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Hydrogen for Transport Advancement Program: expanding hydrogen fuel use in the UK

Lewis Cletheroe[1], Leo Dando-Ladenis[1]

[1]*Office for Low Emissions Vehicles, Great Minster House, 33 Horseferry Rd, Westminster, London SW1P 4DR, lewis.cletheroe@olev.gsi.gov.uk*

Introduction

Efforts to decarbonise transport are driven by tightening regulations governing emissions from road vehicles and government policy. Current regulations require that new vehicles registered in the EU emit no more than 130 gCO_2/km as a fleet average and the target for 2020 requires the fleet average of all new cars to be 95 gCO_2/km [1]. The UK government is aiming for all new cars and vans sold in the UK to be zero emission by 2040, with all cars on Britain's roads producing zero emissions by 2050 [2]. This requires a radical change in the way transport is considered, with multiple options considered as a possible solution.

Using hydrogen as a transport fuel is one of the potential solutions for decarbonising road transport. When used as a transport fuel in a fuel cell, considered on a tank to wheel basis, hydrogen produces 0 gCO_2/km, 0 gNO_x/km emissions and emits only water. It can be produced by carbon neutral methods, using renewable powered electrolysis, or thermal methods if combined with carbon capture and storage [3]. When using hydrogen produced using low carbon methods, Fuel Cell Electric Vehicles (FCEV) offer complementary advantages with Battery Electric Vehicles (BEV) over internal combustion engine vehicles (ICE) and provide an electrified option for most transport modes (Figure 1). Although BEVs are more affordable, FCEVs offer the benefits of high range and low refuelling time compared to electric vehicles, making long distance electrified driving, beyond the range of a typical BEV, a possibility.

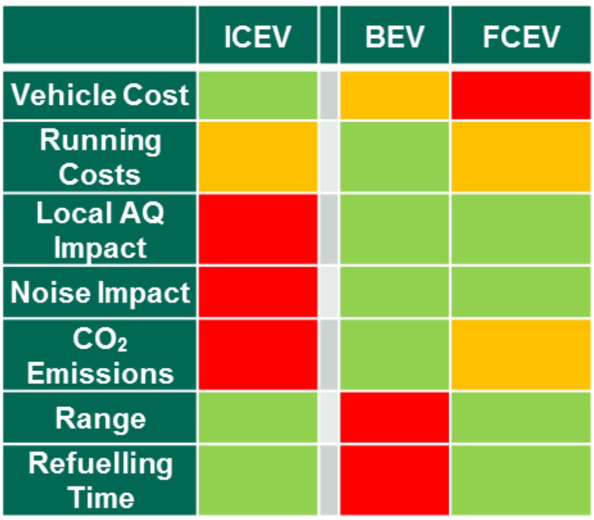

Figure 1 RAG analysis of ICE, BEV and FCEV powertrains, highlighting the FCEV's high range and low refuelling time, but high cost to purchase and run. Red indicates unfavourable, green indicates favourable and amber represents neither favourable nor unfavourable..

Refuelling stations that provide hydrogen cannot presently be considered a commercial undertaking, currently in a pre-commercial phase, as defined in an EU fuel cells and hydrogen joint undertaking (FCH-JU) report [4]. To address this the EU's FCH-JU has committed to providing funding, to transition hydrogen for transport from this pre-commercial phase towards a more commercial phase. These programs provide funding for a range of hydrogen projects in an effort to speed up uptake [5].

Despite offering clear societal advantages and the funding offered by the FCH-JU, hydrogen as a transport fuel faces a take-up challenge due to its limited commercial and consumer offerings. The current HRS network does not cover the whole of the UK, leaving some people with no opportunity to fuel, and there are a limited number of vehicles, providing little consumer choice. The UK government has considered how to address this market barrier and has provided funding through the Hydrogen for Transport Advancement Programme (HyTAP) and the FCEV fleet support scheme. These programmes have increased the use of hydrogen as a transport fuel and provided valuable insight for HRS and fleet operators into the technical requirements for deploying and operating a national hydrogen refuelling network.

