Tyndall°Centre
for Climate Change Research

Shale gas: an updated assessment of environmental and climate change impacts

A report by researchers at the Tyndall Centre
University of Manchester

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Report commissioned by The co-operative

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Executive Summary

This report, commissioned by The Co-operative, is an update on our January report, *Shale gas: a provisional assessment of climate change and environmental impacts* (Wood et al 2011). Whilst some of the analysis remains relatively unchanged from the original document, other areas having undergone important revision, not least because industry estimates of shale gas reserves at the UK and global scales have markedly increased. For example in the UK industry reserve estimates published for a single licensing area are an order of magnitude greater than national estimates published by DECC in December 2010. New papers detailing fugitive emissions have also emerged raising concerns that shale gas production may involve greater greenhouse gas emissions than previously thought.

The analysis within this new report addresses two specific issues associated with the extraction and combustion of shale gas. Firstly, it explores the environmental risks and climate change implications arising from shale gas extraction. Secondly, it outlines potential UK and global greenhouse gas (GHG) emissions arising from an updated range of scenarios built using the latest predictions of shale gas resources.

Since our earlier analysis, a range of reports and journal articles on shale gas have been published, giving the impression of a substantial increase in meaningful data alongside a more developed understanding of the issues. However, whilst the knowledge base has certainly improved, closer scrutiny of the ‘new’ information reveals that much of it builds on similar and very provisional data sources, and accordingly represents only a small improvement in the robustness of earlier analyses. Consequently, and despite there now being a much wider literature on shale gas, the earlier report’s cautionary note, “that a key issue in assessing… shale gas ... has been a paucity of reliable data”, still holds.

To date the only significant development and exploitation of shale gas has been in the United States (US). However, even there significant environmental issues remain unresolved, and reserve estimates show little sign of stabilising (increasing seven times in the last four years). Inevitably therefore, assessments of the environmental impacts, reserve potential and subsequently the greenhouse gas emissions for the European Union (EU) and the UK’s fledging shale gas sector, remain subject to significant levels of uncertainty. In view of continued ambiguity as to the robustness of quantitative data, considerable effort has been made to ensure the veracity of the information in this report. Ultimately however, the analyses can only be as accurate as the information and the assumptions upon which it draws.

Despite these uncertainties, several clear conclusions arise and can be used to inform decisions on the appropriateness or otherwise of developing a shale gas industry within the UK. It is evident that shale gas extraction does not require the high energy and water inputs at the scale of other unconventional fuels, such as oil derived from tar sands. Nevertheless, there are several routes by which shale gas extraction may pose potentially significant risks to the environment. Concerns remain about the adequacy of current UK regulation of groundwater and surface water contamination and the assessment of environmental impact. Although amenable to stringent regulatory control, risks of contamination cannot be fully eliminated.

Consequently, if shale gas is to make a significant contribution to the UK's energy mix, a rigorous monitoring regime is essential to contain the risks of contamination, from thousands of wells, within 'acceptable' levels. Similarly, fugitive emissions arising from the hydraulic fracturing process and emitted around the wellhead could be significant and increase the footprint of shale gas substantially, although with effective capture and process technologies, emissions levels not dissimilar from those associated with natural gas extraction appear possible in principle. If fugitive emissions are to be kept to 'acceptable' levels and not significantly skew the balance between upstream and point of use emissions, it is again paramount that appropriate regulatory, monitoring and enforcement regimes are developed and in place prior to full scale extraction.

Turning to the climate change implications of shale gas extraction and combustion, the report demonstrates that in an energy-hungry world (e.g. EIA energy demand projections 2011)[1] and in the absence of a stringent global emissions cap, large-scale extraction of shale gas cannot be reconciled with the climate change commitments enshrined in the Copenhagen Accord (2009). This is principally an issue of the very short time frames remaining in which to reduce emissions to levels, "consistent with the science", and which would "hold the increase in global temperature below 2 degrees Celsius". Given the Accord also stipulates mitigation efforts need to be on the "basis of equity", the constraints of the Accord are germane particularly to the industrialised (Annex 1) nations. Shale gas subject to best practice extraction and subsequently combusted in high efficiency combined cycle gas turbine (CCGT) powerstations will deliver power at lower emissions per unit of electricity generated than is possible from coal fired generation. However, even if there were to be a rapid transition from coal to shale gas electricity, this could still not be reconciled with the UK's 2°C commitments under either the international Copenhagen Accord or its own national Low Carbon Transition Plan. If instead, conservative rates of recovering shale gas from the latest estimate of global reserves were achieved and only half subsequently combusted by 2050, shale gas could occupy *over a quarter* of the remaining CO_2 emissions budget associated with a reasonable chance of avoiding 2°C of warming. Atmospheric carbon dioxide levels would be expected to rise by between 5 and 16 parts per million by volume (ppmv), with a mid-range of 11ppmv.

