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A greener gas grid: What are the options

Jamie Speirs[a,b,*], Paul Balcombe[a,c], Erin Johnson[c], Jeanne Martin[a], Nigel Brandon[a,b], Adam Hawkes[a,c]

[a] Sustainable Gas Institute,Imperial College London, 11 Prince's Gardens, London SW7 1NA, UK
[b] Department of Earth Science and Engineering, Royal School of Mines, Prince Consort Road, Imperial College London, SW7 2BP, UK
[c] Department of Chemical Engineering, South Kensington Campus, Imperial College London, SW7 2AZ, UK

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ABSTRACT

There is an ongoing debate over future decarbonisation of gas networks using biomethane, and increasingly hydrogen, in gas network infrastructure. Some emerging research presents gas network decarbonisation options as a tractable alternative to 'all-electric' scenarios that use electric appliances to deliver the traditional gas services such as heating and cooking. However, there is some uncertainty as to the technical feasibility, cost and carbon emissions of gas network decarbonisation options. In response to this debate the Sustainable Gas Institute at Imperial College London has conducted a rigorous systematic review of the evidence surrounding gas network decarbonisation options. The study focuses on the technologies used to generate biomethane and hydrogen, and examines the technical potentials, economic costs and emissions associated with the full supply chains involved. The following summarises the main findings of this research. The report concludes that there are a number of options that could significantly decarbonise the gas network, and doing so would provide energy system flexibility utilising existing assets. However, these options will be more expensive than the existing gas system, and the GHG intensity of these options may vary significantly. In addition, more research is required, particularly in relation to the capabilities of existing pipework to transport hydrogen safely.

1. Introduction

The future for natural gas infrastructure is currently uncertain. Gas networks are used across the world to transport natural gas to industrial, commercial and residential consumers, providing energy for a range of uses including power generation, industrial process heat and chemical industries, space and water heating and transport. However, current use of natural gas and associated methane emissions are unlikely to be compatible with climate change goals in countries with ambitious climate targets given the carbon dioxide (CO_2) produced by natural gas combustion (Dodds and McDowall, 2013; Budinis et al., 2016; McGlade et al., 2016). Country level emissions abatement scenarios, particularly in regions with high reliance on gas for heating, typically demonstrate a reduced role for natural gas networks in the future, often preferring electricity networks as the carriers of decarbonised energy for domestic and commercial consumers (Committee on Climate Change CCC, 2008; Department of Energy and Climate Change DECC, 2009; UK Energy Research Centre (UKERC), 2009; Steinberg et al., 2017; Colier, 2018). However, significant technical, economic and consumer barriers to electrifying heat make deep penetrations of electric heat challenging, including uncertainty over heat pump efficiency in situ, significant cost differential between heat pump and traditional gas boiler installation, and consumer resistance to novel heat technology adoption (Committee on Climate Change CCC, 2016; Howard and Bengherbi, 2016; KPMG, 2016). Given these concerns there is a growing argument that decarbonised gas networks (carrying hydrogen or biomethane for example) can play a significant role in the future energy system and that their energy storage characteristics and existing asset value are of value to future energy system decarbonisation (Dodds and McDowall, 2013; Howard and Bengherbi, 2016; KPMG, 2016; Sadler et al., 2016).

The Sustainable Gas Institute (SGI) at Imperial College London has conducted a systematic review of the available evidence surrounding the options for gas network decarbonisation to bring evidence and rigour to the debate. This paper examines the evidence surrounding low pressure gas network decarbonisation options, including the technical characteristics, associated costs and implications for greenhouse gas (GHG) emissions, bringing together research conducted as part of the

Abbreviations: AD, Anaerobic Digestion; BioSNG, Bio Synthetic Natural Gas; CCS, Carbon Capture and Storage; CO_2, Carbon Dioxide; GHG, Greenhouse Gas; SGI, Sustainable Gas Institute; SMR, Steam Methane Reforming; TPA, Technology and Policy Assessment; UKERC, UK Energy Research Centre

* Corresponding author at: Sustainable Gas Institute,Imperial College London, 11 Prince's Gardens, London SW7 1NA, UK.
E-mail address: jamie.speirs@imperial.ac.uk (J. Speirs).