Hydrogen for fuel support schemes

Hydrogen for Transport Advancement Programme

The UK government's Office for Low Emissions Vehicles (OLEV) has committed £5 million to support the installation of 12 publically accessible HRS, which has brought the total number of HRS in the UK up to 14 (Figure 2) [6]. These stations include those with hydrogen sourced from on-site electrolysis or from off-site production; most stations feature facilities to dispense at pressures of both 350 and 700 bar. Installation of these sites has required the development of technical standards, testing procedures and local planning strategies, which will continue to influence future HRS design. The stations are intended to provide an initial network, which can then grow into the much wider rollout of stations needed to provide national coverage.

Location	Status
ITM Station – Advanced Manufacturing Park site, Sheffield	Opened Sep 2015 and upgrade completed July 2016
ITM Station – National Physics Laboratory, Teddington	Opened May 2016
ITM Station – Centre for Engineering and Manufacturing Excellence site, Rainham, Essex	Opened Oct 2016
ITM Station – On Shell site Cobham, Surrey	Opened Feb 2017
ITM Station – On Shell site Gatwick, London	Opened Q2 2017
ITM Station – On Shell site Beaconsfield, Buckinghamshire	Opened Q1 2017
Air Products Station – Heathrow, London	Upgrade completed July 2016
Air Products Station – On Sainsburys site Hendon, London	Upgrade completed July 2016
Air Products Mobile Refueller – based in Southern England	Upgrade completed Dec 2016
Honda/BOC Station – On Honda site Swindon	Upgrade completed April 2016
Fuel Cell Systems Mobile Refueller – based in South East England	Operational July 2017
University of South Wales – Port Talbot	Upgrade completed July 2017
Other HRS	
Bus Depot Station – Stratford, London	Opened 2011
Aberdeen Hydrogen Bus Project Station – Aberdeen, Scotland	Opened 2015

Figure 2 The locations and opening dates of the UK's hydrogen refuelling stations.

Although this funding has allowed the UK's hydrogen refuelling station offering to more than triple since 2014, there have been delays due to the way legislation and regulations are set up to support the safe running of the current transport infrastructure network in the UK. This has been exacerbated by the fledgling state of the supply chains for hydrogen refuelling stations, which have particular requirements for high pressures of 700 bar and infra-red connectivity with the vehicle.

Several challenges are presented when trying to disburse hydrogen for FCEVs at high pressures of up 700 bar. The high pressures required for hydrogen are not seen in the established refuelling infrastructure for

CNG, which typically operates at up to 250 bar. These more demanding conditions means there are stringent requirements for specialised parts, made from high quality materials. The testing at each stage of the manufacturing process adds cost and time, increasing the total cost for the delivery of a hydrogen refuelling station project. Specialised parts required for HRS include high pressure Type II compressed gas tanks, high pressure valves and seals. The nozzle used in 700 bar refilling is specified by international standards SAE J2601 [7] and ISO 17268:2012 [8] and requires an IR communication device to ensure that vehicles can be filled safely at high pressures and flow rates.

Several grant recipients have indicated that lead times for items required to build HRS infrastructure are typically long, with Type II 1000 bar compressed gas tanks having an expected lead time of 1 year and refuelling nozzles expected at 6 months. Other items need replacement more often than would be expected in a less harsh environment, including polymer seals with a nominal lifetime of greater than 20 years failing after 6 months. These issues are compounded by the testing requirements for the materials used in safety critical components, which are necessarily strict, but significantly increase costs where quality cannot be assured for whole batches. These issues all contribute to situations where project timelines cannot be guaranteed, introducing significant risk to entities wishing to invest in HRS infrastructure networks.

