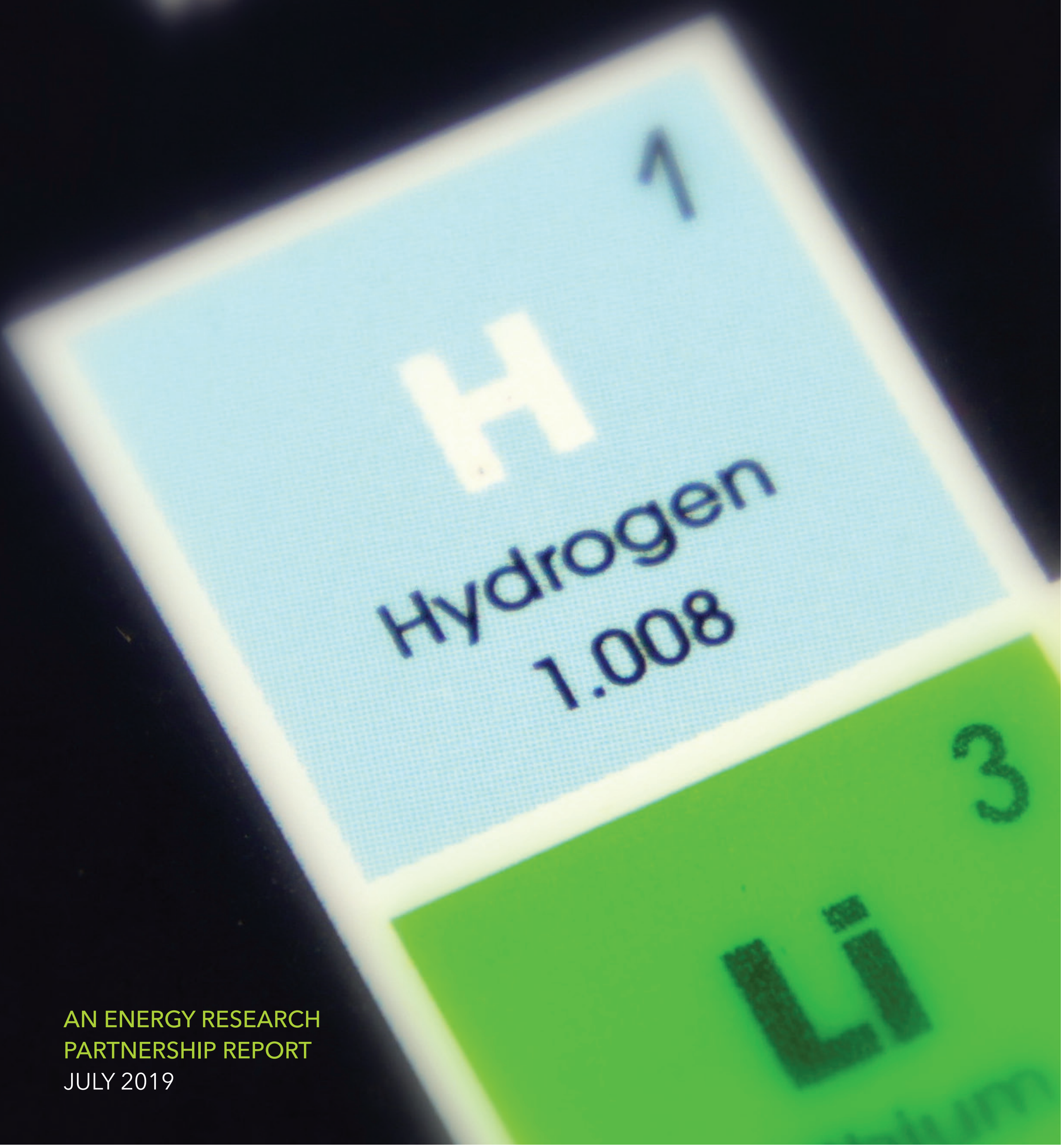
THE POTENTIAL ROLE OF HYDROGEN TO HELP DECARBONISE THE UK ENERGY SECTOR



AN ENERGY RESEARCH PARTNERSHIP REPORT

JULY 2019

EXECUTIVE SUMMARY

In May 2019, the Energy Research Partnership brought together key industry and government stakeholders to conduct a 'state of the industry' review of the potential role of hydrogen in future energy systems.

