Response to Environmental Audit Committee Technological Innovation and Climate Change: Hydrogen Call for Evidence

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This response is submitted to the Environmental Audit Committee Technological Innovation and Climate Change: Hydrogen Call for Evidence by The Energy Systems Catapult, The Offshore Renewable Energy Catapult, The High Value Manufacturing Catapult, The Oil and Gas Technology Centre, The Aerospace Technology Institute and the Advanced Propulsion Centre. These organisations represent world-leading technology centres designed to transform the UK's capability for innovation in areas of strength.

Collectively our centres represent extensive expertise and experience working with government, industry and academia in energy innovation including the potential role of low carbon hydrogen across production, infrastructure and end-use, in supporting the UKs commitment to net zero, improved productivity and economic growth.

5 Key Points

1. Hydrogen is expected to play a significant role in our future net zero energy system. This means creating an entire new energy sector within 30 years, delivering energy volumes which could reach up to 300TWh by 2050, equivalent to that of our power sector today. Creation of a hydrogen economy also has the potential to reduce energy import dependency and presents opportunities for exporting any surplus green hydrogen.

2. There are multiple possible end-uses for hydrogen across industry, transport (including heavy duty land vehicles, rail, shipping and aviation) electricity generation and heating. Whilst the priority for end use is uncertain the earliest opportunities within these sectors are heavily influenced by process compatibility, duty cycles, demand flexibility and location. Hydrogen could provide a valuable resource for managing peak electricity demand in an energy system with significant amounts of installed renewable generation capacity. Biomass gasification with carbon capture and storage (CCS) which can deliver negative emissions, and steam methane reforming with CCS (at 99% capture rate) offer potential solutions for hydrogen production. Innovation will be critical to achieve the high carbon capture rates needed from hydrogen production by steam methane reforming. Demonstrating green hydrogen production from electrolysis at industrial scale in the 2020s is a priority given implementation risks with steam methane reforming and carbon capture and importance of reducing costs and improving performance.

3. Early demonstration of 100% hydrogen networks and boilers is needed to prove the safety case and maintain this as an option for decarbonising heat alongside large-scale deployment of district heating, electric and hybrid heat pumps. There is a need to improve the planning and design of smarter local energy systems to build better evidence on local options and choices for decarbonised heat and help inform national decisions. This can ultimately mobilise public and private investment and enable local delivery of the right low carbon heating infrastructure and technologies, in the right place at the right time.

4. The creation of technology neutral support mechanisms is needed to encourage innovation and drive cost competitiveness in all forms of hydrogen production and its use. There is the potential for the UK to play a leading role in the development of hydrogen technology given the significant renewable energy potential for green and domestic gas reserves for blue hydrogen production alongside the UKs strong supply chain capability. To realise this potential the UK needs to increase investment in R&D and industrial scale demonstration programmes or risk being overtaken with major technology development and demonstration happening elsewhere.

5. The sector requires a clear hydrogen strategy and roadmap that drives innovation and enables effective coordination across sectors as part of the whole energy system and along the hydrogen value chain from production to storage and distribution and ultimately end use of low, zero and negative emission hydrogen.

Detailed Points

1.1. The potential role of Hydrogen in our future net zero energy system

1. Hydrogen is expected to play a significant role in our future net zero energy system. To deliver on our net zero commitments, significant hydrogen switching could be required across industry, heavy transport, shipping and aviation, with annual volumes in the range of 200-300TWh by 2050[1] equivalent to £billions as part of a UK low carbon hydrogen economy.

2. This means creating an entire new energy sector within 30 years to deliver energy volumes equivalent to that of the power sector today. Creation of a hydrogen economy also has the potential to reduce energy import dependency and presents opportunities for exporting any surplus green hydrogen to Europe.

3. The development of a networked system of supply, transport and end-use for hydrogen in the UK at this scale would require significant R&D investment in the 2020s.

