Shale Gas and Annex 1 Energy Policy in the Context of Cumulative Emissions Budgets

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Overview

We have argued in our recent report (Broderick et al 2011) that in an energy-hungry world and in the absence of a stringent global emissions cap, large-scale extraction and combustion of shale gas cannot be reconciled with the climate change commitments enshrined in the Copenhagen Accord (2009). This conclusion is principally due to the very short time frames remaining in which to take action to reduce emissions to levels, described in the text of the Accord as, "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 particularly germane to industrialised (Annex 1) nations.

Cumulative Emissions Budgets

Our argument is based on a framework of cumulative emissions budgeting that provides a scientifically credible way of approaching climate policy questions. Carbon dioxide, the most significant anthropogenic GHG, is considered to be a 'stock pollutant' and atmospheric science indicates that the cumulative quantity of emissions released over time is the best indicator of the final extent of global temperature change (Allen et al, 2009).

Cumulative emissions budgeting starts by identifying an appropriate warming limit or goal. An increase in global mean surface temperature of 2 degrees above pre-industrial times has frequently been taken as the distinction between 'dangerous' and 'acceptable' climate change. However, given the uneven distribution of climate change effects geographically, temporally, amongst and within societies, this limit is clearly contestable. At the Copenhagen COP-15 summit a number of developing countries, notably the Association of Small Island States (AOSIS), pressed for the long term limit of 1.5 degrees to be adopted.

Given a particular temperature target, the next step is to estimate the quantities of carbon dioxide that are likely to cause that particular increase. Climate models with different starting parameters suggest that 1 to 1.5 trillion tonnes of carbon dioxide emitted over the period 2000 to 2050 yields a 50% probability of exceeding 2 degrees (Meinshausen et al, 2009). Work by Anderson and Bows (2011) at Tyndall Manchester has drawn on a range of such estimates. Latest carbon dioxide emissions data describes a rapid increase since 2000 and by deducting emissions to the present day from the total budget, the remaining 'safe atmospheric space' can be deduced. This can then be allocated between nations, industries or consumers and related to rates of change of energy systems.

Scenarios of future emissions constructed by Anderson and Bows (2011) indicate that carbon dioxide emissions from fossil fuel combustion must tend to zero before 2050, even if global emissions peak in 2020. This is because greenhouse gas emissions as a whole may not be able to fall entirely to zero; food production involves the release of substantial quantities of GHGs through fertilisers and land conversion that are unlikely to be entirely eliminated. If one takes the position that industrialised economies like the UK must take the lead, given they have both the greatest resources available and the most historical responsibility, then they would have to decarbonise their economies much sooner.

Continued delays in agreeing substantial emissions reductions have left us in a precarious situation. Although the UK has adopted national cumulative emissions budgeting as a principle, through the Climate Change Act (2008), the levels set in current budgets will likely give rise to warming greater than 2 degrees. 'Orthodox' climate policy, with emissions reductions of 1-3% per annum, implies a reasonable chance of reaching 4 degrees warming with substantial anticipated consequences. Effective climate change mitigation is a matter of urgent and extensive decarbonisation of industrialized economies by 2030 or sooner (Anderson and Bows, 2011).

Shale Gas Resources in Relation to Cumulative Budgets

While much discussion has focused on emissions associated with the extraction of shale gas, Broderick et al (2011) examined the potential impact that the use of shale gas may have in terms of combustion emissions at both UK and global levels. In order to explore this issue two sets of scenarios have been developed; it should be noted that these scenarios are not a *prediction* of what might happen, rather they explore the outcomes if particular amounts of shale gas were to be exploited. Full details of the assumptions, production trajectories and data sources are given in the report.

Assuming that all gas recovered is used domestically, it is then possible to explore the potential implication of shale gas exploitation on UK emissions budgets (Table 1 below). Emissions are calculated as CO_2 from combustion only and do not include any estimate of other associated sources such as fugitive methane emissions from well completions, refracturing, processing or distribution. This is a conservative assumption on the basis of a well regulated industry with full deployment of best practice.

Table 1 Outcomes of UK scenarios

	Cumulative amount of shale gas produced (bcm)		**Cumulative CO_2 emissions from shale gas, ($MtCO_2$)**	**% of UK Domestic Action budget**[1]
	2030	**2050**	**2010-2050**	**2010-2050**
DECC 150bcm	21	132	264	1.9%
EIA 566bcm	79	499	1,015	7.3%
Cuadrilla 1,132bcm	157	997	2,029	14.5%

In these scenarios the majority of shale gas is extracted before 2050 (88%). Over the 2010-2050 time period, using this gas would result in between 264-2029 $MTCO_2$ being emitted by 2050, which equates to between 1.9% and 14.5% of the total UK greenhouse gas budget.

