Leeds Climate Commission

"Enabling climate action in a can-do city"

POSITION PAPER 1 2019

HYDROGEN CONVERSION: POTENTIAL CONTRIBUTION TO A LOW CARBON FUTURE FOR LEEDS

The Leeds Climate Commission has produced this position paper as a constructive contribution to inform decision making in the city.

The Leeds Climate Commission was established in 2017 to help Leeds to make positive choices on issues relating to energy, carbon, weather and climate. It brings together key organisations and actors from across the city and from the public, private and third sectors.

Leeds Climate Commission members have contributed to this paper, but the views expressed in this position paper cannot be attributed to any single member and the Leeds Climate Commission takes responsibility for all views expressed.

Executive Summary

1.1 This Position Paper reviews the potential role of hydrogen in meeting future energy demands and helping to reduce carbon emissions in Leeds, particularly in the areas of space and water heating, cooking, industry and transport.

1.2. Currently, the UK's low carbon plans envisage the electrification of heating and transport in the 2030s. Hydrogen offers a potential alternative – especially where its production is based on renewable energy and/or combined with carbon capture and storage.

1.3. This is an especially significant issue for Leeds given the H21 Leeds City Gate project led by Northern Gas Networks which is exploring the feasibility of replacing natural gas supply to Leeds with hydrogen supply, with switch over envisaged for the late 2020s or early 2030s.

1.4. The paper sets out a number of potential future opportunities relating to greater deployment of hydrogen in the energy mix, including the potential for hydrogen as a

replacement for natural gas in heating and cooking; as an alternative transport fuel; as a way of improving air quality and as a source of economic development. The paper also considers the potential to generate hydrogen from renewable energy sources, including surplus renewable energy in the context of a long term global hydrogen supply system.

1.5. Challenges associated with hydrogen are also summarised including its risk profile; public perception and acceptance issues; the physical disruption of conversion and change of domestic appliances (fires, cookers, boilers etc); the costs of hydrogen conversion; the need for carbon capture and storage (CCS) the funding model; maintaining market competition and consumer choice; and the overall national and local economic costs and benefits compared with other approaches; the need for a national approach; its carbon impact in relation to electrification [the Leeds Climate Commission estimates a hydrogen conversion would reduce carbon emissions in the city by 8%]; and the need for the elimination of fossil fuel generated hydrogen in the future.

1.6. The paper identifies several opportunities for climate and energy policy that need to be considered by decision makers:-

- The first rule of any system of energy management is to consume less energy in the first place. Space heating of homes and other buildings is a significant component of current energy consumption. Insulation of existing buildings and construction of new build to high standards is the most effective way of reducing space heating energy requirements. This also has the added social and economic benefits of improving the comfort of homes and reducing fuel bills.
- A hydrogen energy future may present an opportunity to consider the energy system as a whole (heating, electricity and transport) rather than in terms of separate elements. The establishment of a hydrogen network could play a central role in a new low carbon energy network comprising low carbon electricity, surplus renewable energy converted to hydrogen, district heating for high-rise and other developments, enhanced levels of building energy efficiency and low emission transport options with associated air quality benefits.
- Hydrogen conversion provides an unprecedented opportunity to visit each gas connected property in the city at least 3 times (to assess appliances, to change them and to check that they are working). The opportunity should be taken to use these visits to the maximum extent to deliver co-benefits of energy saving and demand reduction at the same time. Experience from the Town Gas/Natural Gas conversion supports the contention that households may also be prompted to consider other energy saving interventions and improvements at the point of conversion.
- As well as promoting energy efficiency and demand reduction opportunities during the home visits, hydrogen conversion provides at least two opportunities to improve energy efficiency. Firstly, the new appliances that will be needed to replace existing gas cookers, boilers and fires should be as energy efficient as possible. Secondly, the process of producing hydrogen (via SMR, electrolysis or other techniques) offers the potential for further research on how to increase the efficiency of conversion.
- In the long term hydrogen conversion provides the platform for a future hydrogen based economy and an outlet for renewable sources of hydrogen such as hydrolysis utilising ‘excess’ renewable electricity or hydrogen from renewable biogases. The

H21 project should therefore be pursued alongside other measures to increase the production of renewable electricity and gas.

- Hydrogen conversion relies on the reinvigoration of carbon capture and storage which is a technology that is not only essential for H21, but also provides a manner for reducing the carbon impacts of other fossil fuel based consumption process in energy generation or other industrial processes.

