Carbon intensity of Shale Gas

1. The carbon intensity of shale gas currently lacks consensus within the academic field. A 2011 analysis by Howarth et al[1], suggests that the life cycle GHG emissions (LCA) for shale gas is worse than or equal to that for coal, whilst analysis from Jiang et al[2] suggest the LCA 3% higher than conventional gas and 20-50% lower than coal.

2. The most recent report (published this month) on the climate impact of potential shale gas production in the EU was conducted for the European Commission by AEA[3]. The report reviewed the variety of studies which are often referenced in literature. These include the studies by Broderick et al (2011); Howarth et al (2011); Jiang et al (2011), Santoro et al (2011); and Stephenson et al (2011). All of which, with the exception of Santoro, have been published in peer-reviewed journals or publications. The report also reviewed a report for the U.S. Department of Energy National Energy Technology Laboratory by Skone et al (2011).

Sources for the discrepancies in the data

3. The AEA report found that much of the evidence originated in America, with little European evidence due to the current status of the industry. The report summaries the discrepancies in LCA between the various studies, is often due to differing boundary conditions within the studies, such as: Stephenson et al (2011) did not estimate emissions from the construction phase; and Broderick et al (2011) has only examined emissions which are additional to those from conventional gas extraction, so has not examined well construction, and has only considered the horizontal element of drilling.

4. One major factor for the findings of Howarth et al (2011) has used a 100 year GWP for methane of 33 in calculating the CO2eq of methane emissions, whereas all of the other studies have used the GWP for methane of 25, as set out in the IPCC Fourth Assessment Report (2007). Howarth et al (2011) justifies the use of this higher GWP on the basis that more recent modelling (Shindell et al, 2009) which better accounts for the interaction of methane with aerosols. However as Broderick et al (2011) note, these processes are not yet well supported by a robust set of computer models.

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[1] Howarth et al. (2011), Methane and the greenhouse gas footprint of natural gas from shale formations, Climatic Change, 106, 679-690.
http://www.sustainablefuture.cornell.edu/news/attachments/Howarth-EtAl-2011.pdf

[2] Jiang, M et al,(2011), Lifecycle greenhouse gas emissions of Marcellus shale gas. Published in Environmental Resource Letters

[3] Climate impact of potential shale gas production in the EU, AEA (2012)

5. The LCA for shale gas takes into account the direct and indirect GHG gas emissions associated with gas extraction, transportation and use, including pre-production and production phases. What sets shale gas apart from more conventional gas is the pre-production emissions which comprises of well construction, drilling, hydraulic fracturing (fracking) followed by well completion. Whereas the production phase emissions include processing, transmission, storage, distribution and combustion, for Shale gas in Europe these should be comparable to European conventional gas sources. It should be noted that associated GHG emissions with the production phase are likely to be lower in the UK than in the US due to an improved transmission grid; this also one of the sources of the largest discrepancies between the studies.

6. 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.

7. 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. However, the temporary installation of equipment designed to handle the high initial flow of waste water, including gas, is possible, and has recently been mandated by the EPA.

8. After some time, usually a period of a few days, the mixture coming to the surface will be largely free of the water and sand, and then the well will be connected to the permanent gas collecting equipment. The level of emissions will depend upon the volumes of methane in the water flow back, the quantities of water flow back, the length of the flow back period and the management practices that are applied.

9. The well completion stage is also the source of the largest discrepancies between the studies. Estimates of emissions from this stage vary significantly between the studies, with that from Howarth et al (2011) being considerably higher than in the other studies, even after allowing for the use of a higher GWP, which will increase the methane contribution to total emissions by about a third compared to the other studies. It has been suggested in other studies, Cathles et al (2011)[4], that this discrepancy is due to the methodology used to estimate the gas release from one of the sites, Haynesville, the given source for this data, IHS, also dispute this figure claiming double counting.

[4] Cathales, L. M. III, Brown, L., Taam, M., Hunter, A, A commentary on "The greenhouse-gas footprint of natural gas in shale formations" by R.W Howarth, R. Santoro and Anthony Ingraffea, Climatic Change DOI10 1007/s105844-011-0333-0.

10. The second most significant source in this stage is drilling and hydraulic fracturing, where emissions (which range from 0.6 to 2.8 g CO2 e/MJ (for the base cases). The emissions arise from a range of energy using source including: powering drilling equipment; transport of water to site and waste water away from site; processes to supply water and treat waste water, and ‘embedded carbon’ in the proppant and chemicals used in the hydraulic fracturing fluid. The relative importance of these activities varies from study to study, reflecting both site characteristics (e.g. transport distances), and methodological choices (e.g. approach to estimating emissions from waste water treatment).

