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The future role of natural gas in the UK: A bridge to nowhere?

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ABSTRACT

The UK has ambitious, statutory long-term climate targets that will require deep decarbonisation of its energy system. One key question facing policymakers is the role of natural gas both during the transition towards, and in the achievement of, a future low-carbon energy system. Here we assess a range of possible futures for the UK, and find that gas is unlikely to act as a cost-effective 'bridge' to a decarbonised UK energy system. There is also limited scope for gas in power generation after 2030 if the UK is to meet its emission reduction targets, in the absence of carbon capture and storage (CCS). Without CCS, a 'second dash for gas' while providing short-term gains in reducing emissions, is unlikely to be the most cost-effective way to reduce emissions, and could result in stranded assets and compromise the UK's decarbonisation ambitions. In such a case, gas use in 2050 is estimated at only 10% of its 2010 level. However, with significant CCS deployment by 2050, natural gas could remain at 50–60% of the 2010 level, primarily in the industrial (including hydrogen production) and power generation sectors.

1. Introduction

Natural gas has the lowest combustion carbon intensity of the three major fossil fuels (see e.g. IPCC, 2006). However, it has been shown that increases in the consumption of natural gas are not sufficient for reducing global greenhouse gas emissions since this would potentially substitute for both higher-carbon fossil fuels, e.g. coal or oil, as well as for lower-carbon or zero-carbon energy sources, such as renewables (McJeon et al., 2014). McGlade et al. (2014) and McGlade and Ekins (2015) examined possible futures for fossil fuels, with a particular focus on the 'bridging' role that natural gas may be able to play during a transition to a global low-carbon energy system. This research found that there is a good potential for gas to act as a transition fuel to a low-carbon future up to 2035 on a global level under certain conditions.

However, a key caveat to the positive conclusion that natural gas can play a 'bridging' role globally is that its potential varies significantly between different regions. While some national-level studies have demonstrated that increases in natural gas consumption, in combination with certain emissions-reduction policies, can help reduce overall greenhouse gas emissions in the United States (Brandt et al., 2014; Moniz et al., 2010), it does not follow that this is the case in all countries and regions around the world. It is also noteworthy that the International Energy Agency's 'Golden Age of Gas' scenario that explored a future with more natural gas in the global energy system resulted in projected emissions on a trajectory consistent with a temperature rise of 3.7 °C (IEA, 2011), well above the internationally-agreed threshold of "well-below 2 °C" (United Nations, 2015).

One crucial factor affecting the decarbonisation potential of natural gas is the level of fugitive methane emissions that occur during its production, transportation and distribution. This has been an ongoing source of controversy since the first paper on the subject by Howarth et al. (2011) suggested that such emissions from shale gas extraction were so high that they counteracted all benefits of switching from coal to gas, although multiple papers subsequently contested these findings (Lawrence et al., 2011; Levi, 2013; O'Sullivan and Paltsev, 2012). Nevertheless, it is important to recognise that the UK's long-term decarbonisation objectives (see Section 2.2 below) include only 'territorial emissions', or emissions generated within the country. Any fugitive methane from natural gas produced by the UK is included within its territorial emissions but imported gas is effectively 'carbon-neutral' from an upstream emissions perspective (the UK imported 45% of its gas in 2014). An increase in domestic gas production, such as from its putative shale gas resource (Andrews, 2013) might have lower life-cycle emissions than other sources of imports, such as Liquefied Natural

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Gas (LNG) (MacKay and Stone, 2013). However, any fugitive emissions from domestic production would augment the UK's territorial emissions, potentially making it harder to achieve the UK's domestic decarbonisation objectives.

In the UK, natural gas accounted for 34% of total primary energy consumption in 2015: of that 30% was used in the generation of electricity and heat by power stations, 37% by households, mainly in heating buildings, and the remainder by industry and other users (BEIS, 2016). Climate change policies are a key dynamic that will affect future levels of gas consumption but Bradshaw et al. (2014) also highlighted the myriad of technological, economic, and policy factors that will affect gas consumption in the UK. The range of uncertainties around these factors means that how large natural gas consumption might be and what role it might play in the future, in the UK and elsewhere, depends on the assumptions about these factors and therefore remains an open question. This is illustrated in the UK context by the recent Future Energy Scenarios, developed by the national gas system operator (National Grid, 2016). They imply a lower consumption by 2030 under all cases, even those that do not meet the UK climate ambition, with a stronger reduction under the “Gone Green” scenario of around 25%. However, they also point to substantial quantities of gas still being required in the 2030s.