Falling costs of renewable generation, particularly wind and solar, have led to good progress being made to decarbonise the electricity sector. This is now driving demand for new and innovative methods for providing storage and flexibility in the electricity system.

The next challenge is widely accepted to be delivering similar results for the transport and heating sectors. Electrification of cars is gathering pace, but there are still broader challenges around the decarbonisation of heavy goods movement, shipping and aviation.

Similarly, in heat, improving energy efficiency will play a significant role in reducing the scale of the decarbonisation challenge, but will not avoid the significant seasonal fluctuations associated with heat demand. With this, electrification will play a role in new building stock, however it will be challenging to deliver for Britain's homes built before the 21st Century.

The Energy Research Partnership has concluded that hydrogen, together with the advances made in the electricity system, has a potential role to play in meeting the needs of a low or zero-carbon energy system.

Recent research and demonstrator projects have shown that integrating the use of hydrogen into Britain's energy system is technically feasible. Furthermore, for many sectors such as domestic, commercial and industrial heating, the adoption of hydrogen presents an opportunity to upgrade existing technology without significant changes in consumer behaviour.

While there is considerable debate over whether future energy systems should remain highly centralised or take a more decentralised architecture, Energy Systems Catapult analysis indicates that either scenario will require some dependence on hydrogen to meet the Government's legally binding targets on climate change.

The use of hydrogen as a means to store and transfer energy will not be without its challenges. Currently sources of hydrogen are reliant upon the process of Steam Methane Reformation (SMR)[2] of natural gas, which requires Carbon Capture Use and Storage (CCUS) to ensure net carbon emissions are as close to zero as possible.

Looking forward, hydrogen production could come from a wider range of sources as more renewable generation sources drive the economics to support hydrogen adoption, in turn leading to reductions in electrolyser costs through deployment, thereby reducing hydrogen costs further.

In domestic heating, Worcester Bosch, a leading boiler manufacturer, has demonstrated that hydrogen can be safely integrated into the home with no increase in harmful Nitrous Oxide emissions and with overall lower risk to safety than natural gas. While uptake of new technologies can take decades, the uptake of hydrogen in heating is expected to require evolution of existing designs rather than revolutionary new systems.

Britain is in a unique position to lead the way in adapting its energy system to accommodate hydrogen as a new energy vector. It presents an opportunity to develop new skills to support clean growth and the industrial strategy, while refocussing existing expertise in financing, developing, designing and deploying complex energy solutions. This strategy won't be without risk; it will require bold decision making from policymakers, regulators and industry and strong consumer engagement as we adapt to a zero-carbon emitting energy system.

AN EMERGING ROLE FOR HYDROGEN AS A NEW ENERGY VECTOR

'Falling costs of renewable generation, particularly wind and solar are driving demand for new and innovative energy storage solutions. However, the decarbonisation of the energy system has the potential to remove significant long-term storage solutions in the form of fossil fuels that provide inherent resilience to our energy system.'

