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The future of the UK gas network ☆

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HIGHLIGHTS

- We examine the long-term future of the UK gas pipe networks using the UK MARKAL model.
- The iron mains replacement programme will not lead to gas infrastructure lock-in.
- Bio-methane and hydrogen injection have only a small role in our future scenarios.
- The most cost-optimal strategy might be to convert the networks to deliver hydrogen.
- Adopting a long-term gas strategy could reduce the cost of providing heat in the UK.

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ABSTRACT

The UK has an extensive natural gas pipeline network supplying 84% of homes. Previous studies of decarbonisation pathways using the UK MARKAL energy system model have concluded that the low-pressure gas networks should be mostly abandoned by 2050, yet most of the iron pipes near buildings are currently being replaced early for safety reasons. Our study suggests that this programme will not lock-in the use of gas in the long-term. We examine potential future uses of the gas network in the UK energy system using an improved version of UK MARKAL that introduces a number of decarbonisation options for the gas network including bio-methane, hydrogen injection to the natural gas and conversion of the network to deliver hydrogen. We conclude that hydrogen conversion is the only gas decarbonisation option that might enable the gas networks to continue supplying energy to most buildings in the long-term, from a cost-optimal perspective. There is an opportunity for the government to adopt a long-term strategy for the gas distribution networks that either curtails the iron mains replacement programme or alters it to prepare the network for hydrogen conversion; both options could substantially reduce the long-term cost of supplying heat to UK buildings.

1. Introduction

The UK Climate Change Act 2008 requires the UK government to reduce UK greenhouse gas emissions in 2050 by 80% relative to 1990 levels (HM Parliament, 2008). Studies of UK decarbonisation pathways to meet this target, underpinned by the UK MARKAL energy systems model, have invariably suggested that the low-pressure gas pipeline network should be mostly decommissioned by 2050, with heating provided by either electric heat pumps or biomass boilers (e.g. Hawkes et al., 2011; Kesicki, 2012). Since the gas network currently supplies around 22.9 million customers (DECC, 2011b), including 84% of homes, this represents a profound change to the UK energy system.

Notwithstanding these studies, a 30-year accelerated iron mains replacement programme (IMRP) is currently underway to replace around 100,000 km low-pressure iron distribution and attached service pipes near buildings with polyethylene pipes for safety reasons (HSE, 2001). This represents a significant investment in the network infrastructure. Since gas pipes have long lifetimes, the capital stock from the replacement programme will be retired early if gas use is curtailed by 2050. One alternative would be to supply zero-carbon bio-methane, produced from biomass, instead of natural gas (National Grid, 2009). The UK government has yet to adopt a position on the long-term future of the gas system (DECC, 2011a, p. 34) but it has identified bio-methane and hydrogen as potential carbon-neutral sources of heat in future (DECC, 2012b). There is growing pressure from the gas industry for the government to define a clear long-term strategy for the gas networks, as evidenced by the publication of several recent reports (e.g. Arran and Slowe, 2012; Greenleaf and Sinclair, 2012; National Grid, 2009; Redpoint, 2010). In response, the government has recently decided to explore the future of the gas

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network through whole system modelling and through consultations with industry (DECC, 2013). Yet few academic studies have considered the long-term future of the network, with van Foreest (2011) a notable exception.

This paper examines the future prospects for the UK gas pipeline network. First, we address our concerns about the adequacy of the representation of the gas networks in the UK MARKAL model by greatly improving the model using a new estimate of the age of the network and recent data on the costs of investment in gas infrastructure. We then use UK MARKAL to examine whether the pipeline replacement programme will effectively lock-in use of the gas network in the future at the expense of other low-carbon technologies than could have been built instead at lower overall cost. In doing so, we highlight the limitations of MARKAL-type models in representing large network infrastructures and we perform sensitivity studies to test the robustness of the conclusions. We examine whether the supplied gas can be decarbonised through the use of bio-methane, hydrogen injection to the gas stream or by converting the existing network to deliver hydrogen instead of natural gas. Finally, we describe possible scenarios for the future of the gas network and consider policy issues for the UK government.

2. The past and uncertain future of the UK gas pipeline network

It is important to understand the context in which the future of the gas network is being considered. In this section, we provide a brief history of the origins of the network, describe its current use and composition, and examine various debates around its future.

