GM Hydrogen and Fuel Cell Strategy

GM Hydrogen and Fuel Cell Strategy				Document control		
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We would like to thank many of the contributors to developing the strategy.

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Foreword

The analysis in this strategy was conducted in close collaboration with government, industry and academia and led by Manchester Metropolitan University's Fuel Cell Innovation Centre.

Our analysis has identified the most promising immediate opportunities to provide a view of the near-and long-term landscape and to mitigate the need for more widespread infrastructure change that a wholesale shift to alternative low carbon energy sources would require. It also builds on the work of the Greater Manchester Hydrogen Partnership (GMHP) which was founded in 2013 at Manchester Metropolitan University to develop and support hydrogen technology projects and embed a successful hydrogen economy in the wider North West region. The work of developing the strategy was initiated through the GMCA Mission Based Approach challenge groups and in line with the government's 10-point plan where Hydrogen is one of the ten points in the UK Government's new plan for a "green industrial revolution". The UK hydrogen strategy to be released in 2021 will include plans for investment in hydrogen projects, and schemes to boost sales of hydrogen electric vehicles.

Hydrogen and fuel cells have the potential to help deliver very low emissions pathways. As a low carbon energy source, increased use of hydrogen and fuel cells can have a noticeable effect on carbon emissions simply by providing a cleaner alternative and at a scale far greater than any other potential route, whilst at the same time avoiding any unintentional consequences. There is recognition in the region of the importance of hydrogen and fuel cells and what they bring to the decarbonisation route for Greater Manchester, with its ambition of being net zero carbon by 2038.

The Manchester Fuel Cell Innovation Centre (MFCIC) at Manchester Metropolitan University is a regional hub for research, innovation and economic growth in the hydrogen and fuel cell technology sector in the North West and beyond.
The Centre is part-funded by the European Regional Development Fund (ERDF) and is crucial both environmentally and economically for the region, as the UK focuses on increasing its use of renewable energy and lowering carbon emissions.

Executive Summary

To deliver the 2038 net-carbon-zero Greater Manchester target, full decarbonisation of all sectors is necessary. This report highlights the activities and policy initiatives taking place across the Northern Powerhouse to position the North for the introduction of hydrogen as a component of the decarbonised energy mix.

The state of readiness of current technologies is assessed. A number of short-term, recommendations are made to position the Greater Manchester region for the arrival of large volume hydrogen supplies in the late 2020's.

To make widespread use of hydrogen a reality in the future, government, local authorities and academic institutions can take a positive lead in directing the way forward. Cooperation and support from central government is crucial in order to facilitate changes towards new carbon free energy and unlock business opportunities and on scale deployment. This can be achieved by providing financial schemes to support demonstration projects, regulation/incentives on clean fuels, and emission penalties to make end users and industries desire environmentally friendly solutions.

This would drive the demand and change social perception making new and high risk technologies seen as accessible and risk-free, a reliable clean-swap solution.

The report focusses on delivery in 3 phases:

Phase 1 2021–2025: Establish Transport and Heat Supply Chain and Build Confidence in Wider Hydrogen

- **Recommendation 1**: For the Public sector to become early adopters of hydrogen in their fleet vehicles that are not easily replaced by other zero emission (tailpipe) fuels.
- **Recommendation 2**: Promote hydrogen fuel cell vehicles in conjunction with BEV.
- **Recommendation 3**: Planning for wider hydrogen refuelling station deployment:
- **Recommendation 4**: Evaluate hydrogen as a replacement for diesel rail on those hard to electrify lines/routes.
- **Recommendation 5**: Support innovation and demonstration of hydrogen for heat.
- **Recommendation 6**: Utilise academic expertise and facilities to support innovation.
- **Recommendation 7**: Support educational institutions and training providers to develop courses that deliver skills for the hydrogen economy.

Phase 2 2026–2030: Prepare for the availability of large volume hydrogen supply

- **Recommendation 1**: Recommendations commenced in phase 1 should continue to be delivered
- **Recommendation 2** Prepare for the availability of large volume hydrogen supply.

Phase 3: 2031–2038 Continuation of a regional expansion of a CO2-free hydrogen supply

This phase will focus on wide scale deployment to support the move to a hydrogen economy

Introduction

Like cities across the UK and all over the world, Greater Manchester faces the challenge of reducing emissions to limit the impact of climate change and meet the targets set out by the 2015 Paris Agreement and in line with the Governments 10-point plan.

The city region has pledged to become carbon neutral by 2038, more than a decade earlier than the target date adopted by the European Commission, and 12 years ahead of the rest of the UK.

Greater Manchester has modelled potential pathways towards net zero carbon in 2038 (SCATTER model) and set out early actions in its five-Year Environment Plan, however it does not have a long-term plan setting out how it will meet its climate change targets. Widespread adoption of hydrogen and fuel cell technology offers a potential route.

As the challenge of climate change grows, the search for low carbon energy sources has become critical. The interest in hydrogen and fuel cells is now gaining momentum around the world as a clean solution which meets multiple needs. The UK government has announced within the 10-point plan that in addition to domestic heat, hydrogen can be used for industrial heat, power, shipping and trucking. Hydrogen is thought to be particularly important for heavy transport where long distances are covered and electric vehicles are much less suitable. Hydrogen is also being considered for the decarbonisation of industrial processes such as chemical refinery and steel production with hydrogen being substituted for natural gas.