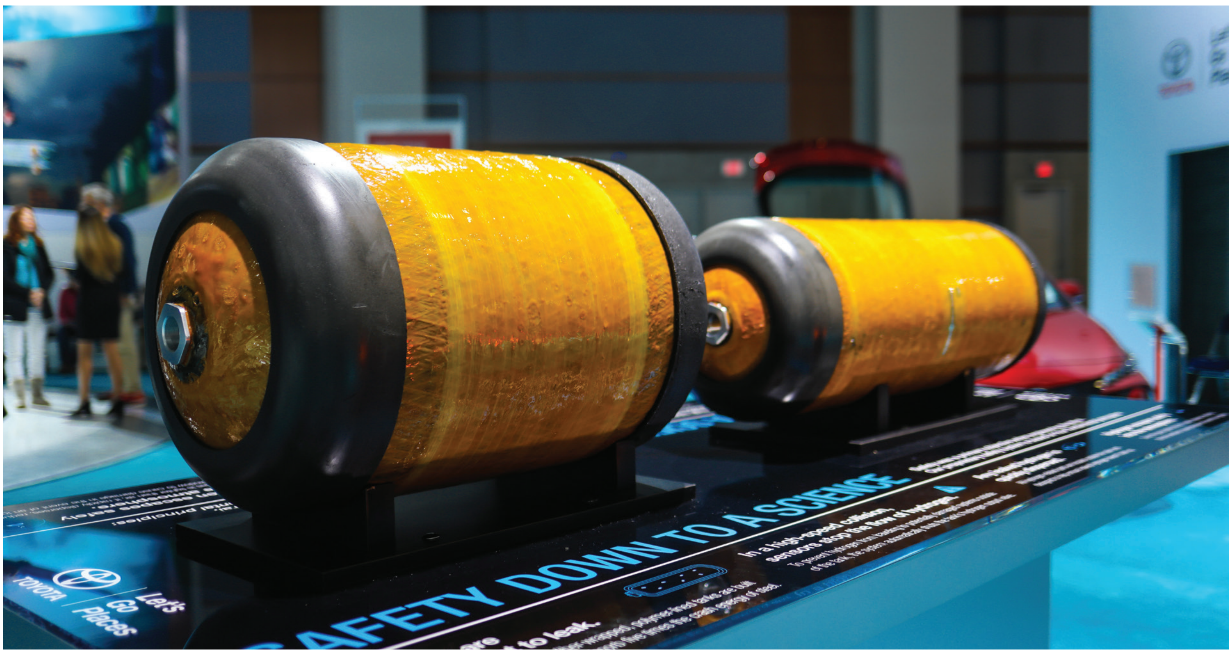
The extent of the future application of hydrogen in the energy system is currently unclear, however, if the major challenges of large-scale production and storage are understood, hydrogen could play a significant part in the future UK energy system.

A combination of energy efficiency and electrification based on zero-carbon electricity can take the UK a great deal of the way towards near-full decarbonisation of the whole energy system.

But it is a strategy that, alone, may not be enough. Producing hydrogen in low-carbon ways and using it to meet challenging demands (e.g. for heat in industrial processes, for heating buildings on colder winter days and for heavy transport) is likely to be an important part of the next stage of the UK's energy transition[1].

Hydrogen has the potential to capture and store renewable energy resource at locations distant from demand centres. Energy that would otherwise not be available for useful deployment.

Hydrogen holds the potential to work closely together with renewable generation by creating a firm energy commodity. Hydrogen is well suited to longer storage horizons, including the inter-seasonal storage needed to accommodate winter peaks in energy demand.



