Scottish Hydrogen Freight Trial (SHyFT) Feasibility Study

Summary for Operators

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Background

The Scottish Hydrogen Freight Trial (SHyFT) feasibility study was delivered in response to the Department for Transport's (DfT's) invitation to the Zero Emission Road Freight Trial (ZERFT) competition. SHyFT is based in and focused on Scotland with links established to enable extending the trial into England, including to the Teesside Hydrogen Hub. Scotland is chosen as it is well placed for green hydrogen supply with significant investment already underway. Existing refuelling infrastructure and vehicle deployments provide a strong foundation for this project, and this proposed trial adds value to creating a strong network of hydrogen refuelling.

The aim of the ZERFT competition was to fund ambitious feasibility studies for a future zero emission road freight demonstration of hydrogen fuel cell trucks. This includes investigation of refuelling infrastructure planning and engineering, costs and project development considerations.

The feasibility study was required to develop the plan to assess the viability of a trial of a fully zero-tailpipe-carbon emission vehicle hydrogen fuel cell electric vehicle targeting 40 or 44t trucks, consider the real-world operations of such a vehicle and provide evidence to support a trial programme that is expected to run for five years. Follow on funding for the trial has been announced by the UK Government on 16th August 2022.

The study assesses the feasibility of the trial considering vehicle and refuelling technology readiness, the required infrastructure and consideration of the costs and business model required to roll out fuel cell electric vehicles (FCEV) into a range of freight use cases in Scotland and beyond. The project has been undertaken by Ballard Motive Solutions, the Hydrogen Accelerator and Arup with additional input from Scottish Power and BOC.

Context

The UK government has produced a Net Zero Strategy “Build Back Greener” which sets out policies and proposals for decarbonising all sectors of the UK economy to meet the net zero target by 2050. Within this strategy all new road vehicles in the UK are set to be zero emission by 2040. This includes requiring all new cars and vans to be zero-emission by 2030, all new HGV’s weighing 26 tonnes and under to be zero emission by 2035, all new HGV’s over 26t to be zero emission by 2040 and the whole transport sector to reach net zero by 2050. In addition, we are aware that there are many freight and logistics operators who have their own targets for decarbonisation and zero emission technologies in their fleets.

There are heavy duty zero-emission vehicles available on the market presently, which use battery electric technology. The DAF CF Electric and the Scania Battery Electric Truck have marketed ranges of 200km and 250km respectively. These ranges are only suitable for niche applications covering very short distances, or where recharging can take place during a shift (1-2hrs of fast charging every 150miles).

Battery technology is expected to advance, for example the Tesla Semi concept has a marketed range of 500 miles, but with current technology there are challenges with the impact of the battery weight on payload, real world range, sustainability of supply chain and the scalability of charging infrastructure.

Fuel Cell Electric Vehicles (FCEV) offer an alternative zero emission solution with attributes that suit higher duty applications and address some of these issues:

- Vehicle weight – A FCEV will have greater range at lower vehicle weight than a BEV equivalent, allowing greater payload capacity.
- Rapid refuelling – the current generation of heavy-duty vehicles can be fully refuelled in around 10 minutes, and we expect this to be similar for this class of vehicles as refuelling technology continues to develop. This is equivalent to a charging power of 5MW.
- Fleet scalability – Hydrogen supply and infrastructure is more cost effective with scale. This means MW scale grid connections, for simultaneous overnight re-charging, are not required at depot locations. The study investigated large scale green hydrogen supply generated through electrolysis close to renewables and transported and stored accordingly. This approach is scalable particularly in areas close to renewables.
- Sustainability of Supply Chain – A FCEV uses fewer materials, particularly much smaller batteries, and a large proportion of the fuel cell itself can be refurbished and recycled. Components are expected to have long lifetime in use as degradation of fuel cell and battery is reduced through system design and operation.

