Written Evidence Submitted by the Centre for Sustainable Road Freight (HNZ0020)

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Brief Introduction of the Centre for Sustainable Road Freight

The Centre for Sustainable Road Freight (SRF) was founded in 2012 to help industry and Government minimise Carbon emissions from the road freight sector. The SRF brings together three of the UK's leading academic groups: Cambridge University Engineering Department, Logistics Research Centre of Heriot Watt University and the Freight and Logistics Research Group at the University of Westminster, along with industry and government partners; to make road freight environmentally, economically and socially sustainable. The SRF receives funding from various UK Government sources, particularly UKRI (EPSRC), ETI, and InnovateUK, as well as from industry members.

Response

This submission discusses the technical and economic challenges faced by hydrogen technologies in meeting the decarbonisation timescales needed, in comparison with the least cost, most efficient option - direct electrification.

Unless specified otherwise, this response is based on a series of articles comparing hydrogen and electrification, by D. Cebon: see references [1], [2], [3], and [4].

Introduction

The Prime Minister Boris Johnson recently announced a new target to reduce UK carbon emissions by 68% (relative to 1990 levels) by 2030. This reduction is an admirable milestone on the way to the government's 'net zero' Carbon emissions commitment by 2050. These targets highlight the fact that extreme measures need to be implemented rapidly (beginning within the current decade) to prevent using up the remaining Carbon budget – so as to avoid global warming exceeding 1.5°C. 'Shovel ready' solutions, with high Technology Readiness Levels (TRLs), and viable business cases are the only ones that can be implemented in time. There are myriad solutions on the table to reach these targets, primarily focused on the use of electrification and/or hydrogen. There are three application areas where use of hydrogen has been highly cited for meeting decarbonisation targets: 1) heavy goods vehicles (HGVs), 2) heating buildings, and 3) energy storage.

Heavy Good Vehicles

HGVs carry 90% of goods lifted [5] and produce 5% of the UK's total greenhouse gas emissions [6]. This represents a vital part of the economy, a significant source of Carbon emissions, and is a 'difficult to decarbonise' sector.

Hydrogen-powered trucks offers hauliers the benefit of fitting into the existing logistics system; they can be refuelled in approximately the same time as diesel trucks and can likely maintain similar operating ranges and patterns without significant change from current logistics practice. However, hydrogen is much more energy intensive than electricity and consequently is inherently more expensive for the economy, the environment and probably for the vehicle operator.

As 2/3 of HGV journeys (by vehicle-miles) are on the major road network, Electric Road System (ERS) technology could provide deep decarbonisation (approximately 90% from 2016 levels by 2040) with the lowest energy requirements [7]. Such a system would distribute the electricity charging requirements around the UK land area, with consistent power requirements through the day, instead of major electricity hot-spots in depots at night, required by battery electric lorries.

European trials have demonstrated that eHighway technology could be rapidly deployed around the UK's major road network within the next 15-20 years at an estimated cost around to be about £20 billion [7].

Compared to direct electrification, via ERS, there are numerous challenges for hydrogen to overcome:

Green Hydrogen

- Using Green hydrogen to power UK HGVs would require 3.3-times the amount of electricity needed for direct electrification via ERS. It would be necessary to install, 35.6 GW of additional renewable electricity generation, compared with 10.6GW needed for powering the UKs HGVs using an ERS [1].
- The largest electrolysis plant in the world is currently being built by Hydrogenic in Canada. It has a capacity of 20 MW, which is about 1/1800 of 35.6 GW needed to run the UK's truck fleet. Given the amount of scaling-up to be done, it is questionable whether Green hydrogen for road freight could be deployed in time (by 2040) to avoid the 1.5°C global temperature rise [1].

Blue Hydrogen

- Due to the inherent inefficiency of hydrogen production and use, the UK would need to import an additional 124 TWh of natural gas per year to power the truck fleet using blue hydrogen [1]. This would increase gas imports from 518 TWh to 642 TWh, increasing imports by 24%, with a consequent adverse impact on the balance of trade and energy security.
- Use of Blue hydrogen to power UK freight would increase ongoing energy costs by 70% compared with using the same natural gas to fuel conventional electricity generation, (with Carbon Capture and Storage (CCS)), and using the electricity in ERS lorries [1].
- It is unlikely that the necessary facilities for manufacturing Blue hydrogen (steam methane reformation with CCS) could be built in time for 2030,or 2040 [1].

Heating Buildings

Heating buildings without carbon emissions poses a significant challenge to the UK's net zero targets. There are three main options for heating using electricity or hydrogen: 1) heat pumps, 2) electric space heaters, and 3) hydrogen boilers. Electric space heaters are significantly more efficient than hydrogen boilers, delivering 90% more heat for the same input energy, and can utilise existing electrical infrastructure [2].

Heat pumps can deliver much more heat into a building than the electricity they use. Assuming a realistic Coefficient of Performance of 3.0, a heat pump can produce 3-times more heat than electricity input (see [8] for a good explanation of how heat pumps work).

Comparing hydrogen boilers to heat pumps, the challenges faced are:

Green Hydrogen

- The 'wind-to-heat' electricity consumption of Green hydrogen boilers is about 6-times higher than that of heat pumps, for delivery of the same amount of heat [2]. The factor of 6 results from (i) the inefficiency inherent in hydrogen processes; (ii) the substantial energy 'leverage' provided by heat pump technology, which can provide approximately 3 times more heat output than electricity input.
- The inefficiency of Green hydrogen generation, compression and transmission means that approximately 385 GW of offshore wind turbines would be needed to heat the UK's buildings via Green Hydrogen [2]. Conversely 67 GW of additional offshore turbines would be needed to heat the UK's buildings via heat pumps.
- In 2020, a Green hydrogen boiler emits 50% more carbon than burning natural gas in a condensing boiler. Green hydrogen will not deliver lower carbon emissions than natural gas

boilers until nearly 2030, when the electricity grid will be significantly lower carbon than now. [2]
- By comparison, in 2020 heat pumps generate only 25% of the emissions of natural gas boilers [2].
- Green hydrogen condensing boilers won't reach the emissions performance of 2020's heat pumps until around 2040 [2].

