy storage technologies. However, many of these solutions are still under development.

In addition as with most proposals for energy development, there are also social barriers to the growth of the renewables sector in the UK. Public perception research has, for example, shown widespread support for the idea of renewable energy, yet at the local level, planning applications for developments are often opposed[31].

So whilst the growth of renewable energy is now becoming well established, the technical and economic constraints favour a long approach to full implementation in the short (to 2020) and medium term (2030). Even in the longer term (2050) there are some gaps that will need to be filled with other energy resources such as nuclear and some fossil fuels, mainly gas. This is why, later in this report, we discuss how essential it will be to ensure that Carbon Capture and Storage (CCS) is developed for any such gas use, to remove carbon to the greatest possible extent.

In the National Grid's 2015 projection of the UK's Future Energy Scenarios[32], renewable energy supplies 11-30% of the annual power demand by 2030. Even in the best case scenario, the National Grid does not consider that renewables can meet all energy demand in the short term. The Task Force is convinced that while renewables, nuclear, and other low carbon sources represent the future for the UK's energy mix – and that the development of a feasible UK low carbon sector should be encouraged – it is simply not possible for renewable energy sources to meet most or all of UK energy demands in the short and medium term. The questions then become:

1. What role will gas play in supplying the UK's short and medium-term needs?
2. If gas is needed, how much gas can be generated from renewable resources?
3. If there is a need for gas derived from fossil fuels, is there a role for shale gas and what impact, if any, will the development of a shale gas industry have on emissions?
4. Will the development of a shale gas industry undermine the renewables and low carbon industry and if so can this effect be mitigated?

"Even in the best case scenario, the National Grid does not consider that renewables can meet all energy demand in the short term."

Estimated future UK energy mix

It is, of course, difficult to predict exactly the future energy mix of the UK. The Task Force is however, interested in establishing whether there is a likelihood and need for gas to play a significant role in the future and for how long. To this end we have reviewed a series of forward-looking energy scenarios from a range of disparate organisations.

Many organisations - public sector, academic, civil society, industry - have published scenarios of how the energy sector might change between now and 2050. All – including those by groups such as WWF and Greenpeace – accept that gas will continue to play a role in the energy mix until at least 2050. However, scenarios differ widely on how much gas will be used in 2050, globally and in the UK, and on the pathways between 2015 and 2050.

Different organisations have looked either at global energy use or UK-specific needs:

Global gas use

The International Energy Agency (IEA) publishes an annual report on Energy Technology Perspectives. The 2015 report includes a scenario of energy use through to 2050 which would keep global warming within 2 degrees. Total global energy use in 2050 would be 17% higher than in 2015.

WWF worked with the energy consultancy Ecofys on a scenario in which total global energy use will be 15% lower in 2050 than in 2005. Global energy use in 2050 is projected to be 100% renewable in 2050. The WWF/Ecofys scenario envisages that gas will provide the following proportions of total global energy use:

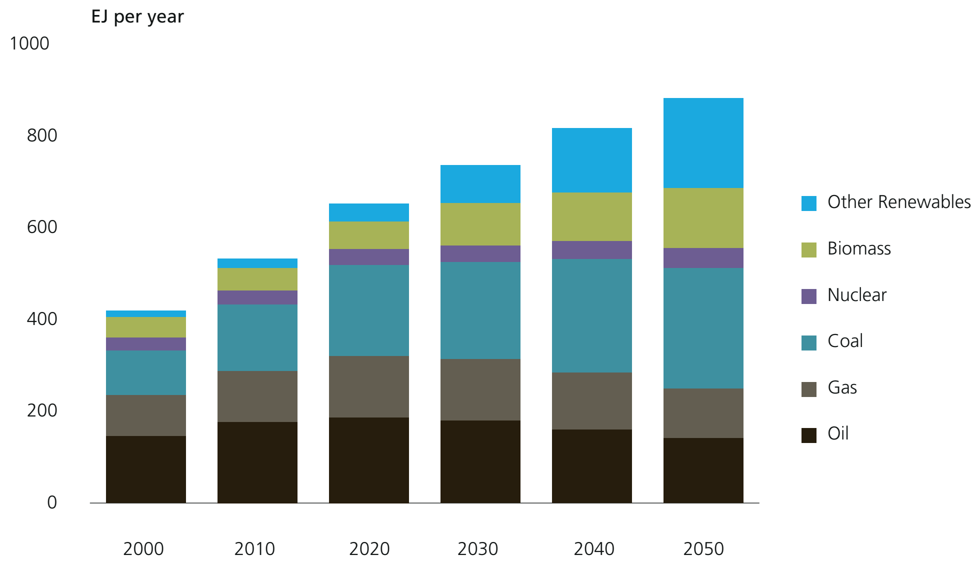
Year	Percentage of total energy use
2020	36%
2030	33%
2040	19%
2050	0%