4. As part of its Innovating to Net Zero analysis supported by Innovate UK ESC defined two potential energy system pathways to net zero by 2050: Clockwork and Patchwork. These represent possible pathways for how the UK's decarbonisation targets might be met, highlighting some of the key opportunities and challenges regarding the role of hydrogen:

    a. Clockwork Scenario
        i. In 2050, around 250TWh of hydrogen is needed to meet demands of industry, space heat, flexible power generation and heavy-duty transport (including shipping).
        ii. Emissions headroom created by 25MtCO_2 of Direct Air Carbon Capture and Storage (DACCS) and high capture rate (99%) Carbon Capture and Storage (CCS) means 216TWh of hydrogen can be produced by steam methane reformation with CCS. The remaining 34TWh is produced by biomass gasification with CCS.
        iii. In some areas, parts of the gas network are decommissioned. In other areas these networks remain strategically important, supporting homes with hybrid heating systems. Those local areas where networks are retained undergo a planned and coordinated hydrogen switchover
        iv. Geological storage of 660GWh of hydrogen is needed in 2050 to ensure homes with hydrogen boilers are supplied with enough hydrogen during extreme weather events during the winter.
        v. Industry adopts a range of fuel "switches" to decarbonise from high carbon fossil fuels to biomass, hydrogen and electricity. Hydrogen replaces natural gas and liquid fuels in several industries including both clustered and dispersed sites.

    b. Patchwork Scenario
        i. In 2050 Production of hydrogen is a mix of biomass gasification with CCS and electrolysis, producing 65TWh and 110TWh in 2050 respectively. Deployment of steam methane reformation is constrained by a combination of the failure to innovate beyond 95% capture rates, and the resulting residual emissions proving prohibitive with less emissions headroom generally (due to limited use of BECCS and DACCS).
        ii. New boilers installed after 2035 are hydrogen-ready in preparation for a big switch including heat pumps installed in combination with hydrogen-ready boilers where gas networks are retained and repurposed.
        iii. Use of hydrogen in industry is predominantly found in the dispersed industries. Electrification and hydrogen provide most industrial heat.

5. There is a clear need to improve the alignment of existing policies related to decarbonisation including the role of hydrogen and to strengthen policy where there are clear gaps. There is the potential to create an economy wide carbon policy framework to deliver Net Zero efficiently[2]. Improved market price signals are needed that incentivise efficient use of the system. This includes reforms to ensure more accurate time-of-use and locational signals to strengthen incentives for supply

[1] https://es.catapult.org.uk/reports/innovating-to-net-zero/
[2] https://es.catapult.org.uk/case-studies/rethinking-decarbonisation-incentives-for-net-zero-policy/

and demand to match user needs and local system circumstances. The creation of technology neutral support mechanisms is most likely to encourage innovation and drive cost competitiveness in all forms of hydrogen production and its use.

6. There is the potential for the UK to play a leading role in the development of hydrogen technology given the significant renewable energy potential for green hydrogen production domestic gas reserves for blue hydrogen production. The UK supply chain also has some of the capability required to capitalise on the potential future global deployment of hydrogen technology. To realise this potential the UK needs to increase and accelerate R&D and industrial scale investment or risk being overtaken with major technology development and demonstration happening overseas.

7. Whilst no breakthrough technological innovation is required for hydrogen to play a major role in our future energy system continued innovation is critical if hydrogen technologies are to be cost competitive. The development of the necessary infrastructure and a functioning market for low carbon hydrogen will be needed to enable investment in both supply and demand technologies. At this time and given the scale of the net zero challenge and potential significant role of hydrogen. There is the need to support innovation through a balanced R&D and demonstration portfolio.

8. The sector requires a clear strategy and roadmap that drives innovation and enables effective coordination across sectors along the hydrogen value chain from production to storage and distribution and ultimately end use of low, zero and negative emission hydrogen. Recognising the potential importance of hydrogen to supporting economic recovery and delivering net zero our technology centres are working together to inform a roadmap for a UK hydrogen economy and enable coordinated focus and government support for hydrogen innovation in the UK.

