Pecyn dogfennau cyhoeddus

Y Pwyllgor Amgylchedd a Chynaliadwyedd

Cynulliad Cenedlaethol Cymru
National Assembly for Wales

Lleoliad:
Ystafell Bwyllgora 4 - Tŷ Hywel

Dyddiad:
Dydd Iau, 7 Mawrth 2013

Amser:
09:30

I gael rhagor o wybodaeth, cysylltwch â:

Alun Davidson
Clerc y Pwyllgor
029 2089 8639
Pwyllgorac@cymru.gov.uk

Agenda

1. Cyflwyniadau, ymddiheuriadau a dirprwyon

2. Nwy siâl a nwyeiddio - tystiolaeth gan UK Onshore Gas Limited (09.30 - 10.30) (Tudalennau 1 - 10)

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Gerwyn Williams, Cadeirydd

3. Nwy siâl a nwyeiddio - tystiolaeth gan UCG Association a Clean Coal Limited (10.30 - 11.30) (Tudalennau 11 - 17)

E&S(4)-08-13 papur 2 : UCG Association
E&S(4)-08-13 papur 3 : Clean Coal Limited

Julie Lauder, Prif Weithredwr UCG Association
Dr Shaun Lavis, Uwch Wyddonydd Daear, Clean Coal Limited

4. Cyfoeth Naturiol Cymru (11.30 - 12.30)

Dr Emyr Roberts, Prif Weithredwr
Yr Athro Peter Matthews, Cadeirydd

Egwyl (12.30 - 13.15)

5. Nwy siâl a nwyeiddio - tystiolaeth gan Ganolfan Tyndall (13.15 - 14.00) (Tudalennau 18 - 54)
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Yr Athro Kevin Anderson, Dirprwy Gyfarwyddwr
Dr John Broderick, Cymrawd Ymchwil

6. Nwy siâl a nwyeiddio - tystiolaeth gan Cyfeillion y Ddaear (14.00 - 15.00) (Tudalennau 55 - 68)
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Gareth Clubb, Cyfarwyddwr, Cyfeillion y Ddaear Cymru
Tony Bosworth, Uwch Ymgyrchydd Newid yr yr Hinsawdd ac Ynni
Naomi Ludhe-Thompson, Ymgynghorydd Cynllunio

7. Papurau i'w nodi (Tudalennau 69 - 70)
Cofnodion y cyfarfod a gynhaliwyd ar 21 Chwefror

Environment and Sustainability Committee

E&S(4)-08-13 paper 1

Shale gas and gasification - Evidence from UK Onshore Gas Ltd

1 **INTRODUCTION**

UK Onshore Gas Limited is the holding company of Coastal Oil and Gas Limited and UK Methane Limited. Coastal Oil and Gas Limited and UK Methane Limited hold PEDL (Petroleum Exploration and Development Licences) that have been awarded by DECC and allow the companies to explore for, bore for and get all hydrocarbons within those licence areas on an exclusive basis. Initially the focus of the companies was Abandoned Mine Methane taken from the former mine workings in the coal field and the Coal Bed Methane (CBM) from unworked areas of coal. In recent years the focus has changed to Unconventional Gas exploration in the form of shale gas and Coal Bed Methane. Coastal Oil and Gas Limited are also reviewing the potential for conventional gas in the Devonian Sandstones. The difference between unconventional gas and conventional gas is mainly how the gas is stored in the resource, the constituents of the gas are broadly the same i.e. largely methane (90%+) with some propane and ethane, in essence the same as North Sea gas. Conventional gas is generated from source rocks then the gas is trapped by a seal of other rocks. When a conventional gas source is drilled into the gas will come out under it's own pressure, the pressure being mainly dependent on depth. Unconventional gas, however, such as shale gas lies in mudstones and shales usually of low permeability and the gas has to be coaxed out of the ground. This is achieved by directionally drilling in the shales and mudstones and stimulating the ground either by using Nitrogen or water to create microscopic cracks thereby creating conduits for the gas to migrate back to the well bore and then to the surface where it is transported to market.

2 BACKGROUND TO INDUSTRY

The Petroleum (Production) Act 1934, as amended by Section 18 of the Oil and Gas (Enterprise) Act 1982 and others, provided for exploration of and production of onshore hydrocarbon resources. The Act vests ownership of petroleum underground in the Crown and empowers the Secretary of State for Energy to grant to such persons as he thinks fit, Licences to search, bore for and get petroleum.

The main objectives of the Licensing regime are to further the general Government policy of establishing the extent of the Country's indigenous hydrocarbon resources. The regime is also intended to provide a framework within which the search for and production of oil and gas onshore can be undertaken in a safe and orderly manner, and to provide a satisfactory balance of safeguards and rights between the Government and Licensees. This regime also maintained unproved acreage on short licence and provided a satisfactory longer-term licence for production.

The Petroleum (Production) (Landward Areas) Regulations 1995, introduced on 30 June 1995 comprises a single exclusive and unitary licence now known as a "PEDL", Petroleum Exploration and Development Licence. Licences are awarded for an initial period of six years although some flexibility may be allowed and then, if required and commitments are met, for further terms. Additional acts were passed in 1998 and 2007 to provide further and better governance.

Planning permission will be required before the deep drilling of exploratory wells can be undertaken. DECC will require proof that the necessary planning permission has been obtained for deep drilling and production also that all necessary consultations have been completed before authorising commencement of these activities.

There had been considerable debate between the industry and the former British Coal, as to the ownership of the gas, in this case Coal Bed Methane and Coal Mine Methane. For the avoidance of any doubt Coal derived Methane was confirmed as a Crown Mineral (hydrocarbon) by virtue of Section 9 of the Coal Industry Act 1994.

Forecast future energy shortages are putting pressure on unconventional gas producers to develop suitable fields.

3 LICENCE AREAS

The licences are split between UK Methane and Coastal Oil and Gas Limited.

Coastal Oil and Gas Limited hold the licences:-

- PEDL 100
- PEDL 216
- PEDL 217
- PEDL 218
- PEDL 219
- PEDL 220

UK Methane Limited holds the licences:-

- PEDL 148
- PEDL 149
- PEDL 214
- PEDL 215

Figure 1: Location of PEDL Licences

The licence area in South Wales extends from west of Swansea along the M4 corridor to Cardiff West Services. The licence area covers 1,060km^2 (260,000 acres) these are split along the national grid lines generally on a 10km x 10km basis. The more recent licences are cut off by the low tide make, however, the older licences are along the high tides mark.

The companies also hold licences in Somerset and Kent

4 RESOURCE TARGETS

There are a number of resource targets in the South Wales area that have been identified as having the potential to produce gas. In the coalfield there have been identified 142 separate coal seams in the total sequence; from this sequence 15-20 seams have been recognised to have the best potential to produce Coal bed Methane. Underlying the coal basin is up to 800m of Namurian Measures that are made up of sandstones and shales. Below the Namurian Measures lie Limestones, then the Lower Limestone Shale which is another good shale gas target. The Devonian Sequence below the Lower Limestone Shales is dominated by sandstones and is a potential conventional gas target where the gas has been trapped in pores of the sandstones. Underneath the Devonian strata is older rocks of Silurian and Ordovician age, these rocks are producing gas in other parts of Europe especially in Poland and also have the potential to produce gas in South Wales.

The Namurian sequence has been identified primarily from two boreholes drilled to look for the possibility of Oil. The first was drilled in 1942 by Anglo American as part of the war effort outside Tonyrefail; this identified over 990ft of dark shales in the Namurian. The Second borehole was drilled just north of Maesteg, near Coegnant Colliery, in 1972-3 by Cambrian Exploration to a depth of 2,648m. We have been able to use the records of these boreholes and have tested samples from the Cambrian borehole and other boreholes drilled by the British Geological Survey (BGS) to confirm the possible gas producing targets. Analysis of thee samples at Aberdeen Laboratories confirmed the shales are good targets and are similar to the Barnett Shales in the USA.

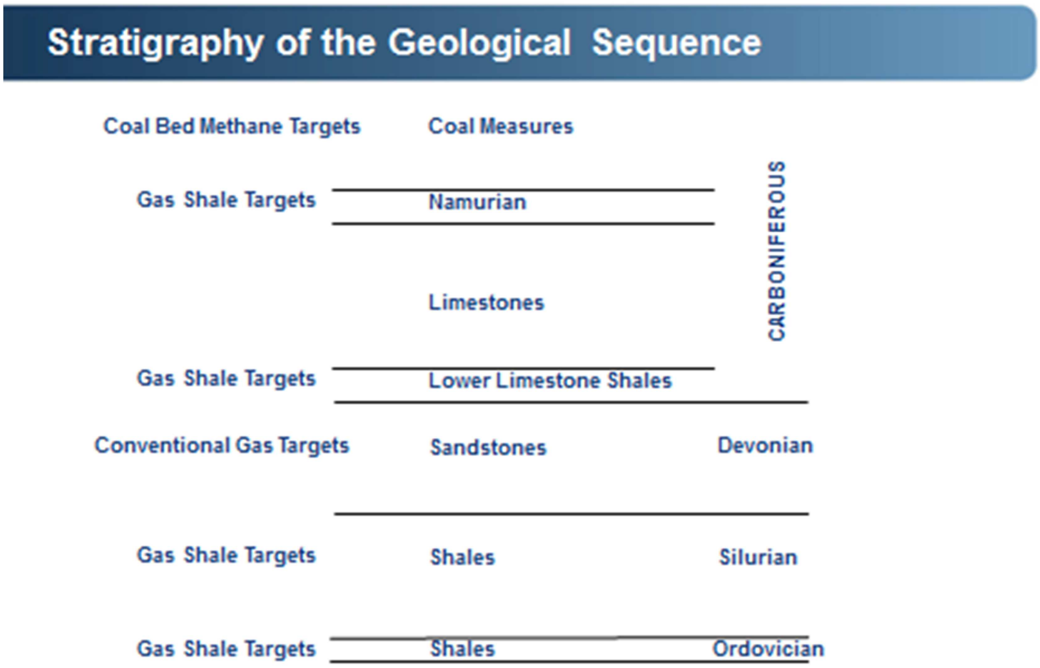

Figure 2: Gas Targets in the Geological Sequence

5 WORK TO DATE

Coastal Oil and Gas Limited and UK Methane Limited have developed a large geological model of the South Wales area using data taken from the mine working and numerous previously drilled boreholes. Onto this model surface constraints have been added to show the location of SSSI's, houses, utilities to locate the ideal locations for drilling exploration wells.

In 2008 Coastal Oil and Gas Limited drilled 3 exploration wells on PEDL100 to explore for CBM potential in Aberavon near TATA steel works, Llangeinor near the Georgia Pacific Paper mill and in Pencoed near to the Rockwool Factory. These exploration wells were targeted to provide lower cost energy to major industrial users.

In 2011 UK Methane drilled exploration wells on PEDL 148 and PEDL 149. The borehole on PEDL148 was drilled near Banwen on the northern crop of the coal field to confirm the geo-stratigraphy and to look at the potential in the Namurian for shale gas. The borehole on PEDL 149 was drilled on the site of the former St Johns Colliery.

A further production borehole has since been drilled at Llangeinor to 650m through a 3.5m coal seam. A planning approval is in place to generate electricity on site in an existing farm building and allows export of electricity to the grid. A field development plan has been approved by DECC (only the second in the UK) for a 3.87km^2 gas field. The Llangeinor field has a GIIP (Gas Initially In Place) of 33.7 bcf (billion cubic feet) with a potential recovery of 16.9 bcf. The field has been defined in the Westphalian Coal Measures as a Coal Bed Methane play.

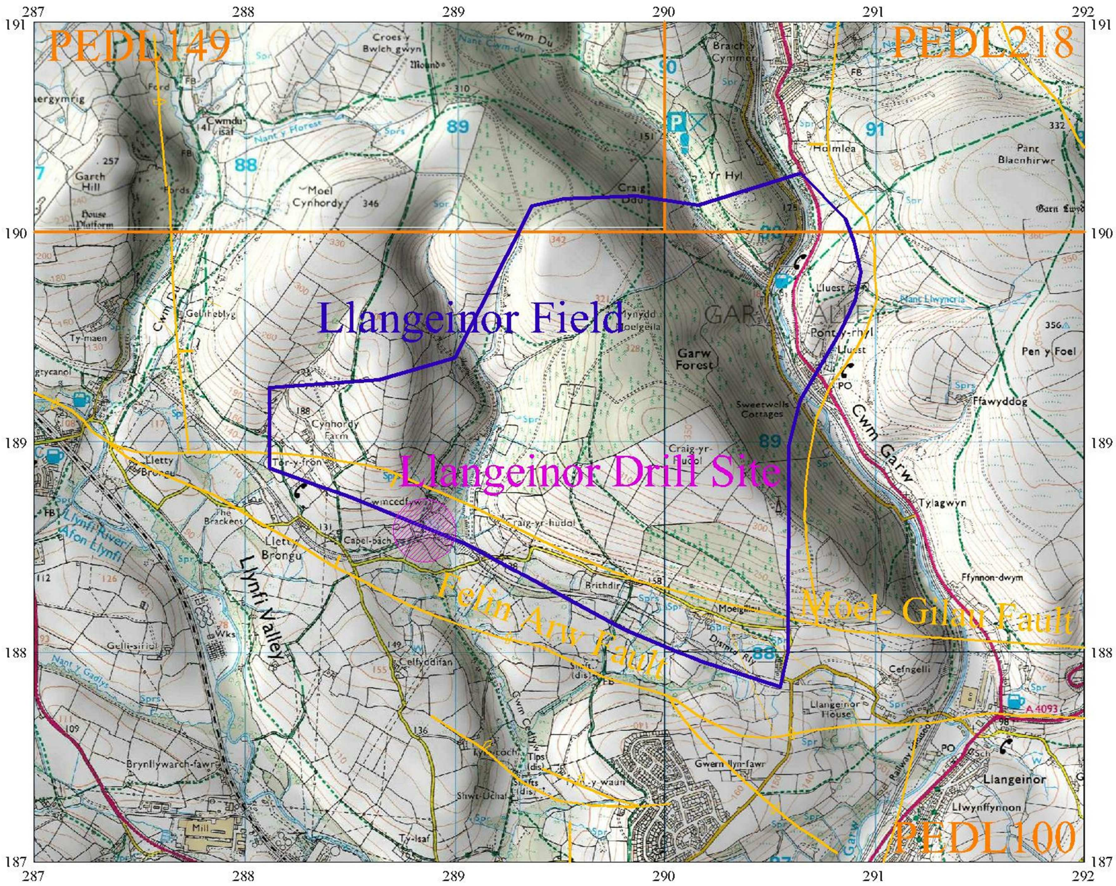

Figure 3: Location of the Llangeinor Field

Figure 4: Drilling of Llangeinor 2 borehole

UK Methane Limited have recently had approved by Bridgend Council the planning for the drilling of 3 boreholes into the abandoned mine workings at the former St Johns Colliery near Maesteg. This is to drill into the void created by the mine workings in the 2ft9 seam and to utilise the gas for onsite power generation. This scheme can be used as a model to look at other abandoned mine methane projects across South Wales.

Previously in South Wales, (1982) Shell shot three seismic lines across the Vale of Glamorgan. These have been utilised in our geological modeling and indicate potential for conventional gas resources in The Vale of Glamorgan.

6 GROUND STIMULATION

At this stage, boreholes are for exploration with no ground stimulation (fracing) planned. Any ground stimulation will be subject to additional planning applications once the information derived from the exploration boreholes has been analised.

The science behind ground stimulation has rapidly evolved and the technology utilised has UK central government approval. Following the exploration program the licences will be evaluated for the most suitable area for any production trials. The location of any appraisal/production site will be selected in conjunction with the Environment Agency and local planning officers.

7 PROVEN RESOURCE

The unconventional gas resources in South Wales have been reviewed by independent assessors. The potential shale gas reserves in the Namurian Measures on the companies South Wales licences have been reviewed by RPS in Dallas, USA.

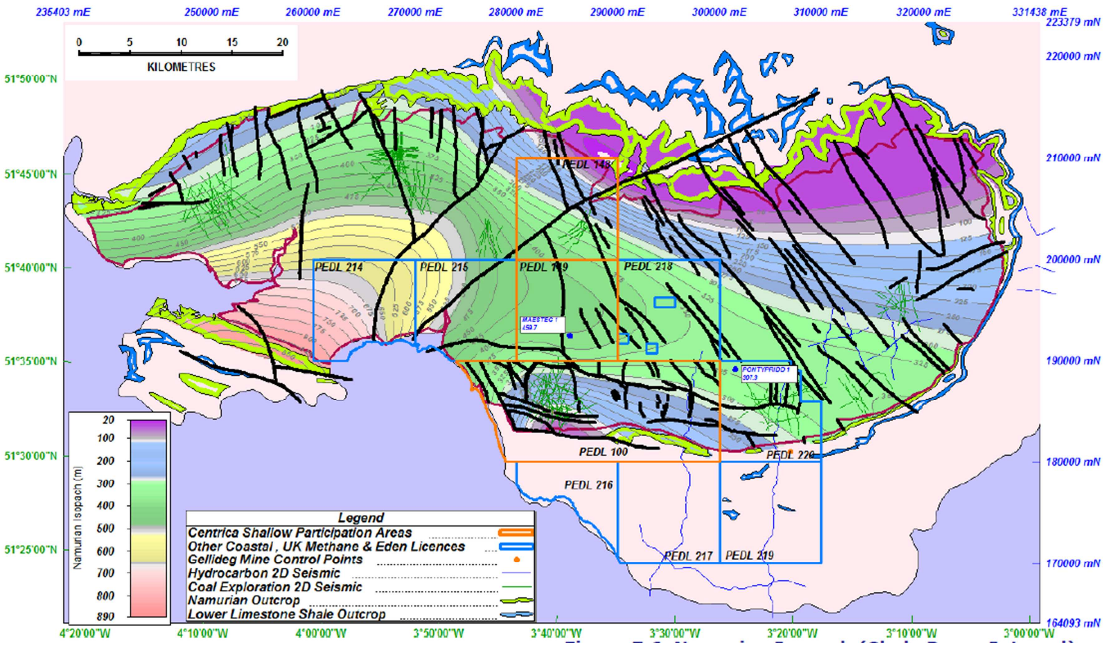

Figure 5: Thickness of Namurian Strata

The RPS report on available data on the Namurian strata indicates gas initially in place (GIIP) of 49,870 bcf (49.87 tcf).

At this stage we have not assessed the potential resources in the other shale gas targets of the Lower Limestone Shale, Silurian and Ordovician. The planned exploration boreholes will sample and test these intervals to prepare reserve calculations. Following further exploration boreholes the Namurian resource is expected to increase substantially. An estimated recoverable recourse of 18tcf+ has been indicated in the report and by way of comparison, the whole of the UK uses some 3tcf per annum.

The Coal Bed Methane resource in South Wales has been assessed by a second consultancy company (RISC of Perth Australia) who have calculated an unrisked GIIP volume of 1,651bcf

(1.65tcf). Additional exploration boreholes that are planned will allow better accuracy and an expected increase in these figures.

8 POSSIBLE REOURCES

There have been a number of studies into the global reserves of shale gas. In 2010 the BGS estimated the UK's onshore shale reserves at 5.3 tcf. A recent study, that is yet to be published by BGS, is suggested to say that possible reserves in the UK are over 1,000tcf. This has yet to be confirmed.

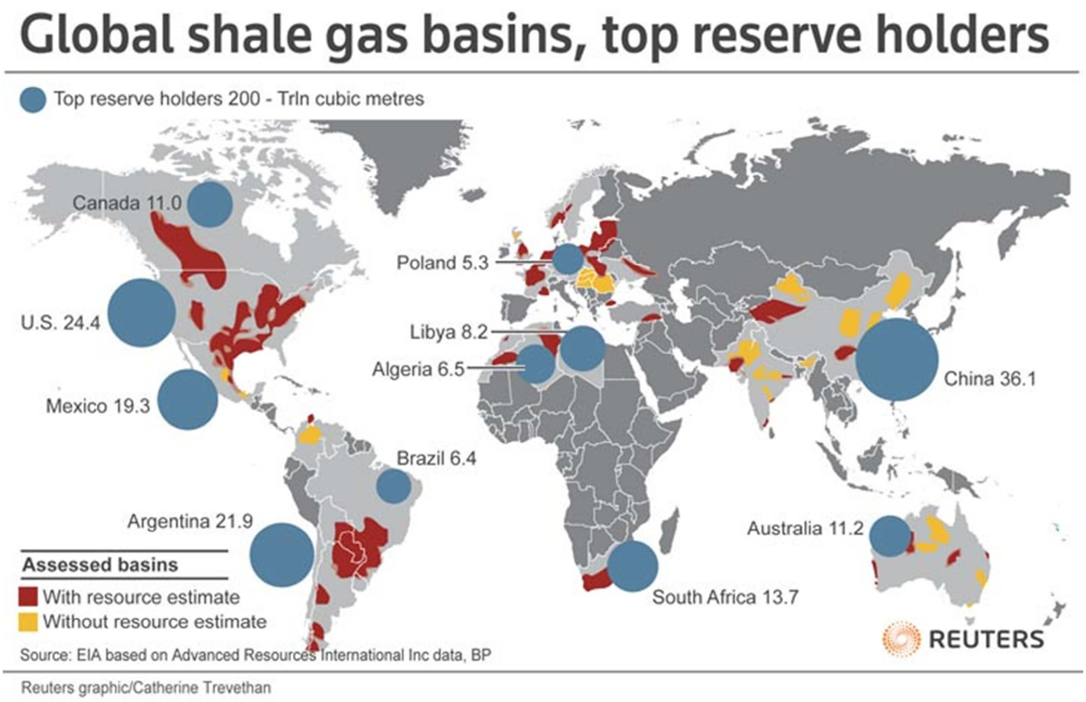

Figure 6: Global Shale gas estimates

9 NEED

- The UK could run out of North Sea oil and gas within 17 years.
- Shale gas can provide Security of National Energy Supply
- A number of older oil and gas Power stations will close by 2015 – Power Cuts are Inevitable if new generating stations are not constructed
- Gas and electricity prices are continually rising – 30% increase in 2011
- There are very limited gas storage facilities in the UK
- Unemployment is on the Increase
- National Economy - gas sales can create huge tax revenues for both local and Central government.

