HGV Energy Infrastructure Opportunities and Challenges

Contents

Abbreviations

The following is a list of abbreviations and associated definitions for terms appearing throughout this document:

Abbreviation	Definition
BET	Battery Electric Truck
Bio- (as a prefix, e.g. to "LNG")	A type of the prefixed fuel that is derived from organic matter (biomass), not fossil sources.
CET	Catenary Electric Truck
CNG	Compressed Natural Gas
EU	European Union
ERS	Electric Road System
FCET	(Hydrogen) Fuel Cell Electric Truck
Fuel Cell	A device that reacts stored hydrogen with oxygen from the air to provide electrical power
GHG	Greenhouse Gases
ICE	Internal Combustion Engine
HDV	Heavy Duty vehicle – road vehicle over 3.5T, e.g. HGV, buses, coaches and 'vocational' vehicles such as gritters, refuse collection vehicles
HGV	Heavy Goods Vehicle
LCF	Low Carbon Fuels
LNG	Liquefied Natural Gas
MCS	Megawatt Charging System
OEM	Original Equipment Manufacturers
RTFO	Renewable Transport Fuel Obligation
R&D	Research and Development
SME	Small and Medium Enterprises
SPV	Special Purpose Vehicle
TCO	Total Cost of Ownership
UK	United Kingdom
ULEV	Ultra Low Emission Vehicle
ZETs	Zero Emission Trucks
ZERFT	Zero Emission Road Freight Trials

1 Introduction

1.1 Purpose of this paper

The purpose of this paper is to develop a common level of understanding amongst Taskforce members of the key infrastructure challenges and opportunities pertaining to the delivery of a zero emission HGV fleet in Scotland. In summary, the paper:

- provides an overview of the current fuelling infrastructure model for HGVs in Scotland
- outlines the different components and types of infrastructure needed for future zero emission HGV fleets;
- sets out progress to date with respect to investment in Scotland's zero emission HGV infrastructure;
- Summarises commitments being made in other countries
- outlines the barriers that need to be overcome to be able to deploy the infrastructure required; and
- identifies opportunities for how such barriers could be overcome.

The Taskforce are invited to take a view on the following questions:

On route energy infrastructure

➢ To what extent is the availability of on route charging/ refuelling a key enabler of change?

➢ If it is a key enabler, what are the decisions that need to be made, and in what order, to ensure appropriate recharging/ refuelling across Scotland?

As a part of this discussion, you may wish to consider

- What does the supply pipeline look like – when do OEMs expect BET and FCET to become commercially available at scale?
- Are ZETT members aware of private sector investment into HGV refuelling/ recharging that is not represented in the papers?
- What additional data is required to make decisions and does it exist already? Are there pieces of work we wish to be commissioned?
- Are there key dates or deadlines to be aware of in addition to the new sale phase out dates?

➢ How can the draft energy infrastructure map be improved and used to drive change?

Depot energy infrastructure

➢ Are operators doing detailed work to prepare for putting in depot recharging/ hydrogen refuelling, including speaking to DNO/hydrogen producers? If not what is preventing them from doing so?

As a part of this discussion, you may wish to consider

- Do operators have access to sufficient basic information? If not, what do they lack?
- Is there confidence in where to get specialist support in planning for infrastructure (eg load management to reduce network connection costs for EV)?
- Are operators waiting for vehicles to become more available?
- Are operators open to sharing depot infrastructure in their vicinity, eg smaller operators with the public sector?
- Are workers and decision makers able to acquire the appropriate skills and knowledge they need?

➢ What are the most effective ways of matching supply and demand as Scotland's hydrogen production builds capacity?

1.2 Definitions and Assumptions

Zero-emission HGVs are defined as HGVs that have zero tailpipe (pump to wheel) greenhouse gas emissions at point of use. Embodied emissions associated with the creation, maintenance and disposal of vehicles, infrastructure and the production and distribution of energy (well to pump) are recognised as being important but are outside the scope of the Taskforce.

This Paper focuses on infrastructure requirements for the three technologies expected to contribute to the decarbonisation of trucks – Battery Electric Trucks (BET), Hydrogen Fuel Cell Trucks (FCET) and (to a lesser extent) Electric Road Systems (ERS).

1.3 Methodology

A mixed methods approach has been used to generate the evidence base for this paper. An initial review of published reports and policy positions was supplemented by interviews with representatives of selected stakeholders involved in the freight and logistics sector. Information from interviews has been anonymised where this is not already in the public domain.

2 Overview of current fuelling infrastructure model

2.1 Fuel station types

Currently, the favoured fuel type for HGVs in the UK is diesel, with HGVs using a mix of depot refuelling, HGV specific refuelling stations and standard fuel pumps at basic refuelling stations (where access for HGVs is available).

We were unable to ascertain from market research and stakeholder engagement the exact proportionate split between the different refuelling methods, but the National Grid has predicted 70-90% of future refuelling to take place at depot and this is in line with our stakeholders expectations for present refuelling.[1]

For HGV specific refuelling sites, there are currently two main types of operating model:

- **Bunkering HGV refuelling commercial sites –** refers to bulk fuel that has been purchased by a company for their own fleet's use. HGV operators are able to purchase fuel in bulk, as well as purchase options or undertake fuel trading.

Generally, a company will store and dispense the fuel itself and have access to refills from varying commercial sites, depending on the bunker fuel supplier. There are currently 70 bunkering fuel sites across Scotland.[2]

- **Non-bunkering HGV service station sites** – refers to fuel that is purchased from fuel stations on a pay as you go basis or with a fuel card membership with discounted prices. There are currently 8 stations that have non bunker fuel services across Scotland.[3]

2.2 Refuelling requirements

Information from stakeholders reveals that refuelling a diesel truck takes between 15-30 minutes, and that - dependent on HGV size and efficiency of pumps at truck stops - between 2-4 trucks can be refuelled per hour.

National Grid led analysis has predicted and modelled the charging profile of the UK's HGV fleet, assuming that 70-90% of HGVs will be charged or re-fuelled overnight in their depot or at their destinations. For the remaining 10-30%, this will need to be delivered on-route, given HGV drivers are legally required to stop for 45 minutes every four and a half hours.[4] These refuelling requirements corroborate with the information provided from our stakeholder interviews.

2.3 Lifespan of stations

A diesel fuel station can have a prolonged lifespan so long as continual maintenance is undertaken on the machinery and aspects of the infrastructure are replaced. An overground fuel tank will have a lifespan of 20 years with maintenance, whereas an underground fuel tank (the favoured option in Scotland) will have a life-expectancy of 20 years without maintenance before a replacement is required.[5] Pumps require replacement every 10 years.