1.2. Innovation needs for hydrogen production

9. As an energy carrier the degree to which hydrogen is decarbonised depends on how it is produced. There are low, zero and negative emission options for producing hydrogen and the optimal future mix of hydrogen production technologies is highly uncertain. Biomass gasification with CCS and steam methane reforming with CCS (at 99% capture rate) look appealing for hydrogen production and achieving net zero. Such facilities could produce hydrogen constantly throughout the year, with surplus during summer being placed into geological storage for use in winter. Without innovation, steam methane reforming at a 95% capture rate is likely to be too high carbon to meet Net Zero. Innovating to make this more efficient and achieve high carbon capture rates is critical to allowing a longer-term role for steam methane reforming whilst remaining consistent with the achievement of net zero commitments.

10. Whilst electrolysis currently appears a less cost-effective option, innovation (including learning by doing) is expected to bring down costs and improve performance. Demonstrating green hydrogen production from electrolysis at scale in the 2020s should be a priority given implementation risks with steam methane reforming and CCS, which, if proven successfully, may then compete to deliver lower cost hydrogen to consumers. Nuclear energy is a possible route to the production of hydrogen with evidence that thermochemical processes driven by heat directly from nuclear energy and electrolysis from electricity generated by nuclear energy could produce cost effective hydrogen.

1.3. Innovation needs for hydrogen Infrastructure

11. Effective planning and coordination of hydrogen production, storage and distribution as part of our wider energy system is essential to ensure cost effective, low carbon supply; and ensuring synergies between end-uses are realised and conflicts avoided.

12. There is a need to strengthen network price controls to support decarbonisation by incentivising and taking forward whole systems local area energy planning and develop a much better understanding of options for decarbonising local energy systems across the UK. This would help to inform national decisions related to hydrogen production, infrastructure and use (including repurposing of the gas grid) that supports net zero objectives. This also has the potential to link to local industry strategies including consideration of regional hydrogen production and use.

1.4. Innovation needs for hydrogen end use

13. There are multiple possible end-uses for hydrogen across industry, transport (heavy duty land vehicles, rail, shipping and aviation), electricity generation and heating. Some industrial processes are not well suited to electricity as a low-carbon energy source; and hydrogen could also provide a very valuable resource for managing peak electricity demand in an energy system with significant amounts of installed renewable generation capacity. Transport and heating are potential end-uses for hydrogen in delivering net zero but within each there are applications and locations where it is likely to be more suited. A blanket approach for these sectors is unlikely to be effective in achieving a net zero economy.

1.4.1. Hydrogen for Industry

14. Demonstration of the safety of hydrogen switching for industrial processes is essential. There is the need to consider the integration of decarbonisation roadmaps for industrial clusters with the development of local area energy plans to enable investment in hydrogen infrastructure in the right places at the right time. Industry also requires stronger policy incentives to invest in emissions reduction through improving industrial processes, fuel switching, and technology innovation. Direct support is needed for innovation and early deployment of CCS and hydrogen production in industrial clusters.

15. Government should prioritise developing and establishing a long-term policy framework for industrial decarbonisation, including developing rewards for delivering verified negative emissions. This could also substantially improve the investability of hydrogen switching, hydrogen production, CCS and domestic biomass supply chains. This would need to be designed in ways that minimises carbon leakage impacts (i.e. reduces offshoring of industrial emissions) and must account for asset turnover rates.

1.4.2. Hydrogen for Heating

16. The potential mix of solutions for decarbonising heating appears broadly unchanged with net zero commitments and likely to require a combination of building retrofits, district heat networks, and electric heat pumps with some heat pumps retaining a connection to gas networks to support peaking boilers. For some buildings, improved thermal performance and control of heating will likely enable them to rely solely on electric heat pumps, along with heat storage. For others, the rate of heat loss in extreme cold periods means they may will still require a boiler to supplement the heat pump.

17. There are many non-technical barriers, including public acceptance and consumer appeal, to low carbon heating technologies including hydrogen for heating. There is a need for innovation to drive the development of compelling customer propositions and cost effective low and zero carbon heating products and services that deliver people the comfort they want at home[3]. Programmes such as BEIS Hy4Heat[4] and H21[5] are contributing valuable evidence to the potential conversion of UK gas networks and use of hydrogen for heating alongside HyNet[6] in demonstrating hydrogen production with CCS. Early demonstration of 100% hydrogen networks and boilers is essential to prove the safety case and maintain this as an option for decarbonising heat. Better evidence is also need on the feasibility of technical integration and large-scale conversion of existing gas heated homes to electric heat pumps through programmes such as BEIS Electrification of Heat Demonstration Project[7].