Whether shale gas substitutes for higher carbon energy supply or meets new energy demand in the UK, it risks doing so at the expense of investment in much lower carbon supply. Energy companies, investment markets and broader UK institutions are all familiar with fossil fuels, and any short-term financial benefit that may accrue to shale gas heating and electricity risks reinforcing lock-in to established supply routes. This has two further implications. Firstly, it reduces the drive for innovation and the scope for 'learning by doing', with the UK subsequently less well equipped to compete in renewable and low-carbon markets elsewhere. Secondly, any investments in shale gas infrastructure over the coming decade would rapidly become a stranded economic asset if the UK were to respect its 2°C commitments. Alternatively, government may be persuaded to withdraw from national and international obligations, and instead sanction continued use of existing high capital value, and high carbon, shale gas infrastructure. This report illustrates how a £32bn

[1] EIA Annual Energy Outlook 2011, http://www.eia.gov/forecasts/aeo/pdf/0383(2011).pdf

capital investment in shale gas could potentially displace up to 12GW of offshore or 21GW of onshore wind capacity and raise the prospect of the UK not meeting its renewable energy obligations.

To summarise: Irrespective of whether UK shale gas substitutes for coal, renewables or imported gas, the industry's latest reserve estimates for just one licence area could account for up to 15% of the UK's emissions budget through to 2050. Therefore, emissions from a fully developed UK shale gas industry would likely be very substantial in their own right. If the UK Government is to respect its obligations under both the Copenhagen Accord and Low Carbon Transition Plan, shale gas offers no meaningful potential as even a transition fuel. Moreover, any significant and early development of the industry is likely to prove either economically unwise or risk jeopardising the UK's international reputation on climate change. Against such a quantifiable and stark evaluation, it is difficult to conclude other than the UK needs to invest in very low carbon energy supply if it is to both abide by its international obligations *and* support economically sustainable technologies.

6. Conclusions

6.1 Background

6.1.1 Exploitation of shale gas

Gas shales are formations of organic-rich shale, a sedimentary rock formed from deposits of mud, silt, clay, and organic matter. In the past these have not been seen as exploitable resources, however, advances in drilling and well stimulation technology has meant that 'unconventional' production of gas from these, less permeable, shale formations can be achieved. Extraction of the gas involves drilling down and then horizontally into the shale seam. A fluid and a propping agent ('proppant') such as sand are then pumped down the wellbore under high pressure to create fractures in the hydrocarbon-bearing rock (a process known as hydraulic fracturing). These fractures start at the injection well and extend as much as a few hundred metres into the reservoir rock. Gas is then able to flow into the wellbore and onto the surface. Wells are usually grouped into well pads containing around six to ten individual wells. These well pads are sited 1 to 3.5 in every square kilometre.

To date shale gas has only been exploited in the United States, where production of shale gas has expanded from around 1.4% of total US gas supply in 1990 to greater than 14.3% of total US gas supply in 2009. From 2000 to 2006 the average annual increase was 17% but from 2006 to 2010 the average rate of increase has grown to 48% per year (EIA 2011). Resource estimates have also grown substantially in this time. The upward trend is rapid and EIA report a threefold increase in the estimate of technically recoverable reserve between 2008 and 2010 inclusive, while the release of the 2011 figures sees a further doubling of the 2010 estimate[74]. Energy forecasts predict that shale gas is expected to expand to meet a significant proportion of US gas demand within the next 20 years with an increase in production from 93bcm in 2009 to 340bcm in 2035, a 266% increase.

6.1.2 The UK case

At present the only shale developments in the form of well pads and horizontal shale wells in the UK are exploratory. The most advanced drilling has been by Cuadrilla Resources, which received planning permission for an exploratory drill site at Preese Hall Farm, Weeton, Lancashire in November 2009. Drilling at Preese Hall was completed in December 2010 and hydraulic fracturing has been conducted from January to May 2011. As of November 2011 drilling, but not yet hydraulic fracturing, had been undertaken at two further sites: Grange Hill Farm and Banks[75].

