Written Evidence Submitted by the Institution of Chemical Engineers (IChemE)

(HNZ0031)

The Institution of Chemical Engineers

The Institution of Chemical Engineers (IChemE) advances chemical engineering's contribution worldwide for the benefit of society. We support the development of chemical engineering professionals and provide connections to a powerful network of around 35,000 members in 100 countries.

We support our members in applying their expertise and experience to make an influential contribution to solving major global challenges, and are the only organisation to award Chartered Chemical Engineer status and Professional Process Safety Engineer registration.

Chemical, biochemical and process engineering is the application of science, maths and economics in the process of turning raw materials into every day, and more specialist products. Professional chemical engineers design, construct and manage process operations all over the world. These operations extend to include renewable and non-renewable energy industries, pharmaceuticals, food and drink, synthetic fibres and water. Chemical engineering plays both a central role (*e.g.* in design, build, operations and decommissioning) and a subsidiary role (*e.g.* raw material feedstock/fuel supply).

IChemE members also can be called upon to use their professional competence to produce evidence-based contributions to policy inquiries.

Introduction

IChemE has significant expertise within its membership on the manufacture, storage, handling and end use of hydrogen. Including the development of safe approaches within all of these and the use of systems approaches that can be readily applied to the complex matters of using hydrogen in diverse scenarios to assist in achieving net zero within the UK.

Many areas of consideration required to assess the achievability and applicability of hydrogen usage within energy have been considered by the experts in our membership over many years. Therefore, we have provided a short, bulleted response to this call for evidence as an introduction to how, IChemE, with its professional chemical engineers, is well placed to provide further information to the Select Committee. Importantly, our membership would be ready to assist in any strategic discussions with the committee or detailed task groups should they be formed by the government departments *e.g.*, BEIS, as the details of government plans develop and roll out.

Question 1. The suitability of the Government's announced plans for "Driving the Growth of Low Carbon Hydrogen".

1. The Government's ten-point plan includes a requirement for the establishment of a 5 GW electrolysis hydrogen capacity. Given that this is larger than the output of current single power stations, it is important to both clarify the source of the requirement that generates this figure and the intended generation points. Is it single or multiple points? Is it continuous or intermittent?

2. Assessment of the suitability of the plans with regards to the use of hydrogen calls for use of a systems approach which is a core skill of chemical engineering. Hydrogen is an energy **vector**, in that energy is required to generate it, this energy requires a source, a means for modifying the source and a system for managing the by-products / wastes. For instance, high wattage electrolysis plant is a very major investment requiring a connection to the Very High Voltage Grid. 5 GW will produce around 100 tonne/hr of H_2 but also 800 tonne/hr of O_2. This oxygen is also a valuable product which would need a use. A systems analysis would recognise that there are oxygen generation facilities throughout the world competing with this source and seek options. We as chemical engineers also recognise the safety aspects inherent in the management of these highly reactive gases requiring specialist and potentially expensive handling and storage facilities.

3. The UK has significant, although historical, experience of the presence of hydrogen in domestic gas usage. Between 1820-1970), coal gas was the primary fuel in the UK, and this consisted of 50% H_2. This would indicate that the national grid is likely to be able to handle a significant percentage of hydrogen within a carrier gas. There are ongoing studies to review the suitability of H_2 in the national gas grid. However, as noted with the electrolysis plant above, a system analysis would be needed to balance the sources of the hydrogen with the downstream usage. Recognising that:

    - if all the electricity generated by solar and wind was used for electrolytic hydrogen production, this would only displace 6% of current natural gas supply suggesting that other 'green' sources would be needed[1,2]
    - historical domestic gas experience was based on localised private supply
    - education about the hazards and safety of this material in a domestic setting would be required of the current and future users.

4. There are practical and commercial issues associated with the production of large volumes of low-carbon hydrogen. Again, a wider systems analysis that considers both technical and profitability aspects on a strategic scale should be developed to consider the end usage of the generated hydrogen considering such aspects as:

    - Is the hydrogen more suited to high grade industrial heat, rather than domestic use?
    - Where, and how significant is the carbon that the hydrogen is displacing?

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1 BEIS, *Final UK greenhouse gas emissions national statistics: 1990-2016*, March 2018, http://bit.ly/3eWsRRd

2 BEIS, *Electricity fuel uses, generation and supply (DUKES 5.6I*, July 2018, https://bit.ly/38pozix

- Which other technologies will be more technically and economically effective in the move to net zero?
- What do we do with the by-products and wastes?

Question 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

5. The technology to deploy a low carbon hydrogen sector is already available. The key limitation to realising this is the establishment of policy and business/economic models to support generation and use. As next steps to encourage development and expansion of technologies the Government should provide additional direction and understanding to potential investors and operators on:

   - What are its ultimate goals for hydrogen usage and where it sees the clear benefits?
   - Where does it want to apply the technologies and what it wishes to achieve from them?
   - The timescales

6. As projects progress, business models need to change too. In the early stages, a support mechanism to incentivise deployment will be essential. As the sector becomes established, then carbon pricing may be the dominant mechanism. To support production and adoption, contract for difference and subsidy are examples of potentially necessary mechanisms.