FCEV support scheme

Beyond the pre-existing FCEV fleet, there are a further 50 funded FCEVs supporting these stations; the purchase and operation of which are funded by an additional £2 million FCEV fleet support scheme from the UK government and OLEV [9], The purchase of a combination of vans and passenger vehicles has allowed public and private fleet owners to demonstrate the advantages of operating FCEVs and will raise awareness of the technology amongst the public. The competition for grant funding from this scheme was heavily oversubscribed, demonstrating the appetite for alternatively fuelled commercial vehicles.

As seen in the HyTAP HRS funding scheme, the FCEV support scheme also demonstrates issues with fledgling supply chains associated with hydrogen fuel. Some vehicles that have been purchased with grant money have faced long lead times with unmitigated delays to the projects planned timeline, due in part to the new technologies being rolled out and the small number of vehicles to inform development. Conversion projects have been particularly affected, as these rely on sourcing both a BEV and the fuel cell powertrain to build a finished vehicle. The other two vehicles purchased as part of a scheme include the Toyota Mirai, a vehicle that is only available in limited numbers, and the Hyundai ix35, which is now out of production. These issues with procuring vehicles do not encourage the uptake of FCEVs despite a generous grant program; the delay in procuring vehicles causes significant difficulties for organizations in planning and operating their fleets. Future funding programmes for FCEVs in the context of developing the UK hydrogen fuel market needs to consider the supply chain readiness level and vehicle availability, then encourage development to prevent this disincentive.

Future funding schemes and supporting work

Future HRS support funding scheme

Although the UK has made a positive start in developing the UK’s ability to use hydrogen fuel, these stations do not have enough utilisation or capacity to reach profitability. Deploying FCEVs increases station utilisation but does not provide a reliable revenue stream for HRS operators to consider unsubsidised installation. To incentivise a market for passenger vehicles, a wider variety of FCEV models than currently available is required. Only two models are offered in the UK, although several others have been announced. Furthermore, to develop a good offering of FCEVs, a strong network of infrastructure is required, which cannot be developed while there is no profitability to stations. The previously mentioned FCH-JU report suggests that only stations with a capacity of 200 kg/day or greater could become commercially successful [4].

To overcome this chicken and egg scenario, the UK government is exploring funding options to support the uptake of hydrogen for transport and promote the transition towards commercial viability. A wide range of vehicles and uses are being considered, as well as the opportunity to tap into related, adjacent undertakings in decarbonising heat and electricity and support the business cases proposed for these.

OLEV will be providing £23 million of funding, up to 2020, for up 17 refuelling stations with capacity to provide 200 kg per day of hydrogen fuel and captive fleets [10]. These captive fleets are aimed at ensuring adequate utilisation of the 200 kg per day stations that have the potential to be commercially viable, according to the FCH-JU. The funding will be provided, through a competition, as grants. This was judged by the UK Government to have the lowest risk to public investment compared to other funding models, such as loans, shared equity or joint ventures. Decisions to continue providing funding via a grant model were compared to the more complex joint venture model employed by the German government, which has not achieved its initial objectives of 100 stations by 2017 [11], and grant funding was found to be suitable for achieving the goals of the UK. However, future funding, if considered and dependent upon the success of this round, may have to take into account whether funding models such as loans, shared equity or a joint venture will be able to deliver a national commercial network of stations.

An appetite for developing hydrogen fuelled vehicles is clear from industry support, with a number of passenger cars, buses, vans, freight vehicles and trains being announced, deployed and developed to meet the challenges associated with electrification of the many modes of road transport. These vehicles include those announced by Honda, Daimler, BMW, Toyota and Hyundai, who have given their support to the HyFIVE project, a European hydrogen fuel support project [12]. Additionally both Ballard Power Systems in conjunction with Kenworth [13] and Hydrogenics in partnership with Scania [14] have announced heavy freight vehicles to meet the challenge of electrifying this sector, which resists electrification using battery technology alone. Alstom have produced a fuel cell electric multiple unit demonstrator train for use on standard gauge railway in Europe [15]. The intentions signalled by these companies suggest that there is a future opportunity for commercially viable hydrogen fuel cell vehicles for multiple modes of transportation.