WWF/Ecofys scenario

Shell's 2015 scenario 'Blueprints' envisages a substantial increase in global gas use between now and 2050, although by 2050 gas consumption is back down to approximately current levels. In their model, (CCS) applied to gas generation has been widely deployed.

BP does not produce scenarios. Instead, it publishes predictions of future global energy trends. Its Energy Outlook 2035 predicts that global energy consumption will increase 37% from 2013 to 2035. Gas will be the fastest growing of the fossil fuels, increasing on average 1.9% a year[33].

Fig.7. Primary energy by source



Biomass includes traditional renewables such as wood, dung, etc.

UK gas use

Turning to predictions of UK gas use, the UK Energy Research Centre (UKERC) published a report in 2013 on 'The UK energy system in 2050: Comparing Low-Carbon, Resilient Scenarios'.

In the lowest-carbon scenario, gas is not used for power generation after 2030, but continues to be widely used for heating. Total UK energy use is 7,500 petajoules (PJ) a year in 2050 (For electricity, 1 petajoule equals 277.78 million kWh.) Just under 2,000 PJ, 26.7%, of this comes from gas[34].

The Energy Technologies Institute (ETI), a partnership between government and energy companies, published a 'clockwork' scenario in February 2015.

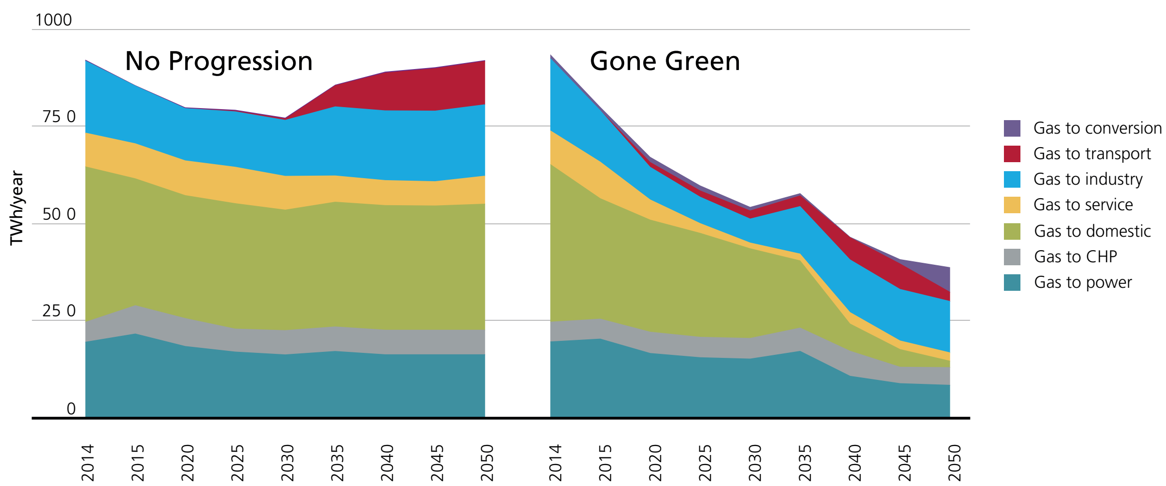
"Well-coordinated, long term investments allow new energy infrastructure to be installed like clockwork. The regular build of new nuclear, CCS plants and renewables ensures a steady decarbonisation of the power sector. National-level planning enables the deployment of large-scale district heating networks, with the local gas distribution network retiring incrementally from 2040 onwards.[35]"

Under 'clockwork', gas will still be playing a significant role in the UK energy mix in 2050, requiring a total of 35 billion cubic metres (BCM). This is made up from:

- 180 terawatt-hour (TWh, where 1 terawatt-hour is equal to a sustained power of approximately 114 megawatts for a period of one year) of space heating, out of a total of 380 TWh;
- 100 TWh of electricity, out of a total of 600 TWh;
- 100 TH of industrial energy, out of a total of 350 TWh.