2.4 Regulatory requirements

An operator of a refuelling equipment must apply to the Scottish Environment Protection Agency (SEPA) for a permit allowing unloading of petrol into storage and motor vehicle refuelling at service stations. SEPA will notify the Petroleum Licensing Authority of the application for a permit for a service station. The Petroleum Licensing Authority exercise controls over service station equipment design, construction and operation and conditions must be met to receive a permit. These conditions can be found in Process Guidance note 1/14(13) within the Department for Environmental and Rural Affairs.[6]

3 Current HGV decarbonisation infrastructure

3.1 Introduction

The infrastructure required to support a zero emission HGV fleet is still at the early stages of deployment within Scotland and globally. An overview of the associated infrastructure for BET, FCET and ERS is provided in the following sections.

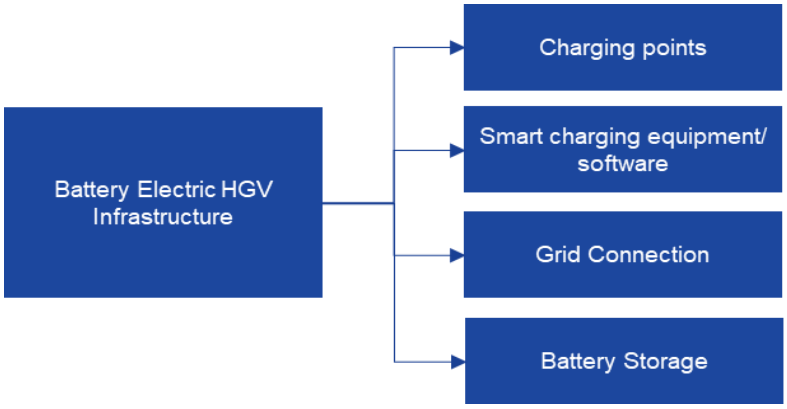
3.2 Battery Electric Trucks (BET)

Required infrastructure components

The infrastructure needed for battery electric HGVs is comparable to that of a battery electric car or van, however the power dispensing capability must be greater, due to the size of the HGV battery. HGVs require 150kW chargers at a minimum, as a BET would take 10 hours to recharge from empty to full using a 43kW charger or 2 hours if a 250kW were utilised.[7] Hence more powerful charging infrastructure i.e. 1MW+, will have to be in place at many public charge sites and some depots to ensure the recharge of electric HGVs can take place in a timely manner, suitable for business and operational needs.

The components needed to service and operate an electric charge station are provided in figure 1.

Figure 1 – BET charging infrastructure



- **Grid connection** - a sufficient grid connection is necessary to allow for the power output of the charger(s) to meet the necessary levels to deploy rapid charge capabilities to an HGV. Whether a grid upgrade will be required will depend on an area's grid capacity and the power supply of the area and these costs can vary drastically. Also, at present the DC (direct current) charging points required to deliver a charge above 44kW are approximately 5-6 times more expensive than AC (alternating current) chargers, which cater for the slow charging small vehicle end of the market.[8]
- **Smart charging equipment/software** – This is required to safely balance the energy usage between BETs charging at the station and other appliances on-site. This ensures the most efficient charging of a BET based on the available power capacity. This is particularly important in areas where the power capacity of the grid in an area is constrained and may negate the need for a grid upgrade.

- **Charging points** –deliver the power from the grid to the vehicle. These vary in power output and capability and as the power dispensing capability increases so does the price, starting at c.£20,000 for a single 150kW charger (sourced from market engagement) and going up to over £680,000 for a 2.5MW charger with the capability to charge over 10 HGVs at once.[9] The larger capacity cables often need to be cooled and are heavier than the lower power equivalents. There is no universal charger connector for HGVs and cars at the moment, however the two most common connector types for HGVs and cars are outlined in appendix 1.
- **Battery storage** – these are devices that enable energy from power supplies to be stored and then released when customers need power most and reduce the required grid connection. This is an optional component but can provide efficiency and cost savings in areas of low grid capacity or points of peak electricity prices in the day.
- **Regulation and permitting –** Charging providers in motorway services and service stations who are supplying electricity are not required to hold a supply licence.[10] However, recharging services must adhere to the Alternative Fuels Infrastructure Regulations 2017 stated by the Office for Product Safety Standards.[11]

Overview of current available infrastructure in Scotland

Figure 2 below outlines that Scotland is leading the UK roll out of ultra-rapid public chargers (capable of recharging BETs) per 100,000 people. These existing charge points were not necessarily designed for BET usage (given the current early stage of vehicle availability) and may not have the appropriate accessibility requisites such as bay size, height allowance, cable length and appropriate turning circle and space to manoeuvre to allow for HGV charging.

Figure 2

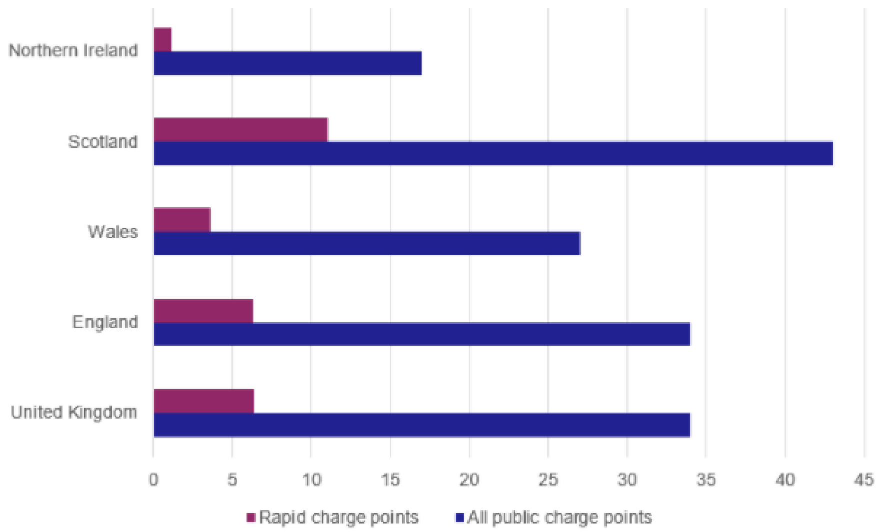


Figure 2. Public electric vehicle charge point per 100,000 population by UK and region (April 2021) – Source: Electric vehicle charging device statistics: April 2021

Forecasts of future requirements

Transport Scotland have produced a paper outlining the energy demand for future BET; however, this does not provide an assumption on the number of chargers required to recharge HGVs or refuelling stations to refuel HGVs. Industry assumptions are that between 0.3 and 0.85 charge points functioning at 150kW or above are needed per battery electric HGV (when there is an electric element in the drivetrain). [12]

Therefore, if the entire 35,000 HGV fleet were to be battery electric going forward Scotland would require between 10,500 and 29,750 150kW or above electric vehicle chargers to support the fleets operation. It is unlikely the full fleet would be BET but the figures provided are to indicate scale. (Further information is provided within appendix 1).