Gas has been delivered by pipeline to buildings in the UK for the last 200 years. 'Town gas', which comprised a mix of hydrogen, carbon monoxide, methane and other gases, was manufactured from coal and provided lighting to replace candles and oil lamps. The principal advantage of gas lighting was economic, with gas costing a third of whale oil (Chandler and Lacey, 1949). Despite this incentive, residential buildings were not supplied with gas until the 1840s because the cost of laying pipes to small buildings with low demand proved prohibitive, particularly when there were often many companies in the same area, each with their own pipeline network.

Gas cookers were widely adopted from the 1870s and provided a market for gas as lighting was gradually electrified. Few households used gas for heating until the introduction of natural gas in the 1960s because of the imperfect combustion of town gas and the accumulation of soot and odours in buildings (Williams, 1981).

The gas industry underwent three major transitions in the twentieth century (Williams, 1981). First, the industry was nationalised in 1948 as 1062 gas companies were merged to create 12 regional Gas Boards overseen by the Gas Council. Second, in the 1960s, natural gas was discovered under the North Sea and the Gas Council decided to switch the entire country from town gas to natural gas. Since the energy content of natural gas is much higher than town gas, this required all gas appliances in the country to be converted in a national programme taking 10 years. A high-pressure national transmission network (the National Transmission System or 'NTS') was constructed to deliver North Sea gas across the country and linked to all of the local distribution networks. The third transition occurred in the 1980s, when the gas networks were privatised to create a transmission network and eight regional distribution network companies (Arapostathis, 2011). These assets are now owned by several companies and their prices and capital investment levels are regulated by Ofgem, an autonomous government regulator.

2.1. UK gas network composition

The NTS has a total length of 7600 km (National Grid, 2011a). Gas leaves the transmission network at 175 locations. Some large power generation and industrial consumers are supplied directly from the NTS but most consumers receive low-pressure gas from the distribution networks (Simmonds, 2000, p. 11). These networks are much larger than the transmission network with a total length in 2010 of 280,000 km (ENA, 2010). This comprises approximately 12,000 km of high pressure pipes, 35,000 km of intermediate and medium pressure pipes and 233,000 km of low pressure pipes (Transco, 1999).

Service pipelines link smaller buildings to the mains distribution networks. They are the narrowest and shortest pipes in the system, but they represent a substantial investment as there are approximately 23 million of them across the country.

2.2. Estimating the age of the UK gas network

Future uses of the gas network depend on how long the existing infrastructure can be expected to remain in good working order. We estimate the age of each part of the existing network in this section.

Construction of the NTS began in the 1960s and the majority of the current network was built over a 10-year period (Williams, 1981). Transmission pipes have an expected lifetime of 80 years (National Grid, 2011b) so we expect the existing network to become obsolete from around 2050.

The mains distribution networks have been constructed over many decades as the number of customers has gradually increased and some pipes are now more than 100 years old. We have estimated the development of the networks using data from several sources (DECC, 2011c; ENA, 2010; Gas Council, 1960, 1970; Mitchell et al., 1990; Transco, 1999; Williams, 1981). The total length of the distribution networks was approximately proportional to the number of customers until around 1960, when construction of higher-pressure distribution pipes commenced to reconfigure the previously fragmented system for national gas delivery. This development added 50,000 km of pipes while the customers totalled 13 million (Fig. 1). The introduction of natural gas also enabled the huge increase in domestic gas consumption per customer since 1960 that is shown in Fig. 2. Estimating the age of the network is more complicated than finding the total length because pipes are occasionally replaced before the end of their life. It was necessary for us to estimate the replacement level, particularly in the early years, as described in Dodds and McDowall (2012a). Nevertheless, we believe that the construction rates we have produced, in Fig. 3, are sufficiently accurate for the purpose of our study.

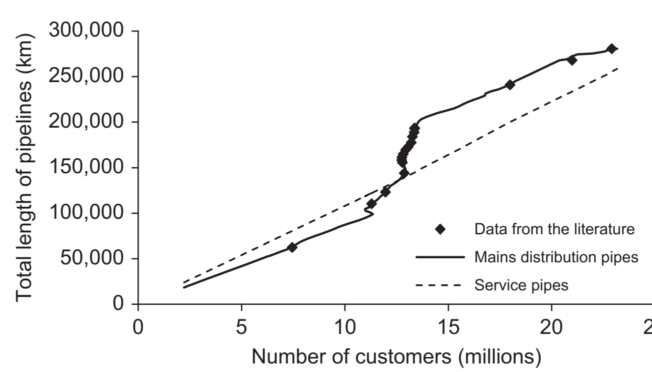

Fig. 1. Total length of the mains distribution and service pipes as a function of the number of customers. The points indicate data taken from the literature. The number of customers is taken from DECC (2011c).