HYDROGEN ALLOWS MULTISECTOR APPLICATIONS

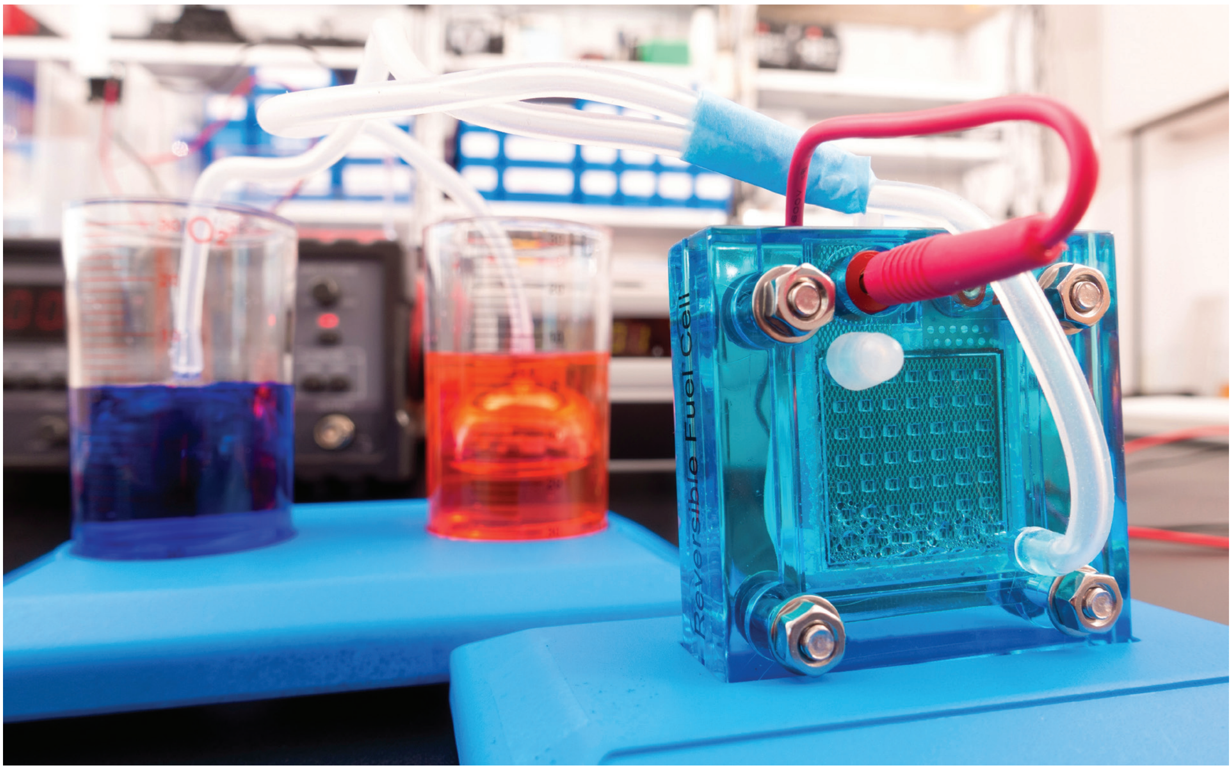
'Hydrogen has the advantage of a multisector application and will be a key enabler for a future net-zero energy system. This flexibility will help optimise its applications to reduce carbon emissions in as cost-effective manner as possible.'

Hydrogen in transport has the potential to decarbonise larger vehicle applications (heavy goods vehicles, trains and public transport systems) where battery capacity and recharging times may make battery technology less viable. Reduced vehicle emitted pollutants in cities will also contribute to improved air quality and the associated health impacts[3].

The application of hydrogen to industry offers considerable process and heating decarbonisation opportunities and focusing on a more regional application will optimise infrastructure requirements and associated costs.

The application of 'hydrogen ready' heating boilers[4], coupled with heat pump technology, would enable intelligent hybrid heating systems, offering the potential to manage effectively, system heating peaks whilst utilising existing gas and electricity infrastructure to domestic premises.

Innovation in end user applications are likely to develop rapidly once a commitment to a widespread hydrogen conversion is made. Consumers will be able to either opt for basic replacement appliances or select more novel solutions. These choices will be determined by a combination of capital and running costs and the functionality they provide.



PRODUCTION OF HYDROGEN IS A KEY CHALLENGE

'The large-scale production of hydrogen presents considerable challenges both in scaling of existing technology but also the extent of the supply chain that will need to be established to support such high volumes of hydrogen.'

Whilst hydrogen production in the chemicals industry is not new, production at the levels required to facilitate a meaningful hydrogen economy will have considerable challenges to overcome. The true costs of hydrogen as part of the energy system will need to be fully understood as early as possible.

Currently the largest method of hydrogen production is by Steam Methane Reformation (SMR)[2]. To significantly reduce the carbon footprint of this process, Carbon Capture Use and Storage (CCUS) technology must be applied to capture the carbon dioxide that is produced from the process. Methane-derived hydrogen is inextricably tied to the successful deployment of CCUS, a process that is not zero-carbon. Further research is needed to demonstrate that fossil fuel derived hydrogen with CCUS is compatible with decarbonisation targets.