Overall, the growth of low carbon hydrogen could deliver savings of 41MT CO2 between 2023 and 2032 which is equivalent to 9% of 2018 UK emissions, the Government states. Whilst initially for domestic energy, public transport and private vehicles, the potential uses of the technology are growing

To seize this opportunity, government and the private sector need to take large scale and real-world actions now. This short-term strategy, which has been prepared with a number of stakeholders under the guidance and support of the Greater Manchester Combined Authority, provides an extensive and independent assessment of hydrogen and fuel cells. It lays out where things stand now; the ways in which hydrogen and fuel cells can help to achieve a clean, secure and affordable future energy; and how we can realise its potential in the region and beyond.

Greater Manchester does not have a single plan setting out how it will meet its climate change targets. However, widespread adoption of hydrogen and fuel cell technology offers a potential route.

The high-level objectives driving this strategy are
as follows:

- To align to the ambitions contained within the Governments 10-point plan for a Green Industrial Revolution and the anticipation of the UK Hydrogen Strategy to be released in 2021
- To align to the wider North West region and Northern Powerhouse agenda, together with Regional and national decarbonisation strategies
- To support the North West in becoming the UK's first Low Carbon Industrial Cluster, by 2030 in support of the National Industrial Strategy. Net Zero North West the industry group developing this have produced an economic prospectus which highlights £207bn green investment, £285bn GVA and over 660,000 jobs
- To integrate with the Greater Manchester Environment and Whole System Smart Energy
- Plan, the focus of which is energy generation and storage, decarbonisation of heat and low carbon transport
- To act as a realistic roadmap to defining a comprehensive research and skills programme that will bring stakeholders together and ensure Greater Manchester's growing clean energy strengths play a part in the global movement to mitigate climate change.
- To incorporate the hydrogen importance into the newly formed Greater Manchester Energy Innovation Agency

The Challenges

Despite significant advances in the decarbonisation of the electricity supply system at both the national level (18% of energy consumption) and local Greater Manchester level (23% of energy consumption), electricity represents only a small part of the overall energy supply (Figure 1[1]). The carbon intensity of electricity generation in 2018 had fallen to 32% of the level in 1990[2]. In contrast, there has been little progress in the decarbonisation of the heat sector, which is mainly delivered by natural gas, and the transport sector.

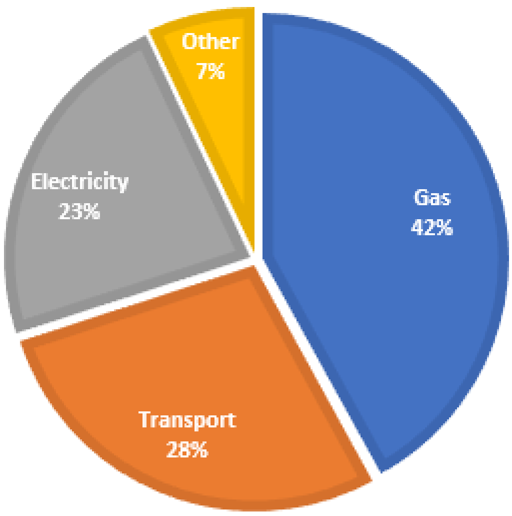

Figure 1 GM Energy consumption

Transport accounts for 28% of GM's energy consumption where hydrogen offers an opportunity to decarbonise those harder to tackle vehicles such as HGV's Buses and coaches together with vehicles that are needed to be operational 24/7, such as emergency services.

Domestic, commercial and industrial heating is responsible for around a third of the UK's overall emissions, which is unchanged from 2009.

There are two basic technical ways to reduce the carbon emissions associated with heating - either by reducing demand through energy efficiency measures or by replacing fossil fuel

[1] Source Greater Manchester Spatial Energy Plan Evidence Base Study
[2] Data provided by Committee on Climate Change

heating systems with less carbon-intensive versions, having due regard to ensure there are no unintended consequences

The UK Position

The UK Context

Policies implemented worldwide to reduce our carbon footprint make the move to renewable and clean energy sources inevitable. This is especially the case in the UK, which has committed to zero carbon by 2050.

The development of hydrogen policy in the UK increased exponentially in the second half of 2020. The House of Lords have launched inquiries into Hydrogen and the role of Batteries and Fuel Cells in achieving Net Zero. There is also a Hydrogen Advisory Council whose purpose is to inform the development of hydrogen as a strategic decarbonised energy carrier for the UK and one that will publish a hydrogen strategy later in 2021. References to hydrogen were apparent in the UK Government's long-awaited Energy White Paper, which was finally published in December 2020. The Scottish Government published its Hydrogen Policy Statement on 21 December 2020. Both the White Paper and the Hydrogen Policy Statement confirm that a UK hydrogen strategy is coming in 2021.

There are already hydrogen refuelling stations and fleets of Fuel-Cell Electric Vehicles (FCEVs) HGV's (Heavy Goods Vehicles), buses, coaches and taxis running on hydrogen on Britain's roads. Equally, there are projects that support further hydrogen network development: focusing on fuel station deployment, looking into the way we heat our homes and assessing how much carbon is generated by UK industry. Hydrogen is now very much part of the Decarbonisation plans across the heat and transportation sectors, as well as providing a long and short-term storage option for electricity generation.