10 BENFIFITS OF UNCONVENTIONAL GAS PRODUCTION

A recent report from the Institute of Directors (IOD) states that:-

- *In 2011, the UK consumed 2.9 tcf of gas. 10% of 2011 UK gas demand is therefore 0.29 tcf. If 10% of the 300 tcf of onshore reserves estimated by the exploration companies were economic to extract, then 30 tcf would be sufficient to meet 10% of current UK gas demand for 103 years*
- *10% of 2011 UK gas demand is equal to 8 million tonnes of oil equivalent, 8% of total UK oil and gas production in 2011. The UK oil and gas industry provides direct and indirect employment for 440,000 people. Assuming that jobs are directly proportional to production, then an extra 8% of 2011 production would generate 35,000 extra jobs, helping to offset job losses from a decline in conventional oil and gas production in the UK.*

A study in Pennsylvania State University showed:-

- *A recent Pennsylvania State University study reports the Marcellus gas industry generated $3.9 billion in total value added revenue, more than 44,000 jobs, and $389 million in state and local taxes. For 2011, the estimated potential was forecast to be more than $10 billion in total value added revenue, 100,000 jobs, and nearly a $1 billion in state and local tax revenues in Pennsylvania. By Q4 2011 the Marcellus Shale related industries total employment figure was 238,400. (From Pennsylvania Dept of Labour & Industry)*

11 THE FUTURE

If Wales is to generate a lower carbon economy and ultimately a nil emission Hydrogen economy, methane can be utilised (in its component parts of Hydrogen and Carbon) as a feedstock.

Methane gas is split into its component parts

- Carbon – To manufacture carbon fibre
- Hydrogen – A Nil Emission Fuel
-

Carbon Can be Used For: -

- Reinforced Concrete – Increased strength and lower weight than steel
- Plastics – Enhanced properties
- Batteries – Longer life
- Carbon Fibre – Lighter vehicles and aircraft therefore increased fuel economy

12 Conclusions

- Wales could become self sufficient in energy and potentially be a gas exporter.
- Thousands of jobs could be created by a new unconventional gas industry in Wales, both new jobs for young people and replacement jobs for those lost recently in the coal and steel industries.
- Millions of pounds can be generated in local and central government taxes.

- The produced gas can be used as an alternative to petrol for road vehicles both lowering the cost of fuel and emissions.
- The produced gas can provide energy security in Wales and the UK together with lower emissions.
- The produced gas can be used as a feedstock for Hydrogen production and Carbon fibre.

Gerwyn Llewellyn Williams C.Eng FIMMM MEI
Chairman
UK Onshore Gas Limited

22nd February 2013

Environment and Sustainability Committee

E&S(4)-08-13 paper 2

Shale gas and gasification – Evidence from UCG Association

The potential for Underground Coal Gasification in Wales

The UK has a long history with coal, which is not always viewed as a positive, but its pivotal role in powering the economic growth and modern development of the nation during the industrial revolution was highlighted for the world to see at the opening ceremony of the 2012 London Olympics.
The UK also has a long history with UCG, as the concept was originally developed here by Sir William Siemens in 1868.

Today advances in science and technology have transformed every aspect of life, eradicated diseases and alerted us to unseen dangers such as carbon emissions - coal has publicly fallen from grace.

But is that about to change?

'The United Kingdom is well placed within Europe in having large reserves of indigenous coal both onshore and offshore in the southern North Sea," points out the UK's Coal Authority.
The department of energy and climate change (DECC) said*: "These reserves have the potential to provide security of future energy supplies long after oil and natural gas are exhausted. UCG has the potential to provide a clean and convenient source of energy from coal seams where traditional mining methods are either impossible or uneconomical.*

So why is UCG now coming to the attention of policy makers as an economic and politically acceptable method to meet growing energy needs?
Advances in science and technology!

The UK resource suitable for deep seam UCG is estimated at **17 billion tonnes, or 300 years'** supply at current consumption, according to a 2004 Department of Trade & Industry report
UCG therefore offers enormous potential to contribute to the energy security and independence of the UK for decades and could constitute a key component of the energy mix that secures transition to a low-carbon economy.

Development of Modern UCG

UCG has been piloted around the world for decades; one installation at Angren, Uzbekistan has been in production for more than 50 years.
There have been too many milestones in the history and development of modern UCG to detail here, but most significant advances have been pioneered in the oil and gas industry.
Sophisticated horizontal and directional drilling techniques, improved control of the process, and better intersection of the coal seam. Plus greater understanding of site selection criteria, hydrogeology, seismic technology and environmental impacts - ***which are fully manageable with the right coal and overburden structure.***
But please note UCG does not involve fracking!

Most recently successful trials of modern UCG undertaken in Australia, Canada and New Zealand have proven the technology viable and capable of recovering up to 80% of the calorific value of coal. This is a significant increase compared with other extraction methods

Costs

In terms of production costs, in 2002 the UK Government's then DTI completed a cost analysis in its study which indicated that UCG could be competitive with above ground coal gasification, maybe at prices of around 2-4p/kWh, depending on carbon capture options and project size the cost of UCG is highly dependent on local conditions and the scale of the project.

UCG – CCS

When coupled with carbon, capture and storage (CCS), UCG becomes an even more attractive proposition. As syngas is produced at temperatures, pressures and CO_2 concentration levels that enable relatively simple, low-cost carbon removal prior to use. The CO_2 can then be used for enhanced oil recovery, or reinjected into spent UCG cavities Other UCG - CCS synergies are also being investigated, including the common spatial coincidence of deep coal seams and deep saline aquifers or depleted gas reservoirs.

UK Licenses

The UK Coal Authority has already issued 20 UCG licenses to six companies to operate in the UK:
BCG Energy, Clean Coal Ltd, Europa Oil and Gas, Five Quarters, Riverside Energy and most recently to Cluff Natural Resources.
Most have not progressed beyond initial licensing, apart from Five Quarters, having recently been awarded funding by the government to explore gas fields in the North Sea, using a variety of available technologies including UCG.
Most of these sites are off the east coast of England and Scotland, two are in Wales
All are close to regions that once thrived on coal production

Benefits for Wales

The benefits for Wales will be economic, due to an influx of skilled workers and increased local spending.
Local employment opportunities, as UCG is a localised energy source, the produced syngas does not travel distances in the way of natural gas, so all processing and probably utilisation of the syngas will be local. This should in turn produce and attract interest from industry.
Added to this a UCG site would also be used for training, adding to local skills, plus as UCG is being looked at globally, opportunities to benefit and participate in overseas projects.
There would also be presumably revenue from taxes and site rents.

Regulatory and Planning Issues

The UCG Association has worked with both UK regulators, the Environment Agency and the Health and Safety Executive to discuss in detail how UCG projects work.
The result is now a clear defined regulatory regime that specifies what conditions UCG projects must meet in order to obtain the necessary permits.
This should provide confidence to local planning authorities that UCG will be undertaken responsibly and safely and that all necessary investigations, monitoring and independent verification will be completed before syngas can be produced.

So what is stopping Commercial UCG Development?

The main issues hindering development are planning consent, financing and public concerns. While the latter two are trying to be addressed by the industry, the former relies on planning authorities having a firm understanding of UCG, its prospects and practicalities.
Generally, the UK's planning authorities have been very open to the idea of UCG.

But on top of the regulatory barriers there is a "barrier of public acceptance".

Reticence towards UCG among those evaluating planning applications is understandable due to public concerns over the process and potential impacts it can have on communities.

Can these concerns be addressed?

The biggest issue is the view of many in today's society that anyone working in the energy sector is driven by financial gain with a total disregard for the environment.

The companies that are promoting the commercial application of new energy techniques are rarely the people who have perfected the process.

New energy technologies are developed by scientists and engineers.

Only when an application is scientifically proven, after many years of applied research, can it be taken to commercial stage. Few companies have R + D departments, most advances are from the scientific and technical communities. This view is not only hampering energy it is hampering the future of the UK economy and the futures of generations to come.

In Wales both Cardiff and Swansea Universities, who have been researching UCG, have young geologists and chemical engineers in earth science departments exploring and learning techniques that have no future if attitudes do not change. Across the whole country there are students investigating every aspect of energy technology and application - there will be no future employment and no energy scenario until both industry and government work to change the public perception of new energy technologies and get past negative media dogma.

But the industry and companies exploring and developing UCG are not shying away from these concerns, they are addressing them and attempting to allay fears through information and application.

It is in the interests of all that the UCG process is safe and fully tested and that public and political concerns are acknowledged and explored.

Enabling Wales and other parts of the UK to again flourish and benefit from a new era of indigenous energy production, industrial and economic growth and back in a position to show the world how to use coal.

Julie Lauder, CEO, UCG Association
February 2013
Email julie.lauder@ucgassociation.org

Further information on UCG can be obtained from:
UCG Association - www.ucgassociation.org
The IEA CCC – www.iaeccc.org
The World Coal Association - www.wca.org
The Coal Authority – www.coal.decc.uk.

More information on the permitting process for underground coal gasification is available at www.environment-agency.gov.uk/business/topics/122756.aspx

Environment and Sustainability Committee

E&S(4)-08-13 paper 3

Shale gas and gasification – Evidence from Clean Coal Limited

Underground Coal Gasification

Underground coal gasification (UCG) is essentially the same well known chemical processes used in surface gasification that converts solid coal into a mixture of gases known as synthesis gas (or syngas). Syngas is made up of mixtures of methane, carbon monoxide, carbon dioxide, hydrogen and water steam. Rather than taking place in an expensive, purpose built reactor vessel, however, UCG takes place in coal seams while they are still buried deep underground.

With a century of experimentation behind it, UCG is not a new technology. Relatively recent advancements in key enabling technologies, however, have allowed UCG to develop into a safe, economic energy technology that is now at the stage of becoming commercialised in many countries around the world.

All UCG processes are similar in that they require a minimum of two physically linked boreholes: (i) an Injection Well to inject the gasifying agents and start ignition; and (ii) a Production Well, to recover the syngas. A linked injection and production well is known as a UCG "module" (Figure 1).

During UCG, air and/or oxygen with steam is introduced to the coal by pumping it down an injection well, which is drilled into a very deep coal seam from the surface. The mixture of oxygen, steam and coal is then heated and gasification takes place. The process of gasification is self-sustaining, as long as oxygen is made available and as soon as the oxygen is withdrawn, gasification will stop. The syngas produced flows back to the surface under pressure via a production well, which is linked through the coal seam to the injection well. In modern UCG technologies, the linkage between the injection and production well is achieved using directional drilling, which eliminates the need for other techniques such as fraccing.

Syngas is a very versatile gas mixture that can be used to produce electricity or converted into a variety of useful products from fertilizers to ultra-clean aviation fuel.

Potential for UCG in Wales

Cardiff University has undertaken extensive assessments of the potential for UCG in Wales and continues research into UCG as part of its Seren project. Application of geographical information systems with detailed site selection criteria identified a number of areas in South Wales with good potential for UCG. These studies showed that the South Wales coalfield contains many areas of deep coal with good qualities for UCG located in areas of sufficient distance from populations or historical mines. The potential of UCG in Wales is further demonstrated by the existence of two UCG conditional licences in Swansea Bay and the Loughor Estuary, Carmarthenshire.

Benefits of UCG

UCG has a number of advantages over other conventional coal exploitation technologies:

1. UCG is Economic

A number of independent studies have shown UCG to be highly economic, producing syngas at a cost competitive with Shale Gas, for example.

2. UCG can exploit deep, otherwise unminable coal resources

Modern technologies allow coal seams over 1000 m deep to be accessed for UCG, greatly expanding the resource base for producing energy in the UK.

3. UCG has limited environmental impacts compared with other coal utilisation technologies

UCG offers the opportunity to exploit coal with greatly reduced environmental impacts, by avoiding the need to mine (which also removes the risks to miners), wash and transport the coal, and by ensuring the bulk of coal-ash and sulphur-compounds remain buried deep underground.

a. Reduced Surface Footprint Impacts

Compared with coal mining, UCG has a negligible surface footprint, largely because the coal extraction ("mining") and coal conversion (gasification) takes place in situ, at greater than 500m below ground level. The coal is accessed via relatively small diameter boreholes, which when removed leave very little evidence of them ever being there at all. Furthermore, the requirements for a coal mine, coal washing and storage facilities, coal transportation infrastructure and complex gasification plants, as well as fly ash storage collection and disposal facilities are completely obviated by UCG.

b. Minimal Groundwater Depletion

Groundwater plays a fundamental role in UCG as it seals and pressurises the underground reactor. For these reasons, UCG operators aim to cause minimal impact on groundwater levels i.e. cause minimal groundwater depletion.

c. Minimal Groundwater Impacts

There are known risks of groundwater contamination from UCG, but lessons learned from previous trials have enabled UCG operators to ensure groundwater resources are protected. Modern site selection techniques ensure that UCG is undertaken in very deep coal seams that are completely isolated from sensitive groundwater resources by thick, low permeability rock layers. With respect to reactor operation, it is possible to stop contaminants from entering the groundwater by ensuring that water only flows into the UCG cavity, because contaminants will not be transported against the direction of water flow. Groundwater will flow into the cavity when the pressure inside the cavity is less than the pressure of the groundwater outside. Modern UCG projects therefore ensure that the pressure in the reactor never exceeds the pressure of the surrounding groundwater.

The effectiveness of modern site selection and UCG operational techniques is demonstrated by the fact that that three pilot projects have been operating in heavily regulated regimes for years with no indications of causing groundwater impacts.

d. UCG is Safe

Coal mining is an intrinsically dangerous activity, where risks of mine collapse, fires and explosions have to be carefully managed on a regular basis. UCG is inherently safer because no people are required to mine the coal. Furthermore, there is no risk of uncontrolled coal seam fires, because UCG takes place beneath many hundreds of metres of rock, which isolates the seams from atmospheric oxygen. Once oxygen injection is turned off, gasification will stop and there will be no risk of uncontrolled fires.

The risk of subsidence from UCG is reduced greatly by ensuring UCG takes place at great depth beneath strong, competent rocks. Furthermore, the "cavities" left after UCG are partially filled with ash, so are not truly open volumes in the same way as the voids left over from mining. The risk of subsidence from UCG is therefore reduced, compared with coal mining for example.

Dr Shaun Lavis

Senior Geoscientist

Clean Coal Limited

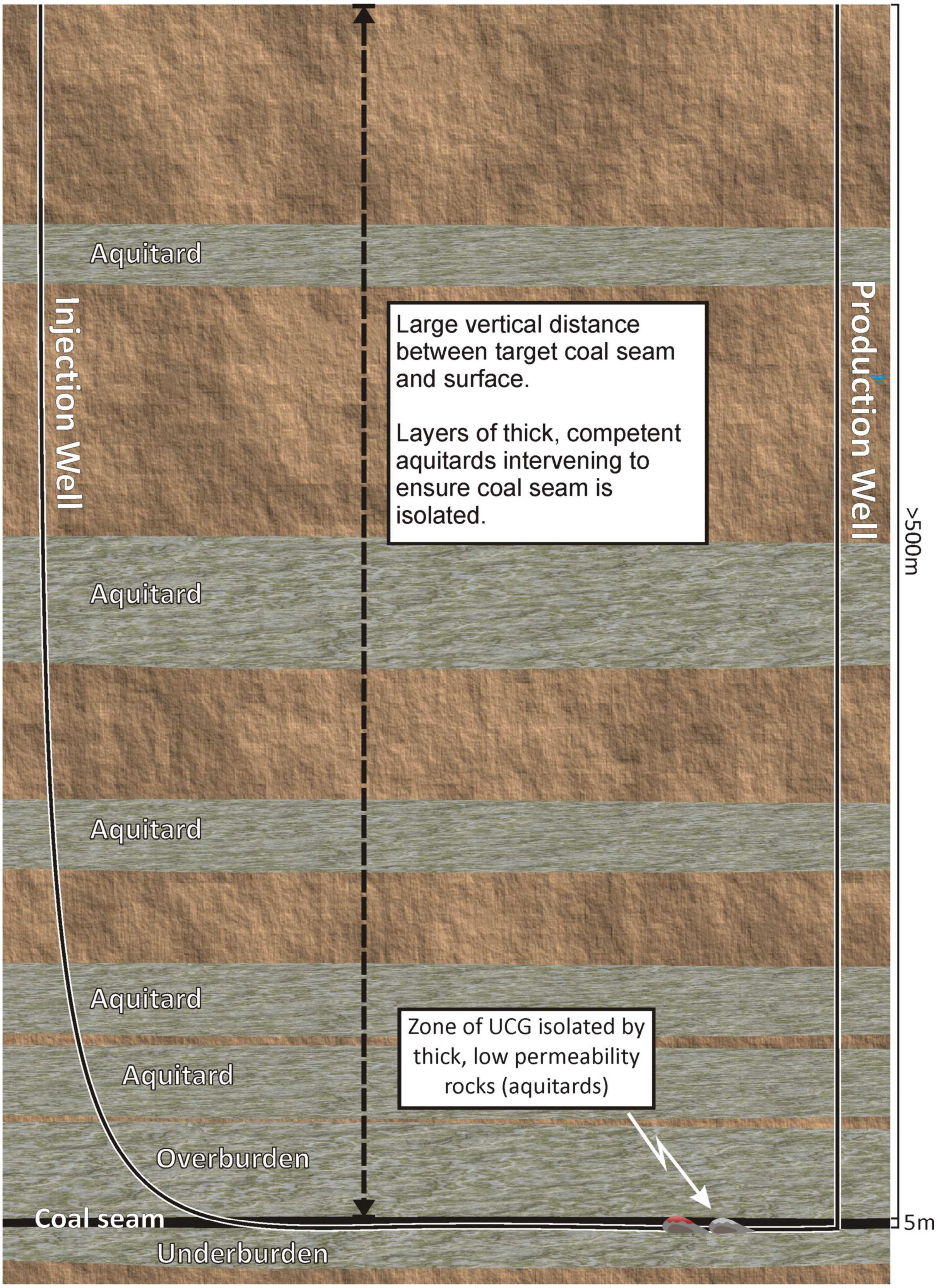

Figure 1. Setting for UCG "module" showing a linked injection well and production well. The aim of UCG site selection is to choose areas that are physically isolated from groundwater resources and coal seams that are very deep to minimise subsidence.

Environment and Sustainability Committee

E&S(4)-08-13 paper 4

Shale gas and gasification – Evidence from the Tyndall Centre

Submission to the Energy and Climate Change Committee Inquiry into The Impact of Shale Gas on Energy Markets

October 2012

Executive Summary

Tyndall Manchester has been investigating the climate change implications of shale gas developments for the past two years. We have raised concerns around the cumulative quantities of emissions that may be released by the extraction and combustion of shale gas and the implications for climate change mitigation of a widespread expansion of the industry in two reports. The most recent report (Broderick et al., 2011) contains research of relevance to two specific questions raised by the committee, namely:

i. What are the effects on investment in lower-carbon energy technologies?
ii. What is the potential impact on climate change objectives of greater use of shale gas?

This submission is a précis of the conclusions drawn by Broderick et al (2011) with additional material from a forthcoming report (Broderick and Anderson, 2012) examining the impact of shale gas on US energy system emissions. We conclude that the issues of lock-in to unabated gas generation, the importance of other drivers of US emissions reductions and the consequence of export of displaced fossil fuels, indicate that novel sources of gas production are problematic from climate change mitigation. It is clear that the production of fossil fuels of all sorts needs to be curtailed in the absence of strict and coordinated international greenhouse gas emissions caps.

Ultimately, the UK's international commitments, under the Copenhagen Accord and Cancun Agreements, cannot be reconciled with the large scale exploitation of shale gas, even with carbon capture and storage. In many respects the response of the UK Government to the prospect of indigenous shale gas production is a bellwether of the veracity or otherwise of the UK's commitments and leadership on climate change.

i) What are the effects on investment in lower-carbon energy technologies?

1. The Energy and Climate Change Committee (2011) has previously noted that a substantial move to exploit newshale gas reserves could attract investment that might otherwise go to renewable energy. The 2011 report states that "…shale gas has the potential to shift the balance in the energy markets that the Department has tried to create away from low carbon electricity generation".

2. In our updated report (Broderick et al. 2011) we estimated the potential scale of such a diversion by assessing the capital costs of gas powerstations burning the output of a mature shale gas industry (i.e. 9bcm/year sustained over a 20 year time period). We refer the committee to section 3.4 of Broderick et al. (2011) for full details and summarise the conclusions below.

3. In total, potential resource substitution was found to be £19bn to £31bn, depending upon the discount rate applied to future investment. The higher figure relates to a Treasury Green Book discount rate of 3.5%, arguably the most appropriate rate for assessing public policy.

4. Table 3.11, reproduced below, illustrates the scale of potential wind energy foregone if capital is diverted to shale gas. Given the need for climate mitigation, the costs of CCGTs with carbon capture and storage (CCS) was also considered. CCS has an energy penalty in operation, in the order of 10% to 20% hence 7GW capacity could be sustained with 9bcm/year gas, and substantially increases capital costs. In the absence of large scale demonstration plants there are considerable uncertainties in the technology's cost and efficiency parameters.