1.7 The paper identifies the following collaborative actions that the Climate Commission would like to support:

- Feed into an evaluation of the economic impact of hydrogen conversion compared with other low carbon alternatives and the options for future funding.
- Promote research on the factors shaping public perception and attitudes towards hydrogen conversion and the opportunities and challenges that this presents.
- Provide support for hydrogen vehicle infrastructure demonstration projects, hydrogen storage (utilising electrolysis) in Leeds, and an understanding of CCS in the context of an assessment of hydrogen's potential role in a low carbon city energy system.
- Promote research on the further development of CCS and renewable hydrogen and related projects.
- Promote research on the implications for the functioning of the competitive energy market in hydrogen conversion areas.
- Promote research on improving the energy efficiency of hydrogen appliances and hydrogen production.
- Help to articulate a roadmap to a clean zero emissions future for Leeds including hydrogen and other fuels.
- Help to define the timescale between the hydrogen conversion project and the move to production of renewable hydrogen; and to promote research/projects to narrow any gap that exists.

1.8. Finally, the Leeds Climate Commission will wish to play an active role in the debate over how to achieve a low carbon future for the city and will continue to evaluate the options, remaining objective and informed by evidence at all times.

2. Background

2.1. The UK Climate Change Act (2008), has set the legally binding target to reduce carbon emissions by 80% of 1990 levels by 2050 to combat the risks of climate change and is now in the process of being updated to reach net-zero emissions by 2050.

2.2. The UK gas network currently runs on natural gas, which is composed of methane (93.9%), ethane (4.2%) and propane (0.3%). When natural gas is burned, carbon emissions and water are released into the atmosphere predominantly in the form of carbon dioxide (CO2), water vapour (H2O) and some carbon monoxide (CO). The release of carbon emissions into the atmosphere is the primary issue with the current gas network in terms of achieving a low-carbon, climate resilient future.

2.3. Heating and hot water for UK buildings make up 40% of total UK energy consumption and 20% of UK greenhouse gas emissions. The national Committee on Climate Change argues that it will be necessary to eliminate these emissions by around 2050 in order to meet the targets in the Climate Change Act. The Committee of Climate Change has also reported on the potential of hydrogen in a decarbonised future energy system for the UK.

2.4. The existing policy direction is to reduce carbon emissions from heating by replacing natural gas heating with heating fuelled by increasingly decarbonised electricity. However, UK peak gas demand is currently 7 times peak electricity demand so pursuing an all-electric approach will inevitably prove challenging in terms of the ability of the existing electricity grid infrastructure to cope with such a large increase in demand.

2.5 Replacing natural gas heating with hydrogen-fuelled heating is an alternative approach, but both options (converting to an all-electric or hydrogen option) are unproven at a national scale. It can also be argued that both options maintain a centralised energy system model which may limit opportunities for more community engagement and present a different resilience profile to a more distributed system of energy generation and supply.

3. H21 (Hydrogen) Leeds City Gate project

3.1. The H21 (Hydrogen) Leeds City Gate project is an innovative new proposal by Northern Gas Networks (NGN) who are pioneering plans to transform the Leeds gas network to use 100% hydrogen rather than natural gas for commercial, industrial and domestic use.

3.2 As this national infrastructure project is being pioneered locally, the Leeds Climate Commission feels it is important to outline its position in regard to this groundbreaking project which could have national and potentially international implications.

3.3. The H21 Leeds City Gate project is now concerned with demonstrating the safety case for a 100% hydrogen gas infrastructure, funded by OFGEM, while the recently launched H21 North of England project looks to roll out the conversion of the gas grid to hydrogen, initially across the major urban centres of the North. Leeds would act in a central role in this work and would also be one of the first cities to convert.

3.4. A very broad timeline for hydrogen conversion across the North of England is:

- Current: Complete safety case;
- 2019 – 2023: Front End Engineering and Design (FEED) study to control project expenses and thoroughly plan project;
- 2023 – 2026: Potential Government Policy Decision;
- 2026 – 2028: Build;
- 2028 – 2034: Conversion.

3.5. This timeline would also need to run alongside development of CCS and increased renewable energy production.

4. Hydrogen

4.1. Once produced, hydrogen can be burnt without producing carbon or other polluting emissions at the point of use. It is a very versatile gas it can be transported as a gas by pipeline, by road in tankers as a compressed gas, or be produced locally in a decentralised energy system. This means it has many potential uses in an overall energy system.