Opportunities beyond transport fuel

The UK government is also more broadly considering the use of hydrogen for fuel in the UK's energy landscape, with calls from the Committee on Climate Change (CCC) for the UK to develop a strategy for the use of hydrogen for heat. Developing a strategy for the wide roll out of low carbon hydrogen generation, distribution and heat appliances strengthens the position of hydrogen as a fuel in the transport sector, due to increased utilisation and economies of scale making the undertaking more commercially viable [4]. This has been demonstrated, using systems modelling, to be a cost effective way to develop a low carbon heat network, with use of the existing natural gas network to roll out hydrogen to homes [16]. Use of hydrogen in the gas distribution network would be a significant step towards developing an integrated plan for using hydrogen for hydrogen and transport.

This consideration of the use of hydrogen in the energy networks could be extended to the electricity grid. Promising results have been see in the use of power to gas to manage electricity grid load and demand. Many of these projects show that it is possible to integrate both power to gas and refuelling infrastructure. Gahleitner notes that as of 2013, 10 power to gas projects have integrated refuelling stations [17]. Schiebahn et al. discuss how hydrogen produced using renewable electricity can be used to power FCEVs and reduce transportation CO_2 emissions; with increasing efficiencies, lower noble metal requirements and dropping costs, FCEVs may be an attractive option for transport in a community with power to gas infrastructure [18]. Efforts in the UK have the potential to manage the expected extra demand from electric vehicles by offsetting it against gas production at off peak times and FCEV use. Combined with other measures that can increase grid resilience, including smart charging and vehicle to grid, power to gas may prevent a catastrophic failure of electricity grids in a post ICE world.

The development of energy and transport use cases requires careful examination of legislative frameworks and planning regulation to prevent delays, as evidenced in the case studies above. Future hydrogen use cases must be surveyed to ensure that delays are not unnecessarily incurred due to a misreading, misunderstanding or ignorance of the frameworks that guide the use of hydrogen fuel. Further scrutiny of how several standards are implemented is required, to futureproof hydrogen fuel use. For example, there are currently two competing standards for vehicle refuelling; SAE J2601 [7] and ISO 17268:2012 [8]. Although these standards are interoperable, using the same equipment and communications hardware to refuel a vehicle, they do not have the same underlying requirements. Proposals to harmonize these standards would go some way towards removing this barrier, but this takes place at an international level and progress is often slow, especially where a market is nascent. This situation makes it very difficult to assume the future standards that need to be adhered to and plan the requirements for funding schemes accordingly. OLEV is working with EU colleagues to ensure that the UK meets the required standards under Alternative Fuels Infrastructure Directive [19] and that these are appropriate for the developing commercial offering.

Conclusion

Hydrogen FCEVs have the potential to lower transport related emissions associated with global climate change and poor air quality, but there has been little uptake of vehicles due to cost and poor refuelling availability. OLEV has provided funding for infrastructure and vehicles, increasing stations to 14 and doubling the number of vehicles on the road to establish the market. The UK government is providing further funding for new infrastructure to build another 17 stations and provide a route to commerciality by supporting utilisation through the funding of captive fleets. Implementation of these programmes have not been without issues; regulatory and supply chain problems have been overcome and mitigating measures have been examined and considered for use in the next scheme. This may also be helped by the exploration of hydrogen solutions in adjacent sectors, such as heat and electricity markets. The UK government expects to keep increasing the number of FCEVs on road to help meet the government policy of all new vehicles produce zero CO_2 emissions by 2040.

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Authors

Lewis Cletheroe is currently a member of the hydrogen and supply chains team at the Office for Low Emissions Vehicles, exploring opportunities for growing ultra-low emissions vehicles supply chains and expanding the use of hydrogen as a transport fuel in the UK. Before joining the UK government, Lewis was investigating methods for producing hydrogen, using solar power and hydrogenase type catalysts, at the University of Sheffield as a doctoral student.