[74] This data was prefaced by the Annual Energy Outlook early release overview in December 2010 (EIA 2010b).
[75] www.cuadrillaresources.com/what-we-do/locations

There is a high level of uncertainty around the potential reserves of shale gas in the UK but, drawing assumptions from similar producing shale gas plays in America, BGS estimates UK shale gas reserve potential at 150bcm [76]. However, based on data from its initial exploration, on the 21st September 2011 Cuadrilla Resources announced its first estimate of the volume of gas within its licence area in Lancashire. It estimated a significant total of 5,660bcm gas which, assuming that 20% is recoverable, translates to around 1,132bcm of recoverable resource, from an area of just 437 square miles.

6.2 GHG emissions

6.2.1 Differences with conventional gas

It has been assumed in this report that the direct emissions associated with the combustion of shale gas will be the same as gas from conventional sources. In considering the UK, the distribution of shale gas would be the same as conventional gas and therefore subject to the same losses. This means that the main difference between shale and conventional gas is likely to be from emissions that arise from the differing extraction processes. The limited verifiable data available made assessment of these extraction emissions problematic. However, it was possible, using data on expected emissions from the Marcellus Shale in the US, to estimate the likely emissions associated with the different processes that occur in extracting shale gas compared to conventional gas.

The report has estimated emissions associated with a number of processes:

- Horizontal drilling;
- Hydraulic fracturing;
- Transportation of water;
- Transportation of wastewater; and
- Wastewater treatment.

The combination of emissions from these processes gave an estimate per well of 348-438tCO_2e. A potentially larger quantity of fugitive methane emissions from flowback must be added to this sum if not controlled effectively. This figure will increase if the well is refractured, something which could happen up to five times and a recent DECC (2010) report has suggested that refracturing could happen every four to five years for successful wells.

The significance of these emissions is dependent on the rate of return for the well – something which is site specific. Looking at examples of expected total production for shale basins in the US we can estimate that, on average, the additional CO_2e emissions associated with the processes above account for 0.14 to 1.63 tCO_2e/TJ of gas energy extracted, with a further potential for 2.87 to 15.3 tCO_2e/TJ from fugitive methane emissions during flowback.

[76] At the same time BGS note that the US analogies used to produce this estimate may ultimately prove to be invalid. Hence it is possible that the shale resource could be larger.

These values depend upon the total amount of gas that is extracted per well and the number of times it is refractured. Examining the UK in particular, although the rate of return per well is not quoted for UK basins, it is thought that additional CO_2 emissions per well would be at the higher end of estimates compared to the US, as UK reserve potential is low in comparison to the US basins. It is unknown how applicable the estimates provided by Cuadrilla Resources are to other formations.

Given that during combustion 1TJ of gas would produce around 57tCO_2e the additional emissions from the shale gas extraction processes identified represent 0.2-2.9% of combustion emissions excluding flowback emissions and 5.3-29.7% if they are not captured. Similarly to conventional gas, there will be further emissions associated with processing, cleanup and distribution.

The technical possibility of relatively low levels of additional emissions suggest that there would be benefits in terms of reduced carbon emissions if shale gas were to substitute for coal. Combustion of coal produces around 93tCO_2e/TJ. Clearly even with additional emissions associated with shale gas, the emissions from gas would be lower, assuming that gas losses during transport, distribution and storage are minimal. These losses are subject to substantial uncertainty at present, although a range from 1.4% to 3.6% does not appear unreasonable (Howarth et al, 2011). The benefits increase when the higher efficiencies of gas fired power stations compared to coal fired power stations are considered.

- Emissions associated with additional processes needed for the extraction of shale gas are small (0.2-2.9% of combustion emissions).
- The potential for fugitive methane emissions during flowback could increase this substantially if not managed on site. This may be up to 30%, however, empirical data is limited.
- Considering extraction and combustion alone, carbon emissions from shale are not significantly more than for conventional gas and are lower than for coal.

6.2.2 Impacts on total emissions

In order to examine the potential impact of shale gas, CO_2 emission scenarios were developed for both the UK and globally.