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SGI White Paper Series (SGI, 2018). The paper focusses on the options for decarbonising fuel sources and the associated infrastructure required, presenting findings in the context of the alternative option; using electricity and heat pumps. While much of the evidence arises from countries where the use of gas networks is common (e.g. UK, Netherlands), implications for these options in other countries are explored. While this study focusses on the implications for the use of hydrogen and biomethane primarily in domestic and commercial sectors, there is clearly a significant potential for these energy vectors in transport and industrial applications. This is not covered in this study but is an important area for future research.

2. Method

This comprehensive review of academic, industrial and governmental literature draws on the methodology created by the UK Energy Research Centre (UKERC) Technology and Policy Assessment (TPA) theme (Gross et al., 2006) and refined by the SGI for its White Paper Series (Balcombe et al., 2015). The methodology uses systematic and well-defined search procedures to document the evidence review, providing clarity, transparency, replicability and robustness. An external expert advisory panel is appointed with a broad range of perspectives to consult on the initial framing and specification of the review procedure, as well as providing additional comments on the emerging analysis and final drafting. The assessment process carried out is presented in Fig. 1.

Over 300 peer reviewed and grey literature articles were examined and interrogated to provide the evidence base used to investigate the options for gas network decarbonisation. Evidence on the technological options, their costs and the associated GHG emissions were extracted from these studies, and analysed as part of the project. These issues are discussed in turn below.

3. What are the future options for gas networks?

There are two gases typically discussed in the literature with a significant potential to decarbonise gas networks: hydrogen and biomethane. These gasses can be produced in a number of ways (as shown in Figs. 2 and 3) and have specific infrastructure requirements.

3.1. Decarbonised hydrogen

Hydrogen can be used for heat or electricity generation, or as a transport fuel. The key benefit of hydrogen over natural gas is that there are no CO_2 emissions at point-of-use. However, producing hydrogen may result in CO_2 emissions, efficiency losses and supply chain emissions. Additionally, differences in the physical properties of hydrogen and natural gas mean that some modifications to existing infrastructure are required, adding costs to natural gas system conversion.

There are several main techniques used to produce hydrogen, including:

- Reforming of oil;
- Steam methane reforming (SMR);
- Anaerobic digestion and SMR;
- Coal gasification;
- Biomass gasification;
- Any of the above technologies in conjunction with carbon capture and storage (CCS); and
- Electrolysis of water.

Fig. 2 sets out these options, excluding oil reforming, which seldom features in studies of future hydrogen production.

Approximately 48% of the 55 million tonnes per year global hydrogen production is by reforming natural gas. Reforming of oil contributes around 30%, gasification of coal (18%) and electrolysis of water (4%) (Muradov and Veziroğlu, 2005; Kothari et al., 2008; Ursua et al., 2012; Kalamaras and Efstathiou, 2013).

The infrastructural implications of using hydrogen in gas networks are significant. First, there will be a need to build hydrogen production plant of some form, with resulting capital and operating costs. It will then be necessary to connect that plant to the gas network, including

	Scope the project	Solicit expert input	Review the literature	Synthesis and analysis	Prepare the draft report	Expert panel review and refine	Publish and promote
TASKS	• Write a scoping note, outlining aims and search and review protocols	• Appoint expert panel • Solicit expert panel comments on scoping note • Finalise aims and search and review protocols	• Apply protocol to literature search • Detailed and transparent 'trawl' • Identify relevant sources	• Apply protocol for evaluation and synthesis of literature	• Write preliminary draft report	• Solicit expert panel comments on draft report • Revise draft report	• Design and format report • Publish and publicise report • Launch event
OUTPUT	• Submit scoping note to expert panel	• Expert panel review of scoping note	• Literature database		• Draft report	• Expert panel review of report	• Publish report

Fig. 1. Diagram of the systematic review methodology.
Source: Speirs et al. (2017)