Table 3.11: Investment equivalents in gas and renewable capacity

	10% Discount rate		3.5% Discount rate	
	8GW CCGT	7GW CCGT +CCS	8GW CCGT	7GW CCGT +CCS
Onshore wind (GW)	12.5	16.5	16.8	20.8
Onshore wind (3MW turbines)	4,172	5,503	5,594	6,925
Offshore wind (GW)	7.0	9.2	9.4	11.6
Offshore wind (5MW turbines)	1,401	1,849	1,879	2,326

5. The potential scale of displacement is comparable to the 2020 ranges in UK Renewable Energy Road Map; 10-13 GW onshore wind and 11-18 GW offshore (potentially 40 GW).

6. If the cost of CCS is included and a 3.5% public discount rate used, then the equivalent 21 GW of onshore wind capacity could generate up to 27% more electricity per annum considering representative capacity factors of 70% for gas and 30% for wind. 12GW of offshore turbine capacity would be expected to generate 5% less electricity than the equivalent gas infrastructure.

7. So as not to renege on UK climate change commitments, it is imperative that investment is directed towards very low and zero carbon energy infrastructure. Construction without CCS would place much greater pressure on other parts of the economy to decarbonise and risk gas infrastructure worth £19 to £26bn becoming 'stranded assets'. However, as we describe below it cannot be assumed that CCS will provide sufficient levels of abatement for gas-fired electricity to continue to be a major energy source in the long term.

8. Our analysis considered only capital costs, not operating costs; a simplification that significantly favoured gas over wind as the latter has much lower operating costs as a percentage of total costs. The levelised cost estimates for gas CCGT (Parsons Brinkerhoff, 2011), with 10% discount rate, suggest that fuel costs account for 88% of the total cost per MWh of electricity. In contrast, the operating costs for wind generation make up only 6% of total costs (Arup 2011). Costs of transmission and distribution infrastructure for both gas and electricity were also excluded.

ii) What is the potential impact on climate change objectives of greater use of shale gas?

9. Much of the discussion on the climate change impact of shale gas centres on its relative emissions intensity compared with other fuel sources. This issue is of interest, but must not distract from the most climatically relevant issue of absolute quantities of emissions from the global energy system.

10. There are important concerns about the possibility of additional climate change impacts from gas produced by hydraulic fracturing; this remains a contentious topic in the academic literature. Life cycle analysis studies include *inter alia* emissions from energy required to produce and distribute the gas, for instance those embodied in water transported to the well pad, and releases of methane itself to the atmosphere both deliberately and inadvertently during the full fuel production, transmission and distribution cycle.

11. Methane is a more potent GHG than CO2 but with a shorter atmospheric life span, with the potential to substantially influence the conclusions drawn by a given study. A conversion factor is required to relate the climate change impact of fugitive methane emissions to the carbon dioxide emissions from other activities and a number of different metrics are available to compare the impact of different greenhouse gases. A gas's contribution to global warming depends upon its absorption of infrared radiation, its longevity and its ability to influence other atmospheric components physically and chemically. The most widely used metric is the Global Warming Potential (GWP) which is the ratio of the change in radiation balance from a pulse release of a given gas, integrated over a specified future time period, against the same change for a release of the same mass of carbon dioxide. GWP is frequently used in climate policy as a way of comparing well mixed, long lived greenhouse gases like carbon dioxide,

nitrous oxide and methane. Typically a one hundred year time period is used for the calculation and revised estimates of GWPs are prepared as atmospheric science progresses. Whilst, these conversion factors are not inherent properties of the gas, their selection can have significant impacts on the conclusions drawn by research and policy.

12. There has been some dispute in the scientific literature of the appropriate GWP timescale to use when comparing conventional with unconventional gas production techniques. There is also a shortage of independent primary research on the actual quantities of such emissions, and many studies use the same underlying empirical data that is recognised to be limited in scope and applicability. Our previous research provides a fuller discussion of this topic (Broderick et al. 2011, Section 3.2.4) as well as an estimate of the additional emissions due to hydraulic fracturing. This estimate is compared with others in a review prepared for the European Commission DG Clima (AEA 2012). A recent comparative statistical approach has concluded that it is difficult to distinguish between the life cycle emissions impact of different gas production and distribution methods and that attention should be paid to energy system impacts (Weber & Clavin 2012).

13. Regardless of the unavoidably contextual framing of life cycle GHG impact, either per unit of gas produced or per unit of electricity generated, the direct carbon content of shale gas means that its widespread use would is incompatible with the UK's international climate change commitments.

14. The absolute necessity of decarbonisation means that technologies with orders of magnitude lower emissions are required to provide energy to UK households and industry in the short to medium term. The Committee on Climate Change (2008) has advised "that any path to an 80% reduction by 2050 requires that electricity generation is almost entirely decarbonised by 2030". Decarbonisation of the electrical supply is an effective way of rapidly reducing emissions. Renewable supply technologies, with very low associated emissions, are available now and are compatible with existing infrastructure. The efficiency of transport and heating can be improved through the deployment of new electric vehicle and heat pump technologies respectively.

15. Understanding timescales is pivotal from a cumulative emission (carbon budget) perspective. The CCC argues that the transition to a very low carbon grid, with an intensity of the order of 50g CO2/kWh, should take place by 2030. Scenarios described by the MARKAL economic optimisation model identify this point as being on the way to a zero carbon grid soon after. It is worth noting that the CCC acknowledges a low probability of keeping below 2°C of warming on the basis of their budgets, this is despite their assumption of unrealistically early global peaking dates (~2016).

16. Accounting for an emissions floor for food production and making fair (but still very challenging) allowance for emissions from non-Annex 1 nations, Anderson and Bows (2011, C+6 scenario) find that complete decarbonisation of Annex 1 energy systems must be accomplished rapidly (i.e. within a decade) for even a 50% chance of avoiding 2°C of warming.

17. It is sometimes argued that shale gas could be burned safely in the short term, however this is not the case. Given that shale gas is yet to be exploited commercially outside the US,

limitations on the availability of equipment mean that it is very unlikely it could provide other than a marginal contribution to UK supply before 2020. However, gas fired power stations produce emissions of approximately 440gCO2e/kWh of electricity and typically have a lifespan of over 25 years. Therefore, unless allied with carbon capture and storage (CCS) technologies, as yet unproven at a large scale, all new powerstations intended to burn shale gas would need to cease generating within five to fifteen years of construction, and at the latest be decommissioned by 2030. Green Alliance scenarios (2011) indicate that if there is a second "dash for gas", emissions from the grid could still be 302gCO2e/kWh in 2030 necessitating 95% deployment of CCS to meet our fourth period emissions budgets (2023-2027). In this respect, the "golden age" may turn out to be a gilded cage, locking the UK into a high carbon future

18. Even CCS is problematic when such low carbon electricity is required. At commercial scale CCS will be significantly less than 100% effective at capturing carbon dioxide. Moreover, it will always add costs to electricity production by reducing the efficiency of the power station requiring additional energy input in transportation and injection of the captured carbon dioxide. Best case emissions performance for gas CCS is in the range 35-75gCO2/kWh (80-90% capture efficiency on 55% efficient CCGT with 10% energy penalty for capture).

19. CCS therefore also increases the net quantity of upstream emissions of gas or coal production and transport; reduced efficiency means that greater quantities of fuel must be used for equal electricity output, increasing emissions over and above those from the fuel combustion. For unconventional gas production these have the potential to be significant if mitigation is not in place; Broderick et al (2011) estimate up to an additional 17gCO2e/MJ of gas produced, equivalent to an additional 120gCO2e per kWh of electricity generated depending upon mitigation during production.

20. With regards to using shale gas for heating purposes, the CCC (2008) note that as the grid decarbonises it is "more carbon efficient to provide hot water and space heating with electricity than with gas burned in a condensing boiler". Non-energy uses accounted for less than 1% of total UK demand for natural gas in 2010 (DUKES 2010). It is therefore reasonable to assume that new gas production in the UK will be combusted and, in the absence of carbon capture and storage, released to the atmosphere.

21. Shale gas has the potential to contribute substantial additional emissions to the atmosphere. Global estimates of reserves suggest this may be up to 30% of a global emissions budget with a 50% chance of avoiding dangerous climate change (Broderick et al. 2011, Section 3.3.2).

22. Substitution between fuel sources cannot necessarily be assumed to reduce emissions in absolute terms. Our forthcoming report (Broderick and Anderson, 2012) explores the CO_2 emissions consequences of fuel switching in the US power sector using two simple methodologies. The analysis presented is conditional upon its internal assumptions, but provides an indication of the scale of potential impacts. It suggests that emissions avoided at a national scale due to fuel switching in the power sector may be up to half of the total reduction in US energy system CO_2 emissions of 8.6% since their peak in 2005. Since 2007, the production of shale gas in large volumes has substantially reduced the wholesale price of natural gas in the US. The suppression of gas prices through shale gas availability is a plausible

causative mechanism for at least part of this reduction in emissions. Although we were not able to isolate the proportion of fuel switching due to this effect other studies note that between 35% and 50% of the difference between peak and present power sector emissions may be due to shale gas price effects. Substantial increases in renewable generation and capacity appear to have had an effect of similar magnitude through policy and cost competitiveness. Air quality regulations, energy efficiency and demand management, and the impact of the recession are cited to have played a considerable part in driving this change.

23. It is essential to note that there has also been a substantial increase in coal exports from the US over this same time period. Without a meaningful cap on global carbon emissions, the exploitation of shale gas reserves is likely to increase total emissions. For this not to be the case, consumption of displaced fuels must be reduced globally and remain suppressed indefinitely, *in effect displaced coal must stay in the ground*. Our calculations suggest that more than half of the potential emissions avoided in the US power sector may actually have been exported as coal. Summing the quantity of implicit emissions exported over the period 2008 to 2011 suggests that approximately 340 $MtCO_2$ of the 650 $MtCO_2$ of potential emissions avoided may be added elsewhere. It is clear that the production of fossil fuels of all sorts needs to be curtailed in the absence of strict and coordinated international GHG emissions caps.

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Has US Shale Gas Reduced CO_2 Emissions?

Examining recent changes in emissions from the US power sector and traded fossil fuels

October 2012

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A research briefing commissioned by The co-operative

This report is non-peer-reviewed and all views contained within are attributable to the authors and do not necessarily reflect those of researchers within the wider Tyndall Centre.

Contents

1 Executive Summary

Since 2007, the production of shale gas in large volumes has substantially reduced the wholesale price of natural gas in the US. This report examines the emissions savings in the US power sector, influenced by shale gas, and the concurrent trends in coal exports that may increase emissions in Europe and Asia.

Electricity generated by the combustion of natural gas is generally considered to have a lower emissions intensity per unit electricity than that generated by burning coal. The relative lifecycle carbon footprint of gas produced by hydraulic fracturing is contested and at present there is a shortage of independent primary data. However, trends in the absolute quantities of CO_2 emissions from combustion are less problematic and no less important when considering the implications of the US shale gas boom.

US CO_2 emissions from domestic energy have declined by 8.6% since a peak in 2005, the equivalent of 1.4% per year. Not all of this reduction has come in the power sector where shale gas has had most impact, and not all of the fuel switching has been due to the low price of gas. This report quantitatively explores the CO_2 emissions consequences of fuel switching in the US power sector using two simple methodologies. The analysis presented is conditional upon its internal assumptions, but provides an indication of the scale of potential impacts.

It suggests that emissions avoided at a national scale due to fuel switching in the power sector may be up to half of the total reduction in US energy system CO_2 emissions. The suppression of gas prices through shale gas availability is a plausible causative mechanism for at least part of this reduction in emissions. However, the research presented here has not isolated the proportion of fuel switching due to price effects. Other studies note that between 35% and 50% of the difference between peak and present power sector emissions may be due to shale gas price effects. Renewable and nuclear electricity incentivised by other policies has also accounted for some of the changes in grid emissions. We estimate that their increase in output appears to have been about two thirds of the increase in gas generation.

There has been a substantial increase in coal exports from the US over this time period (2008-2011) and globally, coal consumption has continued to rise. As we discussed in our previous report (Broderick et al. 2011), without a meaningful cap on global carbon emissions, the exploitation of shale gas reserves is likely to increase total emissions. For this not to be the case, consumption of displaced fuels must be reduced globally and remain suppressed indefinitely; in effect displaced coal must stay in the ground. The availability of shale gas does not guarantee this. Likewise, new renewable generating capacity may cause displacement without guaranteeing that coal is not burned, but it does not directly release carbon dioxide emissions through generation.

The calculations presented in this report suggest that more than half of the emissions avoided in the US power sector may have been exported as coal. In total, this export is equivalent to 340 $MtCO_2$ emissions elsewhere in the world, i.e. 52% of the 650 $MtCO_2$ of potential emissions avoided within the US.

A similar conclusion holds for 'peak to present' trends. The estimated additional 75 million short tons[1] of coal exported from the US in 2011 will release 150 $MtCO_2$ to the atmosphere upon combustion. If added to the US CO_2 output from fossil fuel combustion, the reduction from peak emissions in 2005 would be 360 $MtCO_2$, i.e. a 6.0% change over this whole period or less than 1% per annum. This is far short of the rapid decarbonisation required to avoid dangerous climate change associated with a 2°C temperature rise.

[1] The US Energy Information Administration statistics record coal traded in short tons equivalent to 2000lbs, slightly lighter than both the metric tonne (2205lbs) and the long ton (2240lbs) used in the UK Imperial system. Units are taken directly from the original data source for ease of comparison and review.

2 Introduction

The production of 'unconventional' gas from shales, tight sandstones and coal beds promises to have a substantial impact on global energy systems in the coming decades. At present, the use of hydraulic fracturing as a production method is well developed only within the US fossil fuel industry. In the last few years, wholesale prices have fallen substantially as gas produced from shales and other unconventional reserves has become available in high volumes (Rogers 2011). The gas industry and its supporters claim that this growth in indigenous gas supply is positive from both energy security and climate change perspectives as it displaces imported gas or indigenous coal (Kuhn & Umbach 2011; Lovelock 2012).

Considering the wide abundance of unconventional gas resources and their presence in high demand economies, such as North America and China, there are many energy policy makers, commentators and researchers who suggest that this supply will contribute to decarbonisation, with various qualifications (Helm 2011; The Economist 2012). However, having posed the question "Are We Entering a Golden Age of Gas?" in last year's World Energy Outlook (2011) the IEA reported that this scenario would likely result in 3.5°C warming, well beyond what is generally regarded as dangerous climate change. This lead their Chief Economist, Dr Fatih Birol, to clarify that *"We are not saying that it will be a golden age for humanity -- we are saying it will be a golden age for gas"* (Harrabin 2012).

In our previous research report (Broderick et al. 2011), we concluded that, in absence of wider policies, increasing production of any given fossil fuel was likely to result in an additional atmospheric burden and greater risk of dangerous climate change. Demand for energy of all kinds is growing and, as a scarce and essential resource, energy inevitably constrains the rate of economic growth. If new supply becomes available then there is a downward pressure on energy prices with a consequent rise in its consumption. In the case of shale gas, any putative benefit from the lower emissions intensity of natural gas over coal is therefore likely to be partially or fully negated through a rise in the consumption of fossil fuels as a whole. Climate change is an issue of absolute and not relative emissions, and any analysis that fails to respond to such an agenda risks seriously undermining action to mitigate emissions.

Building on such a system-level and scientifically-informed framing of climate change, this briefing considers the latest energy, trade and emissions statistics from the US and addresses empirically the impact of shale gas on absolute emissions. The following questions structure the research presented in this report:

1. What has been the impact of shale gas on other fuels in the US?
    a. Has it displaced coal in the power, domestic or industrial sectors?
    b. Has the price of coal altered?
    c. Have imports and exports of coal changed?
    d. How has it interacted with other sources of gas?
    e. Have imports and exports of gas changed?
2. What has been the impact of shale gas on US CO_2 emissions?

3. What has been the impact on CO_2 emissions outside of the US? What are the implications of global energy trends and international climate policies?

3 Is shale gas substituting for coal in the US energy system?

In April 2012 mild weather conditions reduced total demand for electricity in the US, with natural gas prices simultaneously falling to a ten year low. As a result, the proportion of electricity generation from gas was only fractionally below that of coal, an unprecedented situation.

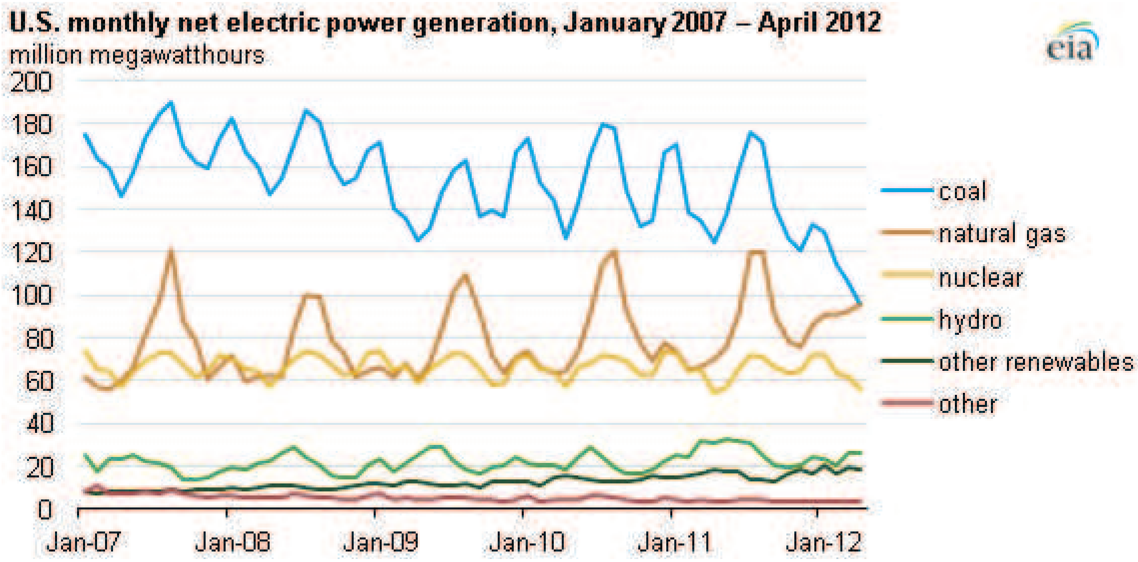

Figure 1 US power generation by fuel source, EIA (2012)

Recent statistics presented by the US EIA show a number of trends in the relative consumption and prices of coal and gas. The following figures and analysis have been assembled from data within the Annual Energy Outlook 2012 (EIA 2012a), Quarterly Coal Report June 2012 (EIA 2012e), Short-Term Energy Outlook June 2012 (EIA 2012f) and the Electric Power Annual 2010 (EIA 2011). It is first worth reviewing the gas supply data, trends and credible expectations, and assessing the impact of shale gas production upon them.

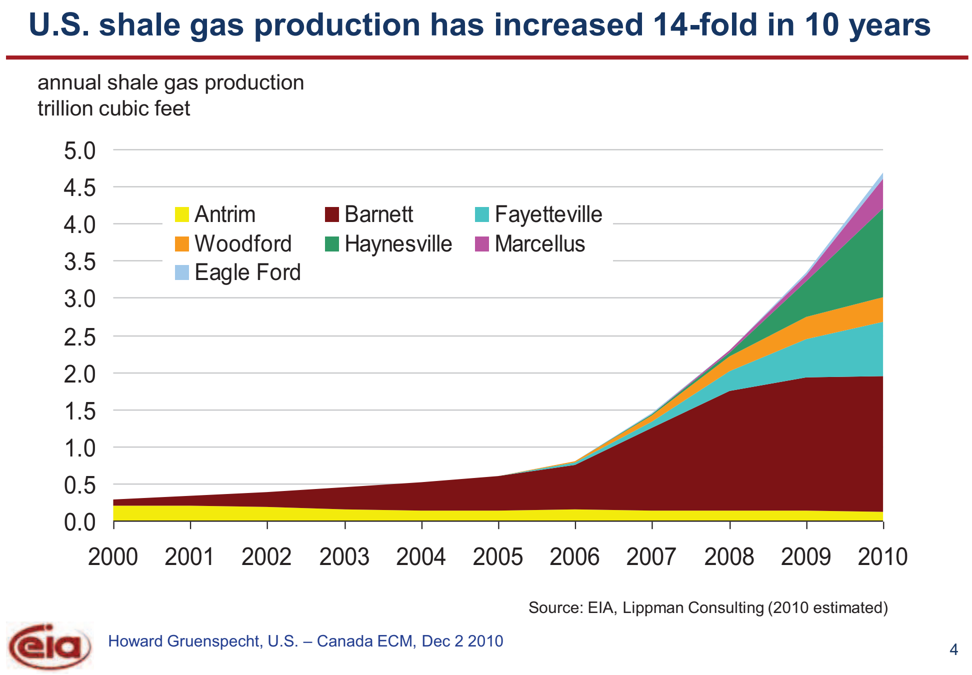

Figure 2 Trend in US shale gas production volume

Total US natural gas production declined over the period 2001 to 2005, from 55bcf/day to 52bcf/day (1.6bcm/day to 1.5bcm/day), but subsequently grew strongly as shale gas wells came online in large numbers (Figure 2, above). Figure 3 illustrates this increase in absolute terms, pro-rating EIA shale production figures for processing losses and displaying the simultaneous reduction of non-shale gas production and net imports to the US. This suggests that shale gas availability has not only substituted for coal in the US energy system but also other sources of gas. There is no physical or chemical reason to preferentially consume shale gas in one end use or another because of its chemical composition. It is not superior for home heating, power generation or petrochemical production; the major gaseous constituent, methane, can be fed directly into conventional natural gas distribution networks.