7. There is a role for both blue and green hydrogen. A study by CE Delft considered the CO_2 emissions associated with both green and blue hydrogen. The study shows that the CO_2 footprint of blue hydrogen (produced from natural gas with CCS) is 0.82-1.12 kg $CO_{2\text{-eq}}$/kg H_2. This is comparable with hydrogen produced via electrolysis with renewable electricity sources (0.92-1.13 kg $CO_{2\text{-eq}}$/kg H_2).[3] There are differences in cost of production and CCS.

Question 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;

8. Careful thought needs to be given to managing the safety aspects of hydrogen from generation to point of use, including the need for public acceptance / understanding of the risks.[4] As referred to earlier, chemical engineering is central to that understanding and can provide much more clarity and definition than exists at present.

9. BEIS should draw on the experience the UK already has in changing over from coal gas to methane (high speed gas). It took eight years to change, explain and educate the country, which is regarded as remarkably fast.

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[3] CE Delft, *Feasibility study into blue hydrogen: Technical, economic & sustainability analysis*, Delft, Netherlands, July 2018, https://bit.ly/3nhA8OS

[4] Further information can be found in: IET, *Transitioning to hydrogen: Assessing the engineering risks and uncertainties*, UK, 2019. http://bit.ly/3nlwROk

10. The reference to a systems approach is important. It should be central to this response as it is the interconnections that will strengthen or weaken the prospect of hydrogen usage.

11. As projects progress, business models need to change too. In the early stages, a support mechanism to incentivise deployment is likely needed. As the sector becomes established, then carbon pricing may be dominant mechanism. To support production and adoption, contract for difference and subsidy are examples of potentially necessary mechanisms.

Hydrogen production by steam reforming natural gas.

12. The use of methane as a feedstock means that this process cannot be described as decarbonisation. The cost of production is linked to the price of the natural gas. This process will produce large quantities of CO_2. There are some commercial markets for CO_2, but this is limited and much of the CO_2 will be a waste product.

13. The hydrogen produced will contain impurities (due to impurities in the natural gas feedstock). This hydrogen could still be used as a heating fuel, but it is not suitable for use in fuel cells

Addition of a CCS system to dispose of CO_2

14. Although it is technically feasible to use CCS to remove CO_2, this adds extra capital and operating expenditure.

15. There are still long-term liabilities connected with underground CO_2 storage. In recent times, fracking trials in the UK have seen issues relating the complex geology in the UK.

16. There has been much discussion between Government agencies, research organisations, NGOs and others on the development and deployment of CCS applied to different industrial processes. There are some, relatively small pilot plants but still no wider, large-scale adoption in the UK. This is, in part due to the private nature of the energy sector and to the impact of CCS investment on profitability.

Electrolytic hydrogen

17. The electrolysis of water to produce hydrogen is about 80% efficient and pure O_2 is produced at the same time. Commercial markets for pure O_2 include welding, chemical processes and medical applications.

18. The economics of electrolysis are tied to those of the electricity market. Although there is discussion about use of “surplus” electricity, particularly at night time, this is not reliable since the wind farm output varies depending on the wind speed. Similarly, in the move to decarbonisation, electricity demand is increasing. Therefore, times of surplus are likely to be less frequent and smaller in magnitude.

19. In current circumstances, hydrogen production from steam reforming is considered to be a cheaper production route.[5] However, this requires a large-scale, commercial CCS. Although these have been developed, they do not exist at scale in the UK.

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

20. Hydrogen can enable the use and re-use of current plant and infrastructure. This may potentially reduce capital expenditure as part of the transition to a net zero future. Examples of (re)use include existing fired equipment and processes and pipeline transmission systems. There is ongoing work to replace the old “iron mains” grid pipeline with safer polyethylene by 2030. This is safer for hydrogen.

21. Projects to design, build and implement hydrogen production, distribution and use infrastructure take time. Business models to support this activity are needed but is recognised that the nature of these will change over time.

Question 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

Not answered

Question 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.

22. There are a wide range of views on hydrogen as a fuel and energy vector. It should not be considered in isolation, but through a systems approach – from generation to storage, transport, use and use of by-products. Chemical engineering plays an important role in all of these aspects.
23. Important considerations are that:
    - Compression and liquefaction of hydrogen are very energy intensive processes
    - Hydrogen fuel cells have limited overall efficiency and require a high purity of hydrogen
    - Alternatives such as batteries face the challenges of charging and reduced efficiency (through loss of payload).
    - There may be an opportunity for hydrogen fuel in freight (HGVs or trains) although, from an environmental management perspective, the most appropriate solution would be hydrogen usage that can manage the waste products centrally rather than within individual usage.

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[5] Everoze Partners Ltd, Offshore Generation, Energy Storage & Systems Feasibility Study, Crown Estate Scotland, April 2019, https://bit.ly/3pRnQhQ