National Grid's 'Gone Green' scenario, published in July 2015, envisages that in 2050 UK *"gas demand reduces to around half today's level in 2050, mainly due to the annual reduction in gas for heating in domestic and commercial application[36]."*

Fig.8. Gas demand: No Progression and Gone Green



Friends of the Earth (FoE) examined only the UK electricity sector – which accounts for less than a fifth of total energy use in the UK at present (though FoE would like to see heating and transport electrified). The FoE scenario envisages that in 2030 24% of UK electricity will be from gas (13% unabated, 11% abated)[37].

All scenarios expect gas to play a significant role, globally and in the UK, between now and 2050 and figures from the UKERC and Energy Technologies Institute suggest this gas requirement will range from 35 to 50 BCM per year.

The next question is to determine the extent to which this requirement for gas can be met from biogas sources (generated from waste, sewage and anaerobic digestion). In 2009, the National Grid reported that enough renewable gas was being produced to meet around 1% of the UK's total gas demand, however it was mainly being used to generate electricity rather than being injected into the grid[38]. More recently, in 2014, 5% of the UK's electricity production from renewables could be attributed to biogas[39] and a paper from the Energy Futures Lab at Imperial College shows that up to 5% of UK primary energy could be met by biogas, representing 14.4% of gas consumption[40].

It seems apparent, then, to the Task Force, that gas from fossil fuels is destined to play a significant role in the UK's future energy mix for several decades. It is also clear that, as the UK (and the world) reduces its climate impact from carbon emissions, there are two options. The first is to make the transition from carbon fuels to non-carbon fuels, or renewables. We have explained above why we see this as a long-term rather than short-term objective. The second option is to encourage an early transition from high carbon-emitting to lower carbon-emitting fuels.

Therefore it is worth comparing natural gas to coal.

> "All scenarios expect gas to play a significant role, globally and in the UK, between now and 2050 and figures from the UKERC and Energy Technologies Institute suggest this gas requirement will range from 35 to 50 BCM per year"

Natural gas versus coal

Last year the United Nations' Intergovernmental Panel on Climate Change (IPCC) concluded that, in order to reduce greenhouse gas emissions, countries should first reduce coal use, then reduce gas use[41].

Natural gas is the cleanest fossil fuel[42]. Compared to coal, the burning of natural gas produces half as much CO_2 and a quarter of the nitrogen oxides (NOx)[43] per unit of energy generated. It also produces negligible amounts of sulphur dioxide (SO2), carbon monoxide, black carbon, particulate matter and mercury[44]. However, natural gas is largely made up of methane, which is itself a powerful greenhouse gas. For the first 20 years following release into the atmosphere, methane traps 86 times as much heat as CO_2 does. However, methane stays in the atmosphere for a shorter period than CO_2. Nevertheless, over 100 years the atmospheric warming potential of methane is still 34 times that of CO_2. If methane is allowed to leak during the extraction and transportation of gas, the climate benefits of gas over coal can therefore disappear. (This is why we placed such importance in our second report on ensuring "green completions" for shale gas, where almost all the methane is contained.)

A forthcoming paper from the Sustainable Gas Institute, 'Methane and CO_2 emissions from the natural gas supply chain', has reviewed 424 academic, government, industry and NGO publications. The Sustainable Gas Institute concludes that, even taking account of emissions from the supply chain before the gas is burnt in a power station, "total GHG emissions would be 419–636 g CO_2 eq. / kWh electricity generated, with a central estimate of 496 g CO_2 eq. / kWh. This is well below typical GHG estimates of coal generated electricity of around 1,000 g CO_2 eq. / kWh." Gas is therefore only half as damaging to the climate as is coal. An increase in gas use at the expense of coal therefore contributes positively to climate protection.

> "Natural gas is the cleanest fossil fuel. Compared to coal, the burning of natural gas produces half as much CO_2 and a quarter of the nitrogen oxides (NOx) per unit of energy generated"

It has also been suggested[45] that, in addition to the reduction in GHG emissions, substituting natural gas for coal could bring additional quality of life benefits. A transition away from coal and towards more natural gas power stations would result in less soot in the atmosphere, and this could sharply reduce adverse health impacts on local communities.