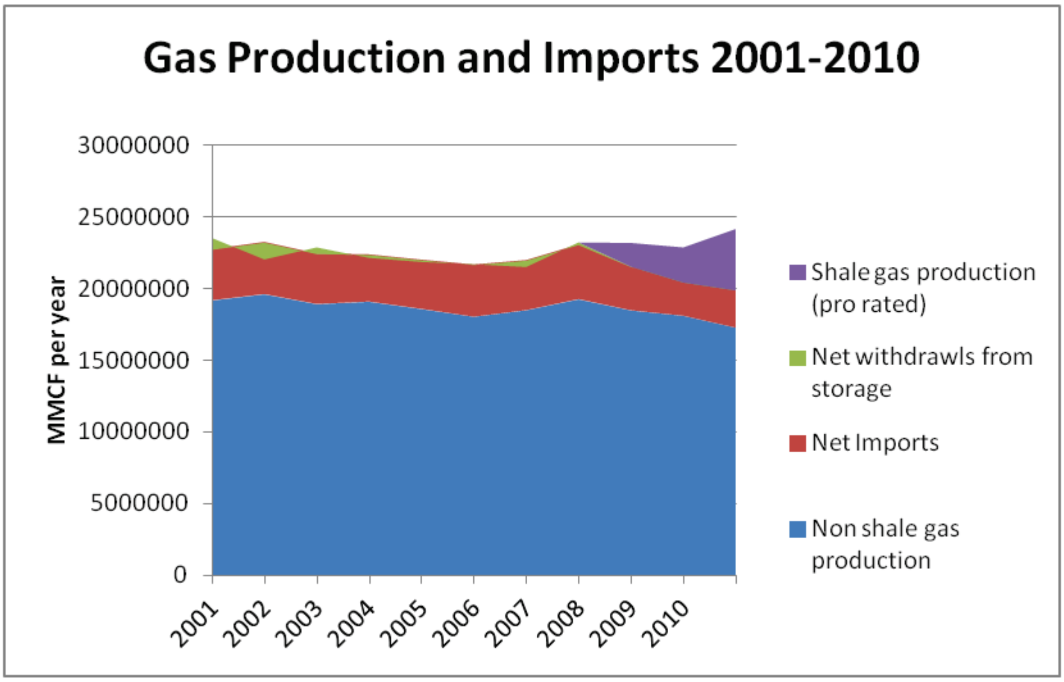

Figure 3 US Gas production and imports

Indexing gas production to 2001 levels (Figure 4) illustrates the relative decline in imports as total gas consumption increases from 2006 onwards.

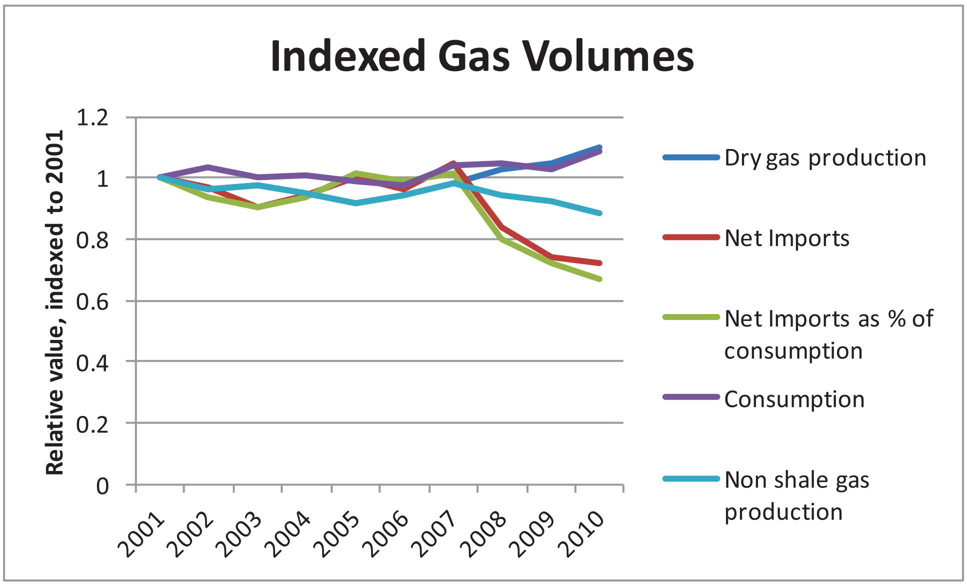

Figure 4 Indexed gas volumes

The most recent production statistics are not yet validated but 2011 gross shale gas production was reported at 66bcf/day (1.9bcm/day) and further increases are expected in coming years. The latest EIA Annual Energy Outlook (AEO) Reference Case (EIA 2012g) is based on shale gas increasing from 23% in 2010 to 49% of US production by 2035. In absolute terms, this would be over 25tcf (710bcm) total annual production, shifting the US from being a net gas importer to a net exporter of approximately 5% of its production by 2035.

Over the last decade, US absolute natural gas consumption has grown nearly 10%, from 22 trillion cubic feet in 2001 to 24 trillion cubic feet in 2011. This rise is predominantly due to increased consumption in the power sector as described below in Section 3.1. The wholesale gas price has not proceeded on a simple trajectory. Having peaked in 2005 and 2008 at around $9/MMBtu[2], it fell back to less than half this price in 2009 and has continued as a low level since. At the time of writing, September 2012, the Henry Hub natural gas spot price is just below $3/MMBtu. This is partly due to the scale and productivity of US shale plays and partly the high value of oil fractions present in the output of some shale plays which reduces the effective price of associated gas[3]. The largest decline in the gas price has been since 2008 which may suggest that the financial crisis and economic downturn has played a part. However, the price of coal has steadily increased over this same time period at an effective rate of 6% p.a.. In the medium term, 2012 US gas prices are below average replacement costs so are not expected to remain so low (EIA 2012g). However, the de-linking of oil and gas prices in the US market is expected to persist out to 2035, along with a decline in coal mine productivity (EIA 2012g).

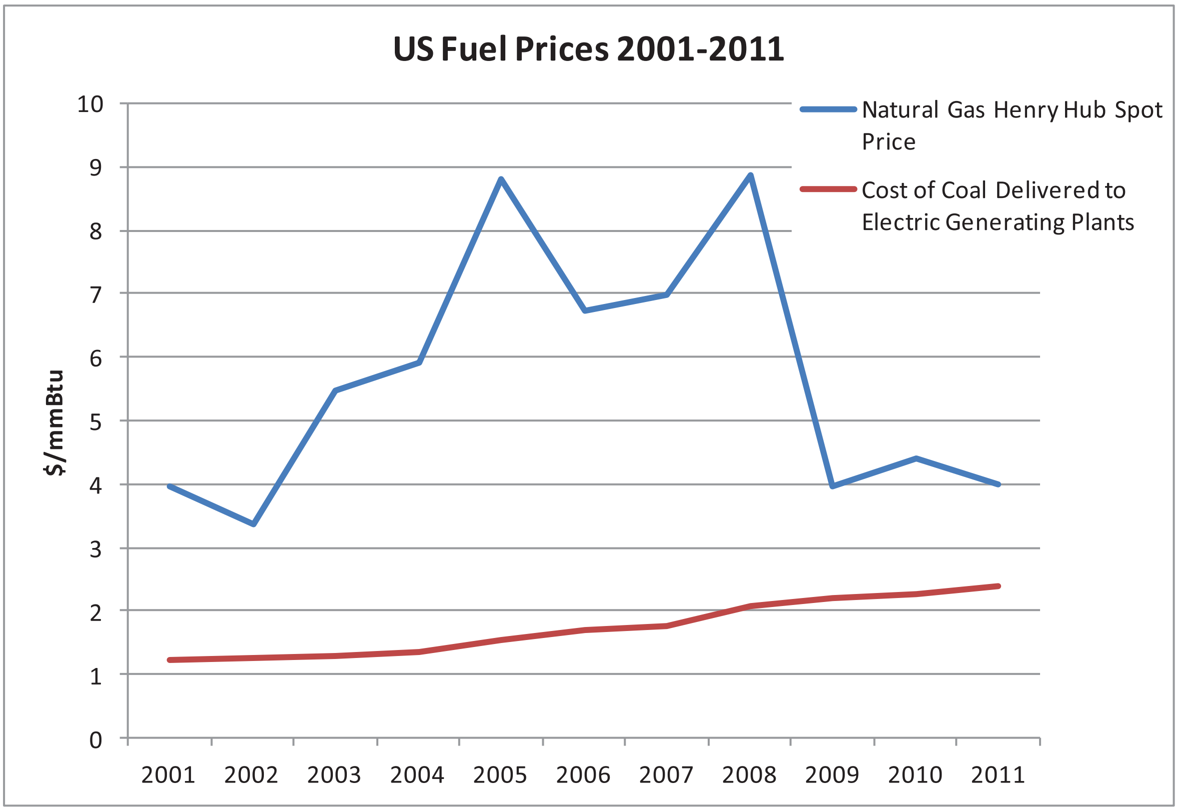

Figure 5 US Fuel prices 2001 to 2011

[2] Natural gas is typically traded in British thermal units (Btu) 'MBtu' representing a thousand Btu and 'MMBtu' a million.
[3] Liquid hydrocarbons produced from these impermeable rock strata are termed light tight oil (LTO) to distinguish them from 'shale oil' which requires heat treatment to liberate the oil. Of formations that produce predominantly gas rather than oil, the produced gas can be described as 'wet' or 'dry'. Wet gas has a higher proportion of heavier, longer chain hydrocarbons such as ethane, propane and butane that can be condensed to liquids. Such gas has a greater commercial value than dry gas that is almost exclusively methane.

3.1 *Power sector composition*

Turning to the issue of substitution, there has clearly been a shift in the primary fuel mix in the US power sector. From 2005 to date, the proportion of electricity generated from gas has increased from 18.8% to 24.8% whilst the proportion generated from coal has declined from 49.6% to 42.2% (Figure 6). During this time, there has been a substantial relative and absolute growth in wind electricity, whilst hydroelectricity and nuclear power have remained approximately static. Total electricity consumption has steadily increased, rising by 9% over the decade, save for a decline 2008-2009 (Figure 7). The rapid shift to gas has been facilitated by the fact that the US gas fuelled generators were previously operating at very low capacity factors[4]; Hultman et al (2011) report that 35% of capacity of combined cycle gas turbines (CCGT) was used in 2008, compared to a 30% capacity factor for open cycle gas turbines (OCGT) and 70% for coal plant. As such the US energy system has been able to substantially fuel switch and increase gas consumption in advance of the construction of new plant. For comparison, in 2010 CCGT plants operated in the UK at a 61% capacity factor, down from a peak of 69% in 2008 due to recent capacity additions, and coal plants at just 41% (DECC 2011).

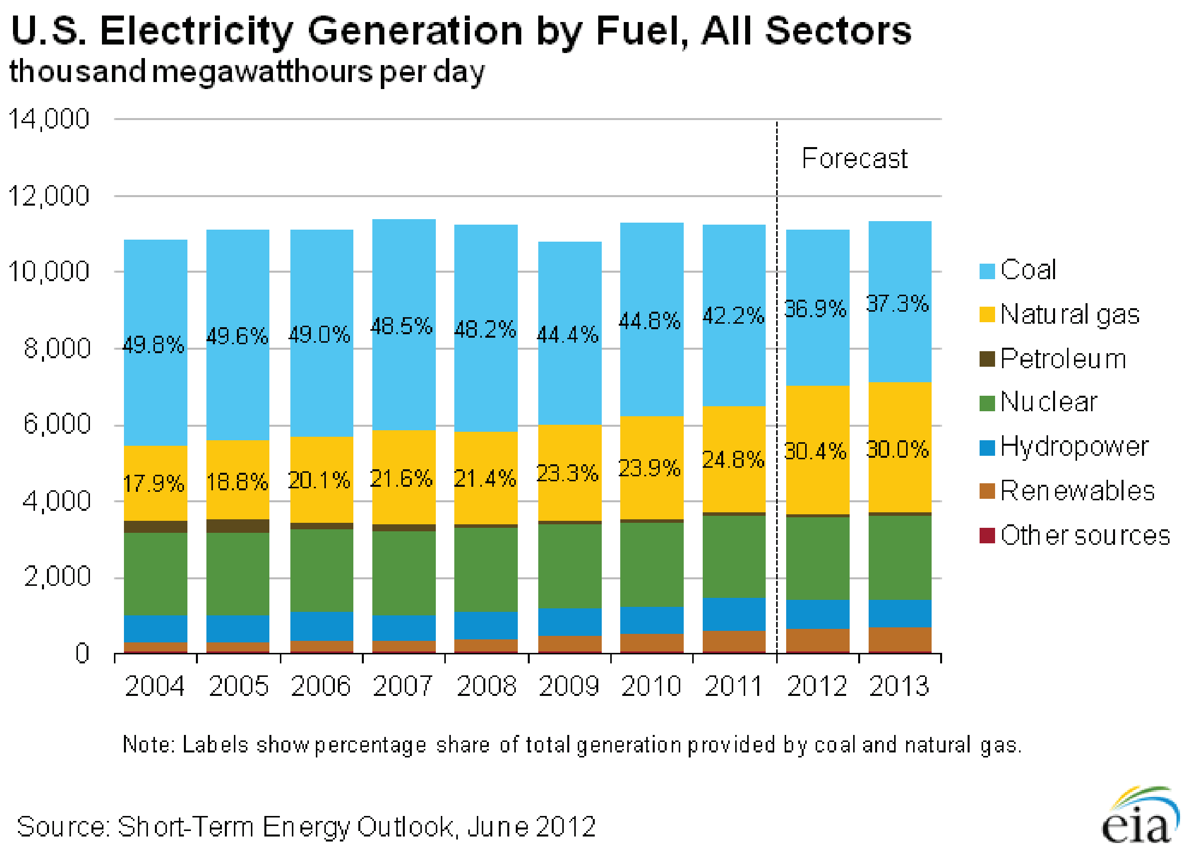

Figure 6 Electricity generation by fuel source

[4] Capacity factor is defined by the EIA as the ratio of the electrical energy produced by a power plant for the period of time considered, to the electrical energy that could have been produced at continuous full power operation during the same period. Load factor is often used synonymously for example in the DECC Digest of UK Energy Statistics.

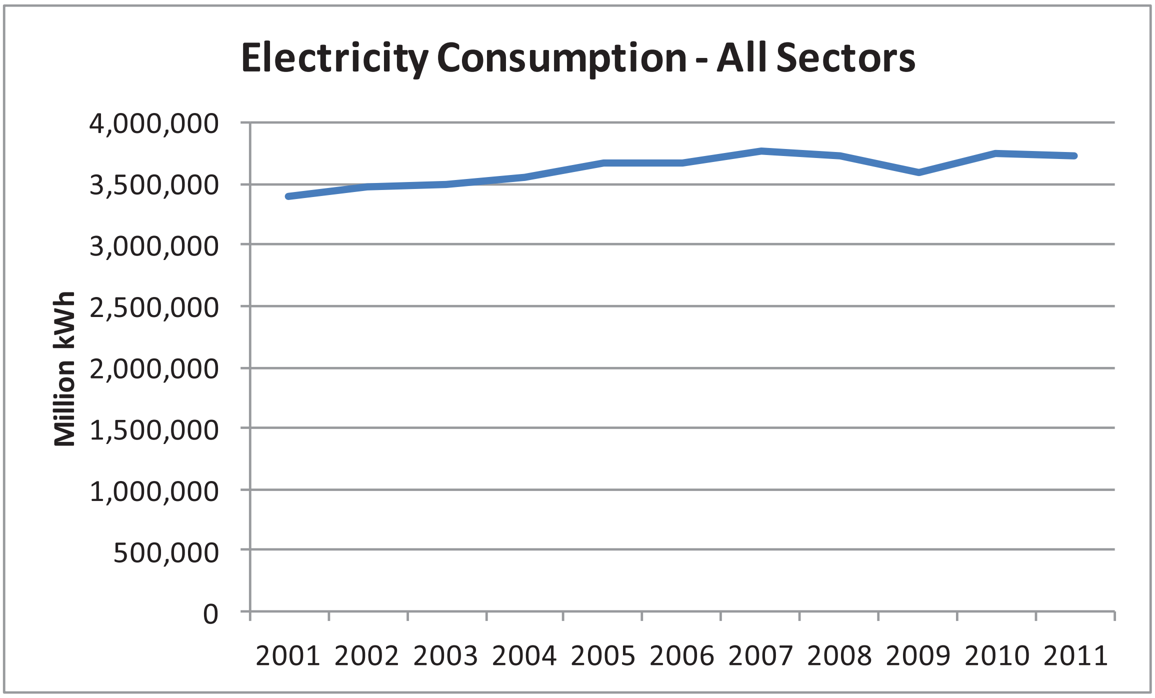

Figure 7 Electricity consumption – all sectors

A breakdown of natural gas consumption illustrates how the power sector has been the dominant source of growth in gas consumption (Figure 8). This trend began before both the large-scale production of shale gas and the recent price crash, and may therefore have other determinants. Regulations to address SO_2, NO_x and mercury emissions, in addition to cooling water and ash disposal, have also contributed to the relative preference for new investments in gas generating capacity over coal (Elmquist 2012; US EPA OAR 2012). For instance, in 2010 2,200MW of new gas fired capacity came on stream, representing 84% of net new capacity added to the US grid; the same year witnessed 585MW and 636MW net of coal and oil plant respectively being retired (EIA 2012c; table 1.4).

This trend is expected to continue in the future, with more than twice as much new planned capacity for gas in 2011 and 2012 than coal, and very little coal capacity to be added to the US grid beyond 2013 (EIA 2012c; Table 1.5). As a result, the proportion of electricity generated by natural gas is expected to increase further, from 24% to 28% by 2035, under the AEO Reference case, despite the share from renewables growing from 10% to 15% (EIA 2012g). Electricity generation from coal is lower in all of the AEO scenarios, however, a small number of the scenarios envisage absolute increases in power generation from coal by 2035 if economic growth is high, gas recovery is low or trends in the price of coal reverse.

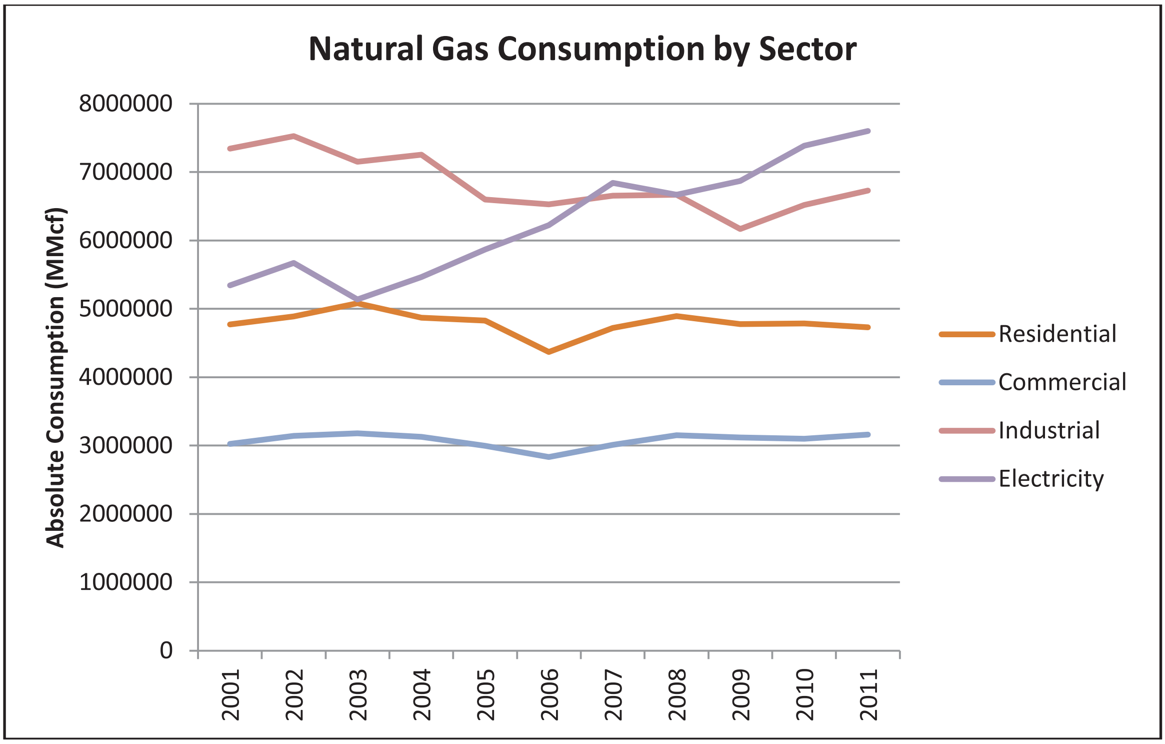

Figure 8 Natural gas consumption by sector

During the last decade the US economy has continuously reduced its emissions intensity of economic activity. Simultaneously, the structural shift towards a service based economy and increased efficiency have reduced the energy intensity of economic activity. These relative changes are illustrated in Figure 9. A separation of emissions intensity and energy intensity from 2007 onwards can be discerned that might be associated with changes in electricity generation and reductions in wholesale gas prices (the divergence of purple and sky blue lines below).