Appropriate LCA for Europe

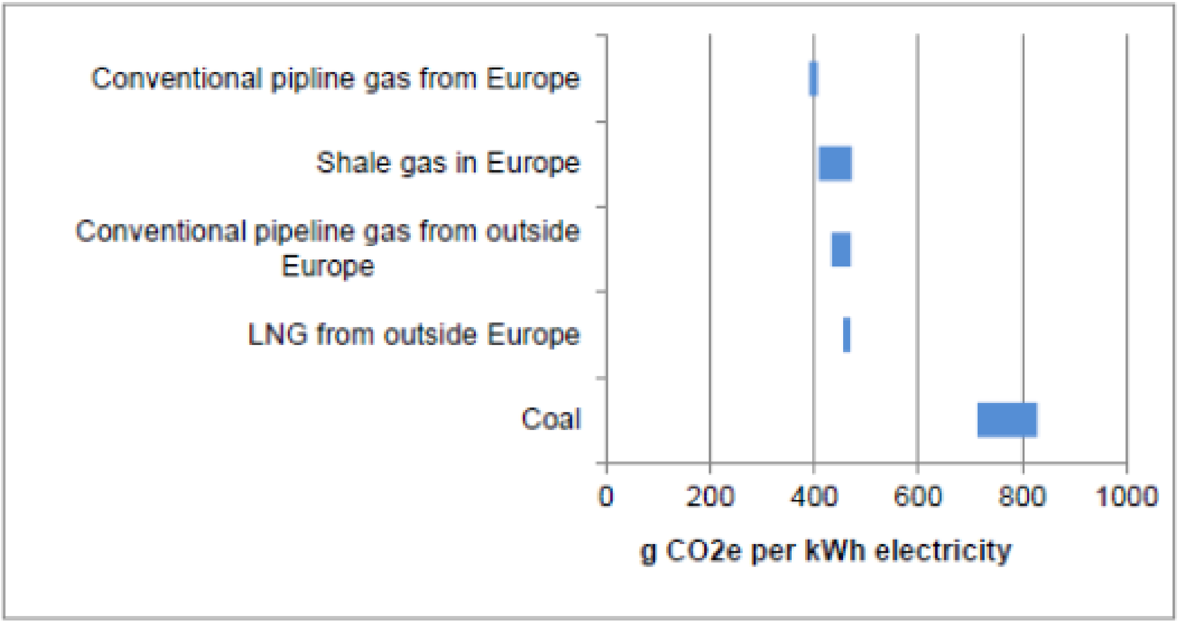
11. AEA conducted sensitivity to develop a hypothetical LCA for shale gas within Europe, analysis from the data within the studies on the key aspects affecting lifecycle GHG emissions which are,
    - Overall lifetime shale gas production of the well;
    - Methane emissions during well completion which are dependent on the quantity of methane in the flow back liquid and the treatment of this methane (e.g. venting, flaring or green completion, which results in 90% of the flow back gas being captured);
    - Number of re-fracturing events and the associated increase in productivity that result from these.

12. AEA state that the analysis is hypothetical, and represents an illustration of the potential scale and significance of emissions from shale gas exploitation in Europe, based upon experiences from the U.S. In practice the actual emissions from shale gas operations in Europe will be influenced by site-specific characteristics, and by the management practices and technologies employed. In the hypothetical analysis the relative influence of these factors has been explored as part of the sensitivity analysis, wherever data is available to do so.

13. Data for emissions associated with processing and transmission of the gas, have been estimated from operations relevant for Europe.

14. Similar LCA analysis was also carried out for generating electricity on other sources of gas and coal. The results of which are shown in Figure 1.

Figure 1 – Lifecycle emissions from coal and gas fired electricity generation



15. It can be seen that shale gas could have similar LCA as LNG and conventional gas from outside Europe, and has significantly lower emissions than coal.

16. LCA analysis from the Tyndall Centre[5], which takes a more limited range of data concurs with AEAs findings stating "The relatively small size of pre-production emissions is dwarfed by the size of direct emissions associated with the combustion of conventional natural gas and coal. Furthermore, additional benefits arise from the use of natural gas rather than coal when converting the fuel to usable energy, due to the efficiencies of conversion."

17. A potential issue with using pre-production data from the US to calculate the potential LCA of shale gas in the UK is that there is insufficient data as to whether the shale experience is transferable to sites found in the UK. The potential extraction rate from each well is as yet unknown in the UK and is a significant factor in the LCA analysis

18. The Environment Agency has commissioned a study to review monitoring and control practices for fugitive methane emissions from unconventional gas, with the focus being on land-based (rather than off-shore) operations. The review will:
    a) compare life-cycle greenhouse gas emissions from unconventional and conventional gas extraction

[5] Shale gas: a provisional assessment of climate change and environmental impacts, The Tyndall Centre, University of Manchester, 2011

b) assess what monitoring and controls might be applied to unconventional operations, if necessary, to minimise fugitive emissions.

19. Existing DECC controls already limit venting to the technical minimum, and limit flaring to the economic minimum. These already ensure that UK emissions will be much better controlled than the historic practices reflected in the US data, even before any further controls that the EA may think appropriate.

Conclusion

20. The AEA report for the European Commission provides the most complete narrative, to date, on the discrepancies in the available studies. The sensitivity analysis on the data contained within the studies provides a well thought out route to assessing the LCA of shale gas within the UK.

21. The LCA analysis by AEA suggests in the worst case scenario that shale gas is similar to that for LPG and significantly lower than coal. A study by Howarth et al (2011) suggests that the LCA for shale gas is the same as for coal, although the finding in this study were skewed from data from one borehole with the use and veracity of this data having been challenged; and the findings are heavily influenced by the choice of time horizon.

22. However the vast majority of the data for pre-production is provided from US sources, and it is uncertain how well this can be applied to the UK. It would be greatly advantageous in order to truly assess the likely GHG emissions from shale gas within the UK to carry out detailed analysis in any future exploration activities of the potential releases during the well completion stage and the energy required for drilling and fracking.

23. The study by Howarth et al (2011), even if the results are being challenged, show the potential GHG emissions associated with shale gas, if bad practices are employed. Strong regulation should enable best practice, to ensure limited releases occur during the completion phase. These practices are already becoming commonplace within the US. Existing DECC controls would also require flaring in place of venting, the most important single step in reducing emissions.

24. It is important to make sure that shale gas extraction operations worldwide all have local measurements to check for fugitive emissions so that we can confirm that these emissions are sufficiently small.

28 September 2012