In the United States (US), the increase in shale gas use since 2005, and the consequent reduction in coal use, has led to a fall in total greenhouse gas emissions; these were 9% lower in 2013 than they were in 2005[46]. (One other study from Maryland, has attributed some of the reduction to a decline in overall consumption[47].) Other studies have credited the development of the shale gas industry with providing a significant boost to the US manufacturing sector, increasing jobs and investment in other industries.

The Task Force will look at the potential impact on UK industry, and consequent economic impacts, in its final report.

The UK has already had a 'dash for gas', in the 1980s and 1990s. However, coal still provided 30% of the primary energy consumed in the UK last year – the same level as provided by gas[48].

So there is still potential for a major, and rapid, shift from coal to gas in the UK.

The Task Force is persuaded that:

- The UK's energy future – increasingly as we attempt to meet our challenging 2050 climate targets and completely at some point probably beyond that – lies in decarbonised energy generation
- However, the present state of technology, infrastructure and economics associated with the renewable energy generation industry sector in the UK simply does not make full implementation viable in the short and medium term.
- Natural gas will play a significant role in the UK's energy mix for the medium term, allowing the UK to reduce the amount of energy that is generated by coal and create a lower-carbon energy mix in the medium term. Natural gas will also continue to be an essential feedstock for a wide range of manufacturing industries essential to our quality of life.
- This move away from coal and towards natural gas should not come at the expense of investment into and development of a long-term renewable energy and nuclear technology.

The Task Force is convinced of the need for gas – we want to ask firstly, how the climate impact of gas in the UK can be minimised. This has led us to consider the future of carbon capture and storage (CCS) for the UK gas industry.

Carbon Capture and Storage (CCS)

CCS is the process by which CO_2 is captured, transported and injected into the subsurface in order to prevent it from escaping into the atmosphere. CCS can be used for both gas and coal. The lifecycle emissions for both differ – gas CCS ranges between approximately 90 – 245 gCO2e/kWh while coal ranges between approximately 140 – 245 gCO2e/kWh and 80-310 gCO2e/kWh, depending on whether the carbon is captured before or after combustion[49].

There are in fact three types of CCS, pre-combustion, post-combustion and oxy-fuel. The first involves capturing the carbon dioxide from an exhaust by absorbing it in a solvent, the second involves pre-treating the coal or gas to convert it to a mix of hydrogen and carbon dioxide, with the carbon dioxide separated, compressed and transported for safe underground storage. Oxy-fuel involves burning the coal or gas in oxygen instead of air, so that it produces a more concentrated carbon dioxide stream, enabling easier separation.

Although CCS has the potential to reduce emissions from gas and coal-fired power stations, there are nonetheless some lifecycle emissions of carbon[50]. The CCC therefore recommends that coal and gas CCS should be used in conjunction with other low-carbon energy sources and that gas CCS is at this stage looking more economically viable than coal CCS.

The Task Force supports this conclusion – and we believe that CCS should be developed as a priority to mitigate the climate impact of gas usage in the UK's future energy mix.

The UK Government is working with existing industry to create an economically-viable CCS industry by 2020[51]. DECC has also published a CCS Roadmap and a summary of policies and actions that the Government has implemented[52].

It is running a CCS commercialisation competition which will make £1 billion capital funding available for the design, construction and operation of the UK's first commercial-scale projects. Two projects have been shortlisted for the funding[53] – the White Rose, run by a consortium of Drax Power and BOC (Brin's Oxygen Company), based in Drax, North Yorkshire[54] and the Peterhead CCS Project in Aberdeenshire, Scotland.

Aside from the projects in the UK, there are a number of key CCS projects underway across Europe. The very first commercial carbon capture project, for example, was initiated in 1996 at the Sleipner gas field, Norway.

The Task Force believes that the development of a CCS industry should not be seen as a pre-requisite for initial exploratory drilling for shale gas in the UK. However, if a shale gas industry begins to develop at scale, CCS will become essential, and a CCS industry should be developed and grown concurrently.

There are of course a number of challenges that must be addressed in the development of large scale CCS projects, including those of cost and ensuring maximum efficiency in the power station.

However, we are disappointed that progress on the development of CCS projects here in the UK has been slow; and we urge the government to take a lead in ensuring a more rapid deployment of this technology. McGlade and Ekins[55] have pointed out, for example, that CCS for gas can make a significant difference to an effective low-carbon contribution by gas in the medium term.

> "... if a shale gas industry begins to develop at scale, CCS will become essential, and a CCS industry should be developed and grown concurrently."

