Written Evidence Submitted by the National Physical Laboratory

(HNZ0088)

1. Hydrogen has the potential to be an important element of delivering net zero and clean growth by decarbonising parts of the energy system – such as heavy industry, seasonal energy storage and heavy-duty vehicle transport – more effectively than other technologies; where specific conditions might suit hydrogen better, for example domestic heating, it is also complementary to other technologies.

2. Hydrogen is a highly interdependent system which incorporates novel production, storage, distribution as well as end-use technologies, at different stages of maturity. For it to succeed in the UK will require public support and policy commitment to de-risk and facilitate private sector investment at all stages of development and into deployment.

3. The UK has a great opportunity to participate in the global leadership of hydrogen solutions through a funded cross-Government Hydrogen Strategy to develop the role of hydrogen across all sectors at all levels. The Hydrogen Strategy should articulate a long-term vision for UK hydrogen, including the roles of both the public and private sectors in delivering this vision. It should focus on the development of technologies and technology demonstrators, including their enablers such as R&D, skills and metrology; creating the large-scale incentives needed to stimulate deployment; and on the management of the interdependencies between development and deployment.

4. The Hydrogen Strategy should support an overarching 'Grand Challenge' initiative encompassing all hydrogen activities along the lines of the Faraday Challenge for batteries, which has highlighted that a strong focus on metrology is critical in accelerating progress. Such a Challenge would catalyse and align fundamental research, R&D and demonstration activities with the needs of the UK economy over the next 30 years.

5. The longer-term success of the UK's hydrogen technologies will also require an effective innovation and commercialisation ecosystem. Trusted and reliable measurement and shared standards are an essential part of supporting innovation, boosting collaboration and knowledge exchange, creating a common landscape and language surrounding emerging technologies. Such standards encourage early engagement by innovators in related fields, underpin markets for, and accelerate adoption of, new technologies both domestically and internationally and, most importantly, support rapid scaling of solutions.

6. Investment in the UK National Measurement System to deliver hydrogen metrology infrastructure, expertise, standards certification and regulation would accelerate the development and deployment of hydrogen technologies and physical infrastructure to enhance confidence of consumers, regulators and investors in their safe, effective and reliable use. This new metrology infrastructure should support a system level approach to meeting the priority challenges, including: measuring the levels of impurities present in the gas at production, and following storage and distribution; ensuring the efficacy and efficiency of gas infrastructure; leak detection; and metering the gas at point of use.

1. The suitability of the Government's announced plans for "[Driving the Growth of Low Carbon Hydrogen](#)", including:

*** the focus, scale and timescales of the proposed measures;**
*** how the proposed measures—and any other recommended measures—could best be co-ordinated;**
*** the dependency of the Government's proposed plans on carbon capture and storage, any risks associated with this and how any risks should be mitigated; and**
*** potential business models that could attract private investment and stimulate widespread adoption of hydrogen as a Net Zero fuel;**

No comment.

2. The progress of recent and ongoing trials of hydrogen in the UK and abroad, and the next steps to most effectively build on this progress;

No comment.

3. The engineering and commercial challenges associated with using hydrogen as a fuel, including production, storage, distribution and metrology, and how the Government could best address these;

7. For wide-spread use of hydrogen as a fuel in the UK, a new metrology infrastructure will be required to inform new standards and underpin a formal regulatory system. The UK's oil and gas sector developed and refined its metrology infrastructure over the course of the 20th century, whereas the hydrogen infrastructure needs to be developed and deployed at an unprecedented rate to provide a stable base for stakeholders to work with and deploy solutions rapidly. As part of the National Measurement System, NPL, and the UK's other measurement laboratories, works with industry, government, and scientific stakeholders to identify, prioritise and address measurement needs and challenges and therefore the metrology infrastructure to enable a hydrogen economy.[1]

8. The priority measurement challenges briefly discussed in this evidence relate only to the production, distribution, storage and end-use of hydrogen (focussing on transport and domestic heating), however there will also be significant measurement challenges in other parts of the system, for example related to the potential emissions / environmental impact of the different hydrogen production and combustion processes. NPL is currently working with stakeholders to identify such measurement challenges and will publish these findings in 2021.

Measurement challenges in hydrogen production

9. In the UK, the most common methods for producing hydrogen are by processing a hydrocarbon source (for example through Steam Methane Reforming), or by electrolysis (splitting water into hydrogen and oxygen using electricity). There are also a number of emerging approaches, including converting biomethane to hydrogen, a technique which, if the carbon dioxide produced is captured, could become carbon negative.[2]

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[1] https://www.npl.co.uk/resources/energy-transition/hydrogen-industry
[2] See eg https://pubs.rsc.org/en/content/articlelanding/2020/se/d0se00222d#!divAbstract

10. With each production method, it is essential to understand and measure the impurities that may be present in the hydrogen produced, and how these might affect the performance of infrastructure and appliances. This measurement is vital in uses such as hydrogen fuel cell electric vehicles where even very small quantities of impurities can cause significant damage. Indeed, several automotive manufacturers (such as Toyota) will only allow their cars to refuel at stations that provide hydrogen fuel that meets the quality specifications of ISO 14687.[3] For hydrogen use in domestic heating, a new gas quality standard (PAS4444) has been developed through the Hy4Heat[4] programme.