Planned infrastructure investments and policy commitments

Industry and stakeholder engagement suggests that there are no publicly announced / planned BET charging infrastructure projects in the pipeline specifically for Scotland or any policy commitments specific to rolling out HGV recharging services.

The Scania, MAN, Daimler, and Volvo Group agreement referenced at section 3.5 will include the UK but details are not yet available.

New UK wide government funding is on the horizon in the form of a Rapid Charging Fund (RCF) (£950m) but this does not currently extend to HGVs. The second phase Zero Emission Road Freight Trial (ZERFT) is looking to provide funding to assist in the roll out of zero emission HGVs and the corresponding infrastructure.[13] It is possible that future trial funding will support the formation of a public HGV charging network, as well as provide those who receive investment with the necessary onsite charging facilities.

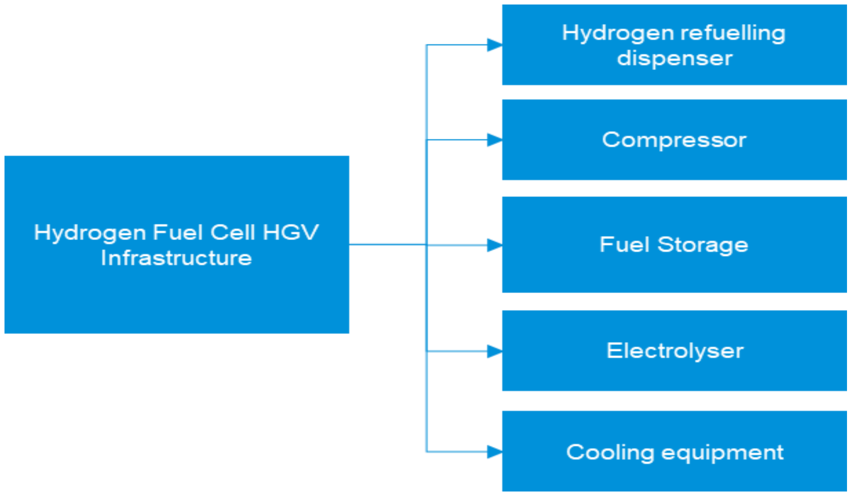
A National Grid report stated that by expanding the RCF to cover all road transport the UK Government could deliver enough capacity for on-route HGV charging and hydrogen re-fuelling at up to 78% of motorway service areas in England. It also states that a small marginal cost increase of 3%-16% to the RCF could provide enough grid capacity to cover 100% of on-route HGV charging and hydrogen re-fuelling – with potential to realise cost savings by coordinating with the ZERFT.[14]

3.3 Hydrogen Fuel Cell Electric Truck

Required infrastructure components

Hydrogen refuelling for the consumer is the closest comparable to petrol or diesel refuelling in terms of refuelling time taken and is between 15-30 mins from parking the HGV to leaving the station. However, the refuelling infrastructure is far more sophisticated and requires cooling and compressing of the fuel into a high-pressure or cryogenic tank to ensure safe storage. The components needed to service and operate a hydrogen fuel station are provided in figure 3.

Figure 3 – Hydrogen (FC) HGV refuelling infrastructure



- **Hydrogen refuelling dispenser –** the component that delivers the hydrogen from the fuel tank into the vehicle. The total cost of installing dispensers will usually depend on the size of the refuelling site and the number of dispensers installed.
- **Compressor -** a device that increases the pressure of hydrogen by reducing its volume resulting in compressed hydrogen or liquid hydrogen moving through the dispenser.
- **Fuel storage –** a high pressure cooled tank to store hydrogen at cryogenic temperatures is required to ensure the hydrogen remains liquid.
- **Electrolyser -** an apparatus that produces hydrogen through a chemical process (electrolysis) capable of separating the hydrogen and oxygen molecules of which water is composed using electricity.
- **Cooling equipment –** a cooling module is used for the thermal management of the hydrogen stack and ensures the stability of the hydrogen.
- **Regulation and permitting –** anyone engaging in hydrogen supply must have a license under the Gas Act 1986.[15] Hydrogen refuelling services must adhere to the Alternative Fuels Infrastructure Regulations 2017 stated by the Office for Product Safety Standards.[16]

Overview of current available infrastructure of Scotland

There are currently four hydrogen refuelling stations available for public use in Scotland. Two are in Aberdeen, one is in Orkney, and one is in the central belt, outside of Edinburgh. The UK has 14 hydrogen stations operational open to the public and the most northerly English station is situated in Teesside.[17] The hydrogen station in the central belt allows drivers to make the trip from England to the North of Scotland using a hydrogen vehicle which was previously not possible due to the lack of refuelling infrastructure between England and Aberdeen.

Forecasts of future requirements

Much like diesel, hydrogen refuelling stations will be needed along routes which expect to service HGVs and other heavy-duty vehicles. Based on research by the European Automobile Manufacturers Association, for areas with high traffic volume one truck-specific hydrogen site should be available for every 200 kilometres of road and should have a daily capacity of at least six tonnes of H2 with a minimum of two dispensers per station.[18] In areas of lower traffic volume it is expected hydrogen stations should be located at a maximum of every 300km of road.[19]

The main trunk road network in Scotland which services 60% of heavy goods traffic is 3,507 km, therefore if the assumption of a refuelling station every 200 km is adhered to 18 hydrogen stations would need to be in operation across the trunk roads.[20] However to service remote areas of Scotland a higher number of hydrogen stations would be required for full fleet operations. Further information is provided in Appendix A on a full fleet transition to hydrogen.

Known planned infrastructure investments and policy commitments

Element 2 is considering investment in a two-acre site in Bridge of Don in Aberdeen which would support up to six pumps capable of dispensing up to three tonnes of hydrogen fuel per day. The firm has plans to invest £1 billion over the next ten years in rolling out a hydrogen refuelling network which will comprise 2,000 pumps across the UK, including more than 250 in Scotland over the next six years, increasing to 300 by 2030.[21]

The Scottish Government has announced £100 million of funding towards the development of hydrogen and the hydrogen economy in Scotland over the next five years.[22]The Scottish government will co-design a framework for and establishing a network of hydrogen multi-modal refuelling stations to support the adoption of hydrogen vehicles across all appropriate modes of transport.