Introducing a UK shale gas industry into the UK gas mix

In its second report, the Task Force made several recommendations around best practice for the establishment of a UK shale gas industry into the UK. For the purposes of this report we reiterate these recommendations and make assumptions that any industry will adhere to them – in particular, for the purposes below, we recommend the mandatory implementation of green completions, to prevent fugitive emissions of gas.

These recommendations can be found in full on our website.

Note that the potential economic impacts and viability of creating a UK shale gas industry will be examined in our fourth report, to be published in December. This report reviews only the climate change impacts.

Shale Gas versus conventional natural gas

The Task Force has examined the academic literature comparing the climate change impact of shale gas with both conventional natural gas and imported Liquefied Natural Gas (LNG). Several studies have explored the potential climate change impacts of shale gas versus conventional natural gas extraction.

These studies have led to a variety of views, according to different forms of measurement and assumptions made. Geographical disparities also play a role in assessing emissions. A full summary of the academic literature can be found as an appendix on our website.

For the purposes of this report it is worth noting that a number of studies have concluded that emissions from shale gas operations mean that the climate impact of shale gas is greater than that of conventional natural gas extraction[56]. These findings, however, are based on US studies, made before the implementation of green completions was mandatory. Other studies, making different assumptions about the processes in place have concluded that the climate impact of shale versus conventional natural gas extraction is neutral[57].

However, the forthcoming Sustainable Gas Institute paper, which reviewed 424 academic, government, industry and NGO publications, found that the same reductions of climate impacts applied not only to conventional gas, but also to shale gas, as long as Reduced Emission Completions (RECs) equipment is used when the well is closed. It states, "In the US this equipment is now compulsory, which implies that this is no longer a significant source of emissions. It is important to note that, as this process is the main differentiator between unconventional and conventional extraction, this report concludes that emissions are comparable as long as methane is captured rather than flared."

In addition, comprehensive pilot studies should be put in place at a small number of sites in the UK to establish very precisely what emissions sources exist and how they can be mitigated. The Task Force recommended in our second report that if a shale gas industry is to be licensed and developed in the UK, then the green completion process should be mandated. Provided this is done, then the impact on climate change from shale gas is likely to be similar to that of conventional gas extraction: in comparative terms, broadly neutral.

Shale Gas versus LNG

LNG has become the most popular method of transporting 'stranded' gas – i.e. gas that cannot be piped to market – to countries where it is required. The liquefaction process, however, involves cooling the gas to a temperature of approximately -160°C, and uses a lot of energy, as does providing the heat to turn the liquid back into gas.

In 2013 DECC published 'A study on the potential greenhouse gas emissions associated with shale gas production and use', by David Mackay and Timothy Stone[58]. This found that "the carbon footprint (emissions intensity) of shale gas extraction and use is likely to be in the range 200 – 253 g CO2e per kWh of chemical energy, which makes shale gas' overall carbon footprint comparable to gas extracted from conventional sources (199 – 207 g CO2e/kWh (th)) (see glossary), and lower than the carbon footprint of Liquefied Natural Gas (233 – 270g CO2e/kWh (th)) (Ibid). When shale gas is used for electricity generation, its carbon footprint is likely to be in the range 423 – 535 g CO2e/kWh (e), which is significantly lower than the carbon footprint of coal, 837 – 1130 g CO2e/kWh (e)."

Mackay and Stone were both employed by DECC at the time. And their paper accepted some industry assumptions on issues such a leakage rates. Nevertheless, the Panel accepts their conclusion that locally extracted, properly regulated shale gas is less damaging to the climate than LNG is.

DECC said in 2014 that it expects up to 45% of the global gas market to be LNG by 2020[59].

The British government also wants to expand UK LNG import facilities, as North Sea gas production declines.

The Task Force considers that the climate impact of liquefaction and shipping cannot be beneficial. If nothing else, the creation of a domestic shale gas industry will reduce the wider climate impact of the transportation and other energy costs of LNG.

Compatibility of shale gas and renewable or low-carbon technologies

In our previous two reports we have made comparisons with the United States (US), as it is a market that has developed a mature domestic shale gas industry. Alongside this they have also utilised a mix of policy tools at both the federal and state level including rebates, tax credits, grants, and loans to spur development of renewable energy. Like-for-like comparisons of the incentive programmes are not useful as they vary widely with respect to the amount of funding they provide, the total number of projects they support, and the length of time they are available. However, it is noteworthy that the development of a US shale industry has not curtailed the development of renewables, which grew to nearly 15% of total installed capacity and 13% of total electricity generation in the US in 2013.