Whereas the supply and demand of electricity must be matched with second-by-second response times at the site of power generation, hydrogen can be supplied from a store, meaning that the investment required in hydrogen production does not need to meet peak demand – as long as there is sufficient capacity to maintain the stores.

National Grid has identified that hydrogen has a major role to play in decarbonisation across heat, transport and industry when supported by approaches that address:

- Whole energy system approaches
- The development of new products and services
- The use of Carbon Capture Usage and Storage(CCUS).

Hydrogen has the potential to meet the majority of these supply stipulations. Its production potential is not limited by the availability of feedstock due to being produced from water. This contrasts with biomethane where national domestic feedstocks, food and agricultural waste, which has a finite supply and would represent around a third of domestic gas demand and a tenth of total natural gas demand.

The opportunity for Greater Manchester

The North of England is poised to be the primary region for the development of a decarbonised, hydrogen-based energy market for the UK. It already features all the necessary components to develop a hydrogen economy – thriving industry, the capability to address the skills of an existing workforce, city regions that collaborate, and natural assets.

The North has infrastructure advantages in key areas, such as hydrogen, tidal and marine energy, and energy storage capability with the potential for further scaling up. It is leading the UK's transition to renewable energy with nearly half of the UK's renewable energy being generated in the North England.

However, to become the leading low carbon energy region, Local Enterprise Partnerships (LEPs), local and combined authorities and academic institutions must take the lead in working collaboratively and directing the way forward together.

Net Zero North West – authored by top analysts at Siemens UK – puts the region on course to spearhead the Prime Minister's Ten Point Plan for a green industrial revolution. Setting out 18 investment cases for a pipeline of long-term and shovel ready green investment projects, the prospectus shows how the North West will deliver the UK's first net zero region by 2040. In doing so it will save 38.5 mega-tonnes of carbon dioxide emissions and deliver £207bn of targeted investment, which will turbocharge the UK economy by £285bn GVA and safeguard or create over 660,000 jobs.

Net Zero North West's prospectus sets out a co-ordinated vision for the region's green industrial revolution with three key aims: establish a fully integrated net zero industrial cluster by 2040; deliver a region-wide clean energy system; and build a hydrogen economy that will become the first UK network of hydrogen generation, storage and distribution.

It is important for key stakeholders in the North to set their own vision and priorities for action, based on regional strengths, in order to rebuild business and drive local industry revolution. Central government, regulators and other national bodies must, however, support these efforts to enable opportunities to be seized, ensure a level playing field for northern businesses and unlock investment and positive change[3].

A number of northern local authorities including Greater Manchester have now demonstrated commitment to local energy strategies and initiatives. They acknowledge the importance of hydrogen and its economic value and understand the opportunities it could bring to their region. Examples of northern local energy strategies include:

- Greater Manchester Low Carbon Hydrogen Hub - Trafford Green Energy Hub was established by Carlton Power and supported by key partners under an MoU signed in March 2021 between Carlton Power, Greater Manchester Combined Authority, Cadent, Electricity North West, Trafford MBC and Manchester Metropolitan University to establish Greater Manchester's first low carbon hydrogen hub. The project aims to:
    - Utilise modular technology for future expansion

[3] (Northern Energy Taskforce, 2017)

    - Renewable energy supplies via private wires
    - 10MWe electrolyser – capable of delivering 3.5 tonnes of hydrogen per day.
    - On-site H2 storage and refuelling
    - Planning submitted in July 2021
    - Commence construction Q1 2022
    - Low carbon hydrogen produced Q4 2023

- Liverpool City Region H2 Project – a pipeline £6.4 million project funded by the government's Office for Low Emission Vehicles (OLEV). The project aims to:
    - create a new hydrogen refuelling station at the BOC plant in St Helens that will initially deliver 500 kg of hydrogen per day
    - deploy up to 25 hydrogen-powered buses on the streets of Liverpool[4]

- H21 Leeds City Gate – a demonstration project converting Leeds' natural gas network into 100 % hydrogen. The project aims to:
    - determine the feasibility of converting from an economic and technological point of view
    - minimise disruption to existing customers
    - deliver heat at the same cost currently incurred by natural gas[5].

- HyTees – UK Research and Innovation project that focuses on the production, industrial use and storage of green hydrogen in Tees Valley and the transition of domestic gas in Leeds City Region to hydrogen. The project aims to:
    - deliver whole energy systems
    - provide demonstration, skills and training support to industry
    - provide equipment and machinery to support the transition by the associated manufacturing sector[6].
    - promote hydrogen vehicles and refuelling infrastructure through a £1.3 million grant from OLEV that will deliver five new hydrogen-refuelling stations, 73 fuel cell passenger vehicles and 33 fuel cell buses across the UK[7].

These projects are supported by wider Local Enterprise Partnership projects:

- The North West Energy and Hydrogen Cluster covers the industrial powerhouses of the Liverpool and Manchester City Regions as well as Cheshire and Warrington. It has a low cost and low risk approach to carbon capture utilisation and storage (CCUS). This project meets Government policy objectives for industrial decarbonisation to be both low risk and low cost and will secure and grow high value manufacturing jobs. The vision is to reduce

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[4] (LCR LEP, 2015)
[5] (H21, 2017)
[6] (Mark Lewis, 2019)
[7] TVCA, 2019

carbon emissions by over ten million tonnes per year and create in excess of 33,000 new jobs by 2030[8].