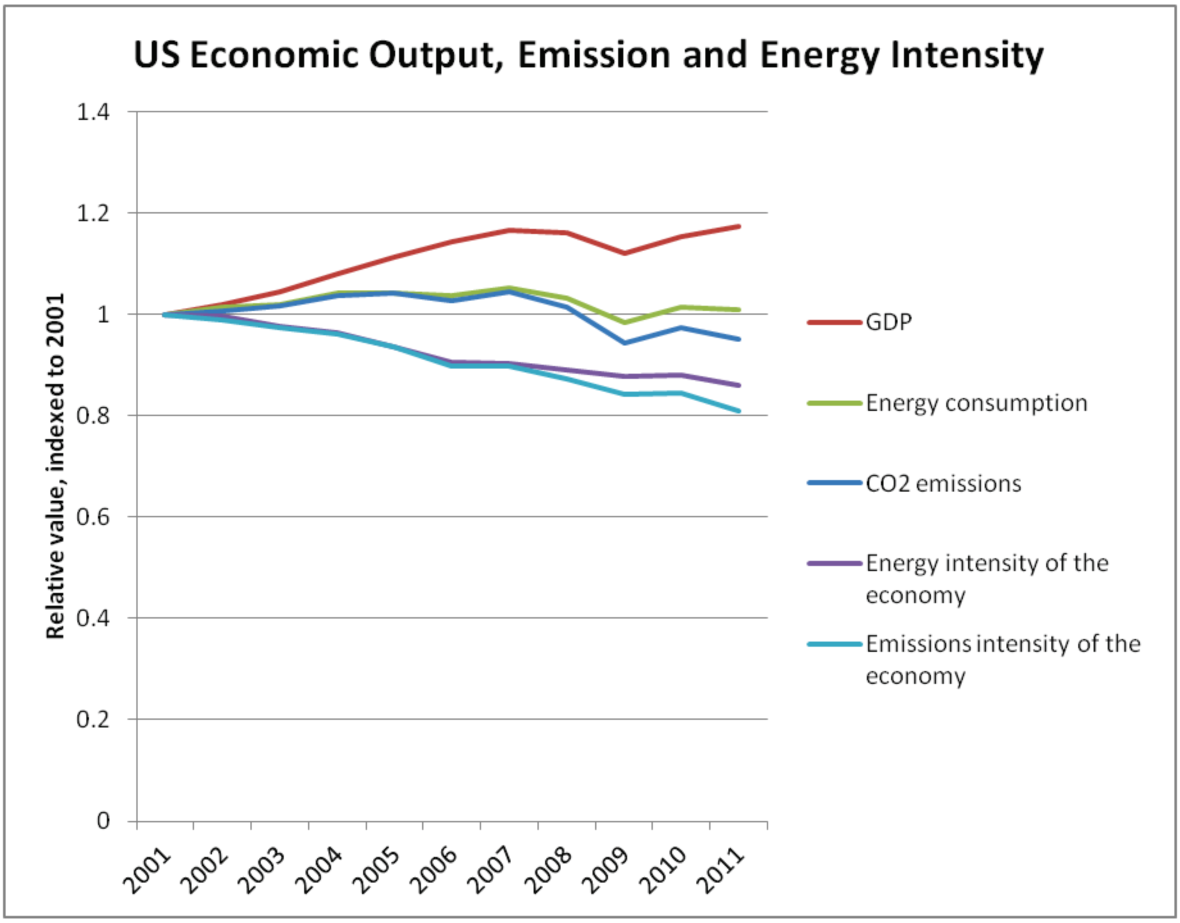

Figure 9 US Energy and emissions intensity trends

The outlook for future price and resource trends is somewhat uncertain, indeed the EIA has recently reported that it expects the trends in gas prices and coal consumption to reverse during 2012 (EIA 2012f). This is expected to result in a 2.8% increase in emissions in 2013.

Estimates of Technically Recoverable Resources (TRR) for US shale wells have also been substantially revised down in the 2012 AEO against the 2011 AEO as new geological and well productivity data have become available. The total shale gas TRR has fallen from 847tcf to 482tcf (Table 14, p57 of AEO 2012). The largest absolute reductions relate to the Appalachian (441tcf to 187tcf), Arkoma (54tcf to 27tcf) and Permian (67tcf to 27tcf) basins, whilst Western Gulf basin estimate has nearly trebled from 21tcf to 59 tcf. However, due to the economic considerations that determine actual production from TRRs, the overall future production expectation is itself highly uncertain. The AEO therefore considers a range of possible scenarios for Expected Ultimate Recovery (EUR) alongside TRR. Anticipated production in 2035 varies from 9.7tcf in the lowest case to 20.5tcf in the highest with the Reference scenario including 13.6tcf of shale gas (Table 19 of AEO, p62). This is against 2011 production of approximately 7.3tcf. Nevertheless, these volumes are all of a sufficient scale to be internationally relevant and in all cases the EIA anticipates the US to be a net exporter of gas in 2035. This will have ramifications for producers and consumers of gas and coal internationally.

4 Trends in the international trade of US coal

As noted previously, climate change is an issue of absolute and not relative emissions. Consequently, if a shift from coal to gas is to contribute to climate mitigation, the displaced coal must not be burned elsewhere within the US economy or overseas.

In considering the repercussions for coal production of increasing shale gas extraction, the first statistics of interest are total coal production, as displayed below. It can be seen that there was a decline associated with the economic downturn but a subsequent stabilisation and then upturn in recent years. Absolute consumption in the power sector shows a similar trajectory but with a marked divergence in 2011. The ultimate fate of this displaced coal consumption must be accounted for if the role of shale gas in mitigation is to be understood.

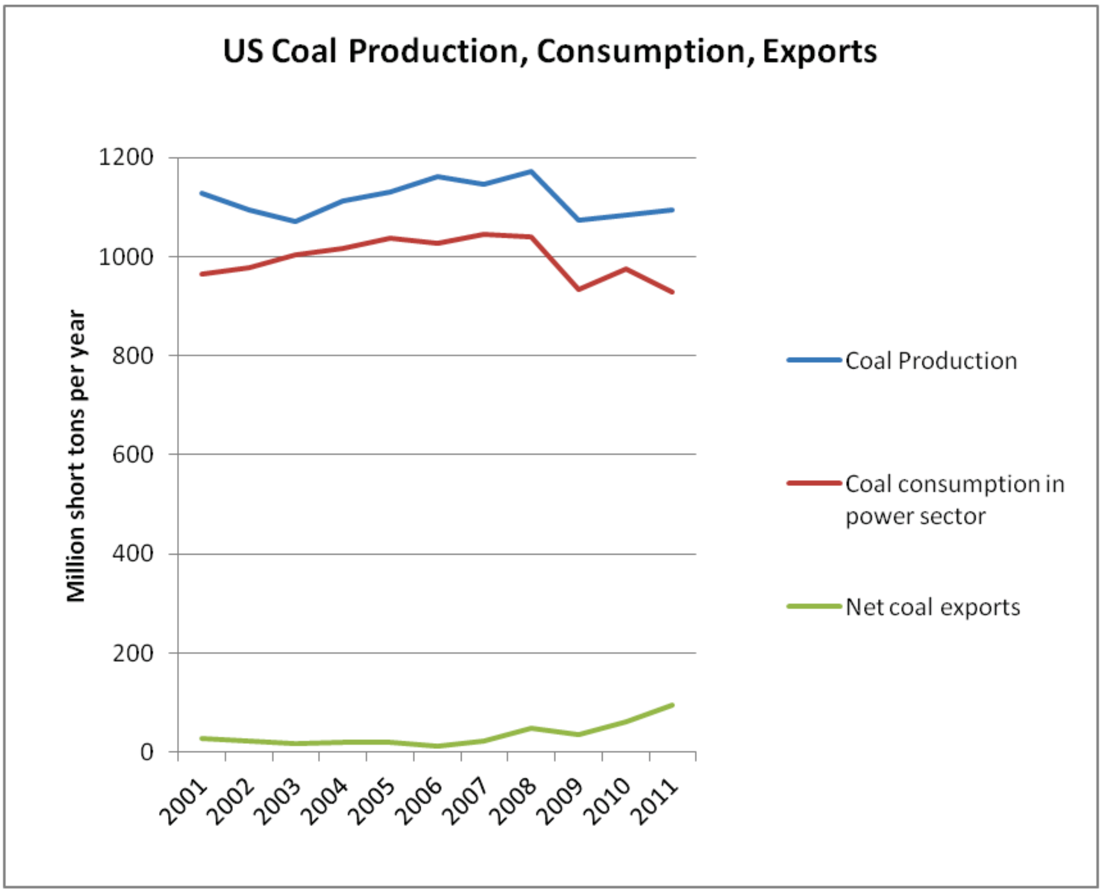

Figure 10 US coal production, consumption and export

As can be seen from the figure above, the net US trade position for coal has changed substantially in the last five years. Figure 11, below, disaggregates this data to provide greater clarity on how US coal imports and exports are changing. Coal imports to the US have declined continuously since 2008 whilst exports have risen markedly[5]. Latest data indicate that just 2 million tons of coal was imported to the US in the first quarter of 2012,

[5] The graph below illustrates data on a quarterly rather than annual basis which must be borne in mind when considering the numerical units.

down 25% from the last quarter of 2011 (EIA 2012e). Against this, gross quarterly exports rose to 28.6 million tons, indicating a net export of over 26 million tons of coal.

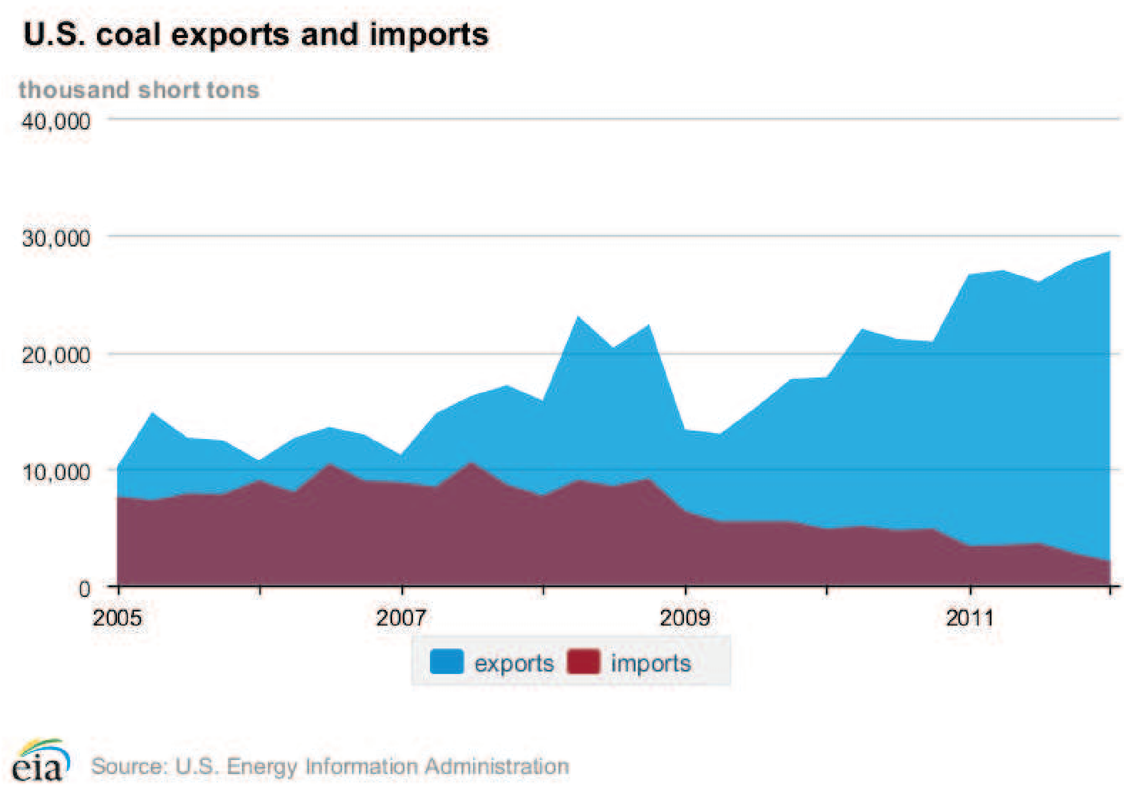

Figure 11 US coal exports and imports 2005 to 2012

The market for this US coal is increasingly seen to be Europe and Asia (EIA 2012d). These two regions together make up 76% of US coal exports and have shown rapid growth since 2009; for example, UK imports of US coal rose to 7 million tons in 2011 and the Netherlands rose to 11 million tons. The EIA (2012e) identifies general upward trends in coal use abroad and disruptions to supply in Australia, Indonesia and Colombia, making the US an attractive source. Within Europe, rising gas spot prices in combination with low permit prices in the EU ETS meant that there was a substantial incentive to generate electricity from coal plants rather than gas. Bloomberg Industries estimates that in the second quarter of 2012, European coal fired plants returned a profit of €16.3 per MWh, up from €9 a year earlier, whilst gas plants only just broke even (Katakey et al. 2012).

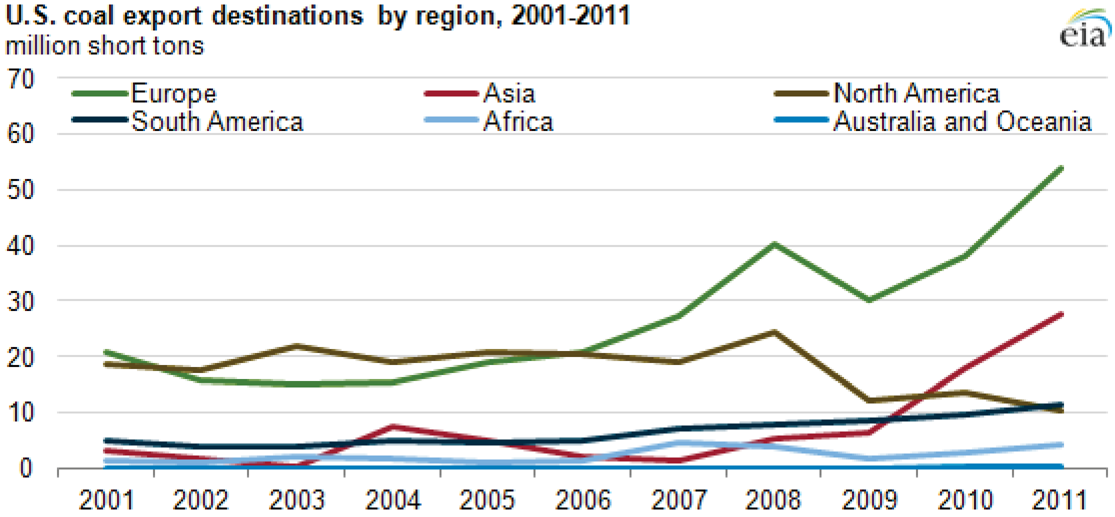

Figure 12 Destination of US coal exports, Source: US Energy Information Administration (2012)

5 Changes in US CO_2 emissions

US CO_2 emissions from energy, excluding those from international aviation and shipping, have declined 8.6% from a peak in 2005, the equivalent of 1.4% per annum over this period. Over the same period annual emissions from coal have declined 308Mt (14%), whilst gas increased 121Mt (10%) in 2011. With additional reductions in oil consumption, total fossil fuel emissions in 2011 were 516MtCO_2 lower than in 2005.

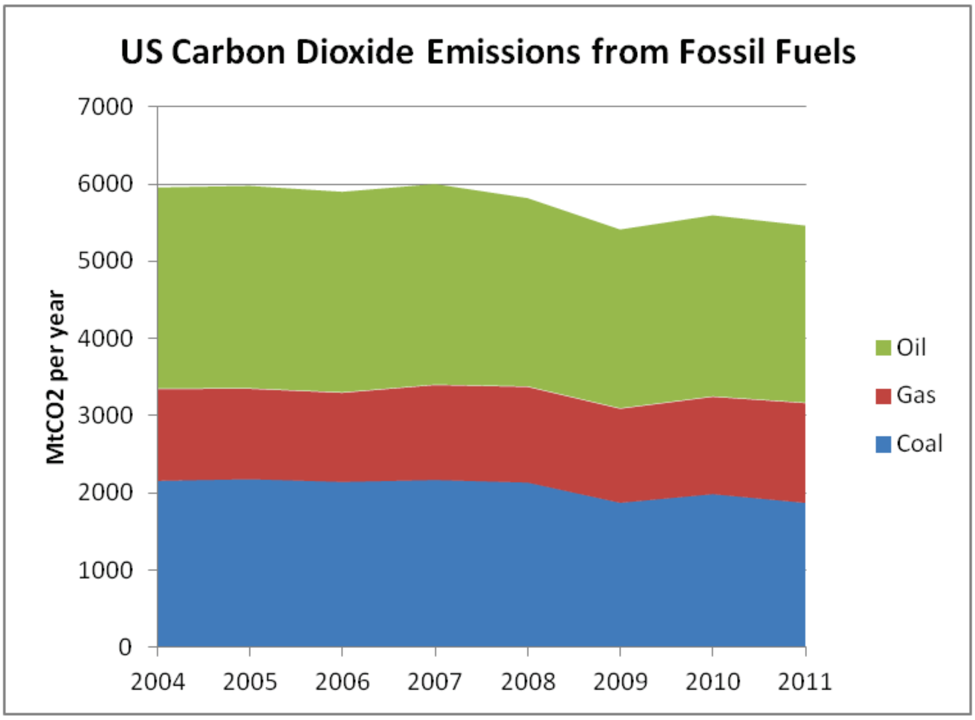

Figure 13 US CO_2 emissions from energy by fuel source

These trends cannot be readily dissociated from changes in economic activity. There was a marked dip due to the 2008-2009 downturn, but it is notable that emissions fell again 2010-2011. This fall was in part due to a slight reduction in total electricity generation in 2010-2011 and increases in absolute quantities of hydro and wind generated electricity[6]. The EIA expect the divergence of sectoral emissions growth, from coal to gas, to intensify further in 2012, before stronger economic growth in 2013 will lead to increases emissions across the board. However, there are unmistakeable differences between trends in energy sources as Figure 14 below illustrates.

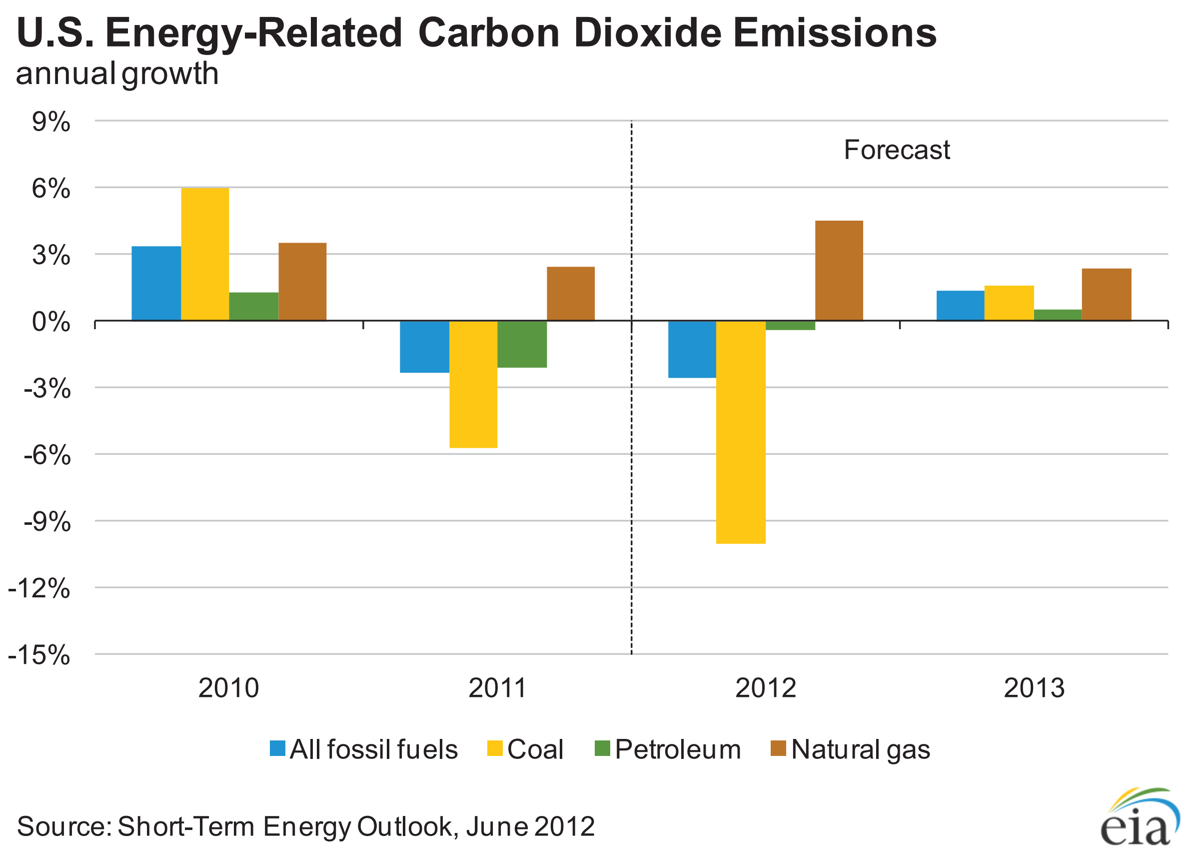

Figure 14 Recent changes in energy related CO_2 emissions

There is sufficient US data to provide a provisional estimate of domestic CO_2 emissions reductions attributable to the displacement of coal by gas in electricity generation. The most up-to-date, but still provisional, data for shale gas production have been derived from submissions of EIA-23 forms presented in the *U.S. Crude Oil, Natural Gas, and Natural Gas Liquids Proved Reserves* report (EIA 2012g). It is assumed in our analysis that figures in Table 3 of EIA 2012g are recorded as “gross withdrawals” i.e. gas volume before the removal of non-hydrocarbon gases and losses from processing. These have been converted to dry gas production figures (i.e. gas fit for transmission, distribution and combustion) by assuming losses at the mean rate for all gas sources derived from the annual national figures in the August 2012 Monthly Energy Review (EIA 2012c). Based on these assumptions, shale gas production grew 48% from 2008 to 2009 and again from 2009 to 2010. To estimate a figure

[6] This is discussed further on page 19, see also (EIA 2012c).

for 2011 production, growth of 40% from 2010 is assumed. The resulting amount is in accordance with the estimates illustrated in Figure 56 of the most recent AEO (EIA 2012a, p61).