In fact, in 2014, the US Department of Energy notes that Texas was the state with the greatest cumulative capacity to produce renewable electricity, (made up mainly from wind)[60], whilst also being a substantial producer of shale gas[61]. In 2014, wind generated over 20 percent of electricity used in three states — Iowa, South Dakota, and Kansas. The boost is due in large part to the wind production tax credit, or PTC, which covers wind projects that began by the close of 2014.

Some people have argued that the development of a shale gas industry will have a chilling effect on the development of renewable and other low carbon technologies which are essential if we are to meet the UK's climate change commitments. As we have explored above, any reasonable assessment of the medium term energy mix for the UK will have to include a proportion of gas use and shale gas has some benefits over some forms of imported gas, in terms of its climate change impact.

Shale gas can, we believe, provide a useful transition to a low carbon long-term future, and government policy should recognise that. In order, however, to ensure that this does not in any way endanger the development of new and innovative forms of low carbon energy generation, storage and distribution, we believe that government should commit to deploying the government energy-specific revenue derived from a developed shale gas industry to investment in research and development (R&D) and innovation in these fields.

"...in 2014, the US Department of Energy notes that Texas was the state with the greatest cumulative capacity to produce renewable electricity, (made up mainly from wind), whilst also being a substantial producer of shale gas."

Conclusions and recommendations

Based on the above, the Task Force is convinced of the following:

If the UK is to meet its long-term climate change commitments then a transition to renewable and low carbon technology energy sources will be necessary.

However the evidence is clear that it is not feasible to create a renewable and low carbon industry in the short term in the UK that can meet the UK's energy needs as a whole.

Therefore the Task Force concludes – in line with the thinking of relevant forecasting organisations – that there is a requirement for gas to play a significant role in the UK's energy mix in the short and medium term.

The evidence suggests that the impact of shale gas on the climate is similar to that of conventional gas and less than that of LNG.

If this is the case, based on the evidence outlined above, the Task Force is persuaded that, if properly regulated, implemented and monitored, shale gas should be explored as a potential gas source to meet UK energy needs. The Task Force also believes that everything possible should be done to minimise the climate impact of gas extraction in the UK.

Therefore we would encourage the Government to expedite the development of a CCS industry in the UK that would, ideally, grow concurrently with any shale gas industry.

In addition, the Task Force is convinced that for a shale gas industry to serve appropriately as a transitional fuel it is important that it is clearly demonstrated that this will not prohibit or slow the development of renewables and low carbon energy industry. We believe that government should commit to deploying the government energy specific revenue derived from a developed shale gas industry to investment in R&D and innovation in CCS and low carbon energy generation, storage and distribution.

Endnotes

[1] Department of Energy and Climate Change. (2015b). 2014 UK Greenhouse Gas Emissions, Provisional Figures. [Online] Available at: https://www.gov.uk/government/uploads/system/uploads /attachment_data/file/416810/2014_stats_release.pdf

[2] Committee on Climate Change. (2015b). The Climate Change Act and UK regulations. [Online] Available at: http://www.theccc.org.uk/tackling-climate-change/the-legal-landscape/global-action-on-climate-change/

[3] Committee on Climate Change, 2015b

[4] Department of Energy and Climate Change. (2011). UK Renewable Energy Roadmap. [Online] Available at:<https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48128/2167-uk-renewable-energy-roadmap.pdf>

[5] Committee on Climate Change. (2015h). Reducing emissions and preparing for climate change: 2015 Progress Report to Parliament. [Online] Available at: https://www.theccc.org.uk/publication/reducing-emissions-and-preparing-for-climate-change-2015-progress-report-to-parliament/

[6] Department of Energy and Climate Change. (2015a). 2010 to 2015 government policy: greenhouse gas emissions. [Online] Available at: https://www.gov.uk/government/publications/2010-to-2015-government-policy-greenhouse-gas-emissions/2010-to-2015-government-policy-greenhouse-gas-emissions#appendix-4-carbon-budgets

[7] Committee on Climate Change. (2015i). Making informed choices on climate change in 2015. [Online] Available at: https://www.theccc.org.uk/2015/05/27/making-informed-choices-on-climate-change-in-2015/