Assuming that the UK carbon budgets are adhered to then additional emissions associated with shale gas would need to be offset by emissions reductions elsewhere. This could be through shale gas substituting for coal, which, given the lower emissions associated with gas fired power

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[1] The 2010-2050 budget was calculated based on figures from the Committee on Climate Change (2010), p.135.

generation would enable more electricity to be produced for equivalent emissions. It could be the case that shale gas substituted for imported gas resulting in no additional UK gas use and hence, no additional emissions, or emissions benefits, associated with that use[2]. However, in a market led system it is also possible that a drop in the price of gas, potentially triggered by increasing UK and global reserves of shale gas, could leave gas-fired power stations substituting for renewable generation.

If shale gas resulted in no additional emissions in the UK, (e.g. it substituted for imported gas, or was combusted within EU ETS regulated facilities rather than domestic heating), in an energy-hungry world any gas not imported to the UK will likely be available at a lower cost to be used elsewhere, with an associated increase in global emissions. World demand for fossil fuels remains high and is projected to increase further in the absence of binding international agreements to limit greenhouse gas emissions (IEA, 2009; EIA, 2011). Based on these projections any new sources of fossil fuel, even if relatively low carbon per unit of useful energy, are likely to be combusted and consequently add to the global emissions burden. See, for instance, EIA projections for US shale gas and coal consumption to 2035, Figure 2.11.

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, 2011b) which is a similar order of magnitude to estimates presented in the IEA Golden Age of Gas publication (2011), 204,000bcm. In calculating this figure, the EIA generally used a recovery rate of between 20-30%. In order to provide three global scenarios here, it is assumed that the EIA figure is based on a recovery rate of 20%, with two additional scenarios of 30% and 10% recovery rates also considered[3].

For each of the scenarios it is assumed that 50% of the total recoverable resource is extracted by 2050, with 100% of the recoverable resource extracted by 2100. In the absence of any substantive and effective policies to significantly reduce global emissions, and with continuing growth in demand for energy, it is entirely possible that any resources would be exploited on a much shorter timescale, hence this is likely to be a conservative estimate of emissions. Again, emissions are calculated as CO_2 from combustion only. This is a conservative assumption on the basis of a well regulated extraction industry with full deployment of best practice internationally.

Given continuing growth in global energy demand it is likely that any additional fossil fuel resources that are exploited will be used in addition to existing resources. Without significant pressure to reduce GHG emissions, it is difficult to envisage that gas would substitute for coal rather than being used alongside it. Looking at these three global extraction scenarios, this additional fossil fuel use would result in additional cumulative emissions over the time period 2010-2050 of 95-286 $GtCO_2$, equating to an additional atmospheric concentration of CO_2 of 5-16ppmv. The CO_2 emissions from burning shale gas may potentially occupy over a quarter, of a budget associated with a better than 50:50 chance of avoiding 2°C warming (Anderson and Bows 2011). Clearly this only represents half the resource being exploited and these figures would double for the period up to 2100 if all the recoverable resource were to be exploited.

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[2] Under the Cuadrilla scenario in the peak year of production over half of current UK gas demand could be supplied by shale gas.

[3] It should be stressed that Russia and Central Asia, Middle East, South East Asia, and Central Africa are not considered in the EIA report primarily because "...there was either significant quantities of conventional natural gas reserves noted to be in place (i.e., Russia and the Middle East), or because of a general lack of information to carry out even an initial assessment." (EIA, 2011b, p.6). Reserve estimates and their implications for GHG emissions may therefore be under estimated.

Table 2: Outcomes of the global scenarios

	Resource recovery rate	Amount of shale gas exploited by 2050 (bcm)	Cumulative emissions associated with shale gas ($GtCO_2$) (2010-2050)	% of global emissions budget with >50% chance of ≤2°C warming[4]	Additional ppmv CO_2 associated with shale gas emissions (2010-2050)[5]
EIA global estimate low recovery	10%	46,884	95	9.5%	5
EIA global estimate	20%	93,768	190	19.0%	11
EIA global estimate high recovery	30%	140,651	286	28.6%	16

The Role of Shale Gas in the UK Energy System

There is little to suggest that shale gas will play a key role as a transition fuel in the UK's move to a low carbon economy. Whilst much attention is taken by the relative emissions intensity electricity generated from shale gas, conventional natural gas and coal, it is the *absolute* quantity of emissions within a time period that is important, i.e. the size and shape of the cumulative emissions budget. The UK Government's Committee on Climate Change (CCC) 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 that are compatible with existing infrastructure. There is also the possibility of increasing the efficiency of transport and heating through the deployment of new electric vehicle and heat pump technologies respectively. The timescale outlined by the CCC is that transition to a very low carbon grid, with an intensity of the order of 50g CO2/kWh, would take place by 2030, on the way to a zero carbon grid soon after[6].