- The North East Local Enterprise Partnership's Energy for Growth strategy aims to drive economic growth in the North East while also bringing sector partners together to deliver at scale on national energy strategy. It has a target of 100,000 more and better jobs by 2024[9].

Implementation of a hydrogen energy supply deployment strategy would contribute to a number of the priorities in the Greater Manchester 5-year Environment Plan (Figure 3).

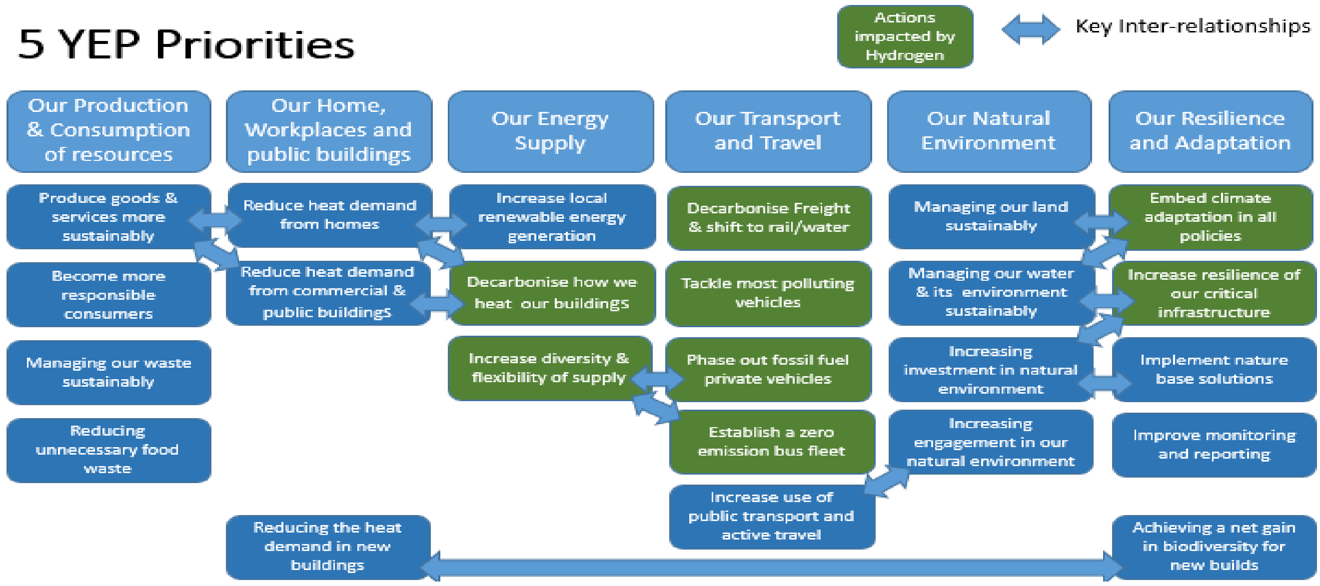

Figure 2 Hydrogen Impact on GM Environment Plan Priorities

European City Region Opportunities

The EU Fuel Cells and Hydrogen Joint Undertaking launched the region's initiative in 2017. It attracted 89 regions and cities from 22 countries and more than 55 industry partners. The Greater Manchester city region was represented in the study by Manchester Metropolitan University. The report identified the important role regions and cities can play in creating a future fuel cells and hydrogen (FCH) market in Europe by channelling public investments into the sector and supporting the build-up of a European FCH value chain.

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8 (NWEHC, 2019)

9 (NELEP, 2019)

Figure 3 Local Benefits of hydrogen and fuel cells for cities and regions

As Figure 2 shows, there is the potential for multiple additional benefits for cities and regions beyond decarbonisation and these include economic growth, job creation and workforce skills, and environmental benefits[10].

Gaining the Benefits of Hydrogen and Fuel Cells for Greater Manchester

Phase 1 2021–2025: Establish Transport Supply Chain and Build Confidence in Wider Hydrogen.

In this phase we seek to take advantage of existing hydrogen and fuel cell technologies to establish demand and build business and public confidence

in the move to hydrogen as part of the energy supply mix.

During this phase the following recommendations should be delivered:

Recommendations

Phase 1 2021–2025: Establish Transport Supply Chain and Build Confidence in Wider Hydrogen

- **Recommendation 1**: For the Public sector to become early adopters of hydrogen in their fleet vehicles that are not easily replaced by other zero emission (tailpipe) fuels, (such as Battery electric vehicles (BEV)), such applications as long haul commercial vehicles or emergency vehicles that are used 24/7.
- **Recommendation 2**: Promote hydrogen fuel cell vehicles in conjunction with BEV as an alternative to fossil fuel vehicles to improve air quality.

10(Roland Berger, 2018)

• **Recommendation 3**: Planning for wider hydrogen refuelling station deployment including the **Trafford Green Hydrogen development which will deliver Green Hydrogen in the region by Q4 2023.** In addition, work should commence on the following recommendations:
• **Recommendation 4**: Evaluate hydrogen as a replacement for diesel rail on those hard to electrify lines/routes.