Building on these estimates two simple methods of calculating avoided emissions due to fuel switching are described below. The first reviews the relative emissions intensities of US generating stations and assumes that all shale gas produced substitutes for coal. This provides a theoretical upper bound for avoided emissions. The second method takes a base case of a static fuel mix and deducts actual emissions from electricity generation as a sectoral whole. This method allows for shale gas to substitute for other sources of gas.

5.1 *Method 1: Relative efficiencies of US power stations*

Assuming that all 'new' shale gas production is combusted in marginal electricity generating powerplants (CCGTs operating at 45.9% efficiency, Hultman et al. 2011, Table 5) then it is possible to estimate both the emissions from the combustion of the gas and the anticipated quantity of electricity generated. If this electricity is assumed to have otherwise been generated by average US coal powerplant (33.9% efficiency, Hultman et al. 2011) then an estimate of potential CO_2 emissions avoided is possible, as well as the equivalent mass of coal not combusted. These calculations are presented below.

Table 1 Calculation of direct fuel switching emissions reductions

Year	Gross Withdrawals from Shale Gas (MMcf)	Emissions from shale gas combustion (MtCO2)	Potential Electricity from shale gas (TWh)	Equiv coal energy input for same electricity (TWh)	Equiv emissions from coal (MtCO2)	Equiv mass coal (Million short tons)	Equiv Emissions avoided (MtCO2)
2008	1,663,878	96	227	669	227	98	131
2009	2,460,453	141	336	989	335	145	194
2010	4,286,792	246	585	1,724	584	253	338
2011	7,355,087	422	1,004	2,957	1,002	435	580
For comparison, 2010 US total figures							
	Total gas production (MMcf)	*Total gas CO2 (Mtonnes)*	*Total electricity consumption (TWh)*	*Total gas consumption for electricity (MMcf)*	*Total coal CO2 (MtCO2)*	*Power sector coal consumption (Mst)*	*Total fossil fuel emissions (MtCO2)*
2010	21,577,211	1,265	3,755	7,680,330	1,874	975	5,601

There are a number of points to note from this analysis. Firstly, a coal to shale gas switch in electricity generation may at most have led to domestic US emissions reductions of 580MtCO_2 in 2011; this is ~10% of total US fossil fuel CO_2 emissions and the same order of magnitude to the total reduction in energy emissions from the 2005 peak. However, the estimated volume of shale gas produced in 2011 is only slightly lower than the total volume of gas burned in electricity production. Therefore, in combination with the trends illustrated in Figure 3, it is reasonable to conclude that other gas imports, as well as coal, are being displaced in the power sector, or that shale gas is also being used in other sectors such as industry and domestic heating.

Similarly, the fuel switch estimated here is equivalent to 44% of 2011 coal consumption. Although 2011 had relatively low coal consumption, it is still comparable to the highest recent year (2007, 1045 million short tons burned in power sector). As a result, the quantity of avoided emissions due to fuel switching calculated here is almost certainly an overestimate.

Caveats

This analysis does not account for:

- Anything other than the availability of shale gas driving or supplying the fuel switch from coal to gas e.g. climate policies such as the Regional Greenhouse Gas Initiative covering 10 states on the eastern seaboard (http://www.rggi.org/).
- Fugitive methane emissions of either fuel at any point in the electricity supply
- Other lifecycle energy consumption and CO_2 impacts
- Changes in demand for electricity resulting from relative price changes
- The actual heat content of coal and composition of coal displaced / exported. Heat content of coal by unit mass varies substantially by coal type, a uniform central figure of 0.33884 kgCO2e/kWh (DEFRA 2010) is used here.

5.2 Method 2: Power sector fuel switching taken in aggregate

Alternatively, emissions reductions can be estimated from an assumed baseline, in the manner of carbon offset calculations performed under the UNFCCC Clean Development Mechanism. In effect we assume that the same quantity of electricity would have been generated in the years after shale gas availability (2008-2011) but with the fuel mix in the period before shale gas availability (2005-2007) and compare emissions output.

Emissions intensity of US electricity production had been stable from 2001 to 2005 at around 660 to 670 tonnes CO_2/GWh, with a slight fall to approximately 644 tonnes CO_2/GWh in 2006 and 2007. Further year on year reductions then occurred from 2007 onwards.

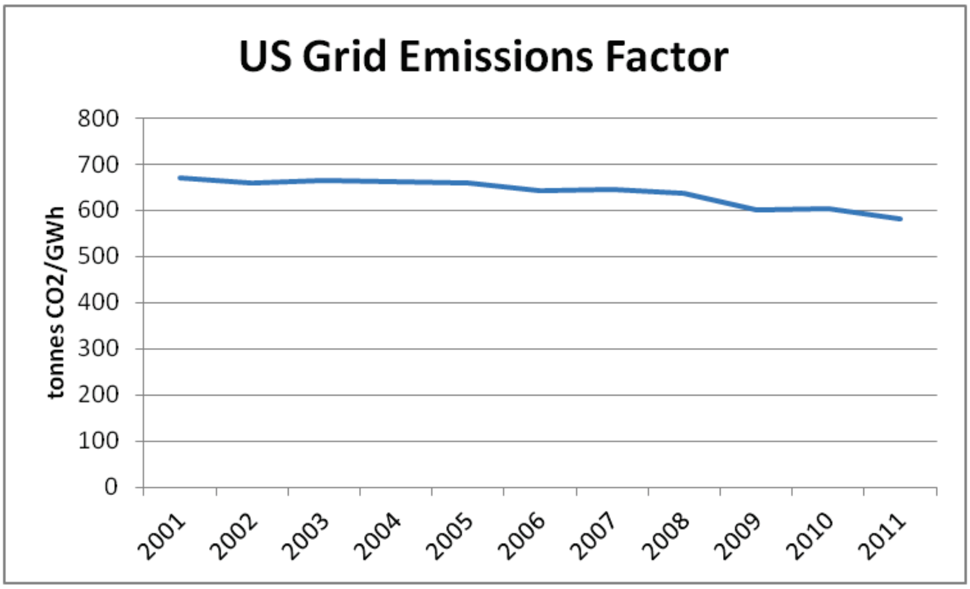

Figure 15 US Grid emissions factor

If we assume a baseline of the grid emissions factor averaged over the three years prior to large scale shale gas production (2005 to 2007) is extended 2008 to 2011, then we have a counterfactual emissions trajectory for electricity generation. Table 2 indicates that emissions would remain at approximately 2400 $MtCO_2$ per annum if electricity consumption was as recorded but the fuel mix remained static. Subtracting actual emissions from this baseline provides an estimate of emissions avoided in the power sector over this period presented as the shaded area in Figure 16 below.

Table 2 Grid emissions reductions from baseline

		2005	2006	2007	2008	2009	2010	2011
CO2 from electricity generation	(MtCO2)	2,417	2,359	2,426	2,374	2,159	2,271	2,166
Consumption of electricity	(GWh)	3,660,969	3,669,919	3,764,561	3,732,962	3,596,865	3,754,493	3,726,163
Emissions intensity of electricity	(tCO2/GWh)	660	643	644	636	600	605	581
Mean emissions intensity electricty 2005-2007	(tCO2/GWh)			649				
Baseline emissions power sector	(MtCO2)				2,423	2,335	2,437	2,419
Avoided emissions in power sector	(MtCO2)				50	176	166	253
Potential max emissions reduction coal to gas switch in electricity	(MtCO2)				131	194	338	580
Potential Electricity from shale gas	(GWh)				227,130	335,868	585,175	1,004,018

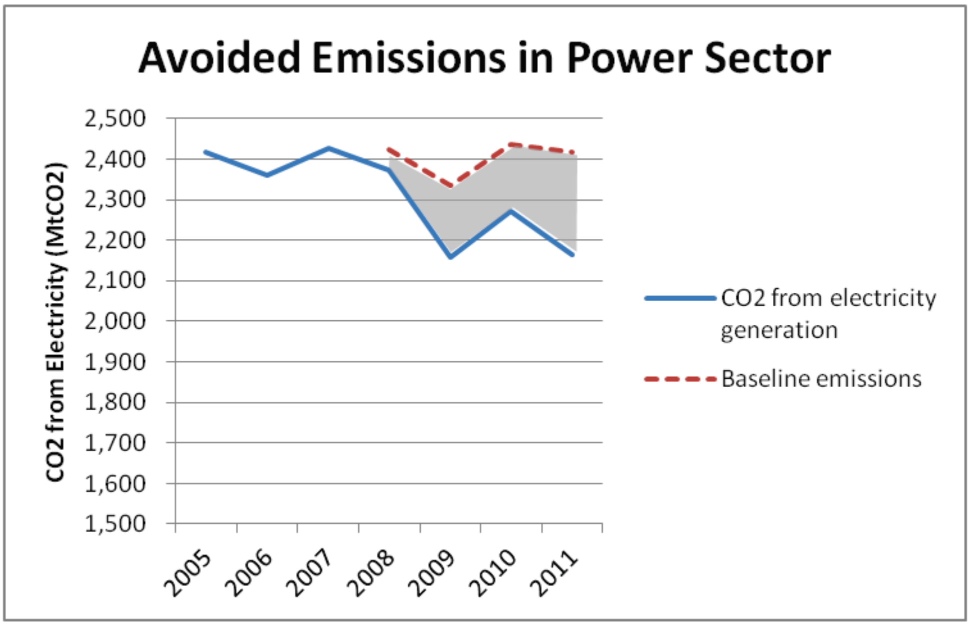

Figure 16 Avoided emissions, baseline method

The resulting potential avoided emissions are calculated to be between 50 and 250 $MtCO_2$ per annum, rising significantly over this period. For 2011, this is less than half the headline figure of 516Mt reduction 2005 to 2011 cited for the US economy as a whole. Clearly, not all of the reduction in US emission output has occurred within the power sector, reductions in other sectors, such as domestic heating and transport, accounting for the other half.

This method implicitly accounts for the substitution of gas imports and domestic gas production unlike that in Section 5.1. However, potential emissions reductions calculated for either method do not account for any substitution by shale gas in sectors other than electricity e.g. in industrial processes.

The estimates shown in Table 2 are less than the emissions reductions calculated by the method in Section 5.1, suggesting that it would be physically possible for shale gas price effects to account for all of the fuel switch were it substituting for coal alone. However, this does not appear to be the case from the trends in gas imports shown in Figure 4, above, and electricity generation from oil outlined in Table 3, below.

Potentially avoided emissions are calculated for the grid as a whole so large scale changes in electricity generation from renewable or nuclear sources are also captured. As outlined in Section 3.1, the changes in these sectors are smaller than the shift from coal to gas combustion. Table 3 (below, and reproduced for clarity on p28) quantifies this shift in terms of the difference between electricity generated in recent years and a 2005-2007 baseline. Reductions are also seen in petroleum consumption, with very small increases in nuclear and hydro when summed across the period 2008-2011 to account for inter-annual variation. The cumulative increase in generation from gas is more than double the increase from wind, although the increase from wind is itself substantial.

Table 3 Trends in generation by fuel source (Data: EIA 2012 Monthly Energy Review Table 7.2b, red indicates reduction, only major fuel sources shown, collectively 99% of generation)

Year	Electricity Net Generation From Coal, Electric Power Sector (Million Kilowatthours)	Coal 2005-2007 baseline generation (Million Kilowatthours)	Electricity Net Generation From Petroleum, Electric Power Sector (Million Kilowatthours)	Petroleum 2005-2007 baseline generation (Million Kilowatthours)	Electricity Net Generation From Natural Gas, Electric Power Sector (Million Kilowatthours)	Natural Gas 2005-2007 baseline generation (Million Kilowatthours)	Electricity Net Generation From Nuclear Electric Power, Electric Power Sector (Million Kilowatthours)	Nuclear 2005-2007 baseline generation (Million Kilowatthours)	Electricity Net Generation From Hydroelectric Power, Electric Power Sector (Million Kilowatthours)	Hydro 2005-2007 baseline generation (Million Kilowatthours)	Electricity Net Generation From Wind, Electric Power Sector (Million Kilowatthours)	Wind 2005-2007 baseline generation (Million Kilowatthours)
2005 **Total**	1,992,054	1,986,727	116,482	79,165	683,829	744,333	781,986	791,877	267,040	266,379	17,811	26,283
2006 **Total**	1,969,737	***Change against baseline***	59,708	***Change against baseline***	734,417	***Change against baseline***	787,219	***Change against baseline***	286,254	***Change against baseline***	26,589	***Change against baseline***
2007 **Total**	1,998,390		61,306		814,752		806,425		245,843		34,450	
2008 **Total**	1,968,838	- *17,890*	42,881	- *36,284*	802,372	*58,039*	806,208	*14,332*	253,096	- *13,283*	55,363	*29,080*
2009 **Total**	1,741,123	- *245,604*	35,811	- *43,354*	841,006	*96,673*	798,855	*6,978*	271,506	*5,127*	73,886	*47,603*
2010 **Total**	1,827,738	- *158,990*	34,679	- *44,487*	901,389	*157,057*	806,968	*15,092*	258,455	- *7,924*	94,636	*68,353*
2011 **Total**	1,714,870	- *271,857*	26,223	- *52,942*	930,568	*186,236*	790,225	- *1,652*	323,141	*56,762*	119,704	*93,421*
Cumulative increase 2008-2011		- *694,340*		- *177,068*		*498,005*		*34,750*		*40,682*		*238,456*

As Figure 3 describes, imports and conventional domestic production of natural gas have been declining during this period, so it is not unreasonable to assume that the increase in shale gas production has contributed to this shift. However, it is important to note that Method 2 does not isolate the price effect of shale on the power sector, nor any simultaneous change in emissions in the non-power sector e.g. chemical and manufacturing industry.

In conclusion, this method is less likely to overestimate potential avoided emissions than the direct fuel switch method presented in Section 5.1 by allowing for internal substitution in the gas market. However, it captures the power sector as a whole, within which the growth in wind generation and the impact of other policies are significant.

5.3 *Econometric approaches to estimating substitution*

A further means of calculating the scale of the shift from coal to gas is to estimate the short term price elasticity of fuel substitution, i.e. the comparative change in consumption of a fuel expected for a given price change. Econometric models are used to identify statistically significant relationships in data sets and estimate elasticities. These values can then be used to make inferences about other parts of the economy where the fuel switching relationship is unclear. The EIA (2012b) has used this method to analyse price and consumption data, at a fine spatial and temporal scale, within the US power sector. It was found that relationships are, on the whole, weak due to a range of confounding but important factors such as available capacity, technical characteristics of generators, and environmental regulations. The EIA (2012b) found substantial regional variations with the elasticity estimates most robust for the Southeastern states but insignificant for Texas and the Midwest. However, this method is recognised within the energy economics literature and offers a causative insight that the methods 1 and 2 above do not.

Two recent studies are worth noting. Lu et al. (2012) use a regional econometric model calibrated with data from 2005-2010 to analyse the reduction in emissions from 2008 to 2009. They estimate that just over half of the observed decrease in emissions from the power sector in this period (215 $MtCO_2$) could be attributed to the reduction in gas price, the remainder predominantly due to the economic downturn.

Afsah and Salcito (2012), using the EIA's mean national estimate of the substitution elasticity of coal to gas of 0.14 (2012b), calculate that coal's relative price increase of 109% from 2006 to 2011 could have increased relative gas consumption by 15%, equivalent to 89 million MWh of electricity displacement. They note that this figure is just 35% of the total reduction in coal fired electricity generation in this period. The remaining reduction in coal burned in the power sector is attributed to regulations, energy efficiency/demand management, improving cost-competitiveness of renewables, the recession and NGO campaigns. In total they estimate that 50Mt of CO_2 reduction from 2006 to 2011 was due to price effects, including the small shift from oil to gas in the power sector.

In conclusion, econometric methods suggest a means of identifying price effects within a system of multiple policy and economic drivers, however a full appraisal of these methods is beyond the scope of this report.

6 Impact on CO_2 Emissions Outside of US

If shale gas has caused displacement of US coal consumption in the power sector then emissions are only reduced in net terms if that coal is not burned elsewhere or at another time. Coal exported to countries with growing economies and without an effective emissions cap is likely to represent an increase in emissions.

Exports of coal to uncapped economies with growing demand for energy are assumed to contribute directly to increased emissions as they serve to reduce effective fuel prices and thereby increase demand. This case is stronger against a background of rising fuel consumption. Global energy consumption trends, illustrated in Figure 17Figure 17, suggest that despite a small reduction in oil and gas consumption from 2008 to 2009, there is no long term indication of demand for coal or gas abating. Indeed data from the BP Statistical Review (2012) shows that coal is the fastest growing fossil fuel in recent years, increasing by an average of 3.8% per annum 2005 to 2011 resulting in a total increase of 25% over this period.

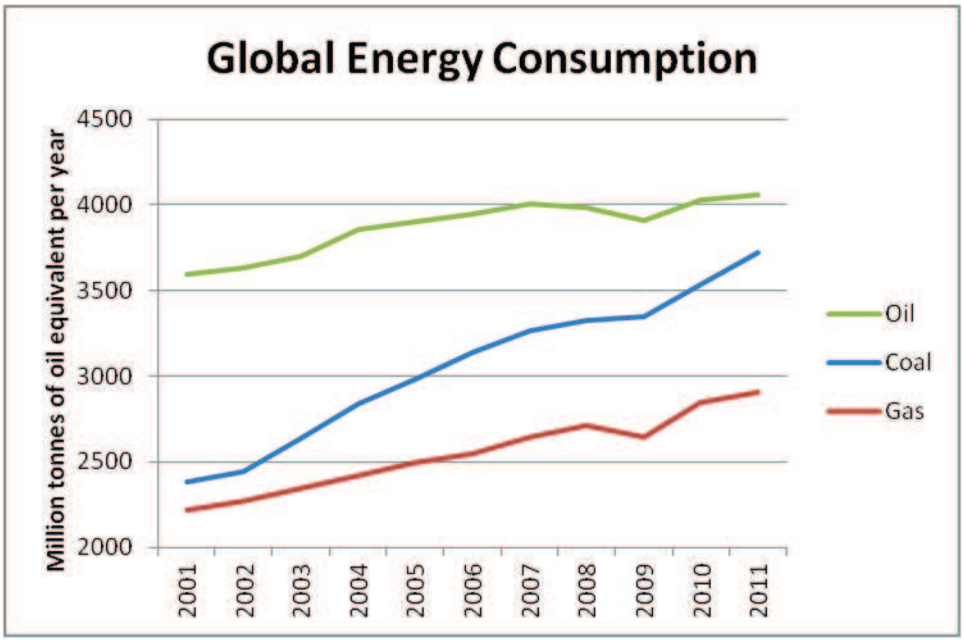

Figure 17 Global energy consumption, data from BP Statistical Review (2012)

It is therefore reasonable to consider emissions from the non-US combustion of displaced US coal as part of the consequences of fuel switching in the US power sector. Wherever displaced US coal is combusted, in the absence of polices to force fossil fuel substitution there will be an absolute increase in global emissions and hence a reduced probability of avoiding the 2°C characterisation of dangerous climate change.

Table 4 estimates the displaced volume of US coal by deducting a baseline average of mean exports in the period 2005-2007 from total net exports in the period 2008 to 2011. Whether or not these exports are entirely due to shale gas or wind displacing coal from the US power sector cannot be demonstrated in this way. However, the calculations in Section 5 show that the mass of coal exported is less than the potential for displacement in the power sector; a position supported by the timing of respective emissions and production trends.

Comparing the scale of avoided emissions due to fuel switching in the power sector to the emissions implicit in coal exports suggests that more than half of the potential emissions avoided may be displaced outside the US. We suggest that 75 million short tons of coal exported from the US in 2011 may be due to displacement, implicitly adding 154 $MtCO_2$ to the atmosphere upon combustion.

Table 4 US Grid emissions reductions in comparison to coal exports

		2005	2006	2007	2008	2009	2010	2011	Aggregate 2008-2011
Net coal exports	(Mst)	20	13	23	47	36	62	94	
Mean net coal exports 2005-2007	(Mst)			19					
Additional exports due to displaced production	(Mst)				29	18	44	75	165
Implicit coal emission exported	(MtCO2)				58	36	89	154	338
Avoided emissions in power sector due to fuel switch	(MtCO2)				50	176	166	253	645
Proportion of avoided emissions represented by displaced coal	(%)				118%	21%	54%	61%	52%
Net avoided emissions due to fuel switch and coal displacement	(MtCO2)				-9	140	77	99	308

Therefore, net avoided emissions due to fuel switching on the US grid in 2011 might better be regarded as approximately 100 $MtCO_2$. Conversely, if this quantity of displaced emissions is added to the US CO_2 output from fossil fuel combustion, see Figure 13, the reduction from the peak in 2005 would be 362 $MtCO_2$ i.e. a 6% change over this whole period or less than 1% per annum. Totalling the quantity of implicit emissions exported over the period 2008 to 2011 suggests that more than half (52%) of the potential avoided emissions from the baseline are lost; 645 $MtCO_2$ avoided, in comparison to 338 $MtCO_2$ exported.