For the UK, three scenarios have been developed. Each of these is based on a different estimate for the amount of technically recoverable shale gas in the UK. The first scenario is based on the figure of 150bcm outlined in the report by DECC discussed earlier (DECC, 2010). The second uses a figure of 566bcm from a recent report by the US EIA (EIA, 2011). The third scenario is based on the figures released by Cuadrilla stating that, in the areas where they are licensed to drill, there are shale gas reserves of 5,660bcm, 20% of which was assumed to be recovered.

All three scenarios see the majority of shale gas being exploited before 2050 and the cumulative emissions associated with the use of this shale gas ranged from 264-2,029 $MtCO_2$. To give this some context, it amounts to between 1.9% and 14.5% of the total UK greenhouse gas emissions budget to 2050 under the intended budget proposed by the UK Committee on Climate Change. Assuming that the carbon budget is adhered to then this should not result in additional emissions in the UK. For example, it is possible that UK produced shale gas could substitute for imported gas, although it would not negate the need for imports. However, it is also possible that extracting additional fossil fuel resources could put pressure on efforts to adhere to our carbon budget by reducing gas prices and directing investment away from renewable energy. It is also important to note that in a market led global energy system where energy demand worldwide is growing rapidly, even if shale gas were to substitute for imported gas in the UK, leading to no rise in emissions, it is likely that this gas would just be used elsewhere, resulting in a global increase in emissions.

As with the UK, the potential shale gas that could be exploited globally is highly uncertain. The most recent estimate of technically recoverable resource has been made by the US EIA at 187,535bcm (EIA, 2011). In calculating this figure, a recovery factor of between 20-30% was generally used. In order to provide three global scenarios, it was assumed that the EIA figure is based on a recovery rate of 20%. Two additional scenarios are then used with recovery factors of 10% and 30%.

Assuming that 50% of this resource is exploited by 2050, these scenarios give additional cumulative emissions associated with the shale gas combustion of 95-286 $GtCO_2$, resulting in an additional atmospheric concentration of CO_2 of 5-16ppmv for the period 2010-2050. These emissions would occupy a substantial proportion, up to 29%, of an emissions budget associated with a better than 50:50 chance of avoiding 2 degrees Celcius warming (Anderson and Bows 2011).

However, in an energy hungry world it is possible that exploitation would be more rapid than this. What we can say with more certainty is that without a meaningful cap on global carbon emissions, any emissions associated with shale gas are likely to be additional, exacerbating the problem of climate change.

- Without a meaningful cap on carbon emissions the utilisation of shale gas will likely increase carbon emissions by potentially considerable amounts.
- Shale gas exploitation could lead to an increase in atmospheric concentration of CO_2 of 5 to 16ppmv and occupy up to 29% of a 2 degrees Celcius emissions budget.
- Shale gas exploitation could increase the difficulty of attaining set targets for carbon reductions through, for example, substituting for renewable energy.
- If global carbon caps were to be agreed and if they were strictly adhered to, then it is possible that shale gas would make no difference as the source of emissions would be inconsequential. However, this would require a very significant deployment of as yet unproven large scale carbon capture and storage (CCS).

6.2.3 Investment in shale gas compared to renewables and implications for decarbonisation

A substantial move to exploit shale gas reserves has the potential to impact upon investments in renewable energy. In order to explore this, we estimated the capital costs of drilling shale gas wells to supply 10% of current UK gas consumption and the equivalent Combined Cycle Gas Turbine (CCGT) power stations that would burn it. Given the need for low carbon generation, the costs of gas CCGT with CCS was also considered. It is estimated that such a programme over the next twenty years would cost between £19bn and £32bn.

If a straight substitution relationship is assumed between electricity from renewables and gas then, considering the capital costs only, 8GW of CCGT plus gas well infrastructure could displace 12.5GW of wind capacity, equivalent to over 4,000 large onshore turbines, at a commercial discount rate. With a 3.5% social discount rate, and the inclusion of CCS technology, potential displacement increases to approximately 21GW of installed onshore wind capacity or 12GW offshore. Either would be expected to generate approximately equivalent quantities of electricity as the gas option even given the lower load factor of wind turbines.

There is also a matter of timing of possible substitution between shale gas and coal. The Committee on Climate Change has argued that transition to a very low carbon grid, of the order of 50gCO_2/kWh, should take place by 2030, on the way to a zero carbon grid soon after. Were a new round of stations to be completed in the next ten years they would become "stranded assets" or require expensive retro fitting of as yet untested CCS technology. As such it seems likely that shale gas would "lock in" high emissions infrastructure in the medium term.