3.4 Electric Road Systems (ERS)

Required infrastructure components

The ERS is when an HGV is supplied charge while travelling on the road and requires overhead lines (catenaries) such as those seen for electric railways and trams, or conductive or inductive tracks where coils or tracks are embedded in the road and charge is dispelled to the under carriage of the vehicle. However, ERS vehicles will still require a battery or alternative powertrain to power the vehicles when they are operating off the network. The components needed to service and operate an ERS are:

- **Electric road operation subsystem–** this component controls the energy management of the overall system, provides user information and handles payment and billing. This subsystem also handles access and lane control of the road based on vehicle identification.
- **Vehicle subsystem –** a component that converts the power from the power transfer subsystem into either propulsion of the vehicle or to energy storage.
- **Power transfer –** power transfer subsystem is divided into three components: road power transfer, vehicle power transfer and control. The road power transfer component consists of in-road and/or roadside equipment that handles detection of the vehicle and transferring of power from the road. Vehicle power transfer controls safe activation and operation of a power receiver, and measures transferred energy after successful acknowledgment. The control component monitors the energy handover and system operation.
- **Road subsystem -** consists of pavement, barriers and auxiliary components. The pavement includes the actual structural body and road markings. Barriers

includes both safety and noise protection components. Auxiliary components are road signs and other necessary roadside components.

- **Electric supply –** consists of transmission, distribution and management components. Transmission includes how the electric power flows from the generation sources over long distances. Distribution is how the power flows through a grid to the power transfer subsystem. The management component controls the operation and balance the energy.

ERS would require an interlinked roll out of ERS across the UK and Europe to ensure Scottish ERS HGVs could operate effectively across the UK and overseas.

Overview of current available infrastructure of Scotland

There is currently no operational ERS in Scotland however a pilot study is taking place within the UK to understand the feasibility of ERS in a real-world operating environment. More information is provided within section 3.5 on this pilot study.

Forecasts of future requirements

Academics from the Centre for Sustainable Road Freight, a joint project between Cambridge and Heriot-Watt universities, found that building a network of overhead catenary cables along 7,500 km of the UK's major road network would electrify approximately 65% of HGV kms, at an estimated cost of £19.3billion.[23]

Known planned infrastructure investments and policy commitments

An ERS backed with £2m of funding, will draw up plans to install overhead cables on a 20km (12.4 miles) stretch of the M180 near Scunthorpe, in Lincolnshire.[24]

3.5 Zero Emission HGV Commitments in Europe

Overview

From 2025 on, manufacturers will have to meet fleet-wide average CO2 emission reductions for their new lorries. The targets are expressed as a percentage reduction of emissions compared to EU average in the reference period (1 July 2019–30 June 2020); from 2025 onwards: 15% reduction; and from 2030 onwards: 30% reduction.[25] This is to culminate in all new trucks to be fossil-free by 2040 and carbon neutrality by 2050 for operating HGVs.[26]

There is limited information on commitments on HGV infrastructure, the majority of publicly available statements refer to projections and forecasts as opposed to concrete plans and commitments. Some of the major commitments have been highlighted below.

The European Union is developing regulations around the deployment of alternative fuels infrastructure (AFIR), including for HGVs on the TEN-T network.

BEV

Charging infrastructure for battery-electric trucks has been the subject of several OEMs announcements over the past couple of years. Scania, MAN, Daimler, and Volvo Group have arranged a non-binding agreement that lays the foundation of a joint venture to deploy more than 1,700 charging points in Europe, investing more than 500 million euros.[27]

Hydrogen

bp and Daimler Truck AG have announced plans to work together to help accelerate the introduction of a hydrogen network, supporting the roll-out of a key technology for the decarbonization of UK freight transport. They intend to pilot both the development of hydrogen infrastructure and the introduction of hydrogen-powered fuel-cell trucks in the UK and Germany.[28]

Shell will set up a suitable infrastructure for hydrogen supply network for Daimler, mainly targeting liquid hydrogen supply for the GenH2 truck with mass production taking place across Europe from 2027.[29]

ERS

Wood transportation experts are currently involved in the Catenary Cable System Demonstrator Feasibility Study, as part of the £20 million UK Government Department for Transport funding boost to accelerate the rollout of zero-emission road freight, being delivered by Innovate UK. The consortium (City Science, Wood, Oxfordshire County Council, Furrer + Frey GB and the University of Exeter) will examine the feasibility for an ERS demonstrator on appropriate sections of trunk roads and/or motorways in Oxfordshire.[30]

There are also ERS operating in Sweden and Germany operating trucks built by Sweden's Scania and electric technology from Germany's Siemens.[31]

4 Challenges with deploying infrastructure

4.1 Summary of Challenges

The literature review and engagement with stakeholders revealed some challenges with the deployment of infrastructure to support a zero emission fleet. The majority of these were summarised in the previous background paper Industry overview and SWOT. However, a summary table is provided below, with additional detail provided in Appendix 2.

Table 1 - Summary of challenges

Challenges	Description
Vehicle demand and availability	There is a lack of clarity in the demand and availability of different HGV fuel types and hence a lack of demand for the corresponding infrastructure necessary to service it.
Infrastructure costs / lack of investment	There is a lack of clarity on the cost to purchase, construct, and operate decarbonised refuelling infrastructure.
Land use and refuelling location	The lack of infrastructure utilisation at present and the difficulty to project the future HGV fuel mix and therefore the corresponding demand for different fuel type infrastructures makes selecting sites difficult.
Total cost of ownership	The cost to not only purchase but maintain and operate the new decarbonised refuelling infrastructure is a barrier to entry in the market.
Owner-occupier fragmentation	The high level of owner-occupied HGVs in Scotland makes investment in private infrastructure more difficult as there is less opportunity to experience economies of scale.

Technological limitations	The current limitations in technology such as battery and charging capacity, as well as hydrogen vehicle range and cost projections, and the uncertainty of future progress in these areas has led to a slow uptake in the deployment of infrastructure.
Regulations	A lack of standards for on-route HGV refuelling options has made infrastructure investment too risky ahead of wide scale vehicle roll out.
Skills	There is currently a gap in the skill sets required to operate and maintain the infrastructure necessary to service decarbonised HGVs at depots and on the public network.
Fuel supply	There is a lack of hydrogen supply to power HGV decarbonised fleets and hence this lack of supply has created a delay in the roll out of the necessary infrastructure to dispense it.