It is important to note that these calculations are dependent upon many assumptions not least that avoided emissions are calculated from a counterfactual baseline. It is also taken that coal displaced but not exported is not burned at any point in future. Finally, it is worth reiterating that it cannot be assumed that the price effect of shale gas availability is responsible for these changes.

The latest data available show the trend in exports to be increasing and also the destination of exports (Table 5), which may have some bearing on the climatic implications due to consuming nations' climate policy framework.

Table 5 Coal exports and implicit emissions[7]

	First Quarter 2012		Annual equivalent
Destination	**Mass Coal (short tons)**	**Emissions (MtCO2)**	**(MtCO2)**
To Europe	16,359,777	37	149
To non-EU	12,281,921	28	112
Total	28,641,698	65	260

In the first quarter of 2012 more than half of US coal exports were to Europe and therefore almost certainly included within the EU ETS. As this is a cap and trade system, the total emissions over the period of its operation should not be breached and there should be no net global increase due to this import, unless this results in secondary changes in the trade of other fuel sources. One might expect displacement of other fuel sources within Europe, for instance away from indigenous fuels or coal and gas imported from other countries. This

[7] Historic monthly export data do not show substantial, consistent, seasonal differences so the annual extrapolation appears reasonable (EIA 2012c).

creates the potential for secondary effects, for instance on the prices of fuels traded with Europe such as Australasian coal or LNG from the Arabian Gulf.

Further, the EU ETS is over supplied with emissions permits primarily as a result of the economic downturn. Although this policy instrument was intended to drive decarbonisation of the power sector, the price of EUAs has been persistently low and is expected to remain so throughout the third phase (2013 to 2020) as the excess from the second phase will be carried over. Presently there appears to be little or no abatement occurring in Europe as a result of the ETS (Morris 2012). Without a radical modification to the EU ETS imports of coal are likely to add to emissions overall and act as a disincentive to investment in lower emissions infrastructure.

Ultimately, even if the imported coal is combusted in a nation or region with emission caps more stringent than the EU, of which none exists at present, there are very likely to be levels of second-order displacement that negate any mitigation benefits. Provided normal levels of profit can be realised from the extraction of fossil fuels, it is difficult to envisage a market-led energy system not extracting and combusting such fuel. Given the global market for fossil fuels is growing and that global economic growth remains dependent on access to such fossil fuels, extraction of a new fossil fuel source is likely to depress overall fossil fuel prices and by definition increase demand i.e. catalyse an increase in absolute emissions. In this regard, and in the absence of meaningful emission caps, shale gas extraction within a market-based energy system will lead to an absolute increase in emissions.

7 Conclusions

This report has explored the emissions consequences of fuel switching in the US energy system using two simple methodologies. The analysis presented is conditional upon its internal assumptions, but provides an indication of the scale of potential changes due to increases in shale gas and wind power. It suggests that emissions avoided due to fuel switching in the US power sector may be up to 50% of the total reduction in US energy system CO_2 emission since their peak in 2005. As discussed in our previous work (Broderick et al. 2011), without a meaningful cap on global carbon emissions, the exploitation of new shale gas reserves is likely to increase total emissions. For this not to be the case, consumption of displaced fuels must be reduced globally and remain suppressed indefinitely; in effect, displaced coal must stay in the ground. Neither the availability of shale gas, nor other policies that transfer power generation away from coal, guarantee this in and of themselves. However, renewable capacity does not directly release carbon dioxide emissions during generation.

Within national boundaries the suppression of gas prices through shale gas availability is a plausible causative mechanism for a proportion of avoided emissions, but the research conducted here has not isolated the proportion of fuel switching due to this effect. Other studies note that between 35% and 50% of the difference between US peak and present power sector emissions may be due to shale gas price effects. The interactions with other US climate and energy policies including cap and trade regulations such as the RGGI have not been investigated.

Whilst there appears to have been a recent shift in US electricity generation that may have realised *localised* CO_2 emissions reductions, it is not clear that there have been substantial net reductions globally. The calculations presented here suggest that more than half of the potential emissions avoided in the US power sector may actually have been exported as coal. Totalling the quantity of implicit emissions exported over the period 2008 to 2011 suggests that approximately 340 $MtCO_2$ of the 650 $MtCO_2$ of emissions avoided may be added elsewhere.

Demand for energy is increasing globally and if this continues to be supplied by fossil fuels then dangerous interference with the climate is increasingly likely. Were an abrupt, internationally simultaneous, fuel switch from coal to gas to occur, the remaining safe carbon budget may be consumed less quickly. In the 'real world' these conditions are unlikely to coincide. The analysis presented in this report suggests that localised fuel switching may not in fact realise the scale of benefits promised by simple comparison of emissions intensity statistics.

Despite downwards revisions to estimates of unconventional gas resources it is likely that this issue will continue to be of relevance to climate policy. It remains to be seen whether the recent trends within the US persist and what the consequences of unconventional gas production outside of the US will be. Further quantitative research into energy system changes is needed if unconventional gas is to be developed globally and the emissions implications understood.

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Reproduction of Table 3 Trends in generation by fuel source

Data: EIA 2012 Monthly Energy Review Table 7.2b, red indicates reduction, only major fuel sources shown, collectively 99% of generation

Year	Electricity Net Generation From Coal, Electric Power Sector (Million Kilowatthours)	Coal 2005-2007 baseline generation (Million Kilowatthours)	Electricity Net Generation From Petroleum, Electric Power Sector (Million Kilowatthours)	Petroleum 2005-2007 baseline generation (Million Kilowatthours)	Electricity Net Generation From Natural Gas, Electric Power Sector (Million Kilowatthours)	Natural Gas 2005-2007 baseline generation (Million Kilowatthours)	Electricity Net Generation From Nuclear Electric Power, Electric Power Sector (Million Kilowatthours)	Nuclear 2005-2007 baseline generation (Million Kilowatthours)	Electricity Net Generation From Hydroelectric Power, Electric Power Sector (Million Kilowatthours)	Hydro 2005-2007 baseline generation (Million Kilowatthours)	Electricity Net Generation From Wind, Electric Power Sector (Million Kilowatthours)	Wind 2005-2007 baseline generation (Million Kilowatthours)
2005 **Total**	1,992,054	1,986,727	116,482	79,165	683,829	744,333	781,986	791,877	267,040	266,379	17,811	26,283
2006 **Total**	1,969,737	***Change against baseline***	59,708	***Change against baseline***	734,417	***Change against baseline***	787,219	***Change against baseline***	286,254	***Change against baseline***	26,589	***Change against baseline***
2007 **Total**	1,998,390		61,306		814,752		806,425		245,843		34,450	
2008 **Total**	1,968,838	- *17,890*	42,881	- *36,284*	802,372	*58,039*	806,208	*14,332*	253,096	- *13,283*	55,363	*29,080*
2009 **Total**	1,741,123	- *245,604*	35,811	- *43,354*	841,006	*96,673*	798,855	*6,978*	271,506	*5,127*	73,886	*47,603*
2010 **Total**	1,827,738	- *158,990*	34,679	- *44,487*	901,389	*157,057*	806,968	*15,092*	258,455	- *7,924*	94,636	*68,353*
2011 **Total**	1,714,870	- *271,857*	26,223	- *52,942*	930,568	*186,236*	790,225	- *1,652*	323,141	*56,762*	119,704	*93,421*
Cumulative increase 2008-2011		- *694,340*		- *177,068*		*498,005*		*34,750*		*40,682*		*238,456*

February 2012

cyfeillion y ddaear cymru
friends of the earth cymru

Submission to the Environment and Sustainability Committee of the National Assembly for Wales

in response to

the Session Examining Shale Gas and Gasification

This submission is *additional* to the submission to the Petitions Committee

Summary

1. There is a significant and growing body of evidence that the use of shale gas (and possibly underground coal gasification) cause a higher level of greenhouse gas emissions than would otherwise be the case.

2. There is also a significant and growing body of evidence that the use of shale gas can cause serious water and air pollution, and could lead to an unsustainable demand on water. Pollution concern is particularly acute in relation to groundwater.

3. The flowback liquid from fracking operations is highly likely to be contaminated with a variety of chemicals and radioactive compounds. This makes it hazardous waste. Wales has no commercial hazardous waste treatment sites, so large quantities of this hazardous material will need to be removed from Wales – presumably by lorry.

4. Welsh planning policy demands that sound science be used responsibly, which in this context entails a precautionary approach. Policy also demands that unconventional gas be specifically acknowledged as a source of greenhouse gas production (and is a process which therefore runs counter to policy seeking to mitigate climate change). A new policy, or an addendum to Planning Policy Wales (PPW), is the appropriate means of dealing with the specific issues arising from unconventional gas exploitation.

5. In view of the urgent need to mitigate climate change, Friends of the Earth Cymru has proposed an additional planning policy that provides for a sound precautionary approach to decision-making:

   Planning permission for unconventional gas operations (including test drilling and extraction) will not be granted unless:
   a) the planning authority is satisfied that all reasonable scientific doubt that there is any risk of adverse impacts including groundwater contamination has been eliminated
   b) the proposal will not compromise the planning authority's duties in relation to climate change mitigation and adaptation; and
   c) the proposal is environmentally acceptable, or it can be made so by planning conditions or obligations.

6. Given that policy in England is strongly in favour of unconventional gas, and given the existing uncertainties over environmental problems the use of the various technologies in the UK could cause, the precautionary principle suggests that a more restrictive planning regime would be of considerable benefit to the Welsh environment. Should unconventional gas operations proceed safely and with no contamination in England for a number of years, consideration could be given to relaxing the planning regime.

7. This is exactly the sort of learning that devolution is designed to elicit. In a corollary of England learning about the environmental benefits for Wales of charging for carrier bags, Wales could learn about the risk associated with unconventional gas activities carried out in England.

8. In the short term we recommend the Welsh Government adopt a moratorium on unconventional gas exploration until sufficient information is available to determine with a high degree of certainty the likely impacts on the environment.

9. In addition, and without prejudice to the recommendations above, the Environmental Impact Assessment Regulations (England and Wales) 1999 should be amended to include the requirement for a full EIA to be conducted for each unconventional gas application. Fracking operations exempt themselves by ensuring they have a surface operation smaller than the 1 ha limit (ordinarily they are 0.99 ha) that would make them subject to these Regulations.

Introduction

10. The UK Government announced in December that fracking for shale gas can resume in principle in the UK. Friends of the Earth believes that this is a gamble that we do not need to take. Fracking for shale gas:

   - Helps keep us hooked on fossil fuels instead of moving towards an energy system based on energy saving and renewable sources;
   - Brings serious risks to the local environment and
   - Is unlikely to cut energy bills.

11. We cover these points in more detail below. We deal briefly with Underground Coal Gasification at the end.

How much shale gas is there?

12. There are no firm figures for either UK shale gas resources (the volume of gas underground) or reserves (the volume of gas that can be extracted, which depends on factors including technology and cost). Cuadrilla, the company drilling in Lancashire, has estimated the resources in its licence area at around 5,660bcm, or around 56 years' worth of current UK gas consumption. Cuadrilla's CEO, Francis Egan, has said that they can supply a quarter of UK gas demand from its licence area alone[1]. DECC is shortly expected to publish new figures from the British Geological Survey (BGS) which have been rumoured to estimate UK shale gas resources at 200 times its previous figure at around 38,000 – 48,000 bcm[2]. However only a small percentage of this – typically 10% - might be recoverable.

13. Experience elsewhere shows that any numbers are very volatile:

   - Estimates of shale gas reserves in Poland were cut by 85% last year, based on analysis of data from wells drilled between the 1950s and 1980s[3].
   - The US Energy Department cut estimates of technically recoverable gas in the Marcellus Shale, one of the most mature shale gas plays, by 66% in 2012, citing improved data on drilling and production[4]

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[1] Sunday Telegraph 1st December 2012 'Cuadrilla set to resume fracking as George Osborne backs UK shale gas' http://www.telegraph.co.uk/finance/newsbysector/energy/9716558/Cuadrilla-set-to-resume-fracking-as-George-Osborne-backs-UK-shale-gas.html

[2] The Times 9th February 2013 'Britain has shale gas for 1,500 years, but bills won't be lower' http://www.thetimes.co.uk/tto/business/industries/naturalresources/article3683377.ece

[3] Bloomberg 26th March 2012 'Shale boom in Europe fades as Polish wells come up empty' http://www.bloomberg.com/news/2012-03-26/shale-boom-in-europe-fades-as-polish-wells-come-up-empty-energy.html

[4] Bloomberg 23rd January 2012 'US cuts estimate for Marcellus Shale gas reserves by 66%' http://www.bloomberg.com/news/2012-01-23/u-s-reduces-marcellus-shale-gas-reserve-estimate-by-66-on-revised-data.html

Environmental risks

14. Fracking brings many environmental risks. The risks for the local environment and human health have recently been assessed in a report for the European Commission. This assessed that there was a 'high risk' of local environmental problems including groundwater contamination, surface water contamination, water resource use and air pollution from the cumulative impact of fracking at several sites[5].

Climate change

15. Advocates of shale gas say it has lower overall emissions than coal or conventional gas, but the academic jury is still out. The key issue for comparing gas with coal is how much methane escapes during gas exploration and production of, known as 'fugitive emissions'. Methane is a much more powerful greenhouse gas than carbon dioxide. Experts say that if fugitive emissions are below about 3.2% of total well production then natural gas has a lower climate impact than coal. The US EPA estimates that fugitive emissions are below this, but recent US monitoring suggests that fugitive emissions could be over 4% and up to 9% in some cases, eroding any climate advantages[6].

16. The Environment Agency suggests that fugitive emissions of 4% would be about twice the amount originally envisaged from desk studies[7]. However, conducting research on this matter in the UK *"would require a significant research budget from such as DECC for the UK or… at a European scale the EC Commission"*[8].

17. In a confidential paper to the DECC's Chief Scientist, an anonymous author notes: *"The largest contribution to emissions in the pre-production phase comes from well completion. Upon completion of hydraulic fracturing a combination of fracturing fluid and water is returned to the surface (flow back). The flow back contains a combination of water, sand, hydrocarbon liquids and natural gas. Equipment historically at production wells are not designed to handle this initial mixture of wet and abrasive fluid. Standard practice has been to vent or flare the natural gas during this step, and direct the waste water into ponds or tanks… Existing DECC controls already limit venting to the technical minimum, and limit flaring to the economic minimum"*[9]. It is worth pointing out that the 'economic minimum' referred to for flaring will be determined by the operator.

18. A confidential briefing note commissioned by DECC confirms that several areas of substantial concern for climate change need either to be reviewed for greenhouse gas accounting or a brand

[5] AEA Technology for the European Commission (2012) Support to the identification of potential risks for the environment and human health arising from hydrocarbons operations involving hydraulic fracturing in Europe' http://ec.europa.eu/environment/integration/energy/pdf/fracking%20study.pdf

[6] Nature 2nd January 2013 'Methane leaks erode green credentials of natural gas' http://www.nature.com/news/methane-leaks-erode-green-credentials-of-natural-gas-1.12123

[7] Environment Agency (2012) 'Monitoring and control of fugitive methane from unconventional gas operations' http://cdn.environment-agency.gov.uk/scho0812buwk-e-e.pdf

[8] Freedom of Information request: Email from E&B Climate Change mitigation team in Environment Agency on 19th December 2012

[9] Freedom of Information request: Paper to DECC's Chief Scientist 'Carbon intensity of shale gas' on 28th September 2012

new methodology developed[10]. These include fugitive releases from equipment, gas venting, gas flaring, shale gas combustion, gas processing, fugitive emissions from fracking and flowback, and emissions resulting from wastewater treatment and disposal (described as a 'high emissions' process). The report concludes that just 330 fracking wells could double the greenhouse gas emissions profile of the entire UK oil and gas sector.

19. Any benefit over conventional gas is also unclear. A study for the European Commission found emissions from shale gas production were 1-8% higher than for conventional pipeline generation within Europe. It also found that shale gas emissions could be lower than for conventional pipeline gas from outside Europe or for LNG imports but that this depends on industry practices, and there might be no benefits[11].

20. If shale gas does have lower climate impact than coal, then any climate benefit depends on shale gas being burned instead of coal. The industry points to shale gas replacing coal in the US helping cut carbon emissions, but analysis from the Tyndall Centre shows that much of the coal not used in the US was exported, meaning that half the emissions benefit was lost. Coal use for electricity generation in the UK rose from 22.9% in the 3rd quarter of 2011 to 35.4% in the 3rd quarter of 2012[12]. In a world with a growing demand for energy, and without a global climate deal, shale gas will probably be used as well as coal.

21. Globally, the International Energy Agency (IEA) has calculated that a 'Golden Age of Gas' with *"an accelerated global expansion of gas supply from unconventional resources"* which more than triples to 2035[13]. This *"puts CO2 emissions on a long-term trajectory ... consistent with a probable temperature rise of more than 3.5 degrees Celsius in the long term"*[14]. This is well above the threshold for triggering catastrophic climate change: as the IEA admits *"we are not saying that it will be a golden age for humanity - we are saying it will be a golden age for gas"*[15].

22. Exploitation of shale gas in the UK could have a major impact on investment in renewable energy. Professor Paul Stevens of Chatham House has written that "*the anticipation of cheap natural gas could inhibit investment in renewables. But again, if the revolution fails to deliver a lot of cheap gas, by the time this is realized it could well be too late to revert to a solution to climate change based upon renewables"*[16].

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[10] Freedom of Information request: Report commissioned by DECC 'NAEI Briefing Note: Shale gas exploration and production and impacts on the UK GHG inventory'
[11] European Commission (2012) 'Climate impact of potential shale gas production in the EU' http://ec.europa.eu/clima/policies/eccp/docs/120815_final_report_en.pdf
[12] DECC 'Energy Trends December 2012' Section 5 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/65835/3945-energy-trends-section-4-electricity.pdf
[13] International Energy Agency (2012) 'Golden Rules for a Golden Age of Gas' p63 http://www.worldenergyoutlook.org/media/weowebsite/2012/goldenrules/weo2012_goldenrulesreport.pdf
[14] Ibid p91
[15] BBC Campaigners' anger over agency's shale gas report 29th May 2012
[16] Chatham House August 2012 'The 'Shale Gas Revolution': Developments and Changes' http://www.chathamhouse.org/sites/default/files/public/Research/Energy,%20Environment%20and%20Development/bp0812_stevens.pdf

Water use

23. Fracking is a water-intensive activity, with each frack in the US using between 2 and 6.4 million gallons. At the one site fracked in the UK, 8.4 million litres or 1.85 million gallons of water were used[17]. There has been little research to date on whether this level of water use is sustainable at the local and regional level in the UK, particularly in areas that have suffered from drought. Water UK, which represents the water utilities, has said *"where a large number of gas boreholes exist in a local area, there is a risk of water shortages for other purposes"*[18]. This could be aggravated by future climate change affecting water supplies: according to the Chartered Institute of Water and Environmental Management (CIWEM) *"whether this level of water use is appropriate in the long term to source energy requires further research"*[19].

Water contamination

24. Methane and fracking fuid may escape / contaminate water via a number of different routes:

- Migration via naturally occurring fractures in the rock or via extension of fractures created by fracking
- Leaks via well-casings that have been inadequately completed or which have subsequently failed
- Leaks or spills of fracking fluid or 'produced water' above ground. The amount of water that returns to the surface varies greatly, and can be from 20% to 80%, depending on the individual well

25. Despite industry claims, there is considerable evidence of contamination from both methane and fracking chemicals. One study of aquifers overlying the Marcellus and Utica shales in the north-eastern US found *"systematic evidence of methane contamination of groundwater associated with shale gas extraction"*[20].

26. The industry claims that fracking is a proven technology, widely used for 60 years. But fracking as proposed in the UK is at best a decade old development based on new technologies that are still being refined.

27. If there is a risk of contamination, what chemicals could be involved? A major problem is that there is limited data on the chemicals that have been used for fracking. This is because US law excludes fracking from federal regulation by the Environmental Protection Agency although disclosure is required by some US states and some companies are posting the composition of the fracking fluid they are using online[21]. In the UK, companies will be required to publish the contents of fracking fluid.

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[17] Cuadrilla Resources 'Composition of components in Bowland Shale hydraulic fracturing fluid for Preese Hall-1 well http://www.cuadrillaresources.com/wp-content/uploads/2012/02/Chemical-Disclosure-PH-1.jpg

[18] Water UK (2012) 'Risks to water supplies posed by gas shale extraction' http://www.water.org.uk/home/policy/positions/shale-gas/water-uk-position-paper-on-gas-shale-extraction--sept-2012-.pdf

[19] CIWEM (2012) 'Hydraulic Fracturing (Fracking) of Shale in the UK' http://www.ciwem.org/media/624838/Fracking_Oct2012.pdf

[20] Osborn et al (2011) 'Methane contamination of drinking water accompanying gas-well drilling and hydraulic fracturing' http://www.pnas.org/content/early/2011/05/02/1100682108.full.pdf+html

[21] See http://fracfocus.org

An assessment[22] of 353 chemicals known to be used in fracking in the US found that a quarter could cause cancer and 40 - 50% could affect the nervous system, immune and cardiovascular systems.

28. The industry says that chemicals are a very small percentage of the liquid pumped underground, but with huge volumes of water used, this still means a huge quantity of chemicals. If you assume take a conservative estimate that the chemicals are just 0.5% of the say 4 million gallons of water used, this means that each fracking operation involves 20,000 gallons (about 75,000 litres) of chemicals.