A precise and accurate value of the life cycle GHG impact, either per unit of shale gas produced or per unit of electricity from shale gas, is not necessary to draw this conclusion. 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.

- Substantial investment in shale gas wells and power plant would be required to produce gas sufficient for 7-8GW of electricity generating capacity, even more so with the addition of CCS.
- This same investment could deliver approximately 21GW of onshore wind capacity or 12GW offshore, when assessed at social discount rates appropriate for policy decisions.
- Gas powerstations built in the near to medium term will require retro fitting of CCS capability or become 'stranded assets' if the UK keeps to its climate change objectives.

6.3 Environmental impacts of shale gas production

6.3.1 Groundwater contamination

The potential for contamination of groundwater is a key risk associated with shale gas extraction. Although there is limited evidence it appears that the fluid used in hydraulic fracturing contains numerous chemical additives, many of which are toxic to humans and/or other fauna. Concerns that the fracturing process could impact on water quality and threaten human health and the environment have prompted the US EPA to instigate a comprehensive research study into the issue. While awaiting the results of this study, New York State has introduced a moratorium on any new wells.

Groundwater pollution could occur if there is a catastrophic failure or loss of integrity of the wellbore, or if contaminants can travel from the target fracture through subsurface pathways. The risks of such pollution were seen as minimal in a study by ICF International; however, this assessment was based on an analysis of risk from properly constructed wells. History tells us that it is rarely the case in complex projects that mistakes are never made and the risk of groundwater pollution from improperly constructed wells also needs to be considered.

The dismissal of any risk as insignificant is even harder to justify given the documented examples that have occurred in the US, seemingly due to poor construction and/or operator error. These examples have seen high levels of pollutants, such as benzene, iron and manganese, in groundwater, and a number of explosions resulting from accumulation of gas in groundwater.

- There is a clear risk of contamination of groundwater from shale gas extraction.
- It is important to recognise that most problems arise due to errors in construction or operation and these cannot be entirely eliminated.
- The US EPA research should provide important new evidence in understanding this issue. Full conclusions are expected in 2014.

6.3.2 Surface water and land contamination

While it may not always be possible to pinpoint the exact cause of groundwater contamination, identifying the source for land and surface water pollution is more straightforward. There are a number of potential sources of pollution including: well cuttings and drilling mud; chemical additives for the fracturing liquid; and flowback fluid – the liquid containing toxic chemicals that returns to the surface after fracturing. There numerous routes by which these potential sources can cause pollution incidents including failure of equipment and operator error. Unsurprisingly, a number of incidents have been reported in the US.

While these hazards are similar to those found in numerous industrial processes, for shale gas extraction, they occur over a short period of time during the construction of the pad and initial drilling. This means that investment in physical containment, as would be expected in many cases with such hazards, is perhaps less likely.

- High standards of hazard management will need to be maintained at all times if surface pollution is to be avoided.

6.3.3 Water consumption

Shale gas extraction requires very significant amounts of water. Based on US data, to carry out all fracturing operations on a six well pad takes between 54,000 and 174,000 cubic metres of water. Based on water volumes used in Cuadrilla Resources' operations, if the UK were to produce 9bcm of shale gas each year for 20 years this would equate to an average annual water demand of 1.3 to 1.6 million cubic metres. This compares with current levels of abstraction by industry (excluding electricity generation) of 905 million cubic metres. While this appears to be a small additional level of abstraction, a number of points need to be made:

- This gives annual average water requirement assumed over the whole country. Clearly actual water requirements will be focused in the areas where shale gas is being extracted and this could add a significant additional burden in those areas;
- Water resources in the UK are already under a great deal of pressure making additional abstraction difficult; and
- The impacts of climate change may put even greater pressure on water resources in the UK.

Given that the water is mainly used over a short period of time during initial fracturing the most likely means of getting this water to the site in the UK would probably be by truck or abstraction.

- Significant amounts of water are required to extract shale gas and this could put severe pressure on water supplies in areas of commercial exploitation.
- The impacts of climate change may further exacerbate this problem.

6.3.4 Other issues

In considering the potential extraction of shale gas in the UK it is important to recognise the different circumstances compared with the US, which gives rise to a number of other areas that should be considered.

Noise pollution

Given the high population density and the likelihood that any shale gas extraction may be located relatively close to population centres, noise pollution may be an important consideration. Activities such as drilling mean that each well pad requires around 800-2,500days (and nights) of noisy surface activity.