5 Opportunities to overcome challenges

5.1 Summary of Opportunities

Opportunities to overcome some of the challenges are summarised in Table 2, with additional detail provided in the following sections.

Table 2 - Summary of opportunities

Opportunity	Description
Private investment	Private investors have started to combine forces and develop joint initiatives/ventures such as EV Network and bp Pulse and Hyundai and H2Energy to build out zero emission vehicle infrastructure.
Demand aggregation	The coordination and deployment of zero emission vehicles and infrastructure through improved market insights in vehicle and infrastructure demand based on desired use cases.
New infrastructure models	The utilisation of different commercial and business models to aid in the deployment of infrastructure i.e. shared ownership or revolving fund models, or partnership initiatives.
Public funding initiatives	The utilisation of different government funds to support the upfront capital costs of transitioning to a decarbonised fleet.
Technological solutions	Improved technological solutions such as 1MW chargers, mobile chargers and hydrogen refueller pods have improved the functionality of fuel types and improved demand aggregation of technologies.

Scottish business opportunities	Scottish businesses could overcome the challenges for the deployment of zero emission vehicle infrastructure by leveraging already existing footholds in the market and build out the capabilities further, such as carbon innovation schemes at the Michelin Scotland Innovation Parc or Scottish Biofuel programmes.

5.2 Private investment

BET

Producers of EV infrastructure will be at the forefront of deploying chargers throughout Scotland and for this to be effective and sustainable they must work together to ensure uniformity in charging capabilities and functionality. This will help define a consistent technology and negate the need for stipulated regulation and standards from the government as technology and infrastructure providers are taking the responsibility. Some examples of where this has occurred previously are:

- The EV Network and bp pulse combined forces in 2021 to develop a new UK network of rapid and ultra-fast e-forecourts and hubs that are suitable for supporting electric vans, which could lead the way for wider infrastructure suitable for trucks. Siemens has also tied up with Digital Charging Solutions to ensure agnostic products for all drivers are being rolled out throughout the economy.
- Similar schemes are being run in the HGV charging market with Traton, Daimler and Volvo signing a joint venture agreement to operate a public charging network for battery electric, heavy-duty, long-haul trucks, and coaches across Europe.[32]
- Fleet support will continue to expand and evolve as vehicle technology develops. For example, all new warehouse operations invested in by DHL (early adopter of the UK's first 16-tonne EV) are being proactively prepared for EV charging infrastructure, and as this becomes more commonplace across retail the roles that electric trucks are suitable for will diversify: charging while loading or unloading via electric hook-up or even wirelessly.

FCET

Possible solutions will have to come in a variety of forms and a mixture of different types of delivery models which will help spur on investment and reduce initial capital outlays for operators to ensure the fastest roll out of infrastructure and vehicles. Examples are:

- Hyundai has formed a joint venture with Switzerland based H2Energy, which coordinated the search for a truck manufacturer to deliver hydrogen trucks and associated refuelling infrastructure in Switzerland. The joint venture agreed to deliver hydrogen trucks to the Swiss market on a per km charge basis. This means truck operators do not need to pay high upfront capital costs and are guaranteed truck maintenance and fuel supply. This offer has proved very successful in Switzerland and the number of trucks under order increased several times, with over 1,600 hydrogen trucks to be delivered between 2020-2025.
- There are also initiatives in the form of refuelling infrastructure suppliers aiming to deliver the necessary public refuelling and recharging networks to service fleet operators, such as ITM Power agreeing a joint venture with Vitol Holdings in

March 2022 to enable the creation of further green hydrogen refuelling stations in the UK and accelerate the adoption of fuel cell vehicles.[33]

5.3 Demand aggregation

The aforementioned issue of lack of clarity in demand for different HGV fuel types can be overcome through coordinating deployments of vehicles and infrastructure, as well as setting a clear vision, and providing funding support for the different fuel types during the early stages.

Data collection will be critical to understanding real world refuelling and recharging behaviour and infrastructure reliability to enable deployment of vehicles and infrastructure throughout the transition.

5.4 Opportunities for new infrastructure models

There is an opportunity for private and public operators of zero emission infrastructure to go beyond sole ownership and leverage new ownership models to de-risk and accelerate the deployment of zero emission infrastructure. This will help de-risk investments and reduce the initial capital outlays for operators. The different ownership models have been outlined below.

- **Shared Ownership Model** - there is an opportunity to leverage relationships with local authorities or other recharging/refuelling infrastructure owners who are currently investing in decarbonised fleets and the corresponding infrastructure to service their public or private sector decarbonised fleets. By providing access to this infrastructure additional revenue streams for local authorities or private operators could be created and smaller HGV operators could benefit from lower upfront capital costs. An example of this could be HGV operators gaining access to the refuelling infrastructure being provided for the 19 hydrogen-fuelled refuse trucks going into operation in Glasgow City Council in 2022.[34]
- **Revolving Fund Model** - a principal financier (via a Special Purpose Vehicle / SPV) would provide capital for investment into charging/refuelling infrastructure (e.g. cost of grid connection). The SPV would do this on behalf of energy suppliers who would benefit from the developed infrastructure. The underlying premise is that energy suppliers benefit from the initial investment in infrastructure (as additional revenue is generated from increased energy demand from fleet operators, due to having the infrastructure in place already), and therefore can provide better deals to fleet operators for their energy use. This can generate proceeds to repay the SPV for the initial investment into the infrastructure and ensure fleet operators have access to affordable infrastructure.[35]
- **Partnership initiatives** - An option open to fleet and smaller scale HGV operators is to create partnerships across the HGV operator network to roll out the necessary infrastructure needed for the decarbonisation of HGV fleets. Sharing the costs proportionally of constructing, maintaining, and operating hydrogen, battery electric, or biofuel refuelling/recharging sites within private depots. Alternatively, a larger operator could construct the necessary infrastructure on the basis that smaller operators agree to use the facilities on a commission/pay-as-you-go basis. This could drastically reduce the initial capital outlay and overheads for operators and allow them to benefit from larger economies of scale and wholesale prices for fuel.