• **Recommendation 5**: Support innovation and demonstration of hydrogen for heat with with no change in experience for domestic consumers through hydrogen blends.

• **Recommendation 6**: Utilise academic expertise and facilities to support innovation.

• **Recommendation 7**: Support educational institutions and training providers to develop courses that deliver skills for the hydrogen economy.

Phase 2 2026–2030: Prepare for the availability of large volume

Hydrogen supply

- **Recommendation 1**: Recommendations commenced in phase 1 should continue to be delivered
- **Recommendation 2:** Prepare for the availability of large volume hydrogen supply. With the planned delivery of large volume hydrogen supplies anticipated in the mid-late 2020's this phase will prepare businesses and the work force for the new opportunities this will offer.

Phase 3: 2031–2038 Continuation of a regional expansion of a CO2-free hydrogen supply.

This phase will focus on wide scale deployment to support the move to

a hydrogen economy

The Technology

Hydrogen Supply

Although hydrogen (H_2) production is a mature technology with over 70 million tons produced worldwide per year, nearly all hydrogen is currently produced from fossil fuels.

Low-carbon hydrogen is produced using one of the four established technologies:

- steam reformation of methane (SMR) with carbon capture, utilisation and storage (CCUS)
- auto-thermal reforming (ATR) of methane with CCUS
- electrolytic production of caustic soda which produces hydrogen as a by-product
- electrolysis of water (H_2O) using alkaline electrolysis for bulk supplies or proton exchange membrane (PEM) electrolysers for smaller or local supplies.

NB only the latter two produce zero-carbon hydrogen

The purity of the delivered hydrogen is an important consideration for selecting hydrogen generation technology. The semiconductor industries require extremely pure hydrogen (>99.9999%) for technologies such as chip fabrication but petroleum refining processes require only 80 – 90 % purity. Hydrogen fuel cell technologies are currently rated for < 0.2 ppm CO and 1.0 ppm CO_2 impurities under operating conditions.

Supply Options 2021 – 2026

Large scale production of hydrogen (SMR and ATR) is located close to disused off-shore gas fields to provide the necessary long-term stores for carbon dioxide.

The Institution of Engineering and Technology (IET) has estimated that to produce sufficient hydrogen to heat Greater Manchester's 1.2 million homes would require electrolyser capacity of 140GW. This would have an estimated footprint of 1,000 hectares and a water demand equivalent to 0.3 million homes[11].

The use of PEM electrolysers to service transport and heat demand for hydrogen is a mechanism to provide a hydrogen supply. This scalable technology is well established and widely deployed both in the UK and internationally for on-site hydrogen generation. The Trafford Green Hydrogen Project is based upon PEM electrolyser technology.

Supply Options from 2026

The Trafford Green Hydrogen in currently seeking planning approval for on-site renewal generation linked to a large 10MWe PEM electrolyser with a project first date of delivery of zero-carbon hydrogen by Q4 2023

In addition two of the UK's potential low-carbon hydrogen production projects, HyNet and H21 North of England, propose the construction of hydrogen supply pipes to service Greater Manchester.

HyNet, with production on the Wirral, could service the Greater Manchester and Liverpool city regions with an anticipated supply from 2026. The estimated price for heat delivery using hydrogen from HyNet is currently£38/MWh, which represents a £23/MWh uplift on today's natural gas price of around £15/MWh.

H21 North of England envisages a trans-Pennine link between the Tees-based hydrogen production facilities that will supply Leeds and HyNet. Estimated timescales are 2028-2035. Indicative prices are not yet available.

Fuel Cell Types

Fuel cells come in two basic types: polymer electrolyte membrane fuel cells (PEMFC) or solid oxide fuel cell (SOFC). PEM fuel cells are primarily used for transport applications and SOFC for stationary applications.

Today's PEMFCs have an efficiency rating of approximately 60 %. A PEM-FC unit of 25 kW costs ~$1,350/kW in CAPEX (total capital cost, assuming 50,000 units). This is expected to fall dramatically as the scale of production ramps up, driven largely by the take-up by vehicle manufactures, for example, the Toyota Mirai, Honda Clarity and Hyundai Nexo.

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[11] IET 2019 The Future of Hydrogen

Unlike batteries, fuel cell technologies decouple storage from the power-generating portion of the device. Therefore, in terms of volume and weight, these two energy storage technologies scale very differently from each other. In the case of a battery, to double the capacity (energy stored), one must double the volume of the module. Conversely, to double the capacity of a hydrogen fuel cell, the volume of the storage tank is doubled, not the fuel cell.

Today, hydrogen fuel cell technologies are used predominantly in the transportation sector, although stationary backup power generation fuel cells are also available commercially and deployed in a few locations.

One important note regarding PEM-fuel cells is that this technology cannot tolerate >0.2 ppm CO concentrations in the hydrogen streams.

SOFC systems, which run on natural or bio-gas rather than H_2, are replacing diesel generators as backup and stand-by emergency power generators. While these systems are largely SOFCs, some manufacturers already sell backup PEM-FC generators tailored for micro-grid applications, as well as baseload power rated at 1 MW.