18. Whilst hydrogen converted boilers could still have a role in heating many homes, there is the possibility for a very significant reduction in gas network capacity requirements by 2050. The implications of this for gas distribution networks in different areas will depend on a variety of factors but could challenge the economic case of operations.

[3] https://es.catapult.org.uk/reports/how-can-people-get-the-heat-they-want-at-home-without-the-carbon/
[4] https://www.hy4heat.info/
[5] https://www.h21.green/
[6] https://hynet.co.uk/
[7] https://www.gov.uk/guidance/electrification-of-heat-demonstration-project#:~:text=The%20Electrification%20of%20Heat%20Demonstration,of%20the%20barriers%20to%20deployment.

19. More effective local area energy planning is a potentially important enabler to decarbonising heat. This can help to (1) understand the optimal combination of different local energy system designs, based on local resources (and constraints) and (2) provide sufficiently granular evidence related to the decarbonisation of heat to inform national decisions and (3) providing a practical mechanism for engaging local communities and people including a means of targeted deployment of hydrogen infrastructure and heating technologies in the right place at the right time.

1.4.3. Hydrogen for Transport

20. Transport currently accounts for almost third of UK emissions and continues to rise[8]. There is a potential role for hydrogen throughout the transport ecosystem, and current thinking suggests that for road vehicles hydrogen powertrains will be most economically deployed in large vehicles with appropriate duty-cycles: a variety of technological paths to low emissions in these vehicle segments are being investigated. When vehicle use cases are considered in the context of net-zero, along with practicalities of re-fuelling/charging, it is possible that the use of hydrogen will be required to decarbonise transport in these vehicle segments in the future.

21. Long term planning and coordination is needed to support the deployment of infrastructure for low carbon heavy duty vehicles. Support is needed for emerging technologies, such as hydrogen fuel cells for use in commercial and Heavy Goods Vehicles (HGVs) and the rail sector. The role of short-lived transition technologies such as natural gas and hydrogen duel-fuel vehicles and diesel hybrid also requires further cost-benefit consideration.

22. There is a potentially significant role for hydrogen in shipping, which appears attractive from a carbon abatement perspective. Coordination will be essential to ensure deployment of hydrogen fuelling at UK ports, including access to affordable hydrogen from production facilities, low cost transportation, or potential on-site production via electrolysis.

23. Hydrogen is also being explored for aviation applications, including directly for short-haul flights and as an intermediary in the production of e-fuels for other types of flights and the UK aerospace sector is well positioned to become one of the leaders in developing hydrogen-based propulsion systems.

24. Hydrogen can be used as a fuel for aircraft when it is combusted in a hydrogen-burning engine or reacted in a fuel cell which powers electric motors. Despite the higher gravimetric energy density compared to kerosene, hydrogen's higher volume requires larger volume for storage, which in turn requires larger tanks aircraft and adjusted aircraft designs. The technical challenge for aircraft design is significant. However, given the significant reduction in emissions associated with hydrogen propulsion, increased research and development efforts should continue to explore and accelerate its application for air transport. Hydrogen eliminates CO2 emissions in flight and can be produced carbon-free. Considering also non-CO2 emissions, and the uncertainties of these effects, estimates show that hydrogen-combustion could reduce climate impact in flight by 50 to 75 percent, and fuel-cell propulsion by 75 to 90 percent. This compares to about 30 to 60 percent for synthetic aviation fuels[9].The ATI programme is already funding one project to develop a hydrogen fuel cell powered aircraft, with more in the pipeline.

25. Establishing an operating industrial scale UK low-carbon hydrogen economy by the 2030s could provide important mitigation against the risk that hydrogen will play a more significant role in decarbonising transport than currently expected.

[8] https://www.theccc.org.uk/wp-content/uploads/2019/07/CCC-2019-Progress-in-reducing-UK-emissions.pdf

[9] Hydrogen-powered aviation: A fact-based study of hydrogen technology, economics, and climate impact by 2050, McKinsey, May 2020