Traffic

Linked to noise is the issue of increases in traffic associated with shale gas extraction. It is estimated that the construction of each wellpad would require between 7,000-11,000 truck visits. This could clearly have a local impact on roads and traffic in the locality of shale gas well heads. Damage to roads not suited to the levels of truck traffic associated with gas drilling has been an issue in the US.

Landscape impacts

The construction of well pads is an industrial activity and requires access roads, storage pits, tanks, drilling equipment, trucks etc. As has been mentioned previously, to produce 9bcm of gas annually in the UK over 20 years would require around 300 well pads. In the Blackpool area alone, commercialisation by Cuadrilla resources suggests between 40 to 80 pads (for the medium and high scenarios) with production only sufficient for the equivalent of 5 to 10 months of UK gas consumption.

Seismic impacts

It is well known that injection of water or other fluids during processes such as oil extraction, geothermal engineering and shale gas production can result in earthquake activity. Hydraulic fracturing was stopped at the Cuadrilla Resources' Preese Hall exploratory site after a magnitude 1.5 earthquake on 27 May in the Blackpool area and in the light of a preceding magnitude 2.3 earthquake on 1 April 2011. An investigation concluded that it is highly probable that the hydraulic fracturing at Preese Hall-1 well triggered the recorded seismic events (de Pater and Baisch, 2011). The two events reported by BGS and 48 much weaker events that were detected make it hard to dismiss them as an isolated incident. The report also discusses the fact that the Preese Hall 1 well was deformed from a circular shape to an oval shape from approximately 2580m to 2630m down the wellbore. The casing above and below that interval was not observed to be significantly deformed and it was determined that the deformed casing did not affect the overall wellbore integrity, posing no risk to any shallow groundwater zones.

It is clear, then that seismic events can be caused by hydraulic fracturing and, whilst these are unlikely to be of a sufficient magnitude to cause structural damage on the surface, structural damage to the wellbore itself (and in all likelihood other wellbores in the vicinity) is possible and has been documented in this case.

Cumulative impacts

Cumulative impacts may be a particular issue, when one considers the development of shale gas at a scale sufficient to deliver gas at meaningful volumes. To sustain a 9bcm level of production for 20 years in the UK would require around 2,500-3,000 horizontal wells. This would require some 25 to 32 million cubic metres of water and scale up other per well impacts and risks to a similar degree.

- For the UK, high population density and the likely proximity of wells to population centres could result in certain impacts such as noise pollution, traffic, landscape and seismic impacts being exacerbated.

6.4 European regulatory framework

6.4.1 Overview

The view of the UK Government witnesses to the House of Commons Energy and Climate Change Committee is that UK regulation is “well-designed with clear lines of responsibility among several different bodies including DECC, the HSE, the respective Environment Agency, and Local Planning Authority” (2011; para 32) and that the UK has a “robust regime which is fit for purpose” and will ensure that unconventional gas operations are carried out in a “safe and environmentally sound manner” (2011; para 92).

In addition, the perception is that the regulatory framework that operates in the UK and EU is likely to be much more robust than that operating in the US where it is acknowledged that there have been problems and issues. From a regulatory perspective, many of the problems experienced in the US have been blamed on the US federal Energy Policy Act of 2005 which excluded hydraulic fracturing from the Safe Drinking Water Act, effectively delegating it to State responsibilities to protect groundwater.

This study has reviewed the key regulatory instruments that are in place in the UK and EU to identify the extent to which these views hold true and, therein, the extent to which the current regulatory framework and its application has (and will) provide adequate and consistent control of risks and impacts of exploratory and commercial shale gas development. The conclusions of this can be summarised succinctly as follows in relation to each of the areas examined.