Beyond power generation, SOFC fuel cells operate at high temperature so can also generate heat during their operation. This offers the opportunity for combined heat and power (CHP) applications, particularly for heating residential and commercial buildings, due to their high electrical efficiencies and lower power-to-heat ratio.

Hydrogen Use for Transport

Complete decarbonisation can be achieved using proton exchange membrane fuel cell (PEMFC) in Fuel Cell Electric Vehicles.

Hydrogen produced by electrolysis is perfect for transport fuel as it produces hydrogen at the very high levels of purity required by PEMFC. The use of electrolysers also provides an additional “demand side management” balance resource for the electrical power system.

Hydrogen Fuel Cell Fuelling Stations

Deployment “at scale” of hydrogen fuel cell vehicles requires an established fuel supply to meet demand.

Typical refuelling of light weight FCEV requires 4-5kg of H_2 at 700 bar, taking 3-5 minutes to refuel. HGVs and Buses, with their larger size, can be refuelled at 350 bar.

Technology Recommendations

Recommendation 1: For the Public sector to become early adopters of hydrogen in their fleet vehicles that are not easily replaced by other zero emission (tailpipe) fuels, such as

Battery electric vehicles (BEV), such applications long haul commercial vehicles or emergency vehicles that are used 24/7. Follow the example of Manchester City Council who are investigating the feasibility of making the switch of those refuse collection vehicle routes not suited to BEV to hydrogen.

The ambition for Manchester City Council aims to identify a location for investment in hydrogen refuelling infrastructure and encourage the wider use hydrogen fuelled vehicles that operate in return-to-base fleets of vehicles, for example: emergency services, public buses, refuge collection trucks. Defining the user demand is key to hydrogen infrastructure projects and this will be delivered through defining the user demand for either heat or transport led demand.

Focusing initial transport decarbonisation on heavy vehicles has a disproportionate impact on carbon reduction and air quality (**Error! Reference source not found.**).

Table 1 HGV Contribution to GHG and NOx Emissions

HGVs as % all vehicles	2%
HGV miles as % of all miles	6%
HGV GHG emissions as % all roadside GHG	16%
HGV NOx emissions as % all roadside NOx	21%

What's more, public access to these hydrogen refuelling hubs may encourage higher mileage drivers to consider a switch away from traditional fossil fuel vehicles as it would alleviate range anxiety of electric vehicle drivers.

Recommendation 2: Promote hydrogen fuel cell vehicles in conjunction with BEV as an alternative to fossil fuel vehicles to improve air quality.

Introduce incentives to encourage the uptake of fuel cell vehicles, for example for council commissioned refuse collection or to include as a viable alternative to BEV

Recommendation 3: Planning for wider hydrogen refuelling station deployment

Identify key locations for investment in hydrogen refuelling infrastructure such as return-to-base fleets of vehicles, for example emergency services, coaches, logistics hubs for HGV operators, refuge collection trucks, forklift trucks in warehouses.

Recommendation 4: Rail Evaluate hydrogen as replacement for diesel rail on those hard to electrify lines/routes.

Work with Network Rail and local train companies to evaluate those lines that are not economic to electrify and support any required change to franchise agreements to allow investment in hydrogen powered trains for these lines.

Investigate the feasibility of future Tram Train vehicles being dual fuelled electricity and hydrogen fuel cell technology

Greater Manchester, including the trans-Pennine routes to Leeds and Sheffield, lies at the heart of a largely non-electrified network (Figure 4) and is therefore ideally located for the deployment of hydrogen powered trains.

Recommendation 5: Support innovation and demonstration of hydrogen for heat

Figure 4 Non-Electrified Rail Network

Prior to the availability of large volume hydrogen supplies innovation and demonstration projectsfor the delivery of heat using hydrogen will build confidence to building owners.

95% of postcodes in Greater Manchester are connected to the gas grid. Gas is primarily used for space and water heating and in 2017 it totalled 42% of the total energy consumption, contributing 34% of total CO_2 emissions.

The challenge for decarbonising heat is not only this total energy consumption, but the very high peak demand and daily and seasonal variability which does not easily lend itself to being met by an energy vector without high levels of built-in storage (Figure 5).