5.5 Public funding initiatives

Public funding initiatives can provide operators and HGV owners with support for the upfront capital costs of transitioning to a decarbonised fleet or make it more attractive for private finance to fill this role. They can also provide assistance with operating and maintenance costs, decreasing the cost disparity between diesel and decarbonised fleets and providing operators with the opportunity to transition earlier. There is currently much more wide-spread grant support for cars and private vehicles than specifically for HGVs, therefore increasing HGV and its corresponding infrastructure support is a future opportunity to aid in the deployment of HGV recharging/refuelling infrastructure. Below are some examples of UK wide public funding initiatives offered by governments:

Infrastructure grants

- Transport Scotland's Business chargepoint grant (delivered through Energy Savings Trust) covers up to 50% of the purchase and installation cost for SMEs in rural and island areas. The purchaser must operate EVs or provide proof of future ownership, or demonstrate that it will be used by visitors/ customers/ guests to be eligible for the grant.[36]
- The UK government has announced phase 2 of the Zero Emission Road Freight Demonstrators. This is to provide up to £140m of funding for zero emission HGVs and its corresponding infrastructure.[37]
- The UK Office for Zero Emission Vehicles has provided £23 million worth of funding and has signposted a further £100 million for the deployment and implementation of zero emission vehicles and refuelling stations.[38] This fund does not solely focus on HGVs but provides funding for all vehicle types.
- The UK Department for Business, Energy and Industrial Strategy (BEIS) has confirmed a £105m funding package to help industry, including the haulage, construction, quarrying, and mining sectors shift from fuels such as natural gas and red diesel to cleaner alternatives including hydrogen.[39]

Tax incentives

- Renewable Transport Fuel Obligation (RTFO) supports the UK's policy on decarbonising transport by providing a 100% fuel duty rebate for renewable fuels and hydrogen and stipulates that a 5% increase of fuels supplied by sustainable means must occur by 2032.[40]

5.6 Technological solutions

Technological limitations in the infrastructure for the fuel types are being heavily invested in and MW charging solutions are currently being tested in the UK with the goal being to develop new high-power charging standard for medium- and heavy-duty vehicles called the Megawatt Charging System (MCS). MCS offer fast-charging capability for large battery packs in 15-20 minutes at 1MW/h. The industry is now targeting 3.75 MW peak (3,000 A at 1,250 V). 1 minute at 3.75 MW is about 62.5 kWh, and - in 5 minutes - would be over 312 kWh. It is not clear when this technology would be available but hopeful estimates are within one to two years.[41]

SME owner-operators who do not wish to adopt a different business model such as leasing may wish to explore options other than installing their own infrastructure. Both public and private sector fleets are exploring the provision of charging / refuelling as an income generation opportunity and there are market needs and business opportunities for interim solutions including containerised battery solutions. Voltempo has trialled modular solutions including 1MW ultra chargers and scalable, modular hyperfast HyperCharging stations. This DC HyperCharging system can support up to 24 EVs and has the capability to support a full charge in approximately 6 minutes depending on the EV onboard charging support.

5.7 Scottish business opportunities

Some examples of how Scottish businesses are taking advantage of the new refuelling/recharging opportunities for green fuel types are provided below, along with measures being put in place to secure a footing in this vastly expanding market.

Hydrogen

- Scotland aims to become a leading hydrogen nation and has set a goal to generate 5GW of renewable and low-carbon hydrogen by 2030.[42] Hydrogen pump installations could create up to 100 skilled jobs from a partnership between Logan Energy, the Edinburgh-headquartered green power pioneer, and clean fuel specialist Element 2. The initial three-year agreement will see Logan design, manufacture, and maintain hydrogen refuelling stations on sites developed by Element 2, which plans to deploy some 800 pumps onto the UK network by 2027 and 2,000 by 2030. The partnership will triple Logan Energy's current headcount, creating up to 70 new roles over the next two years alone with further positions to follow by 2025.[43]
- Hydrogen manufacturing companies, Tokheim and Pure Energy Centre, provide a strong research and development ecosystem to fuel hydrogen mobility infrastructure and create the environment for further expansion in the hydrogen fuel cell and refuelling sector.[44]

Battery electric

- ScottishPower launched a public electric vehicle charging business as part of a £2 billion clean energy investment. Based within its retail division, the new business has installed slow and rapid chargers in over 6,500 strategic commercial locations across Scotland and the UK.[45] There is therefore an opportunity for expansion into the HGV market if the accessibility for these sites meets HGV requirements.[46]
- Investments will also target the digitalisation of the grid providing ground-breaking artificial intelligence systems that will control and balance the energy distribution across areas.

Appendix 1 – Background and technical analysis

Estimated infrastructure necessary to decarbonise HGVs

Table 3 – Summary of minimum infrastructure needs for full road coverage

Fuel scenario	Refuelling infra. required	Assumption
Entirely battery electric HGV fleet	10,500 - 29,750 x 150kW chargers	Between 0.3 and 0.85 150kW-350kW charge points per HGV *(it is likely larger charger capacities will make up the charger mix in the future as technology advances, but this is a minimal view)*
Entirely hydrogen HGV fleet	200 - 220 hydrogen stations	A refuelling site available every 200km - 300 km and a daily capacity six tonnes of H2 with two dispensers for areas with high traffic volumes
Plurality fuel mix	3,045 - 8,628 x 150kW chargers And 200 - 220 hydrogen stations	Assumptions based on section 6.3 plurality of fuel mix calculations

Introduction

- Deployment of new HGV fuelling/charging infrastructure is a substantial challenge and depends on a number of factors such as availability and skill-level of labour, financial capital, resource and material availability, planning permission processes, government policy and the market landscape.
- Currently there are 35,000 HGVs operating in Scotland all of different sizes and composition, from 3.5 tonnes to 44 tonnes.[47] All new HGV sales in the UK will be zero emission from 2040.[48]
- Research and analysis including stakeholder engagement suggests that the infrastructure required to decarbonise new fleets by 2040 could be delivered.[49]

Battery Electric

- A significant requirement for infrastructure for battery electric HGVs is the need for a higher proportion of recharging points per electric vehicle. This is in comparison to the lower proportion of refuelling outlets needed per vehicle for gasoline, hydrogen, or biofuels (due to these fuel technologies providing greater mileage range capacity). This is also due to the additional time taken to recharge a battery vehicle compared to refuelling a fuel cell vehicle. Currently battery electric vehicles tend to use chargers overnight or at other extended times when the vehicle is not in use due to the low power output of chargers.

Depot chargers (150kW)

- Industry assumptions are that between 0.3 and 0.85 charge points functioning at 150kW-300kW are needed per battery electric HGV (when there is an electric element in the drivetrain).[50]
- Therefore, assuming the entire HGV fleet were to be battery electric going forward, Scotland would require between 10,500 and 29,750 150kW or above electric vehicle chargers to support the fleet's operation. We are aware it is unlikely the full fleet would be BET but the figures provided are to indicate scale.
- This would require a roll out of between 620 to 1,750 electric depot and public chargers per year from 2023 to meet the necessary demand of 10,500 or 29,750 chargers by the 2040 decarbonised fleet deadline. It will also require the replacement of additional charge points due to a number of the deployed charge points reaching the end of their useful life during this time (charge point useful life is between 8[51] to 30[52] years). The large discrepancy in useful life assumptions is because a lot of this technology is still unproven. The main potential limitations for this roll out are:
  - the potential competition for supply with the light duty vehicle sector,
  - the financial capital required for investment, and
  - the lack of clarity in the plurality of fuel mix.