4.2. There are two main ways of producing almost all of the world's hydrogen at scale at the moment and the cheapest is Steam Methane or Auto Thermal Reforming (SMR/ATR) of natural gas. Converting natural gas to hydrogen using reforming produces carbon dioxide. To make it low-carbon, it needs to be combined with Carbon Capture and Storage. At present, reforming technologies are the only available processes to produce hydrogen at a scale required for a city such as Leeds so that a hydrogen conversion strategy would initially be dependent on SMR. As outlined below, in the long term hydrogen conversion could only be considered a success when it is less reliant on methane (or any other non-renewable fossil fuel) as a source of hydrogen, and technologies such as electrolysis are operating at scale.

4.3. Carbon Capture and Storage (CCS) is the process of capturing waste carbon dioxide from large point sources, such as biomass or fossil fuel power plants, or in the case of hydrogen production, reforming technologies, transporting it to a storage site, and depositing it where it will not enter the atmosphere, normally an underground geological formation. Examples of CCS do exist around the world, but less so in the United Kingdom, which lacks a supportive policy environment at present.

4.4. Hydrogen can also be produced through gasification processes and, to a lesser extent, by electrolysis of water, which uses electricity to split water into hydrogen and oxygen. This is more expensive than SMR (even without CCS) and requires more energy, but it produces very pure hydrogen. More affordable catalysers are being developed (e.g. nickel and recently a promising melamine/cobalt catalyst being developed in Scandinavia) which may reduce costs of electrolysis in the future.

4.5. Electrolysis is also more applicable for small-scale generation compared to SMR but can have a use to convert and store excess power generated by renewable installations as hydrogen, for localised generation to fuel low emission vehicles.

4.6. The production, storage, distribution and use of hydrogen does generate risk. Levels of public acceptance of/confidence in the H21 project depend on effective risk management and on effective stakeholder engagement and risk communication from an early stage in the project development cycle.

4.7. A potential precursor to full-scale 100% hydrogen conversion is hydrogen blending, introducing a proportion of hydrogen into the existing gas supply (up to c20%) and removing the need for appliance conversion. A project to evaluate this is currently being carried out at Keele University (HyDeploy) while existing hydrogen blending systems operate in Hong Kong, Singapore, the Netherlands and Germany. It should be noted that pre-North Sea Gas, Towns Gas did include up to 50% hydrogen.

4.8. Retaining the existing national gas grid and repurposing it for hydrogen has the advantage that it still retains an element of choice for a significant majority of customers currently connected to the gas grid in terms of their ability to choose their primary heating fuel. The current alternative of only providing decarbonised electricity would limit this element of customer choice. Retaining the gas grid also ensures that a significant national asset (which has been invested in for decades) would not be stranded. In terms of localised energy security (indicated by occurrence of power cuts), a gas system is likely to maintain the higher levels of security (and low frequency of gas interruptions) currently enjoyed by gas customers.

4.9. As is the case at present whereby a significant proportion of the UK's electricity is generated by burning gas, a hydrogen gas network could provide centralised generation of (low carbon) power through hydrogen combined cycle gas turbine generating stations.

4.10. A hydrogen gas network offers the potential for innovations at the domestic scale including low carbon electricity production, vehicle to grid technologies and micro combined heat and power plants.

4.11. However it can be argued that maintaining a centralised system, may support few incentives for energy demand reduction, and arguably also risk diverting scarce financial and technical resources from alternative configurations and solutions.

5. Future Opportunities and Challenges

5.1. Initial research suggests that there are a number of potential opportunities from converting the gas grid to hydrogen:

- Economic opportunities and job creation for building and maintaining the infrastructure, keeping the gas industry operational into the future, and other socio-economic opportunities.
- The distribution and availability of hydrogen could increase the potential of Hydrogen Powered Vehicles, which could lead to further carbon savings through replacement of petrol and diesel vehicles. Especially if at some time in the future hydrogen