6.4.2 Groundwater

In the UK: The Environment Agency’s intention is not to routinely require an environmental permit, suggesting that shale gas operations do not constitute groundwater activity. Only ‘normal’ operations are considered when determining whether to require an environmental permit. ‘Abnormal’ operations such as from full or partial loss of well integrity are not considered in this decision. As such, regulation of these risks is via domestic health and safety regulation with regard to well construction and design. As this regulation does not include environmental risk in the consideration of what measures are justified to reduce risk “so far as is reasonably practicable”; the study finds that this set of regulation is inadequate and needs to be updated if it is to be used to control environmental risks in the place of an environmental permit. The current approach (which considers only health and safety risks avoided) is considered unlikely to provide the same level of construction and design standard as one that considers ALL of the risks avoided by proper well design and construction. As such, either well design and construction regulation needs to be updated if it is be used for this purpose, or all development should be covered by environmental permits to build in the additional controls. In a recent report on shale gas (IGEM, 2011), the Institution of Gas Engineers and Managers (IGEM) identifies that, for technologies such as horizontal directional drilling and hydraulic fracturing, there is a "distinct lack of standards for these processes". It has recommended that "standards are needed within the UK and internationally to ensure the consistency of safety measures and to guarantee that environmentally damaging or dangerous practices such as have been recorded in the US do not occur within the UK".

In the EU: The experience of the UK suggests that, for control of environmental risks from 'abnormal' operations, domestic regulation on well design and construction may be used instead of permitting under the Groundwater Directive. As there is no harmonised regulation on well design and construction in the EU, any Member State doing the same will be relying on its domestic regulation. This means that the risks associated with abnormal operations, such as from full or partial loss of well integrity, may not be consistently controlled across Europe and may rely on procedures and regulations operating in the Member State concerned, where these may or may not offer an adequate standard of risk control.

6.4.3 Chemicals used in fracturing fluids

In the EU and UK: the REACH regulations should, in theory, provide adequate control and oversight of chemicals used in fracturing fluid given proper enforcement. However, recent work by the European Chemicals and Health Agency suggests that none of the substances that it has examined has yet been registered for use in fracturing fluids. One of these substances has already been used in hydraulic fracturing operations in the UK. The European Commission is currently investigating whether this use failed to comply with the REACH regulations despite its use having been declared to the regulator in advance. As such, whilst the regulations have the power to ensure that any substance must be registered for that use, and associated chemical safety assessments undertaken, the possible non-compliance of the UK underlines the necessity of careful enforcement.

6.4.4 Wider environmental impacts

In the EU: Environmental impacts of projects come under the scope of the Environmental Impact Assessment (EIA) Directive which lists two categories of projects for EIA. Those in Annex I always require EIA but we conclude that the volumes of gas production from individual project units (well pads) are too low to allow them to be included as Annex I projects. They do, however, fit the description of Annex II projects that require Member States to consider whether full EIA is required based on the characteristics and locality of the projects and associated impacts. This requires consideration of cumulation of projects (i.e. impacts of one project in the context of similar ones in the same locality) amongst other matters in what is known as a 'screening procedure'.

In its ongoing review of the EIA Directive, the European Commission has expressed concern that Member State screening procedures are not adequate and are inconsistent with one another. There have also been European Court of Justice rulings on the use of criteria based only on the size of a project, where this is deemed not to be satisfactory and non-compliant.

In the UK: No EIAs of existing wellpads have been undertaken because the Local Planning Authority (LPA) determined that the projects were outside the area based (size only) criteria in the UKs implementing regulation. As such, none of the existing projects have been fully considered as is indicated by the EIA Directive. In addition, the LPA failed to identify a lower area criterion that also fits the description of the project. This places the existing developments at risk from legal challenge.

Overall: Given the specific example of the failure to properly consider shale gas projects under Annex II of the EIA directive, combined with the European Commission's existing concerns about the adequacy and consistency of Member State screening procedures, the study finds that shale gas projects are unlikely to be consistently required to undertake EIA in the EU. Here, again, whether EIA will be undertaken rests with procedures operating in individual Member States.

6.4.5 General conclusion

As noted above, from a regulatory perspective, many of the problems experienced in the US have been blamed on the US federal Energy Policy Act of 2005 which excluded hydraulic fracturing from the Safe Drinking Water Act, effectively delegating the responsibility to protect groundwater to individual states. From this perspective, then, the regulatory situation in the EU is not so very different. Whilst there are harmonised requirements for the protection of groundwater, environmental impacts and chemicals across all Member States, there is variation in interpretation of how these requirements are to be met and powers applied as well as different regulation (particular with regard to well design and construction). This means that in the EU also, control of risks and impacts may be delegated to Member State domestic regulation, interpretation and enforcement – a situation that is not dissimilar to that which is blamed for many of the problems in the US.

