
Climate Change impacts of unconventional oil and gas (UOG) development in Scotland

Annex - review of literature on impact of shale gas on global emissions

Introduction

In requesting advice on the climate change impacts associated with unconventional oil and gas (UOG) development in Scotland, the Scottish Government requested that this should cover the interactions between Scottish UOG production and global emissions:

"What are the likely net impacts on Scottish, EU and worldwide emissions of Scottish UOG production compared with a base case with no UOG production?"

To help inform this consideration, we have conducted a quick review of literature which considers implications of increased supplies of gas (conventional or unconventional) for global emissions, from which we consider if there are lessons that might be drawn for the wider impacts of UOG development in Scotland.

In the time available, the review is limited (a list of references is included at the end of this annex). It does not separately consider the impacts of gas leakage, which are covered in the main report. The specific and uncertain circumstances of UOG production in Scotland may also be very different to the circumstances modelled or assumed in the available literature. We only attempt, therefore, to draw very high level implications.

Background - impact of increased shale gas production in the US

It is clear from the work of, for example, McGlade and Ekins (2015), that in global 2°C consistent scenarios, gas has an important role in displacing coal in power and industry. Large resources of unconventional gas are left un-burnable in their scenarios, but to the extent that unconventional gas is produced they conclude this is possible only if coal reserves are left undeveloped.

The rapid development of shale resources in the US is generally held to have led to reduced use of coal and a reduction in US emissions. This has led to a more general suggestion that increased use of natural gas could be a bridge to a low-carbon future.

However, even the scale of the impact on US emissions from increased shale gas, and the implications for global emissions, is disputed. For example:

- Kotchen and Mansur (2016) estimate that low natural gas prices, resulting from shale gas availability, account for between 20 and 41% of the emissions reduction between 2007 and 2013. Feng et al (2016) take issue with this and while agreeing increased natural gas supplies played a role, do not see it as the main driver.

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- Broderick and Anderson (2012) estimate that more than half of US emissions avoided between 2008 and 2011 from coal to gas switching (645 MtCO_{2e}) were displaced outside the US, including in Europe, as a result of increased coal exports (338 MtCO_{2e}).

Disentangling the various impacts is not straightforward.

The emissions impact of shale gas taking account of substitution effects and impacts on overall energy demand

If natural gas substitutes for coal, then - barring substantial gas leakage - it is straightforward to show (e.g. Hausfather (2015), Zhang et al (2016)) that a transition to near-zero emission technologies can be delayed for some years without increasing overall emissions.

Such estimates are illustrative, but rather beg the question of what this increased use of gas might actually substitute for. There is widespread agreement that assessment of the full impact of abundant gas on climate change requires an integrated approach to consider the energy-economic-climate system as a whole.

A view of this was set out by the International Energy Agency (IEA) in their special report on a "Golden Age of Gas" scenario, IEA (2011). This compared a scenario taking a positive outlook for natural gas to 2035¹ with an existing "WEO-2010 New Policies" scenario². The "New Policies" scenario was not enough to put emissions on a path consistent with an average global temperature rise of no more than 2°C, and the report suggested that the "Golden Age of Gas" scenario made very little difference to that conclusion:

- Increased use of natural gas displaced some coal and, to a lesser extent, oil, but also displaced some nuclear power, and lower prices resulted in higher overall energy consumption;
- The net effect on emissions was small - global energy-related CO₂ emissions in 2035 only slightly lower (down 160m tonnes), less than a 1% difference as against the "New Policies" scenario;
- Limiting the increase in global temperature to 2°C required a much greater shift to low-carbon energy sources, increased efficiency in energy usage and new technologies;
- The "Golden Age of Gas" scenario assumed that support for renewables was maintained, but the report noted that - in a scenario where gas is relatively cheap - there was a risk that government resolve to provide such support might waiver, pushing gas demand higher.

The report therefore noted a set of competing interactions resulting from the "Golden Age" assumptions.

Considering the impact on global emissions of UK shale gas, MacKay and Stone (2013) also set out that the complexities. Short-term they suggest that the impact is dependent on:

- The price of shale gas relative to the price of coal and to the price of LNG imported to the European market;

¹ Assumptions in this scenario included a more ambitious policy for gas use in China, lower growth of nuclear power, greater production of unconventional gas and lower gas prices. Underlying the assumption that unconventional gas production increases, would be a view that barriers to production are largely overcome and that increased supplies become available in other regions at costs comparable to those in North America.

² The New Policies scenario took account of existing government policies and declared future intentions as of mid-2010.

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- The price elasticities of demand and supply for gas and coal;
 - The transport costs of gas and coal;
 - The substitutability of gas and coal in different regional markets.

Their assessment was that development of shale in the UK was unlikely to have much impact on the price of gas in Europe, so any impact on overall gas demand and on coal-to-gas switching is likely to be small. For the impact on emissions, longer-term, they concluded that the impact is strongly dependent on the strength of global climate policies. In the absence of such policy they consider that any fossil fuel use displaced in the shorter-term by greater shale gas availability will end up being used (so that cumulative emissions rise).

For the US, there is evidence that increased gas supplies may not lead to lower emissions. Brown et al (2010) use the NEMS-RFF³ model to consider the impacts of scenarios with varying levels of US shale gas resources (comparing US shale gas resource of 616 as against 269 trillion cubic foot):

- Gas prices are lower, and consumption higher, with increased natural gas supplies
- Greater gas use substitutes for coal, but also for some nuclear generation and renewables
- Overall energy consumption is higher
- CO₂ emissions in 2030 are 1% higher in the high shale gas resource case.