powered vehicles are used for heavy goods vehicles, where electric vehicles are currently unable to meet this demand.
- Improvement of air quality through hydrogen vehicles (e.g. as used at Rungis wholesale food market in Paris with a combined gas refuelling facility for hydrogen vehicles (as well as compressed and liquid natural gas options), and in cities such as Aberdeen where hydrogen buses are being used at present) and also through hydrogen boilers, reducing polluting emissions at the point of use.
- The future opportunity to produce hydrogen from 100% renewables by electrolysis would mean hydrogen would be a completely clean fuel, releasing zero carbon emission to produce hydrogen. This will only be possible once the capacity of renewables increases.
- The H21 project allows the future potential to store previously wasted excess renewable electricity during times of low demand by converting it to hydrogen, which could then be stored for times of high demand. This could enable carbon savings by reducing the energy requirements of non-renewable energy sources. By using renewable electricity to generate hydrogen during times of over supply helps to mitigate the intermittent nature of renewable energy.
- In the long term the H21 project allows for the potential to utilise the areas with high renewable energy potential, which are currently not being used (e.g. storing substantial surplus renewable energy from off shore wind turbines operating at night when demand for electricity is low). Places like Australia, Africa and Patagonia do not utilise their renewable energy potential. However, if hydrogen could be produced by the renewables in these places and transported as ammonia, it would mean that renewable, clean energy could be more abundant. This would having significant global carbon savings and would be a way to balance global renewables.

5.2. However, a number of important challenges associated with hydrogen conversion have also been identified:-

- Hydrogen does have a different risk profile for use as a domestic and commercial fuel when compared with natural gas and electrical alternatives, and it requires effective management of this risk at all stages. As with any energy vector (electricity, oil, gas), hydrogen needs to have associated safe systems to manage any associated risks to a tolerable or acceptable level. Risks need to be fully quantified to ensure confidence that hydrogen conversion represents a comparable risk to natural gas. This raises technical, behavioural and regulatory challenges.
- A hydrogen conversion maintains the current centralised approach to energy generation and supply which may stifle innovation from more decentralised energy options and operators, and may not incentivise the pursuit of energy demand reduction. How the role of decentralised, community and local energy schemes would be affected by hydrogen conversion needs to be considered. Would they be crowded out by such a significant infrastructure project, or would it provide an outlet for locally produced renewable energy?
- While hydrogen conversion can be introduced with relatively little disruption in terms of the existing gas infrastructure (much of which has been upgraded to polyethylene pipework capable of transporting hydrogen), it is understood that it would entail gas appliance replacement (e.g. boilers, fires and cookers) which would involve a degree of disruption to householders. There may be benefits (e.g. in terms of safety) in an effective national ‘reset’ of these appliances, but the considerable carbon and waste implications of an appliance replacement programme would need to be considered.

- As natural gas supplies would need to be replaced by hydrogen supplies on an area-by-area basis, there would be an element of compulsion in the switch-over that may not be as acceptable as the conversion from Town Gas to natural gas in the 1960s/70s. Conversion and/or replacement of appliances would need to be carried out by a third party.
- Active consideration will need to be given as to how the competitive energy market can be adapted to enable the supply to hydrogen by domestic and business energy suppliers. In addition, a customer's right to choose their energy supplier will also need to apply to hydrogen as well as gas and power.
- Hydrogen conversion also raises significant issues about public perceptions and confidence about the social 'license to operate', especially as H21 is a novel approach that requires public participation and buy-in. However a more significant issue may be that the public are unaware that a 'do nothing' option is not available and therefore some form of mandated change is necessary, if national carbon reduction targets are to be achieved.
- The costs of conversion are not clear at present, especially when compared with other low carbon alternatives, such as all electric options. Some possible funding mechanisms were presented in the original H21 report and these need to be examined more thoroughly
- It is also not clear who should bear the costs of conversion: the tax-payer, gas customers, the gas industry or a combination of all three; and whether the gas industry should be taking a greater share of the responsibility in safeguarding the future of the gas industry in low carbon future.
- The overall contribution of a project such as H21 to the local economy of Leeds has not been assessed particularly in terms of its economic value alongside other measures
- A project such as H21 is effectively a national infrastructure project (hydrogen conversion could not happen in only one part of the UK), requiring a national policy response (and potentially additional legislative intervention) not only in terms of hydrogen conversion, but also CCS, even if only deployed in some areas alongside a portfolio of low carbon solutions (such as district heating, heat pumps etc).
- The carbon benefits of hydrogen conversion depend on hydrogen substituting natural gas. The Leeds Climate Commission science based carbon budget, carbon targets and carbon roadmap for Leeds estimates that switching the heating network to decarbonised hydrogen would close the gap between current emissions and carbon neutrality by 8%. If heating was electrified (with electricity coming from renewables) the carbon benefits of switching to hydrogen would be reduced or negated. The overall carbon reducing potential of H21 could therefore depend on the period between its adoption and the electrification of heat, with that forecast or called for in the existing UK carbon budgets. If that period is longer - with H21 being adopted earlier and/or electrification of heat delayed - then the carbon benefits would be higher, but if the opposite was true they would be reduced. If H21 roll out was delayed to 2040, and if electrification of heat was brought forward to 2040, then H21 would not generate any carbon benefit (even without taking into account the energy burden of converting natural gas to hydrogen).
- A hydrogen conversion policy is necessarily dependent (at least in the foreseeable future) on a reinvigoration of CCS and although hydrogen conversion would provide a clear market opportunity for CCS, such a policy would need to be carefully evaluated in terms of its economic viability compared with the alternatives.