11. Novel and emerging hydrogen production processes, such as hydrogen production from biomethane, may produce different kinds and amounts of impurities[5] which standards will need to account for. To enable this requires investment in measurement infrastructure to develop new analytical methods, calibration gas standards and high-pressure hydrogen sampling techniques, in addition to developing a regulatory framework.

12. The current rapid development of electrolysers for use in both electrolysis and in fuel cells is supported by measurements that range from investigating the fundamental physical properties of individual materials and components to measuring the performance and lifetime of prototype devices and assuring quality of systems produced at scale and the development and parameterisation of digital' twins' for 'grid scale' electrolysers. Such a breath of activity requires central coordination to ensure consistent and reliable measurement and standards across the often very different research, development, manufacture and deployment environments.

Measurement challenges in hydrogen storage

13. There are a number of possible strategies and mechanisms for storing hydrogen. For a decision to be made about which one(s) will be most suitable for deployment in the UK will need the ability to measure the efficiency and effectiveness of each approach. For example :

14. Storage in underground caverns – such as man-made or natural salt caverns, or in depleted gas fields – is already used in the UK for natural gas and, in a more limited way, for hydrogen. For this approach to be expanded, there needs to be an agreed approach to measurement of hydrogen leakage to both better understand and manage the safety and efficacy of the storage method. There is also a need to develop measurement of impurities introduced into the hydrogen while in storage, particularly if the gas will be ultimately used to fuel appliances which require high purity, such as fuel cells.

15. Storage of hydrogen as ammonia is an established industrial chemical process, and there is an emerging field of alternative liquid organic hydrogen carriers (LOHC)[6] which focusses on storing hydrogen within safe and easy-to-handle oils. However, there are several challenges to be addressed around understanding and ensuring the purity of hydrogen when extracted from ammonia or released from the liquid organic hydrogen carrier, particularly if the gas is to be used in fuel cells.

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[3] https://eur-lex.europa.eu/eli/dir/2014/94/oj or ISO 14687:2019, Hydrogen fuel quality — Product specification, International Organisation for Standardisation, https://www.iso.org/standard/69539.html

[4] https://www.hy4heat.info/

[5] https://www.npl.co.uk/gas-particle-metrology/energy-gases

[6] https://hydrogeneurope.eu/member/hydrogenious-lohc-technologies-gmbh

16. Hydrogen can also be stored as a cryogenic liquid; this approach allows for more hydrogen to be stored per unit volume compared with storage as a gas. For this approach to succeed there will need to be an agreed approach to measuring the capacity of storage, the rate at which hydrogen can safety be added or removed from storage, degradation of storage containers, and also of the overall efficiency of the approach (including the energy required to liquify the hydrogen).

17. Storing hydrogen inside solid materials is a fast-developing field for which there is a need to establish internationally accepted standard test methods for assessment of storage capacity. This process is extremely sensitive to the experimental configuration and procedure used, and generation of more reliable and inter-comparable data would accelerate advances in the field.

Measurement challenges in hydrogen distribution

18. A leading option for distributing centrally produced hydrogen to domestic users is through the existing natural gas grid, adapting existing infrastructure where necessary. The National Grid HyDeploy[7] project has piloted this approach, initially adding hydrogen to the existing natural gas in the network at low concentrations and increasing this proportion over time. To enable rollout of this approach will require a regulatory and measurement framework to be established by government and its agencies for the transport of hydrogen at low and high concentrations to ensure safety and stability in all parts of the grid. This should include:

19. **Addition of odorants** – hydrogen does not have an odour, and so it is likely that an odorant would be added to the gas to aid in the detection of leaks (in the same way that an odorant is currently added to the similarly odourless natural gas). The SGN Hydrogen 100 "Hydrogen Odorants and Leak Detection" project recommended the continued use of *Odorant NB* for mixed hydrogen/natural gas or 100% hydrogen gas grids[8] (as long as the hydrogen is not supplied to fuel cells). If gas grid hydrogen is supplied to refuelling stations for transport, there will need to be an agreed approach to removing the odorant or to identify a new odorant that does not affect fuel cell performance. This research has not yet been carried out and remains a challenge.