[8] DECC, 2015a

[9] DECC, 2011

[10] Statistics- National Statistics. Energy Trends Section 5: Electricity. [Online]. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/437802/Electricity.pdf

[11] Departement of Energy and Climate Change. (2013). The Future of Heating: Meeting the Challenge. [Online] Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/190149/16_04-DECC-The_Future_of_Heating_Accessible-10.pdf

[12] National Grid. (2014). UK Future Energy Scenarios; UK Gas and Electricity Transmission. [Online] Available at: http://www2.nationalgrid.com/uk/industry-information/future-of-energy/future-energy-scenarios/

[13] DECC, 2013

[14] Hughes, J. D. (2014). Drilling Deeper: A Reality Check on U.S. Government Forecasts for a Lasting Tight Oil & Shale Gas Boom. [Online] Available at:http://www.postcarbon.org/wp-content/uploads/2014/10/Drilling-Deeper_FULL.pdf

[15] Departement of Energy and Climate Change. (2013c). Digest of UK Energy Statistics 2013. [Online] Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/279523/DUKES_2013_published_version.pdf

[16] DECC, 2015a

[17] Energy Information Administration. 2014. UK became a net importer of petroleum products in 2013. [Online] Available at: http://www.eia.gov/todayinenergy/detail.cfm?id=16971

[18] Department of Energy and Climate Change. (2014d). UK Energy Statistics. [Online] Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/296183/pn_march_14.pdf

[19] Department of Energy and Climate Change. (2014c). UK Energy in Brief 2014. [Online] Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/350941/UK_Energy_in_Brief_2014_revised.pdf

[20] DECC, 2014c

[21] DECC, 2014d

[22] DECC, 2014c

[23] Cooper, J., Stamford, L. and Azapagic, A. (2014). Environmental Impacts of Shale Gas in the UK: Current Situation and Future Scenarios. Energy Technology. 2(12), 1012-1026

[24] DECC, 2015a

[25] DECC, 2014c

[26] DECC, 2014c

[27] DECC, 2014d

[28] DECC, 2014d

[29] The Highland Council. (2006). Highland Renewable Energy Strategy and Planning Guidelines Online]Available at: http://www.highland.gov.uk/downloads/file/1009/highland_renewable_energy_strategy_may_2006

[30] Pike Research. (2011). Smart Grids in Europe, Pike Research Cleantech Market Intelligence. [Online] Available at: http://www.pikeresearch.com/research/smart-grids-in-europe

[31] Public perceptions of renewable energy technologies: challenging the notion of widespread support. Demski, Christina 2011

[32] National Grid. (2015). UK Future Energy Scenarios; UK Gas and Electricity Transmission. [Online] Available at: http://investors.nationalgrid.com/~/media/Files/N/National-Grid-IR/reports/future-energy-scenarios-2015.pdf

[33] BP Energy Outlook 2035. (2015) [Online] Available at: http://www.bp.com/en/global/corporate/about-bp/energy-economics/energy-outlook/outlook-to-2035.html

[34] UK ERC (2013). The UK energy system in 2050: Comparing Low-Carbon, Resilient Scenarios.[Online] Availale at : http://www.ukerc.ac.uk/publications/the-uk-energy-system-in-2050-comparing-low-carbon-resilient-scenarios.html

[35] Energy Technologies Institute. (2013) The UK energy system in 2050: Comparing Low-Carbon,Resilient Scenarios. [Online] Available at: http://www.eti.co.uk/wp-content/uploads/2015/02/Options-Choices-Actions-Hyperlinked-Version-for-Digital.pdf

[36] National Grid. (2015). UK Future Energy Scenarios; UK Gas and Electricity Transmission. [Online] Available at: http://investors.nationalgrid.com/~/media/Files/N/National-Grid-IR/reports/future-energy-scenarios-2015.pdf

[37] Friends of the Earth. (2012b). Summary: A Plan for Clean British Energy. [Online] Available at: http://www.foe.co.uk/sites/default/files/downloads/electricity_mix_2030.pdf

[38] National Grid, 2009

[39] Department of Energy and Climate Change. (2014e) Chapter 6 Renewables 2014. [Online] Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/449426/Chapter_6_Renewables.pdf

[40] The prospects for biogas integration with fuel cells in the United Kingdom, Brandon et al 2015 (Unpublished)