In principle, it may be argued that shale gas could be burned safely in the short term, however in practice this is not the case. Given that shale gas is yet to be exploited commercially outside the US, limitations on the availability of equipment and expertise mean that it is very unlikely it could provide other than a marginal contribution to UK supply by 2020. Gas fired power stations produce emissions of approximately 440gCO2/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

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[4] A series of emissions pathways with a cumulative twenty-first century CO_2 budget of 1,321$GtCO_2$ have previously been assessed using the PRIMAP tool (Meinshausen et al.) and are estimated to have an approximately 36 per cent probability of exceeding 2°C (Anderson and Bows 2011). If emissions to 2009 are subtracted, including those from deforestation aviation and shipping, then this leaves approximately 1,000Gt of 'safe' emissions space for the remainder of the century.

[5] Assumes an airborne fraction of emissions of 45%, see for example Le Quere et al (2009), and that 1ppmv CO_2 = 2.13Gt carbon.

[6] It is worth noting that the CCC acknowledges a low probability of keeping below 2C of warming on the basis of their budgets.

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 302gCO2/kWh in 2030 necessitating 95% deployment of CCS to meet our fourth period emissions budgets (2023-2027). Even CCS is problematic when such low carbon electricity is required. At commercial scale CCS will not be 100% effective at capturing carbon dioxide and will always add costs to electricity production by reducing the efficiency of the power station and requiring additional energy input in transportation and injection of the captured carbon dioxide. CCS therefore 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 15gCO2e/MJ.

Therefore, if investments in shale gas were to be sanctioned and new gas powerstations constructed in the near future, there would be substantial stranded assets[7] or conversely incentives for government to surrender its 2°C obligations and remain "locked in" to a fossil fuel energy supply. The House of Commons Energy and Climate Change Committee (2011) concluded "that if a significant amount of shale gas enters the UK market (whether from domestic sources, imported from another European country, or from the global market via LNG) it will probably discourage investment in more-expensive—but lower carbon—renewables." We estimate that, considering the capital costs only, 8GW of gas powerstation capacity with CCS, plus shale gas well infrastructure, could displace 21GW of onshore wind capacity, assuming a Treasury Green Book discount rate of 3.5% for the gas well infrastructure. The same investment could also provide nearly 12GW of capacity 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, and be available to produce electricity across their full operating life.

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.

Conclusion

Given the cumulative emissions constraints outlined shale gas cannot contribute meaningfully to any UK energy future beyond 2030; whether in terms of electricity or heating. In the short term it is likely only to displace investment in low carbon electricity supply and energy demand reduction measures, contributing to the problem of "lock-in" to fossil fuel infrastructure. We conclude that exploitation of UK shale gas reserves is incompatible with avoiding dangerous climate change greater than 2°C, and the UK's commitments under the Copenhagen Accord.

References

Allen, M.R. et al., 2009. Warming caused by cumulative carbon emissions towards the trillionth tonne. *Nature*, 458(7242), pp.1163-1166.

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[7] Should retro-fit options for gas powerstations become available, it is very unlikely to deliver the level of CO2/kWh that is called for by the CCC. Best estimates of even purpose built CCS gas plant give an emissions intensity of at least 100gCO2/kWh, double the CCC's average grid target.

Anderson, K., and Bows., A., 2011, Beyond dangerous climate change: emission pathways for a new world, *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 369, 20-44

Anderson, K. & Bows, A., 2008. Reframing the climate change challenge in light of post-2000 emission trends. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 366(1882), pp.3863 - 3882.

Broderick. J., et al, 2011, *Shale gas: an updated assessment of environmental and climate change impacts,* A report commissioned by The Co-operative and undertaken by researchers at the Tyndall Centre, University of Manchester

Committee on Climate Change, 2008, *Building a Low-Carbon Economy - the UK's Contribution to Tackling Climate Change*, The Stationery Office, London.

DUKES (2010), *Digest of UK Energy Statistics, Commodity Balances Table 4.1*. Department for Energy and Climate Change, London.

Energy Information Administration (EIA 2011), 2011. *International Energy Outlook 2011*. U.S. Energy Information Administration, Washington, DC.

Energy Information Administration (EIA 2011b), 2011, *World Shale Gas Resources: An Initial Assessment of 14 Regions Outside the United States*, U.S. Energy Information Administration, Washington, DC

House of Commons Energy and Climate Change Committee, 2011, *Shale Gas – Fifth Report of Session 2010–12, Volume I*, London: The Stationery Office Limited

International Energy Agency (IEA 2009). *World Energy Outlook 2009*. International Energy Agency/ Organisation for Economic Co-operation and Development (IEA/OECD), Paris.

International Energy Agency (IEA 2011). *World Energy Outlook 2011 Special Report: Are we entering a golden age of gas?*.International Energy Agency/ Organisation for Economic Co-operation and Development (IEA/OECD), Paris.

Meinshausen, M. et al., 2009. Greenhouse-gas emission targets for limiting global warming to 2°C. *Nature*, 458(7242), pp.1158-1162.

Smith, J.B. et al., 2009. Assessing dangerous climate change through an update of the Intergovernmental Panel on Climate Change (IPCC) "reasons for concern." *Proceedings of the National Academy of Sciences*. 106(11), pp.4133-4137.