Whilst these technologies are in widespread use, work is currently being undertaken on more innovative reformation processes which are more efficient and have a lower CO_2 footprint.

Electrolysis via renewables is a method in which the generated electricity splits water into hydrogen and oxygen. The hydrogen can then be stored, and the oxygen can be released into the air or stored. Whilst this method has a near zero-carbon footprint, challenges associated with volume production and costs, currently limit the extent of its early application at volume[2].

Although indigenous UK hydrogen production through renewable or other decarbonised means will be important, there is an emerging perspective which envisages globally traded hydrogen moving from parts of the world with ubiquitous renewable resource to those areas which are less well provisioned.

Hydrogen storage will become an increasingly important component of the overall supply chain. There is an opportunity for the UK to explore and lead in this area of large-scale hydrogen storage technology.

HYDROGEN CAN UTILISE EXISTING GAS INFRASTRUCTURE ASSETS

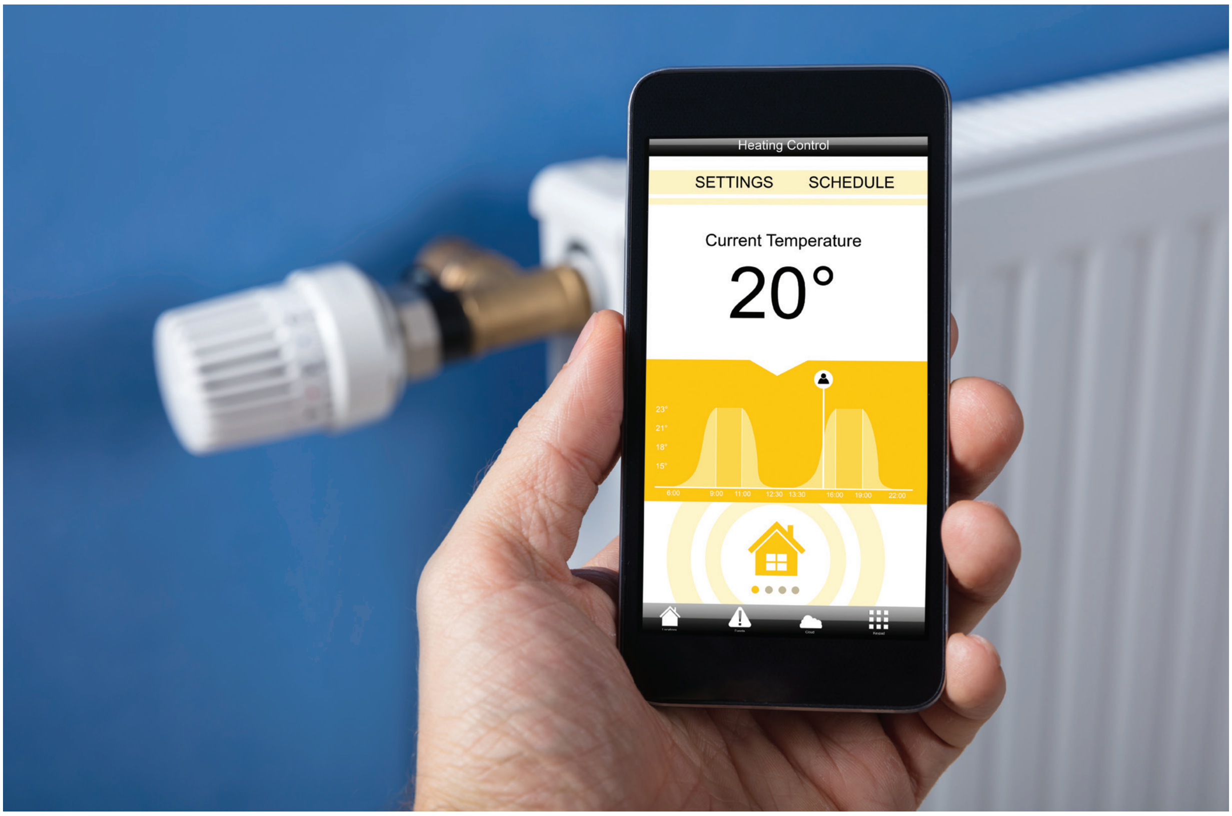
'One of the major advantages of the supply of hydrogen as a replacement for natural gas is the repurposing of the existing natural gas network to distribute hydrogen to industry and domestic properties. This repurposing of existing natural gas network assets will considerably improve the viability of the wider application of hydrogen.'