6.5 Final comment

It is important to stress that one of the main findings of this work is that there is a paucity of information on which to base an analysis of how shale gas could impact GHG emissions and what environmental and health impacts its extraction may have. While every effort has been made to ensure the accuracy of the information in the report, it can only be as accurate as the information on which it draws. In itself, this lack of information can be seen as a finding, as along with the growing body of evidence for ground and surface water contamination from the US and the requirement for the application of the precautionary principle in the EU, shale gas extraction in the UK must surely be delayed until clear evidence of its safety can be presented. The US EPA study on risks to groundwater will hopefully add to knowledge on the subject. With this considerable uncertainty surrounding the environmental impacts of shale gas extraction it seems sensible to wait for the results of the US EPA investigation to bring forward further information.

The argument that shale gas should be exploited as a transitional fuel in the move to a low carbon economy seems tenuous at best. EIA projections for the US do not anticipate that shale gas will substitute for coal in the medium term. Further, in the UK currently, a little under two thirds of coal consumption is imported from the global coal market; accordingly any reduction in coal demand from the UK will, *ceteris paribus*, trigger reductions in global coal prices. The supply-demand relationship of relatively liberalised markets makes clear that a reduction in the price for coal will facilitate increased demand elsewhere. Consequently, whilst the UK may be able to reduce its national emissions through indigenous shale gas consumption, this risks triggering a net increase in global emissions; with the atmosphere receiving relatively unchanged emissions from coal *and* additional emissions from shale gas.

It is possible that some level of substitution may occur in other countries but, in the current world where energy use is growing globally and expected to continue to do so, without a meaningful constraint on carbon emissions, there is little price incentive to substitute for lower carbon fuels. It is difficult to envisage any situation other than shale gas largely being used *in addition* to other fossil fuel reserves and adding a further carbon burden. This could occupy over a quarter of the remaining carbon budget for keeping below 2^oC warming, and lead to an additional 16ppmv of CO_2 over and above expected levels without shale gas – both figures that will rise as and when the additional 50% of shale gas is exploited. It should be stressed the extraction process does not necessarily result in significant emissions itself compared to conventional extraction but there is the potential for substantial fugitive emissions. However, given the urgent and challenging requirements facing us with regards to carbon reductions, any additional fossil fuel resource just adds to the problem.

The idea that we need 'transitional' fossil fuels is itself open to question. For example, in the International Energy Agency scenario that outlines a path to 50% reduction in carbon emissions by 2050, fuel switching coupled with power generation efficiency, only accounts for 5% of the required reductions (IEA, 2010). If globally we are to achieve the considerable reductions in carbon emissions that are required then it is energy efficiency, carbon capture and storage, renewable energy etc that will make the difference.

While a strong case could be made for the domestic extraction of shale gas from an energy security basis – replacing a proportion of imported gas with domestic production, this is not the focus of this report. Within the UK shale gas could substitute for coal and thereby reduce the UK's emissions, however, with a carbon budget in place coal (without CCS) is likely to be phased out anyway – shale gas is not required to make this happen. Even if this was the case, given the radical reduction in emissions required and the need for a decarbonised electricity supply within two decades[77], it would risk being a major distraction from transitioning to a genuine zero-carbon grid. Given the investment in infrastructure required to exploit

[77] The Committee on Climate Change has suggested that electricity will need to be effectively decarbonised by 2035 (CCC, 2010).

these resources there is the danger of locking the UK into years of shale gas use, leaving unproven carbon capture and storage, as the only option for lower carbon electricity. Consequently, this investment would be better made in real zero-carbon technologies that would provide more effective long-term options for decarbonising electricity.

At the global level, against a backdrop of energy growth matching, if not outstripping, that of global GDP and where there is currently no carbon constraint, the exploitation of shale gas will most likely lead to increased energy use and increased emissions resulting in an even greater chance of dangerous climate change. While for individual countries that have a carbon cap, for example in the UK, there may be an incentive to substitute shale gas for coal, the likely result would be a fall in the price of globally-traded fossil fuels and therefore an increase in demand. Consequently, there is no guarantee that the use of shale gas in a nation with a carbon cap would result in an absolute reduction in emissions and may even lead to an overall increase.

In addition to concerns about groundwater and GHG emissions, it is also important in considering possible shale gas extraction in the UK to recognise that high population density is likely to amplify many of the issues that have been faced in the US. If meaningful amounts of gas were to be extracted in the UK (the example of 9bcm has been used in the report but the scenarios see annual production rising above this level for periods of time) then this could have a considerable impact on scarce water and land resources.