Public chargers (>350kW)

- Industry assumptions across Europe are that as charger capacities increase and public charge points and charge stations are deployed in greater numbers the following charge points should be available at each public charge station. The below table outlines the number and types of chargers that need to be deployed across different road network types up until 2035 to service the uptake in electric heavy duty vehicles.[53]

Table 4: Electric charging infrastructure[54]

Core road network	**1 July 2025**	**1 July 2030**	**1 July 2035**
Power out per recharging station	>5,000kW	>6,500kW	
Number / power of recharging points	4 x 350kW 4 x 800kW	4 x 1,200kW	
Support road network	**1 July 2025**	**1 July 2030**	**1 July 2035**
Power out per recharging station	>1,400kW	>3,000kW	>5,000kW
Number / power of recharging points	2 x 350kW	2 x 800kW	2 x 1,200kW
Parking areas	**1 July 2025**	**1 July 2030**	**1 July 2035**
Number / power of recharging points	2 x 100kW		
Urban nodes	**1 July 2025**	**1 July 2030**	**1 July 2035**
Power out per recharging station		>1,600kW	
Number / power of recharging points		All 150kW + 2 x 350kW	

Hydrogen

- Hydrogen refuelling is very similar to that of petrol or diesel and depending on the volume will typically take 15-30 minutes to finish refuelling and be back on the road. The fuel range of a hydrogen HGV is also equivalent to that of petrol or diesel at over 400km and hence the quantity of hydrogen refuelling stations to service the demand derived for fuel from HGVs is similar to that of petrol or diesel stations.
- Hydrogen refuelling stations will predominantly be needed along routes which expect to service HGVs and vehicles that require higher powertrain engines. Based on research by the European Automobile Manufacturers Association, one truck-specific hydrogen refuelling site should be available for every 300 kilometres[55] of road in areas of lower traffic volume and every 200km for areas of higher traffic volume.[56] Considering there is around 60,000 kms of road in Scotland, this implies a minimum of 200-220 hydrogen stations would be required to service a nationwide fully hydrogen Scottish HGV fleet, with a varying number of dispensers at each station dependent on the level of traffic.

Plurality HGV fuel mix

Market research and industry experts state that although battery electric HGVs are the cheapest and least polluting alternative for diesel in terms of infrastructure deployment and fuel consumption, their greatest issue is delivering the range offered by a conventional diesel engine.[57]

HGVs have come a long way with Mercedes[58], Nikola[59], and Volvo[60] delivering vehicle ranges of 186 - 250 miles for HGVs above the 25-tonne weight category.

To project a medium-term view of the possible fuel mix of HGVs in Scotland and the resulting impact on the necessary infrastructure, it is assumed that the mileage range capabilities of HGVs will drive the fuel mix.

If the current range of electric vehicles exceeds that of the average daily mileage of an HGV type it is assumed the vehicle will be electric. This report applies this assumption and the current mileage capacity for BETs to the information presented in table 5 below in order to project the different possible fuel mix of HGVs in Scotland. It therefore concludes:

- 80% of small and large articulated HGVs (over 25 tonnes) would need to be run on hydrogen and 20% would be run on battery electric (in total representing 35% of the total fleet) in order to achieve a fully decarbonised fleet.
    - The high-end delivery miles of small and large articulated HGVs exceed or run close to the mileage capacity of battery electric HGVs (250-miles). Achieving this maximum range using battery electric HGVs is also dependent on perfect weather and driving conditions.
- 100% of very large, large, and medium HGVs (7.5 tonnes and above) which is 43% of the overall fleet would likely need to be run on hydrogen because they are either extremely close to the mileage capacity of battery electric or exceed the mileage capacity of battery electric.
- 100% of small rigid HGVs (3.5 – 7.5 tonnes) which is 22% of the overall fleet would likely be run on battery electric as the battery electric HGV options have the sufficient range for the average daily mileage.

This is similar to the high uptake in hydrogen and low uptake in electric HGVs in the Transport Scotland National Demand Forecasts for Electricity and Hydrogen paper. However, not all HGV owners or fleet operators will be operating on routes of the stated mileage in table 5.

Also, some manufacturers are in the process of developing battery electric trucks beyond the ranges stated in table 5. This would inevitably change the plurality of HGV fuel mix for each HGV type, as it will change the proportion of dependence on hydrogen and battery electric, and allow operators/HGV owners to take a more tailored approach to their requirements/preferences.

- Therefore, the scenario outlined within this plurality of HGV fuel mix is based on the assumed use of hydrogen only where the average delivery miles per day exceed that of which a battery electric HGV could feasibly deliver based on current solutions. In actuality more factors will play a role such as future technology readiness, cost, human factors, and a number of other influencers that could create a variation from what is projected below.

Table 5: Breakdown of HGVs[61]

HGV Type	Proportion of overall fleet	Number of HGVs	Annual average delivery miles per day	Range of electric HGV as at 2022 (miles)	Number of assumed electric HGVs	Number of assumed hydrogen HGVs
Small Rigid (3.5- 7.5t)	22%	7,700	125 - 155	160[62] - 245[63]	7,700	0
Medium & Large Rigid (7.5-25t)	22%	7,700	155 - 205	160[64] - 186[65]	0	7,700
Very Large Rigid (Over 25t)	21%	7,350	155 - 217	125 – 186[66]	0	7,350
Small & Large Articulated (Over 25t)	35%	12,250	186 - 233 217 - 280	186[67] - 250[68]	2,450	9,800

Source: Element Energy (Note: % of the fleet was previously calculated using 2016 Transport Scotland statistics with the categories adjusted to match UK DfT categories. This has been updated to reflect the change in trends in the 2019 data in which there is a lower percentage of small rigid HGVS and higher percentage of very large HGVs.