20. **Network fugitive leak detection** – sensors to detect leaks from the transmission and distribution networks and from storage and other gas handling facilities will need to be developed. In the case of hydrogen mixed with natural gas, sensors able to tell the difference between the two gases will be required. Metrology support will be required to aid the development of these new sensing technologies, performance standards and test protocols to assess sensor performance, and measurement standards detecting hydrogen emissions. Additional requirements for monitoring and quantifying hydrogen leaks could arise due to possible atmospheric impacts of hydrogen requiring methodologies for detecting and quantifying hydrogen leaks, providing similar capabilities to those being developed for monitoring methane and VOC fugitive emissions.[9]

21. **Gas mixtures** – if there are several different producers adding hydrogen to the natural gas grid at different times and locations, there will need to be an agreed approach to measuring and monitoring the relative concentrations of the two gases

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[7] There are a number of projects ongoing to demonstrate how this could be deployed including: '**H21 Leeds City Gate**' project and the National Grid's '**HyDeploy**' project.
[8] https://www.sgn.co.uk/about-us/future-of-gas/hydrogen/h100-nia/hydrogen-odorant-and-gas-detection
[9] NPL has recently led the development of standardised methods for VOC emission detection in CEN TC264 WG38

across the network, at point of use and in flow metering. Gas distribution networks currently monitor quality of natural gas before supplying to homes.[10] These measurements allow customers to be billed for the amount of energy that they are actually using, and ensure domestic appliances are able to operate efficiently. If switching to hydrogen mixed with natural gas or 100% hydrogen gas grids, new gas quality methods, instrumentation and calibration standards will be required, in addition to new gas quality specifications and the assignment of regulators to enforce these requirements.

Measurement challenges in hydrogen end-use

22. The leading candidates for early take up of hydrogen technologies are domestic heating and transport (through fuel cell electric vehicles)**.** There are also a number of small-scale hydrogen technologies, such as phone chargers, hydrogen-fuelled torches and drones that use miniature fuel cells. Each of these uses have their own measurement challenges that will need to be addressed to enable and support take-up of the technology.

23. A focus of fuel cell R&D (and the closely-related electrolyser R&D for hydrogen production) is on improving performance, minimising performance loss over time and reducing materials and manufacturing costs. To achieve this requires measurement of performance and lifetime of new materials, new devices and existing devices under new operating conditions that more accurately mimic real-life operation – for example how external air quality such as pollution or other contaminants, affects performance and lifetimes of fuel cells in vehicles. The lack of internationally accepted standard test methods in this rapidly developing area is a challenge that NPL and other metrology institutes are seeking to address.

24. For hydrogen to replace natural gas in domestic heating there needs to be a greater understanding of how current boilers will need to be adapted, or even replaced, as the concentrations of hydrogen in the grid are increased, for example the levels of hydrogen concentration at which boilers will need to be upgraded. Additionally, there is a need to understand how the emissions and efficiencies of boilers change at different ratios of natural gas and hydrogen and how hydrogen flames behave in boilers. There are similar challenges for other types of heating appliances such as combined heat and power, solid oxide fuel cell or alternative fuel cell processes,[11] particularly when considering acceptable purity levels for supplied hydrogen.

4. The infrastructure that hydrogen as a Net Zero fuel will require in the short- and longer-term, and any associated risks and opportunities;

25. The physical infrastructure required for hydrogen to be effectively deployed as a fuel will need to be developed and deployed alongside standards, certification and regulation to enhance the confidence of consumers and investors in their safe, effective and reliable use. To achieve this will require hydrogen metrology infrastructure, and expertise, to meet the challenges described in Q3.

[10] https://www.nationalgrid.com/uk/gas-transmission/data-and-operations/quality
[11] https://www.npl.co.uk/getattachment/bebd3592-e413-43e7-9556-e4dc2c0533d7/energy-transition-measurement-needs.pdf?lang=en-GB&ext=.pdf

5. Cost-benefit analysis of using hydrogen to meet Net Zero as well as the potential environmental impact of technologies required for its widespread use;

No comment.

6. The relative advantages and disadvantages of hydrogen compared to other low-carbon options (such as electrification or heat networks), the applications for which hydrogen should be prioritised and why, and how any uncertainty in the optimal technology should be managed.

26. The Energy Networks Association recently published an extensive analysis of the options for de-carbonising the UK gas network.[12]

The National Physical Laboratory (NPL) is the UK's National Metrology Institute (NMI), responsible for developing and maintaining the nation's primary measurement standards on which all measurements rely. NPL is owned and funded (in part) by BEIS. NPL is a Public Sector Research Establishment (PSRE), which works in partnership with government, academia, applied research laboratories and industry to deliver the maximum societal and economic benefit for the UK and the world.

NPL sits at the heart of the UK's National Measurement System (NMS) which maintains and develops the UK's national measurement infrastructure and delivers the UK Measurement Strategy on behalf of BEIS. As the UK's NMI we represent the UK within the international network of national metrology institutes.

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[12] https://www.northerngasnetworks.co.uk/wp-content/uploads/2019/11/Navigant-Pathways-to-Net-Zero-2-min.pdf