[41] Intergovernmental Panel on Climate Change. (2014). Working Group 3, 5th Assessment Report 2014. [Online] Available at: http://www.ipcc.ch/report/ar5/wg3/

[42] American Gas Association. (2015). Environmental Benifits of Natural Gas. [Online] Available at: https://www.aga.org/environmental-benefits-natural-gas

[43] Jenner, S. and Lamadrid, A. J. (2013). Shale gas vs. coal: Policy implications from environmental impact comparisons of shale gas, conventional gas, and coal on air, water, and land in the United States. Energy Policy. 53(0), 442-453

[44] Jenner and Lamadrid, 2013

[45] Jenner and Lamadrid, 2013

[46] Broderick, J., Anderson, K., Wood, R., Gilbert, P., Sharmina, M., Footitt, A., Glynn, S. and Nicholls, F. (2011). Shale gas: an updated assessment of environmental and climate change impacts. A report commissions by the Co-operative and undertaken by researchers at the Tyndall Centre, University of Manchester. [Online] Available at: http://www.tyndall.ac.uk/sites/default/files/coop_shale_gas_report_update_v3.10.pdf

[47] University of Maryland. (2013). Greenhouse Gas Reduction in Marland: New State-Level Strategies For Changing Times. [Online] Available at: http://faculty.publicpolicy.umd.edu/sites/default/files/nelson/files/0000a_--_660_--_greenhouse_gas_full_report_october_8_final.pdf

[48] Department of Energy and Climate Change. (2014e) Chapter 1 Energy 2014. [Online] Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/447628/DUKES_2015_Chapter_1.pdf

[49] Committee on Climate Change. (2013). Reducing the UK's carbon footprint. [Online] Available at: http://www.theccc.org.uk/wp-content/uploads/2013/04/Reducing-carbon-footprint-report.pdf

[50] Committee on Climate Change, 2013

[51] DECC, 2015a

[52] DECC, 2014b

[53] Oil and gas – guidance. (2013). UK Carbon capture and storage: government funding and support. [Online] Available at: https://www.gov.uk/guidance/uk-carbon-capture-and-storage-government-funding-and-support

[54] White Rose. About White Rose. [Online] Available at: http://www.whiteroseccs.co.uk/about-white-rose

[55] McGlade, C., Ekins, P., Bradshaw, M. and Watson, J. (2015). Conditions for environmentally-sound UK shale gas development (UKERC: London). [Online] Available at: http://www.ukerc.ac.uk/publications/publications.html

[56] Stephenson, T., Valle, J. E. and Riera-Palou, X. (2011). Modeling the relative GHG emissions of conventional and shale gas production. Environmental Science & Technology. 45(24), 10757-10764; Hultman, N., Rebois, D., Scholten, M. and C., R. (2011). The greenhouse impact of unconventional gas for electricity generation. Environmental Research Letters. 6(4), 044008; and Karion, A., Sweeney, C., Pétron, G., Frost, G., Michael Hardesty, R., Kofler, J., Miller, B. R., Newberger, T., Wolter, S., Banta, R., Brewer, A., Dlugokencky, E., Lang, P., Montzka, S. A., Schnell, R., Tans, P., Trainer, M., Zamora, R. and Conley, S. (2013). Methane emissions estimate from airborne measurements over a western United States natural gas field. Geophysical Research Letters. 40(16), 4393-4397.

[57] Weber, C. L. and Clavin, C. (2012). Life cycle carbon footprint of shale gas: review of evidence and implications. Environmental Science & Technology. 46(11), 5688-5695;Stamford, L. and Azapagic, A. (2014). Life cycle environmental impacts of UK shale gas. Applied Energy. 134, 506-518.

[58] MacKay, D. J. C. and Stone, T. J. (2013). Potential Greenhouse Gas Emissions Associated with Shale Gas Extraction and Use. pp. 39

[59] Department of Energy and Climate Change. (2013b). Fossil Fuel Price Projections. [Online] Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/360598/DECC_2014_fossil_fuel_price_projections.pdf

[60] U.S. Departement of Energy. (2013). Energy Efficiency & Renewable Energy. [Online] Available at: http://www.nrel.gov/docs/fy15osti/62580.pdf

[61] Energy Information Administration. 2013. Shale gas provides largest share of U.S. natural gas production in 2013. [Online] Available at: http://www.eia.gov/todayinenergy/detail.cfm?id=18951

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