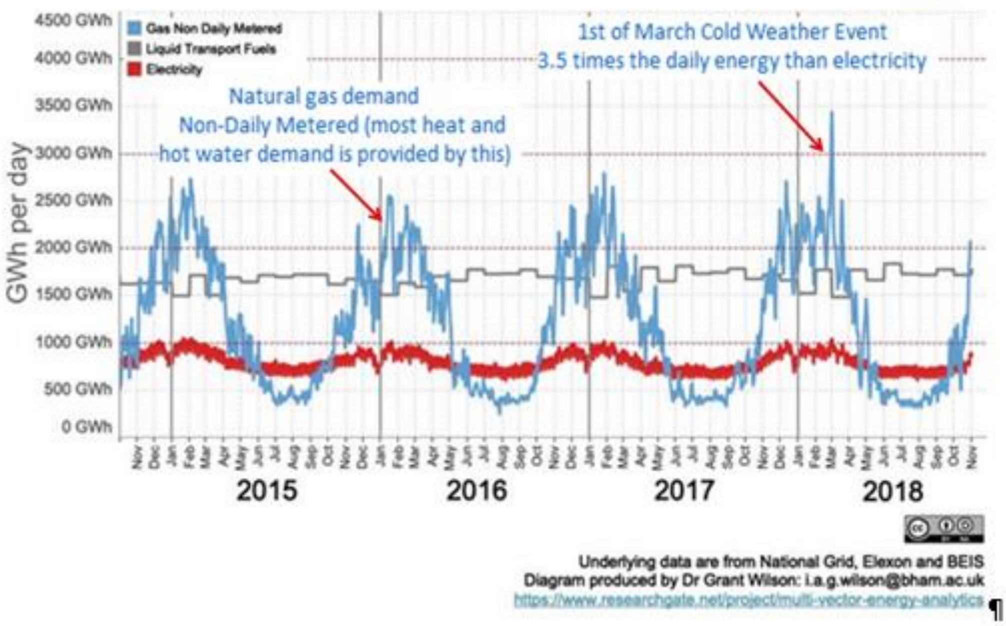

Figure 5 Great Britain's Energy Vectors – daily demand for energy in GWh per day courtesy of Dr Grant Wilson University of Birmingham (Wilson, 2018)

Peak gas demand in winter is typically 2-3 times peak electrical demand but on very cold days it can reach 3.5 times. Hence, a very significant investment in electrical generation and supply infrastructure, combined with extensive retrofit, would be required to bridge this energy gap.

The Institute of Engineering and Technology have analysed the decarbonisation of heat and shown that only hydrogen and district heating are able to provide similar heat performance to natural gas (Figure 6). It is recognised however that there is a need to reduce the overall energy demand if our carbon target is to be met and therefore energy for heating must be

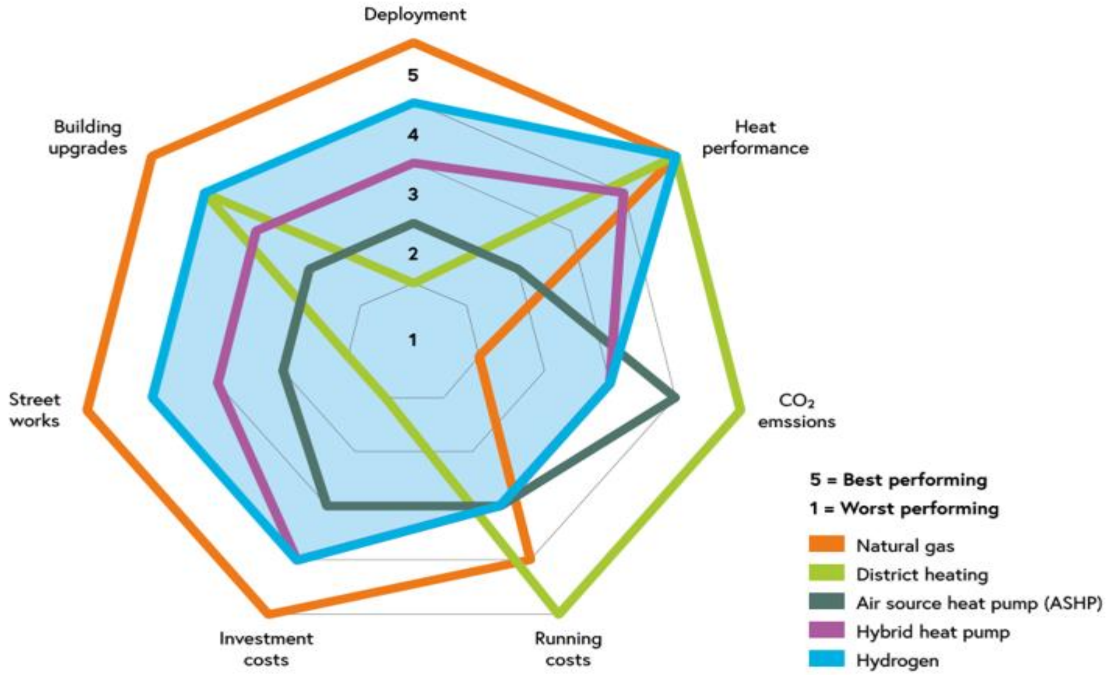

Figure 6 Comparison of Natural Gas and Low Carbon Heating Systems for Mass Retrofit in Domestic Properties

supplemented by retrofitting buildings to improve their insulation properties.

Safety and environment

A number of projects are working to establish the safety of hydrogen within the gas system. This is complicated as blends of hydrogen with natural gas fall within the Gas Act while pure hydrogen supply does not, although this is under review.

The Health and Safety Executive, which has responsibility for enforcing Gas Safety Management Regulations within the Gas Act, has stated that approvals will only be given where it is demonstrated that the proposed change is “no less safe” than the current situation.

Hydrogen and Natural Gas Blending

Ofgem, the government’s regulator for UK gas and electricity markets, funded the HyDeploy project which is being conducted by Cadent and Northern Gas Networks and which is exploring the injection of up to 20% by volume into the normal gas supply. The project is predicated on the standards certification of gas appliances which, since 1996, have involved testing with 23% hydrogen. It may therefore be possible without change to any of the existing appliances.

The project initially used the private gas network at Keele University and is now moving to testing on parts of the public network in the North East and North West.