40t/44t Hydrogen FCEV tractor units are being developed by large scale vehicle OEMs, but these are not expected until 2028, and it is unlikely that these will be developed or manufactured in the UK at least in the initial roll-out. Anecdotal evidence from our engagement indicated that there was a real demand for high-performing zero emission vehicles now, as end users and their supply chain look to decarbonise well before government mandated requirements.

Understanding use cases and vehicle requirements

Several operators representing operations in timber, construction, wholesale food and drink, utilities and general logistics including project partner NewCold were engaged to understand real world duty cycles and applications of 44t freight vehicles. Vehicle daily range varied with the 75th percentile being around 350 miles per day. Applications were also varied, ranging from use cases maximising volume payload such as curtain-sided haulage, to applications which were weight limited, and as such, did not utilise the full volume available for an articulated lorry

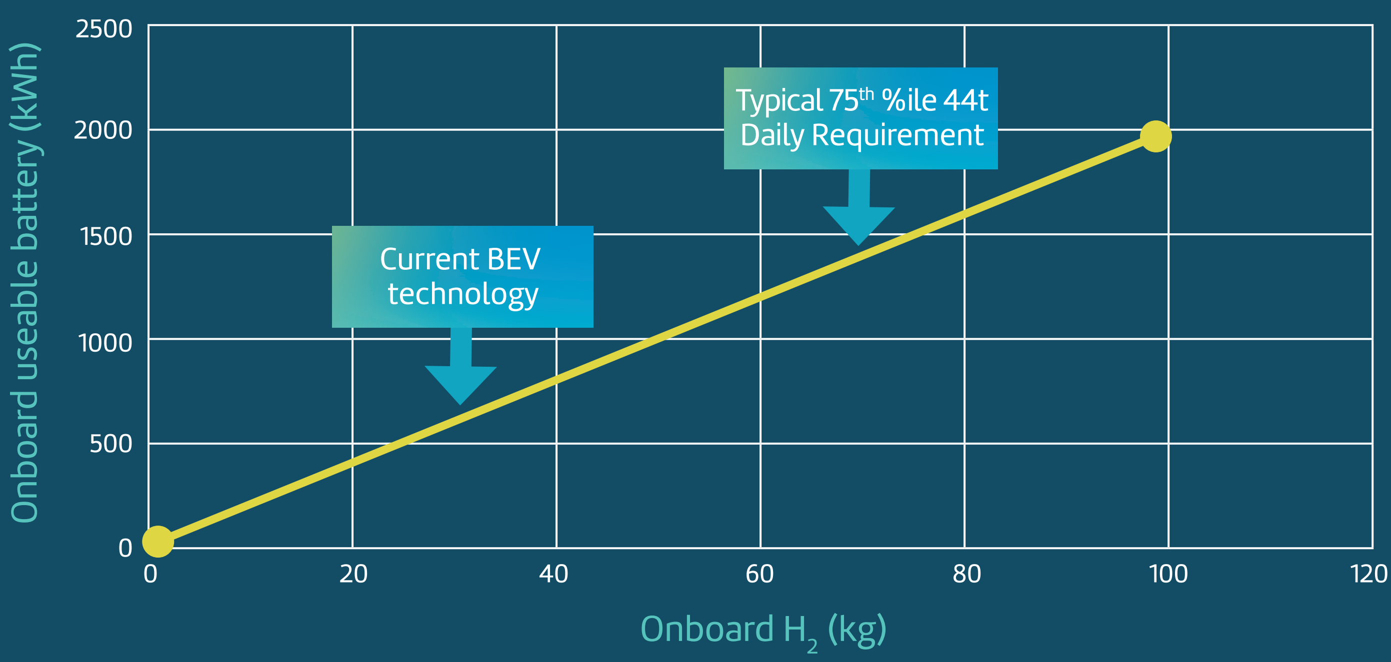
Required FCEV Architecture

Using vehicle data from tracking systems we carried out detailed modelling and simulation of the power and energy demand on vehicles for the different real-world use cases. Our modelling indicates that 75% of daily duty cycles can be executed by a hydrogen truck with 70-80kgs of hydrogen. By way of comparison to BEV vehicles, this is equivalent to around 1500kWh of battery capacity using the same real-world analysis, well surpassing proposed vehicle concepts and representing a significant payload loss owing to the weight of batteries.