Blue Hydrogen

- Heating all UK buildings by blue hydrogen would require a 25% increase in natural gas imports, taking the imports to 60% of national consumption. This would be detrimental to the balance of trade and energy security [2].
- Fugitive Carbon emissions is always be significant in methane supply chains. These are very damaging to the environment, with approximately 25 times the global warming potential of CO_2 [2].
- The CCS processes used in production of Blue Hydrogen leak at least 10% of the carbon from the input methane into the atmosphere – because CCS is not perfect at scrubbing the CO_2 from flue gases. Consequently, use of Blue hydrogen for heating would prevent the UK government from meeting its legal commitments for 'net zero' emissions by 2050 [2].

It is unlikely that the infrastructure needed for Blue or Green hydrogen could be built in time for 2040, and to meet net-zero targets.

Government policy should promote and encourage heat pumps for heating new and retrofitted buildings. Heat pumps provide the most effective way to reduce carbon emissions from heating, and are available off-the-shelf, now.

Energy Storage

A key issue in the low carbon future is electricity storage. Because of the variability of sustainable electricity (wind, solar) and its lack of synchronicity with the peaks of electricity demand, there is a need to store electricity at times of excess supply for use at times of high demand. Proponents of a Green hydrogen Economy propose to solve the electricity demand problem by using excess electricity to make hydrogen by electrolysis; storing it in underground salt caverns; and converting it back to electricity at peak times. In the renewable electricity future, the UK will need an estimated 65 GWh of intra-day storage and 16 TWh of inter-seasonal storage, both supplied at powers in the range 5-8 GW [3].

Challenges for hydrogen to store grid-scale energy include:

Green Hydrogen

- The alternative to large-scale intra-day storage is to have a significant over-supply of renewable electricity generating capacity and to curtail generation at times of low demand. The UK would need an additional 16GW of offshore wind generating capacity (1,300 x 12MW turbines) for a typical day [3].
- The only viable candidates for grid-scale electricity storage are:
    - Pumped Hydro (limited potential for further development in the UK.).
    - Cryogenic (Liquid Air).
    - Compressed Air.
    - Green hydrogen.
- The economics of 'arbitrage' electricity storage are dominated by the 'round-trip' efficiency of the energy storage system. Pumped-hydro, Liquid Air and Compressed Air storage can have round-trip efficiencies up to 70%, whereas Green hydrogen has a round-trip efficiency of around 30-35% [3]. The 'break-even' sale price of electricity stored via Green hydrogen is

around 2.2-times the break-even sale price of electricity stored via other available technologies.

- Green hydrogen electricity storage will not be economically competitive with the alternative grid-scale storage technologies at any wholesale electricity price. It is unlikely that the fundamentals of this calculation will change significantly with time.
- Storage technologies such as liquid air, compressed air and pumped hydro are significantly more efficient than Green hydrogen storage. Consequently, much less energy is wasted in the energy storage round-trip.
- One viable alternative to grid-scale storage is the use of interconnectors to transfer electricity from country to country. This is particularly attractive for inter-seasonal electricity fluctuations, which otherwise require vast quantities of energy to be stored.

Key Points and Summary

The time is rapidly approaching for the UK Government to 'pick technology winners' in this area. Without Government decisions on which technologies to support and the legislative and financial environments to support them, there is little chance of achieving the 2030 target. The challenges associated with hydrogen decarbonising the UK are:

- Hydrogen is a poor energy vector that suffers from fundamental efficiency problems.
- Hydrogen is at a low stage of technology readiness, and there is insufficient time to viably utilise it widely across the UK by 2050.
- For heavy goods vehicles, direct electrification via batteries and electric road systems are options with higher Technology Readiness Level, lower energy consumption, lower carbon emissions and lower costs than hydrogen-powered fuel cell vehicles.
- For heating buildings, heat pumps are a better option than hydrogen boilers, with higher technology readiness, much lower energy consumption and carbon emissions and much lower fuel costs.
- For electricity storage, Green hydrogen is unlikely to be able to compete with more efficient alternatives such as cryogenic (liquid air) storage and compressed air storage, which offer lower cost and higher TRL.
- Shifting the energy for both lorries and heating to Blue hydrogen would result in the UK importing and burning an additional 260 TWh of natural gas per year. This would increase natural gas imports by 50%, reducing the UK's balance of trade and energy security.
- The total carbon sequestration capacity of the world is currently (0.1%) of global emissions, and there is a long way to go before carbon capture and storage can have a significant impact on Blue hydrogen production.
- Carbon capture and storage can only be financially viable with either a carbon price above the cost of capture usage and/or storage, or heavy Government subsidies.
- The proposed Green hydrogen economy is unlikely to be realisable in the UK in comparison to direct electrification, requiring the Government to subsidise the hydrogen price in the long term which would dent the UK economy's competitiveness.
- Future Green hydrogen production should focus on replacing industries that already use grey hydrogen (e.g. fertiliser).
- Hydrogen could play a role in aviation and maritime, but given the long service life of these vehicles it will difficult to achieve net zero by 2050. It is thought that biofuels and efuels will be better alternatives in these sectors.

References

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