- In the longer term the H21 project would only be considered a successful contributor to a low carbon future for the city when it is less reliant on methane (or any other non-renewable fossil fuel) as a source of hydrogen. Development of renewable, non-fossil fuel sources of hydrogen will have to be developed in the long term with the potential for this to be traded internationally and is to be examined.

6. Opportunities for climate mitigation and adaptation that need to be considered by decision makers

6.1 The first rule of any system of energy management is to consume less energy in the first place. Space heating of homes and other buildings is a significant component of current energy consumption. Insulation of existing buildings and construction of new build to high standards is the most effective way of reducing space heating energy requirements. This also has the added social and economic benefits of improving the comfort of homes and reducing fuel bills.

6.2. A hydrogen energy future may present an opportunity to consider the energy system as a whole (heating, electricity and transport) rather than in terms of separate elements. The establishment of a hydrogen network could play a central role in a new low carbon energy network comprising low carbon electricity, surplus renewable energy converted to hydrogen, district heating for high-rise and other developments, enhanced levels of building energy efficiency and low emission transport options with associated air quality benefits.

6.3. Hydrogen conversion provides an unprecedented opportunity to visit each gas connected property in the city at least 3 times (to assess appliances, to change them and to check that they are working). The opportunity should be taken to use these visits to the maximum extent to deliver co-benefits of energy saving and demand reduction at the same time. Experience from the Town Gas/Natural Gas conversion supports the contention that households may also be prompted to consider other energy saving interventions and improvements at the point of conversion.

6.4. As well as promoting energy efficiency and demand reduction opportunities during the home visits, hydrogen conversion provides at least two opportunities to improve energy efficiency. Firstly, the new appliances that will be needed to replace existing gas cookers, boilers and fires should be as energy efficient as possible. Secondly, the process of producing hydrogen (via SMR, electrolysis or other techniques) offers the potential for further research on how to increase the efficiency of conversion.

6.5. In the long term hydrogen conversion provides the platform for a future hydrogen based economy and an outlet for renewable sources of hydrogen such as hydrolysis utilising ‘excess’ renewable electricity or hydrogen from renewable biogases. The H21 project should therefore be pursued alongside other measures to increase the production of renewable electricity and gas.

6.6. Hydrogen conversion relies on the reinvigoration of carbon capture and storage which is a technology that is not only essential for H21, but also provides a manner for reducing the carbon impacts of other fossil fuel based consumption process in energy generation or other industrial processes.

7. Collaborative actions needed and the role of the Leeds Climate Commission

7.1. The following collaborative actions have been identified as areas of activity where members of the Leeds Climate Commission can assist with furthering the decision making on the place that hydrogen may play in Leeds's energy future. In identifying these areas of action, it is recognised that the scale of the challenge to develop a decarbonised energy system for the city is huge and will require the contribution of a number of different low carbon options:

7.1.1. Feed into an evaluation of the economic impact of hydrogen conversion compared with other low carbon alternatives and the options for future funding.

7.1.2. Promote research on the factors shaping public perception and attitudes towards hydrogen conversion and the opportunities and challenges that this presents.

7.1.3. Provide support for hydrogen vehicle infrastructure demonstration projects, hydrogen storage (utilising electrolysis) in Leeds, and an understanding of CCS in the context of an assessment of hydrogen's potential role in a low carbon city energy system.

7.1.4. Promote research on the further development of CCS and renewable hydrogen and related projects.

7.1.5. Promote research on the implications for the functioning of the competitive energy market in hydrogen conversion areas.

7.1.6. Promote research on improving the energy efficiency of hydrogen appliances and hydrogen production.

7.1.7. Help to articulate a roadmap to a clean zero emissions future for Leeds including hydrogen and other fuels.

7.1.8. Help to define the timescale between the hydrogen conversion project and the move to production of renewable hydrogen; and to promote research/projects to narrow any gap that exists.

7.2. Finally, the Leeds Climate Commission will wish to play an active role in the debate over how to achieve a low carbon future for the city and will continue to evaluate the options, remaining objective and informed by evidence at all times.