On the other hand, a 44t FCEV product with less than 40kgs of hydrogen is unlikely to offer hauliers significant benefit over BEV as intermediary refuels will still be required 'mid-shift'. While this refuelling is still quick, our study proposes that the target and key point of differentiation for hydrogen FCEVs should be to provide a full daily shift between refuels.

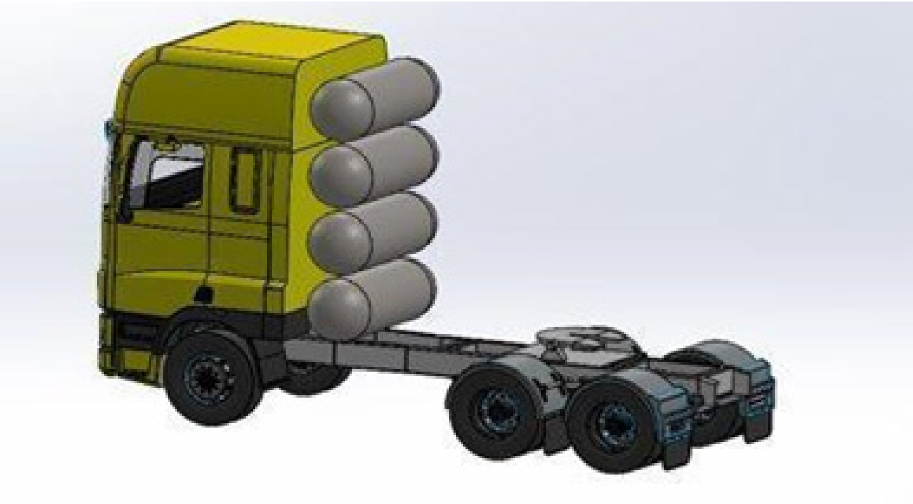
The FCEV powertrain uses a hybrid of small capacity/high power battery and fuel cell to propel the vehicle. For full performance the battery must provide peak power demands for acceleration and hill climbs while the fuel cell must be able to provide sufficient power to sustain motorway speeds for significant durations. For a laden 44t vehicle this required around 100kWh of battery and a 250kW fuel cell. To provide 80kg of hydrogen storage to fulfil at least 75% of duty cycles in a reasonable packaging space it is necessary to use 700bar hydrogen storage tanks and corresponding refuelling systems. There are limited refuelling stations in the UK. Those that we have are unable to provide high volume high pressure refuels required for the above.

BEV vs FCEV Energy Equivalence



Concept design for a fully performing vehicle

We developed a design concept for a vehicle that would deliver the expected performance with fuel cell, hydrogen storage, cooling systems and battery components all placed in the existing engine bay, in the chassis rails or behind the cab. The image below is a 44t concept vehicle with 700bar hydrogen tanks.



The study concluded that 44t FCEV with 250kW fuel cell, 80 kg of hydrogen and 100kWh of battery is feasible, however a number of these technologies are either not widely available in the market or not mature. This includes a suitably sized fuel cell, integrated multi-speed e-axles and high-volume 700bar refuelling infrastructure. While there are clear technology roadmaps for these elements, with the development and testing required by developers and OEMs, a fully performing vehicle is unlikely to be commercially available until 2025 at the earliest.

Additionally, when packaging up the equipment, particularly the hydrogen storage, more space is required compared to a conventional diesel vehicle. This proved to be challenging as the existing tractor unit has been designed to maximise payload, so there is very little space left to work with.