Following the H21 Leeds City Gate[5] study, which demonstrated the technical feasibility of repurposing the gas distribution network for hydrogen, there are now a number of research projects underway, largely funded by government bodies and the gas distribution companies. These are looking at a diverse range of issues including safety, technical feasibility, economics and consumer acceptance.

This repurposing of existing natural gas network[6] assets will considerably improve the viability of the wider application of hydrogen. It is the co-ordination between government and industry players that is the key challenge in converting this infrastructure from natural gas to hydrogen. This will not be the first time such a large-scale repurposing of an energy distribution asset has taken place in the UK. In the 1960's the gas network was converted from "town gas", manufactured from coal to "natural gas" from the North Sea. A very similar process would be required to convert to hydrogen.

HYDROGEN IS LIKELY TO HAVE LOW CONSUMER BEHAVIOURAL IMPACT

'Hydrogen, particularly when replacing natural gas for domestic heating, has the potential for minimal consumer behavioural impact.'



Manufacturers of hydrogen boiler technology have produced prototype boilers which are physically similar to natural gas boilers[4] with similar functionality and performance. This approach has been driven by the technology but also very significantly by hydrogen technology having little or no negative impact on daily life, promoting consumer acceptance.

Whilst the impact of hydrogen technology offers the potential of least behavioural impact, consumer acceptance[7] of the hybrid applications of hydrogen and other low carbon technologies will be fundamental to its wider application.

HYDROGEN – A GLOBAL OPPORTUNITY FOR THE UK

'The UK has accumulated significant knowledge and experience in the production, application and distribution of hydrogen and the potential exists to create a new exportable opportunity for the UK to lead globally in hydrogen economy technologies and systems.'

In recent years considerable progress has been made within the UK hydrogen industry with projects across production, transportation and application, projects include:

- Orkney Surf & Turf[8] and Levenmouth Bright Green Hydrogen[9] demonstrators
- Health and Safety Executive approval for the HyDeploy[6], a project trialling up to 20% hydrogen blend in the gas network
- Transport sector using hydrogen-powered trains[10], buses[11] and fleet vehicles
- Demonstrations of hydrogen fuelled domestic central heating boilers[4]

Britain is in a unique position to lead the way in adapting its energy system to accommodate hydrogen as a new energy vector. It presents an opportunity to develop new skills to support clean growth and the industrial strategy, while refocussing existing expertise in financing, developing, designing and deploying complex energy solutions.

HYDROGEN ECONOMY FUTURE ACTIONS

'The Energy Research Partnership considers that hydrogen has the potential to play a significant role in the future low or zero-carbon economy. A co-ordinated approach to a cost-effective low carbon hydrogen economy is now required.'

The ERP has concluded that the following actions are required:

INITIATION OF PILOTS AND 'AT SCALE DEMONSTRATIONS'

To support the development of policy, business cases, technology, consumer confidence and build supply chain capacity.

IMPROVE PUBLIC UNDERSTANDING

Improve consumer understanding of potential application of hydrogen to the energy system and determine consumer acceptability of differing hydrogen-based solutions to ensure adoption risks are reduced to a minimum.

COORDINATED RESEARCH

Formation of a centrally coordinated group from across academia and industry to determine knowledge gaps and agree a portfolio of evidence gathering research.