The objective of the project is to ensure that the regulatory package required to enable this technique to be used is in place as soon as pipeline hydrogen is available post 2026. National roll-out would save the same amount of carbon CO_2e equivalent to removing 2.5million cars from the road.

Pure Hydrogen

Burning pure hydrogen in current household appliances is not possible without redesign of the appliances. The Department for Business, Energy and Industrial Strategy is currently funding the Hy4Heat project to examine the changes needed to develop new appliances and establish the likely conversion costs to burn pure hydrogen in existing appliances.

A number of boiler manufacturers have demonstrated initial prototypes. Further work will be required to establish the practical use of such appliances. Pure hydrogen burning for heat cannot be successful unless concerns regarding NOx emissions are resolved because of the higher flame temperature relative to natural gas when hydrogen is burnt.

Recommendation 6 Prepare for the availability of large volume hydrogen supply.

Policy and public engagement should be linked to the availability of hydrogen supply such as Hydrogen being available in Greater Manchester by Q4 2023

Research, Skills and Innovation

There is a substantial increase in research and demonstration activities worldwide in the transport, infrastructure and heat sectors.

Fuel cells have found applications in power units, the automobile industry, residential buildings and electronics. The Greater Manchester Universities are a regional hub for research innovation and economic growth in many areas that are complementary to the developing markets for Hydrogen and Fuel Cell technology.

The specialism of research at Manchester Fuel Cell Innovation Centre is on making use of advanced materials such as graphene in both fuel cell and electrolyser design. The Centre is a regional hub for SMEs and industry to develop hydrogen and fuel cell products using the range of equipment in the Centre itself or by tapping into the research expertise the Centre's academic and technical team can provide.

Academic expertise across the UK is detailed within a capability document that was commissioned by the UK Hydrogen and Fuel Cell (H2FC) SUPERGEN Hub to create a database of researcher capability on hydrogen and fuel cells in the UK.

Recommendation 7: Utilise academic expertise and facilities to support innovation.

Developing a research and skills base that can help achieve the net zero carbon targets, (without any adverse impact on air quality), like the 2038 target for Manchester, and align to the Local Industrial Strategy by exploiting and the expertise offered by academia in developing the supply chain of regional businesses contributing to sector.

The shift to carbon neutrality will mean that some firms, particularly those with carbon intensive operations, will need support to speed up their progress towards carbon neutrality without constraining growth. Certain skillsets will be required if we are to accelerate the implementation of energy and material efficiency measures in the design and production of green products and services.

Businesses and policy makers have a key role and need to respond to this agenda and put pressure on educators to develop the courses that they require. The region can use its networks to make clear the benefits of investment in green skills – and the opportunities they provide in terms of innovation, sustainability, efficiencies, productivity and improvements in health.

Recommendation 8: Support reskilling of those already in the labour market.

Commit to working with skills development leads in growth and development teams within each applicable Local Authority as they already have a policy framework for education and skills in progress to support workers already in the labour market, or those with transferrable skills valuable in a zero-carbon economy, who need to upskill in order to adapt to the range of projects offered either by the cluster or arising as a result of policy or technological developments in the ambition for clean

The skills system already faces challenges to meet the demand for future skills e.g., those required by digitisation and automation. The long-term skills demand projections are uncertain for key emerging technologies such as Hydrogen and Fuel Cells so further phased research is needed in this area. This is being developed through academic institutions and educators and supported by regional government and the private sector. However, we know that education and skills will underpin our ability to reach our ambition of a zero-carbon economy and achieve the social and economic drive; by ensuring our residents and students are equipped with the necessary skills to fill these roles.

Recommendation 9: Support educational institutions to develop courses that deliver skills for the hydrogen economy

Schools, Colleges and Universities must deliver the right courses so that employers can find people with the skills they need. Individuals need to be able to make better-informed choices in order to develop their careers in the emerging economies.

Conclusion

The UK government has committed to delivering a Hydrogen Strategy in 2021. Greater Manchester has a clear role to play within the context of the UK and the strategy we present is a starting block on which to build back better in our region and is one that fully supports the regional 5-year environment plan to adopt an approach that mobilises various actors across traditional sector boundaries to come together in new ways.

The global hydrogen economy is estimated to be worth $2.5 trillion by 2050, supporting 30 million jobs. In 2020, the Commission adopted a new dedicated strategy on hydrogen in Europe. It will bring together different strands of action – from research and innovation via production and infrastructure to the international dimension. The strategy will explore how producing and using renewable hydrogen can help decarbonise the EU economy in a cost-effective way, in line with the European Green Deal (and also helping the post-COVID-19 economic recovery).

As demonstrated by campaigns such as UK Hydrogen Strategy now there is a fundamental need for a national hydrogen strategy to be released which is imminent to really develop the UK strengths around a recovery mechanism post COVID that is economic, green and clean. We all really need to take advantage of the natural environment of the UK with the potential that hydrogen can bring through many areas of generation. The benefits of having a strong hydrogen economy are clear – it will contribute to the reduce carbon emissions, improve air quality, and create new, green jobs across the country. It can help usher in a new era of hard to decarbonise transport modes as well as zero-carbon heating. It will also provide a huge boost to manufacturing in this country and give the UK the opportunity to lead the world in an exciting renewable and low-carbon technology.