They conclude that having low-carbon policies in place is essential if natural gas is to serve as a bridge to a low-carbon future - without this, they would not expect increased gas supplies to be consistent with reducing CO₂ emissions.

The uncertainty of impacts arising from an increase in global gas supplies from unconventional sources is clear from analysis by McJeon et al (2014). They examine, across 5 models⁴, the implications of more than 30,000 EJ cumulative natural gas production at a cost up to \$3 per GJ (as compared with a maximum 11,000 EJ conventional gas only).⁵

For some outputs, there are significantly different results across the 5 models. In other respects, however, there is enough in common for McJeon et al (2014) to draw some general conclusions - in particular, that whilst an increase in global gas supplies from unconventional sources has potential to produce substantial changes in the global energy system, it does not lead to a discernible reduction in greenhouse gas emissions:

- There is an increase in gas consumption in all models, but with a wide range of results (from 11 to 170% higher in 2050).
- Gas substitutes for both coal and low-carbon energy sources (renewables and nuclear generation). Using McJeon et al (2014) results, Davis and Shearer (2014) show that the use of gas for power generation, averaged across the 5 models, increases relative to renewables across the period to 2050 (as against a declining gas to renewables ratio post-2020 in scenarios limited to conventional gas).

³ National Energy Modelling System, Resources for the Future version.

⁴ BAEGEM, G-CAM, MESSAGE, REMIND, WITCH.

⁵ This scenario is not presented as a likely case, but more like an upper bound to test implications.

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- Lower gas prices lead to increased economic activity and reduced incentives to invest in energy efficiency, both of which cause global primary energy consumption to rise (an average 6% increase).
 - CO₂ emissions overall are either little affected (3 models, change in emissions less than 2% in 2050), or increase (2 models, plus 5-11%).

Hilaire et al (2016) also find an abundance of gas on world markets leads to a net increase in emissions. They consider a number of scenarios, differing in the strength of climate policy. Modelling using the REMIND IAM finds that greater gas use substitutes for less nuclear, less renewables and less coal, but in all scenarios:

- Overall energy use per unit GDP increases;
- Emissions increase in the first half of the century, with lower energy system costs in the short-term, but higher mitigation costs beyond 2030.
- Imports of gas to Europe (and to the USA and Southern Asia) are reduced.

The authors speculate that higher abatement costs in the longer-term might make implementation of low-carbon policy, post-2030, more difficult.

Few et al (2016) use the TIAM-Grantham IAM to explore a range of scenarios with different assumptions for global gas supplies and costs. They cite a number of other studies to suggest that shale gas only looks to be competitive with conventional gas - and thereby play a significant role in global energy supplies going forward - if optimistic assumptions for shale gas costs are combined with higher-end assumptions for conventional gas costs.

In a world that is committed to climate policies limiting global temperature rise to 2°C they find:

- Differences in gas availability do not have a large impact on the cost or feasibility of meeting the 2°C target. Energy system costs (abstracting from methane leakage) are similar across the scenarios considered;
- The assumed cost of conventional gas is a more significant factor for global natural gas demand and for overall energy system costs than assumptions about the supply curve for shale gas.
- Meeting the 2°C target requires that the share of natural gas in total primary energy peaks around 2030 and then declines. The share of gas in primary energy is little affected by assumptions around availability or costs of shale gas. Modelled natural gas use is 4% higher over the period 2012-2100 in a case where shale gas is assumed available at "medium cost" than in a "no shale gas" scenario.
- In general, the availability of shale gas has very little impact on cost-optimal rates of decarbonisation. A "dash for shale" scenario, which prioritises extraction of all lower and medium cost shale gas by 2050, has the biggest impact. In this case, decarbonisation slows down in the 2020s (from an annual average rate of around 5.0% to around 4.6%), but has to speed up in the 2030s (annual average rate around 4.1% as against 3.5% otherwise).

The authors also consider the possibility that development of shale gas resources might lead to a slow-down in development of low-carbon technologies. As mechanisms for such a slow-down they suggest competition for scarce capital or increased uncertainty surrounding policy support for low-carbon measures. However, the impacts they present are purely illustrative and not based on empirical estimation.

Conclusions

There is limited evidence, using integrated systems models across economy-energy-emissions, to consider the impact of increased gas supplies on global emissions.

There are a few studies, as reported above, which look at the implications of global increased gas supplies. Considering what can be drawn from these of relevance to the implications of Scottish supplies from unconventional sources, demands caution, for a number of reasons including:

- the assumed supply curve for unconventional gas (how much gas, at what cost) is speculative;
- results reported here relate, in general, to global increases in supply, and do not differentiate impacts as between specific regional markets;
- Scottish supplies are likely to be very small relative to the European market;
- results show significant variation depending on the assumptions and set-up of the specific model employed.

To the extent that a few broad conclusions can be drawn, these would be:

- greater gas supplies lead to some displacement of coal, but also to displacement of low-carbon sources (renewables and nuclear);
- net impacts on global emissions tend not to be negative (i.e. emissions down), but are either very small or positive (i.e. emissions up);
- net impacts depend on the strength of climate policy;
- impacts on the overall costs and feasibility of meeting a 2°C target (if gas leakage is controlled) are small.

References

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