Our findings showed that payload volume would need to be reduced unless a derogation in the 16.5m length regulation is obtained (thought unlikely). The space behind the cab is required to be given up to new components, and full-length trailers would require to be shortened. This would be more than 1m for 350 bar hydrogen storage but can be reduced if 700 bar hydrogen storage is used as in our concept design. This length reduction means that there is likely to be a compromise for applications which presently utilise the maximum allowable vehicle length and shorter trailers would have to be used. Also, careful design is required to ensure that maximum axle loadings are not exceeded.

In the long term this challenge may be addressed by using liquid hydrogen storage, but there is currently no supply of green liquid hydrogen in the UK and the refuelling infrastructure is at an early development stage, so this was discounted.

250kW FUEL CELL

700bar HYDROGEN TANKS

Comparable daily performance to current diesel alternative.

100kWh BATTERY

80kg/day HYDROGEN

Roadmap to 44t Vehicles

There are several OEMs developing heavy duty FCEV vehicles in the UK at present, however it is thought unlikely that these will be fully operational on a 44t GVW until at least 2025 and not available from the major OEMS until 2028. However, there are alternatives that can be explored in the meantime to develop understanding of hydrogen FCEV vehicles in operation. Some start-up OEMs and integrators are developing 18-26t GVW rigid heavy goods vehicles and refuse collection vehicles which should start becoming available from 2023. In addition, we have also developed a concept for a 26t tractor unit which uses lower power, and less hydrogen so can be more readily achieved with more mature technology. The image below is a 26t concept vehicle with 350 bar tanks, using technology that is available at present or in the next year. This tractor unit would be suitable for lightweight operations and shorter trailers, for example for urban delivery use cases. Ballard are actively pursuing opportunities to work with OEMs to bring these vehicle concepts to market.

Alternatively, 40 or 44t trucks could be available but with performance compromises such as limitations on range or sustaining motorway speeds. This would go some way to support infrastructure roll-out but does not necessarily demonstrate the key differentiating features of hydrogen FCEVs.

The conclusion of the study is that while fully performing 44t trucks are likely to be available later in the decade there are shorter-term vehicle options that can be used to develop infrastructure and experience with the technology as a pathway and roadmap to the deployment of full scale, fully performing 44t trucks.

Trial Design

Following the feasibility studies, the DfT are making £140m available for a funded project to help accelerate the uptake in FCEV. As required our study designed a 5-year trial that could be eligible to apply for this follow-on funding and we welcome discussion with operators and other partners who wish to be part of a trial.

Our approach includes:

- A vehicle designed to be able to carry out an entire day's duty cycle with refuelling at the beginning or end of shifts.
- Initial introduction of vehicles for niche applications aligning with technology capability and introducing fully performing vehicles as they become available.
- Refuelling infrastructure close to depots with a number of operators sharing a refueller and additional refuelling along routes to provide resilience.
- Vehicles provided on a lease potentially with fuel included as a package on a £/mile basis. Depending on the nature of the DfT funding it is envisaged that this will offer parity with the diesel equivalent.
- Vehicle maintenance support provided by vehicle suppliers and specialist fuel cell support from Ballard.
- Support and training for operators at all levels of the business.

Feedback

This paper was prepared as an extract of the main feasibility report, relevant to freight operators.
Should you have any feedback on its contents, require further information on anything contained, or you would like to show your support for the next phase of the funding, please contact Michael.Ward@ballard.com.

Ballard Motive Solutions is a leader in hydrogen and fuel cell integration, offering full powertrain assimilation capability to accelerate the adoption of fuel cell mobility.

Ballard Motive Solutions has established strong modelling and design capabilities that combine a deep understanding of the underlying electrochemistry with powertrain engineering expertise and validation from real-world trials across all transport sectors.

Working with leading OEMs, fleet operators and authorities to meet zero-emission targets, Ballard Motive Solutions' complete systems decrease complexity and development time for fuel cell electric vehicles, increase production volumes, and lower cost and time-to-market.

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