WHOLE CARBON ANALYSIS OF HYDROGEN DEPLOYMENT

Implications for decarbonisation require further analysis, in particular taking a whole system view, including production, carbon storage, transport of CO_2 and H, as well as hydrogen end product.

INTERNATIONAL COLLABORATION

Whilst the UK is leading some elements of the hydrogen economy, there are opportunities to learn and build on best practice from across the world, from advanced blending to repurposing transmission pipelines.

POLICY AND MARKET DESIGN

Government and industries must work together to develop innovative market structures that provide value for money for taxpayers and offer options to de-risk for the industry.

REFERENCES

1 **Hydrogen in a low-carbon economy**
Committee on Climate Change November 2018
www.theccc.org.uk/wp-content/uploads/2018/11/Hydrogen-in-a-low-carbon-economy.pdf

2 **Global Trends and Outlook for Hydrogen**
IEA Hydrogen Technology Collaboration Program (TCP)
http://ieahydrogen.org/pdfs/Global-Outlook-and-Trends-for-Hydrogen_Dec2017_WEB.aspx

3 **Clockwork & Patchwork**
UK Energy System Scenarios – ETI 2018
https://d2umxnkyjne36n.cloudfront.net/insightReports/Options-Choices-Actions-Updated-Low-Res.pdf?mtime=20181003113219

4 **The Future of Fuel**
Worcester Bosch
https://www.worcester-bosch.co.uk/professional/hydrogen-future-of-fuel

5 **Leeds City Gate H21 Project**
Northern Gas Networks, Wales and West Utilities, Kiwa, AMEC Foster Wheeler
https://www.northerngasnetworks.co.uk/wp-content/uploads/2017/04/H21-Report-Interactive-PDF-July-2016.compressed.pdf

6 **Hydeploy**
Cadent,Northern Gas Networks, Keele University, Health and Safety Laborator, ITM Power, Progressive Energy
https://hydeploy.co.uk/

7 **Net Zero The UK's contribution to stopping global warming**
Committee on Climate Change 2019
https://www.theccc.org.uk/wp-content/uploads/2019/05/Net-Zero-The-UKs-contribution-to-stopping-global-warming.pdf

8 **Orkney Surf & Turf**
Community Energy Scotland
http://www.surfnturf.org.uk/page/introduction

9 **Levenmouth Project**
Bright Green Hydrogen
https://www.brightgreenhydrogen.org.uk/levenmouth-community-energy-project/

10 **Alstom and Eversholt Rail unveil a new hydrogen train design for the UK**
Alstom
https://www.alstom.com/press-releases-news/2019/1/alstom-and-eversholt-rail-unveil-new-hydrogen-train-design-uk

11 **London to have world-first hydrogen-powered double decker buses**
The Guardian
https://www.theguardian.com/uk-news/2019/may/10/london-to-have-world-first-hydrogen-powered-doubledecker-buses

ABOUT THE ENERGY RESEARCH PARTNERSHIP

ERP is a public private partnership which brings together a diverse range of participants from across the energy sector, with senior level representation from industry, academia and government. Its primary purpose is to offer a consultative forum, which aims to accelerate innovation in the energy sector through enhanced dialogue and communication across industry and government. It is an independent, not for profit organisation whose activities are funded by Member contributions.

www.erpuk.org

CONTRIBUTING ERP MEMBERS TO THIS REPORT

ABB

ARUP

Atkins – member of SNC-Lavalin Group

Worcester Bosch

Carbon Trust

Committee on Climate Change

Department for Business, Energy & Industrial Strategy

Department for Transport

EDF Energy

Energy Saving Trust

Energy Systems Catapult

Environment Agency

Engineering and Physical Sciences Research Council (EPSRC)

Hitachi

Innovate UK

National Grid

National Infrastructure Commission

Origami Energy

Turquoise International

Scottish Enterprise

Welsh Government

UK Energy Research Centre (UKERC)

ENERGY RESEARCH PARTNERSHIP

www.erpuk.org