Here we use the energy system models UKTM (Daly et al., 2015) and ESME (Heaton, 2014; Pye et al., 2015b) to examine changes in the role of gas in the UK under a range of future energy scenarios. We use two alternative models here for different reasons. First, the two models are better suited to constructing different types of scenarios. ESME allows for the exploration of a large number of simulations, under a wide set of parametric uncertainties. This allows for a better assessment of the range of possible pathways, and a more systematic assessment of under what conditions different pathways emerge for natural gas. UKTM is a more complex model, with a more detailed representation of the energy system, but which is unable to run a very large number of simulations. UKTM includes a resource-upstream sector, with a more detailed characterisation of domestic gas production, processing and distribution, and imports. It also captures the greenhouse gas (GHG) emissions across the energy system, important given the potential for methane emissions associated with gas production and distribution. Finally, end use sectors which use gas, the carbon capture and storage (CCS) system, and hydrogen production all have enhanced detail compared to ESME. Second, the set-up and assumptions within these models vary and so we avoid drawing firm conclusions based only on a single model.

In discussing the central question of this paper, whether or not gas can act as a ‘bridge’ fuel, there are two conditions that we consider need to be fulfilled. In a scenario that is consistent with maximum 2 °C temperature average global warming, gas consumption should increase either absolutely from 2010 or relative to another scenario that does not meet this temperature constraint. More specifically:

- Natural gas acts a ‘relative’ bridge in a region (or globally) when total consumption is greater in some period in a scenario consistent with at 2 °C temperature rise*, relative to* a scenario that contains no GHG emissions reduction policies.
- Natural gas acts as an ‘absolute’ bridge in a region (or globally) when total consumption rises above *current* levels over some period until it reaches a peak and subsequently enters a permanent or terminal decline.

The remainder of this paper is organized as follows: Section 2 describes the modelling approach and the scenario framing; Section 3 follows with a presentation of the results from both models; and Section 4 develops the discussion around the modelling insights, before drawing some key conclusions around the future role of gas in the UK.

2. Modelling approach and scenarios constructed

This section gives a brief overview of the two energy system models that have been used for the analysis—UKTM and ESME—and the scenarios that will be implemented with each. These models have some features in common—within physical and technical constraints, they optimise energy system development over time (minimising energy system cost or maximising a measure of social welfare) by assuming rational decision making by a central policy planner who has perfect information about the future. While the model frameworks necessarily provide a proxy representation of the actual energy system and its evolution, they nevertheless provide important insights about how energy systems could change in response to drivers, such as fuel prices and emissions limits, and some of the trade-offs and choices that could be important. A detailed description of the two models used in this paper is provided in Appendix A.

2.1. Energy system models

ESME (Energy Systems Modelling Environment), developed by the Energy Technologies Institute (ETI), is a fully integrated energy systems model, used to determine the role of different low carbon technologies required to achieve the UK's mitigation targets. The model has been used in this capacity by the former UK Department for Energy and Climate Change (DECC), now known as the Department for Business, Energy and Industrial Strategy (BEIS), and the UK Committee on Climate Change (CCC, 2013, 2010; DECC, 2011a). The model uses linear programming to assess cost-optimal technology portfolios. Uncertainty around cost and performance of different technologies and resource prices is captured via a probabilistic approach, using Monte Carlo sampling techniques. Gas extraction, production and distribution, and the associated emissions from this sector, are not represented explicitly, nor is there a distinction between domestic and imported gas resources. The limited representation of domestic gas production and distribution, and associated CH_4 emissions, means, for example, that any potential methane emissions penalty that would be incurred under stringent climate policy is not taken into account.

The UK TIMES energy system model (UKTM) is based on the model generator TIMES (The Integrated MARKAL-EFOM System), which is developed and maintained by the Energy Technology Systems Analysis Programme (ETSAP) of the International Energy Agency (IEA) (Loulou and Labriet, 2007). UKTM is a technology-oriented, dynamic, linear programming optimisation model representing the entire UK energy system (as one region) from imports and domestic production of fuel resources, through fuel processing and supply, explicit representation of infrastructures, conversion to secondary energy carriers (including electricity, heat and hydrogen), end use technologies and energy service demands. It minimises total welfare costs under perfect foresight to meet the exogenously given sectoral energy demands and thereby delivers an economy-wide solution of cost-optimal energy market development. Distinctive from the ESME model, all GHGs associated with the energy system are accounted, including CH_4 emissions from domestic production and distribution of natural gas. For gas and other energy commodity imports, only emissions at the point of use are accounted, as per the territorial or production basis for inventory accounting.

2.2. Scenarios constructed

ESME is well suited to exploring the effects of uncertainty on future energy and emissions pathways. We therefore use this strength here to explore the effects of uncertainty in technology investment costs in the power and transport sectors, fuel costs and resource potential (e.g. biomass imports), on future levels of gas consumption in the UK under different emissions assumptions. In the context of these uncertainties, recognising that there are others we have not included, we explore three specific scenarios that have been shown previously to have a large