- Using the assumptions and logic from the battery electric and hydrogen sections in this Appendix the number of HGVs for each fuel type has been estimated. The assumptions have been used in order to derive a high-level projection for the number of electric charge points and hydrogen refuelling stations needed to service this mixed fuel type fleet which has been outlined in table 3.
- The assumption for hydrogen stations is derived from the distance between each station and the size of the road network. The number of stations needed to service this smaller fleet will remain the same. This is due to the hydrogen vehicles ranging from large articulated vehicles to medium rigid trucks that will be able to operate on any road network and will therefore need an all-encompassing refuelling network. Hence, a minimum of 200-220 hydrogen stations would be required of varying sizes and dispensing capacity.
- In terms of charge points, the industry assumptions are that between 0.3 and 0.85 charge points are needed per battery electric HGV across both depots and public charging.[69] Therefore, with an estimated 10,150 electric HGVs in the projected fuel mix, Scotland would need between 3,045 and 8,628 ultra-rapid charge points (<150kW) to service the electric fleet.

Appendix 2 – Challenges with infrastructure delivery

Vehicle demand and availability

- There is currently a lack of clarity in demand for the exact (fuel) types of vehicles that fleet operators plan to invest in (and also how many) and the availability of these vehicles. This is due to a lack of clarity of the capability and functionality of the different fuel type HGVs and the different use cases each best fit. This creates a 'chicken-and-egg' problem as it's unclear how much infrastructure is needed, to what extent, and when. Leading to a level of reluctance amongst infrastructure investors and providers, due to the risk of sunk costs, and could lead to infrastructure that doesn't encompass the entire network.

Infrastructure costs / lack of investment

- A number of components have to be taken into consideration when costing new refuelling/recharging sites. These include the land for the site, the construction of the refuelling/recharging infrastructure, and the different refuelling components that go into each specific refuelling type. These costs can vary dramatically depending on the current local capacity of the grid, the location of the refuelling site, and whether or not the site needs reinforcement. For a fleet operator operating over 20 HGVs the cost estimates are provided below

  Hydrogen – refuelling infrastructure and upgrades to sites for hydrogen could cost between £1m and £2m.[70]

  Battery electric - the grid connection alone could vary in cost between £60,000 for an easily upgraded site to £2m, for a poorly located/ connected site.[71] An ultra-rapid charge point (>150kW) can range from £20,000 to £60,000, therefore a charge site could cost between £260k - £2.5m for 10x 150kW chargers.[72]

Land use and refuelling location

- Any EV charging provider needs access to a grid connection of suitable capacity combined with land and associated planning permission at a suitable location adjacent to the road network. For a public charging station there also needs to be suitable utilisation rates and therefore traffic.

Total cost of ownership (TCO)

- The TCO of a decarbonised fleet/HGV can be heavily inflated by the necessity to invest in infrastructure at a location and the maturity of road and energy infrastructure within the area.
- Hydrogen - The cost of maintenance for a hydrogen station is predominantly driven by the need to replace an electrolyser cell every 7 years which is 25% of the total capital purchase cost and can be between £40,000[73] and £200,000 depending on the capacity of the electrolyser.[74]
- Electric - The cost of maintenance for recharging infrastructure is mainly driven by the need to replace charge points every eight years, however future costs for charge points are forecast to decline, meaning this could be more affordable for operators when the time to renew does come.[75]

Owner-occupier fragmentation

- Unlike some other markets, Scotland and the UK has many thousands of owner-occupied HGVs.[76]
- Without a change to that status quo, many SMEs will be heavily reliant upon public or shared implementation of refuelling/recharging infrastructure and may therefore hold off investing in zero emissions vehicles until the necessary infrastructure is in place.

Technological infrastructure limitations

- Due to the expected size of batteries in HGVs the charging of vehicles at public stations will likely have a charging rate requirement in excess of the capability of the current charging infrastructure, and sites will require substantial grid infrastructure reinforcement. The two major connectors to date for charging infrastructure have the following limits:
    - CHAdeMO – Up to 150kW DC (@400V and 375A) (and potentially up to 400kW with CHAdeMO 2.0)
    - CCS – Up to 150kW DC (new charging infrastructure aims to provide charge at 800V and could go up to 350kW DC, e.g., Ionity).
- Currently the majority of chargers deployed throughout Scotland fall into the rapid (<150kW) and AC charger categories which are not sufficient to functionally charge an HGV in transit. A recent workshop conducted by National Grid with industry stakeholders found that any downtime from charging would have to be no longer than current refuelling times. This is to avoid loss of productivity or financial penalties from late delivery and maintain profit margins across the HGV sector as they tend to be tight.[77]

    - Hydrogen stations will require either an electrolyser onsite in order to produce liquefied hydrogen for vehicles or the distribution channels necessary to transfer liquid hydrogen to fuel tanks at refuelling stations. An electrolyser requires high initial capital cost and maintenance cost to replace the electrolyser cell every 7 years. Hydrogen distribution channels require either a pipeline connection or cooled fuel trucks to transport the hydrogen and costs. A pipeline connection is comparable in cost to diesel, however the new infrastructure needs to be constructed. Distribution costs for the same power equivalence of hydrogen[78] to one litre of diesel[79] is over five times the price of distributing diesel due to the compression costs and low density of the fuel.[80] However, these costs are projected to fall as higher density hydrogen production is expanded.

    - Both ways of procuring hydrogen results in its storage within cryogenic fuel tanks.

Regulations

- There is currently a lack of standards for on-route HGV refuelling options. On-route refuelling could be provided via a range of options such as high-speed chargers, Electric Road System (ERS) or 700bar hydrogen refuelling. However, without European wide standards, it is risky for a provider to install infrastructure ahead of wide scale vehicle rollout. Also, with some of the Scottish fleet undertaking cross-border journeys via EuroTunnel or RoRo, an equivalence and ability to re-fuel/charge in destinations is critical.

- Steps have been taken by the European Commission to counteract a lack of European wide standards and an evaluation of the Directive 2014/94/EU on the deployment of alternative fuels infrastructure (‘the Directive’). This has led to a proposal for a set of interlinked policy initiatives (including AFIR) under the ‘Fit for 55’ package. However, this policy needs to work in synergy with the Energy Performance of Buildings Directive (EPBD) and a number of other directives to ensure widespread uptake of these policy initiatives.[81]

Skills

- There is currently a gap in the skill sets required to operate and maintain the infrastructure necessary to service decarbonised HGVs at depots and on the public network. Engagement from stakeholders outlined that HGV operators will need to train or source staff with the necessary skills to operate and maintain the new types of infrastructure required to ensure the longest useful life, as they currently don’t have the skills inhouse. However a climate emergency skills development strategy is being developed alongside a skills academy at the Michelin Scotland Innovation Parc to plug this skills gap. There are also learnings that can be taken from the bus sector transition to zero emission vehicles.

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