29. In addition to the chemicals, fracking waste water may also contain substances from deep underground such as strontium, benzene, toluene and Naturally Occurring Radioactive Material (NORM) such as Radium 226[23]. An investigation by the New York Times found that nearly three-quarters of the more than wells studied in the north east US produced waste water with high levels of radiation, including at least 116 wells with levels that were hundreds of times the US EPA's drinking water standard, and at least 15 wells with levels thousands of times the standard[24].

30. The Tyndall Centre for Climate Change Research considers that the flowback fluid is *"likely to be considered as hazardous waste[25] in the UK"*[26]. We know that there are no commercial hazardous waste landfill sites in Wales[27]. However, we do not know if there are any hazardous waste treatment sites in Wales that could treat fracking flowback fluid. Treatment of this fluid offsite is certain to require significant numbers of lorry movements. The Environmental Services Association has called for the Environment Agency to review its permits for hazardous waste treatment[28].

31. The UK Government claims that the current regulatory system is adequate: Energy Secretary Ed Davey has said that *"there are already in place robust regulatory controls on all oil and gas activities"*[29]. The Welsh Government concurs: *"We consider that the precautionary approach adopted in national planning policy is sufficiently robust"*[30]*.* Although regulations will be tougher in the UK than in the US, it is impossible to say whether they will be tough enough: the Environment Agency, the principal regulator, has at the time of writing not completed a consultation draft of its technical

[22] Colborn et al (2011) 'Natural Gas Operations from a Public Health Perspective' http://cce.cornell.edu/EnergyClimateChange/NaturalGasDev/Documents/PDFs/fracking%20chemicals%20from%20a%20public%20health%20perspective.pdf
[23] Food & Water Watch (2012) 'Fracking: the new global water crisis' http://documents.foodandwaterwatch.org/doc/FrackingCrisisEU.pdf
[24] New York Times 26th February 2011 'Regulation Lax as Gas Wells' Tainted Water Hits Rivers' http://www.nytimes.com/2011/02/27/us/27gas.html?pagewanted=all&_r=0
[25] Environment Agency 'What is hazardous waste?' http://a0768b4a8a31e106d8b0-50dc802554eb38a24458b98ff72d550b.r19.cf3.rackcdn.com/geho0411btqz-e-e.pdf
[26] Tyndall Centre for Climate Change Research (2011) 'Shale gas: a provisional assessment of climate change and environmental impacts' http://www.tyndall.ac.uk/sites/default/files/tyndall-coop_shale_gas_report_final.pdf
[27] Environment Agency, 'Hazardous waste in Wales' http://www.environment-agency.gov.uk/research/library/data/98052.aspx
[28] Resource UK 16th January 2013 'ESA calls for better treatment of hazardous waste' http://www.resource.uk.com/article/UK/ESA_calls_better_treatment_hazardous_waste-2634#.UStSQB3OKSo
[29] Ministerial Statement 13th December 2012 'Exploration for shale gas' https://www.gov.uk/government/speeches/written-ministerial-statement-by-edward-davey-exploration-for-shale-gas
[30] Environment Minister 8th November 2012 Letter to the Petitions Committee http://www.senedd.assemblywales.org/documents/s11852/08.11.12%20Correspondence%20-%20Minister%20for%20Environment%20and%20Sustainable%20Development%20to%20Chair.pdf

guidance on shale gas exploration, and is unable to say when this will be ready. It has not started looking at regulations needed for shale gas production. The approach of the Health and Safety Executive is perhaps instructive: around 5% of the resource of the six wells inspectors is being expended on shale gas issues[31].

32. Mark Menzies, Conservative MP for Fylde where Cuadrilla is active, and Parliamentary Private Secretary to former Energy Minster Charles Hendry has said *"I do not believe that the regulatory system is robust or transparent enough to instill public confidence"*[32]. Professional bodies have also expressed concerns: CIWEM has said that *"the UK should … not encourage fracking as a part of our energy mix until there is more evidence that operations can be delivered safely, that environmental impacts are acceptable and that monitoring, reporting and mitigation requirements are comprehensive and effective"*[33].

33. The Government has set up an Office for Unconventional Gas and Oil which it says will provide a regulatory regime which will be *'simplified and streamlined'* yet also *'robust'*[34]. These potentially competing demands have been questioned by the Chair of the House of Commons Energy and Climate Change Committee, Tim Yeo MP, who has referred to *"The combination of roles in the Office for Unconventional Gas and Oil, which appears to be acting as a cheerleader for the industry as well as a regulator"*[35].

Air pollution

34. Fracking for shale gas has also been linked to increased levels of air pollution and associated health problems. Monitoring[36] of air quality near fracking sites in western Colorado found over 50 non-methane hydrocarbons (NMHCs) near shale gas wells. Of these, 44 have health impacts including 35 which affect the brain and nervous system. Some of these were found at levels which could potentially harm children exposed pre-birth. Although the pollution was not conclusively linked to the gas wells, there is little other industry and not much traffic in the area monitored.

Earthquakes

35. Earthquakes triggered by test-fracking in Lancashire in early 2011 prompted the *de facto* moratorium on fracking. In addition to the concerns of local people about damage to properties, an even greater risk is to the integrity of the well-linings, typically made of steel and cemented in place, designed to reduce or eliminate the possibility of leaking methane or flowback water. Tony Grayling, Head of

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[31] House of Commons Hansard Written Answer 12th February 2013 http://www.publications.parliament.uk/pa/cm201213/cmhansrd/cm130212/text/130212w0002.htm#130212w0002.htm_wqn23

[32] House of Commons Hansard 24th October 2012 column 1038 Adjournment debate on onshore gas

[33] Chartered Institute of Water and Environmental Management (CIWEM) Hydraulic fracturing (fracking) of shale in the UK

[34] DECC (2012) 'Gas Generation Strategy' paras 5.17 and 5.25 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/65654/7165-gas-generation-strategy.pdf

[35] Energy & Climate Change Committee 'The impact of shale gas on energy markets' oral evidence 16th January 2013 Q280 http://www.publications.parliament.uk/pa/cm201213/cmselect/cmenergy/c785-iii/c785iii.pdf

[36] Colborn et al (2012) 'An Exploratory Study of Air Quality near Natural Gas Operations' http://www.endocrinedisruption.com/files/HERA12-137NGAirQualityManuscriptforwebwithfigures.pdf

Climate Change at the Environment Agency, has acknowledged that this could be a problem, saying in relation to the Lancashire earthquakes: *"we need to understand what is the maximum damage that might be done in such circumstances to a well and the integrity of the casing, whether it would increase the risk of a leak. If there is groundwater in the vicinity, that could be a problem"*[37].

36. Evidence from the US shows that the Lancashire experience is not unique. Several US states have experienced seismic activity following shale gas drilling and fracking in areas where this has not previously happened. Although a causal link has not been proved in all cases, a close correlation between fracking and earth tremors can be seen[38]. According to the US Geological Survey's Earthquake Science Center, in the US at least *"the future probably holds a lot more in induced earthquakes as the gas boom expands"*[39].

Will shale gas cut energy bills?

37. Shale gas advocates say it will lead to big cuts in gas prices, as it has done in the US, but there is great scepticism among experts that this will be the case.

38. Shale gas production costs in Europe are likely to be higher than in the US. The reasons for this include higher population density and associated problems of land availability, the lack of a competitive onshore drilling and services industry and tougher environmental regulation[40]. Such factors led the IEA to conclude that operating costs in Europe will be 30-50% higher than in the US[41].

39. Claims of cheaper gas prices also ignore global market dynamics. Demand for gas is rising fast, particularly from China, India and other emerging economies. This growing demand is likely to soak up new gas supplies, potentially keeping supply constrained and prices high. According to energy expert Professor Paul Ekins: *"UK households and industry would be tied to a highly unpredictable roller coaster of gas prices that are generally high and can spike higher due to volatility"*[42].

40. Overall, Bloomberg New Energy Finance has concluded that *"given conditions in the UK, it is hard to see shale gas coming to market at much below $8 per MMBtu – around the same as the wholesale*

[37] The Times Feb 6th 2012 'Blackpool tremors reopen questions over fracking' http://www.thetimes.co.uk/tto/business/industries/naturalresources/article3310081.ece

[38] See for example http://stateimpact.npr.org/pennsylvania/2011/08/26/how-fracking-causes-earthquakes-but-not-the-one-in-virginia/

[39] Ibid

[40] See Chatham House (2010) 'The shale gas revolution: hype and reality' http://www.chathamhouse.org/sites/default/files/public/Research/Energy,%20Environment%20and%20Development/r_0910stevens.pdf and Florence Gény (2010) 'Can unconventional gas be a game changer in European gas markets?' http://www.oxfordenergy.org/wpcms/wp-content/uploads/2011/01/NG46-CanUnconventionalGasbeaGameChangerinEuropeanGasMarkets-FlorenceGeny-2010.pdf

[41] International Energy Agency (2012) 'Golden Rules for a Golden Age of Gas' op cit p54

[42] Paul Ekins New Scientist 6th December 2012 'The UK's new dash for gas is a dangerous gamble' http://www.newscientist.com/article/dn22594-the-uks-new-dash-for-gas-is-a-dangerous-gamble.html

prices that have been driving up utility bills in recent years"[43]. The IEA's analysis shows that gas prices in Europe will be around 40% higher than today in both 2020 and 2035[44].

Will shale gas improve energy security?

41. Another claim from shale gas advocates is that shale gas will improve the UK's energy security, as we will not have to rely on gas supplies from unstable regions or be heavily dependent on countries such as Qatar. However DECC believes that *"It is still too early to come to firm conclusions on whether shale gas production in the UK or elsewhere in Europe is likely to have a significant effect on … security of supply"*[45].

42. Friends of the Earth believes energy security should be defined more broadly than just about supply and geopolitics, also including price security (providing energy at reasonable prices) and environmental security (achieving emissions targets and minimising other impacts)[46]. In a report for Friends of the Earth, energy security expert Professor Michael Bradshaw concluded that *"the best way to reduce the energy security risks associated with the UK's growing gas import dependence is to hold the course, promote renewable power generation, improve energy efficiency and reduce overall energy demand"*[47].

43. The use of energy in Wales is on a decreasing trend. Since 2005 electricity use (industrial and residential) has decreased by 13%[48] and gas use by 28%[49]. Energy security needs to be viewed in the context of decreasing energy use.

Jobs and local economy

44. The shale gas industry paints an overwhelmingly positive picture of its local economic impact through job creation. A report for Cuadrilla has claimed that shale gas production in Lancashire could create up to 6,500 full-time equivalent jobs in the UK as a whole, with 2,500 of these in Lancashire[50]. However US experience shows that such claims should be treated with scepticism: numbers are

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[43] Bloomberg New Energy Finance 31st October 2012 'UK energy policy – a time of consequences' http://about.bnef.com/2012/10/31/bnef-chief-executive-michael-liebreich-vip-comment-uk-energy-policy-a-time-of-consequences/
[44] International Energy Agency (2012) 'Golden Rules for a Golden Age of Gas'op cit p74
[45] DECC evidence to House of Commons Energy and Climate Change Committee inquiry 'The impact of shale gas on energy markets' http://www.publications.parliament.uk/pa/cm201213/cmselect/cmenergy/writev/isg/m01.htm para 2
[46] Bradshaw (2012) for Friends of the Earth 'Time to take our foot off the gas?' http://www.foe.co.uk/resource/reports/time_to_take_our_foot_off.pdf
[47] Ibid
[48] DECC http://www.decc.gov.uk/media/viewfile.ashx?filetype=4&filepath=11/stats/energy/sub-national-energy/4820-subnat-auth-electricity-cons-2005-2010.xls&minwidth=true
[49] DECC http://www.decc.gov.uk/media/viewfile.ashx?filetype=4&filepath=11/stats/energy/sub-national-energy/3954-subnat-gas-sales-2005-2010.xls&minwidth=true
[50] Regeneris Consulting (2011) 'Economic Imopact of Shale Gas Exploration & Production in Lancashire and the UK' http://www.cuadrillaresources.com/wp-content/uploads/2012/02/Full_Report_Economic_Impact_of_Shale_Gas_14_Sept.pdf

often over-stated[51]; most employment is in the drilling phase, which only lasts around a year[52]; and many jobs go to transient workers who move from one well to another[53].

45. Nor has any estimate been made of potential negative impacts on other economic sectors such as agriculture and tourism. Experience in the US shows that fracking can create problems for local agriculture, including the loss of agricultural land and concerns about water resources[54]. Nationwide Mutual, the largest US farming insurance underwriter, has said that *"from an underwriting standpoint we do not have a comfort level with the unique risks associated with the fracking process to provide coverage at a reasonable price"*[55]. In Australia, local tourism bodies are among the opponents of unconventional gas development[56].

46. Alun Cairns MP has expressed concerns about the potential impact of fracking on the Vale of Glamorgan: *"The Vale is a great place to live and work; and I want it to remain that way. The small rural villages, the fantastic coastline, country roads and a focus on agriculture to the west and the vibrancy of Barry, Wales' largest town to the east, with its own coastline, history and heritage. Any future gas exploration could put this at risk"*[57].

47. Research form the US shows that investing $1 million in renewable energy creates more than two to three times as many jobs as investing the same amount in gas[58]. Government figures show that 20,848 jobs were created in the renewables sector in the UK between April 2011 and April 2012[59] and the renewable energy sector could support 400,000 jobs by 2020[60].

48. Fracking could affect house prices. An estate agent in Poulton-le-Fylde, near one of Cuadrilla's drilling sites, in Lancashire, told the Observer *"There are a lot of properties coming on to the market, and some of the owners are saying they want to get out before prices start dropping"*[61].

[51] See for example Industry Week August 11th 2011 The great debate over shale gas employment figures
[52] Research for Cuadrilla shows that the number of jobs created at around 1,600 in Lancashire and 5,600 in the UK for four years from 2016 to 2019, falling to under 200 from 2022 onwards. Regeneris Consulting Economic impact of shale gas exploration & production in Lancashire and the UK
[53] In Pennsylvania, 70% of gas well drilling jobs go to out-of-state employees. ENR New York March 7th 2011 Hydrofracking Offers Short-Term Boom, Long-Term Bust
[54] Food and Water Watch Fracking and the food system
[55] Nationwide Mutual 13th July 2012 Nationwide statement regarding concerns about hydraulic fracturing
[56] Northern Rivers Echo 31st May 2012 Tourism joins call to halt CSG
[57] http://www.aluncairns.co.uk/2012/07/dismay-over-shale-gas-planning-inquiry-decision/
[58] Investing $1 million dollars in gas creates 5 jobs compared to 13 for wind, 14 for solar and 17 for building retrofits from the same amount of investment. Political Economy Research Institute, University of Massachusetts The economic benefits of investing in clean energy
[59] DECC Renewables Investment and Jobs
[60] Renewable Energy Association April 2012 Renewable energy: made in Britain
[61] The Observer 23rd June 2012 'Worry for homeowners who face the threat of fracking' http://www.guardian.co.uk/money/2012/jun/23/fracking-undermine-value-home

Underground Coal Gasification

49. Another unconventional process starting to receive more attention is Underground Coal Gasification (UCG), which produces 'syngas', a mixture of carbon dioxide, carbon monoxide, hydrogen and methane, which can be used for power generation, chemical feedstocks or processed to produce diesel fuel. Clean Coal Ltd has an exploration licence and is developing proposals for UCG in Swansea Bay, and another company has exploration licences for two UCG projects in the Llwchwr and Dee estuaries[62].

50. The UK Government has said that carbon capture and storage (CCS) will be needed if syngas is to be used for power generation[63]. Although Friends of the Earth believes that CCS is a vital part of the UK's energy future, both for power stations and for energy-intensive industry, we believe that placing blind faith in the ability of industry to deliver CCS which works at scale and which is cost-effective, is extremely risky because:

    - CCS has not yet been demonstrated at scale anywhere in the world, there is no certainty that it will work and commercial deployment is at best still many years' away
    - CCS is not a zero-carbon solution: coal with CCS still has significant carbon dioxide emissions.

51. Friends of the Earth does not see UCG as part of the UK's energy future.

Conclusions

52. Friends of the Earth believes that shale gas and UCG are unconventional and unnecessary

53. To meet our legally-binding climate change targets, Friends of the Earth agrees with the Committee on Climate Change[64] that we must almost totally decarbonise electricty generation by 2030. This is critical not just because electricity generation is a major source of carbon emissions, but because decarbonised electricity will help emissions reduction in heating and transport by allowing a shift from gas and oil respectively.

54. Friends of the Earth Cymru believes that we should move from generating roughly three-quarters of our electricity from fossil fuels currently, to generating all of Wales' electricity from renewable sources as soon as possible (and in any case by 2030).

55. In this context, seeking out new sources of fossil fuels is the wrong direction for UK energy policy, and particularly for Welsh energy policy. Given the inherent risks for the local environment and human health and major scepticism about its impact on energy prices, the exploitation of unconventional hydrocarbon reserves through fracking and UCG is a gamble we don't need to take.

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[62] Energy-pedia News 14th January 2013 http://www.energy-pedia.com/news/united-kingdom/new-153070
[63] Environment Agency 'Underground Coal Gasification' http://www.environment-agency.gov.uk/static/documents/Business/UCG_factsheet_16_Aug10.pdf
[64] Committee on Climate Change 2011 The Renewable Energy Review p40

56. If the Welsh Government would like to reserve the ability to exploit these resources in the future while paying due proper regard to the precautionary principle and making good use of the full potential of devolution, the logical strategy is as follows:

- Given that policy in England is strongly in favour of fracking, and given the existing uncertainties over environmental problems the use of this technology in the UK could cause, the precautionary principle suggests that a more restrictive planning regime would be of considerable benefit to the Welsh environment.
- Planning law should be modified so as to include the following clauses:
  Planning permission for unconventional gas operations (including test drilling and extraction) will not be granted unless
  - *the planning authority is satisfied that all reasonable scientific doubt that there is any risk of adverse impacts including groundwater contamination has been eliminated*
  - *the proposal will not compromise the planning authority's duties in relation to climate change mitigation and adaptation; and*
  - *the proposal is environmentally acceptable, or it can be made so by planning conditions or obligations.*
- Should unconventional gas operations proceed safely and with no contamination in England for a number of years[65], consideration could subsequently be given to relaxing the planning regime.
- This is exactly the sort of learning that devolution is designed to elicit. In a corollary of England learning about the environmental benefits for Wales of charging for carrier bags, Wales could learn about the risk associated with fracking, underground coal gasification and other unconventional gas exploration carried out in England.
- In the short term we recommend the Welsh Government adopt a moratorium on fracking until sufficient information is available to determine with a high degree of certainty the likely impacts of fracking on the environment.

57. Without prejudice to the above proposals, the Environmental Impact Assessment Regulations (England and Wales) 1999 should be amended to include the requirement for a full EIA to be conducted for each unconventional gas application. Fracking operations exempt themselves by ensuring they have a surface operation smaller than the 1 ha limit (ordinarily they are 0.99 ha) that would make them subject to these Regulations.

[65] Or other criteria to be specified by the National Assembly for Wales

Y Pwyllgor Amgylchedd a Chynaliadwyedd

Lleoliad:	**Ystafell Bwyllgora 3 - y Senedd**
Dyddiad:	**Dydd Iau, 21 Chwefror 2013**
Amser:	**09:30 - 14:50**

Cynulliad Cenedlaethol Cymru
National Assembly for Wales

Gellir gwylio'r cyfarfod ar Senedd TV yn:
http://www.senedd.tv/archiveplayer.jsf?v=cy_800001_21_02_2013&t=0&l=cy
http://www.senedd.tv/archiveplayer.jsf?v=cy_400001_21_02_2013&t=0&l=cy

Cofnodion Cryno:

Aelodau'r Cynulliad:	**Dafydd Elis-Thomas (Cadeirydd)** **Keith Davies** **Mark Drakeford** **Russell George** **Vaughan Gething** **Llyr Huws Gruffydd** **William Powell** **David Rees**
Tystion:	**Alun Davies, Y Dirprwy Weinidog Amaethyddiaeth, Bwyd, Pysgodfeydd a Rhaglenni Ewropeaidd** **John Griffiths, Gweinidog yr Amgylchedd a Datblygu Cynaliadwy** **Stuart Evans, Llywodraeth Cymru** **Christianne Glossop, Prif Swyddog Milfeddygol** **Gary Haggaty, Llywodraeth Cymru** **Matthew Quinn, Llywodraeth Cymru** **Andrew Slade, Llywodraeth Cymru**
Staff y Pwyllgor:	**Alun Davidson (Clerc)** **Catherine Hunt (Dirprwy Glerc)** **Nia Seaton (Ymchwilydd)** **Elfyn Henderson (Ymchwilydd)**

TRAWSGRIFIAD
Trawsgrifiad o'r cyfarfod.

1. Cyflwyniad, ymddiheuriadau a dirprwyon

1.1 Cafwyd ymddiheuriadau gan Mick Antoniw, Julie James ac Antoinette Sandbach. Roedd Mark Drakeford yn dirprwyo ar ran Julie James.

2. Craffu ar waith Gweinidog yr Amgylchedd a Datblygu Cynaliadwy

2.1 Bu'r Gweinidog a'i swyddogion yn ateb cwestiynau gan aelodau'r Pwyllgor.

2.2 Cytunodd y Gweinidog i ddarparu rhagor o wybodaeth ar gais y Pwyllgor.

3. Craffu ar waith y Dirprwy Weinidog Amaethyddiaeth, Bwyd, Pysgodfeydd a Rhaglenni Ewropeaidd

3.1 Bu'r Dirprwy Weinidog a'i swyddogion yn ateb cwestiynau gan aelodau'r Pwyllgor.

4. Papurau i'w nodi

4.1 Nododd y Pwyllgor gofnodion y cyfarfod a gynhaliwyd ar 31 Ionawr.