Zemo Partnership
Accelerating Transport to Zero Emissions

Market opportunities to decarbonise heavy duty vehicles using high blend renewable fuels.

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Contents

Glossary

APC	Advanced Propulsion Centre
BEV	Battery Electric Vehicle
Bio-SNG	Bio-Synthetic Natural Gas
BSOG	Bus Service Operators Grant
BTL	Biomass To Liquid
CCC	Climate Change Committee
CNG	Compressed Natural Gas
CH_4	Methane
GVW	Gross Vehicle Weight
HBRF	High Blend Renewable Fuels
HEFA	Hydroprocessed Esters and Fatty Acids
HFC	Hydrogen Fuel Cell
HDV	Heavy Duty Vehicle
HGV	Heavy Goods Vehicle
HVO	Hydrotreated Vegetable Oil
LCEB	Low Carbon Emission Bus
LNG	Liquified Natural Gas
N_2O	Nitrous Oxides
NRMM	Non Road Mobile Machinery
RTFO	Renewable Transport Fuel Obligation
SMR	Steam Methane Reformation
WTT	Well-To-Tank
TTW	Tank-To-Wheel
WTW	Well-To-Wheel

Executive Summary

The Committee on Climate Change (CCC) recently published the 6th Carbon Budget highlighting that the UK will need to rapidly advance greenhouse gas (GHG) reduction to meet the net zero emissions target by 2050. This will require lowering emissions by 68% by 2030 compared to 1990 levels. Accelerating the decarbonisation of road transport emissions will play a critical role in achieving this ambition. Road transport is responsible for 24% of UK GHG emissions, with heavy goods vehicles (HGVs) contributing 20% of these[1]. The Renewable Transport Fuel Obligation (RTFO) has set the UK a road transport renewable fuels target of 12.4% by volume by 2032. More wide-scale adoption of high blend renewable fuels (HBRF) in heavy duty vehicles fleets could provide a technology-ready solution for helping to achieve the RTFO target and concurrently deliver sizeable reductions in road transport GHG emissions over the next decade. Longer term benefits could be gained from the continued decarbonisation of the legacy diesel HDV fleet.

This study explored the opportunity for HBRF to decarbonise heavy duty vehicles (HDVs) – HGVs, buses, and coaches over the next decade and beyond. The renewable fuels covered were biodiesel, hydrotreated vegetable oil (HVO) and biomethane – considering blends of more 20% renewable fuel content. The methodology entailed stakeholder engagement with biofuel suppliers, fleet operators, trade associations, vehicle manufactures and local authorities. A modelling exercise was undertaken to demonstrate how the roll-out of zero tailpipe emission HDVs could be complemented by HBRF deployment in terms of cumulative GHG emission savings between 2020 and 2050. The study has been framed around answering the three questions outlined below.

What is the current market uptake of HBRF in HDVs and what are the challenges precluding more wide-scale adoption?

To date, the greatest adoption of high blend biodiesel has been in the bus market (17% of the fleet). For biomethane and HVO, the highest deployment has occurred in HGV fleets (less than 1% of the fleet). Lack of wide-scale public refuelling infrastructure and the high cost of installing infrastructure at depots were the most frequently mentioned challenges for biomethane. For HVO and biodiesel blends above B20, higher operational cost than diesel was a recurring theme. Limitations in vehicle manufacturers' engine compatibility and warranty positions for high blend biodiesel was another key barrier raised. Stakeholders highlighted that demonstrating the business case for high blend biodiesel and HVO was difficult without any financial incentive in place, especially for SMEs.

Corporate carbon reporting was mentioned as motivating large companies to decarbonise their HGV fleets and contractors' fleets. Fuel cost savings, and short payback times, were factors encouraging operators to adopt certain biofuels, biomethane being the prime example. Stronger acknowledgement of the role of renewable fuels in decarbonising HGVs by Government was considered an important factor in giving fleet operators confidence in adopting them.

What are the key opportunities for decarbonising HDVs using HBRF over the next decade and longer term?

The greatest opportunity for deploying HBRF was identified to be in HGV fleets using back-to-base 'depot' refuelling. HBRF were considered to offer an immediate solution for mitigating GHG emissions from diesel HGVs during the transition to zero tailpipe emission technologies. They present an important route for decarbonising the legacy diesel fleet over the next twenty plus years. The next decade was perceived to offer highly valuable opportunities for fleet GHG savings. HBRF can deliver significant well-to-wheel (WTW) GHG savings in incumbent diesel and gas HGVs. Complete replacement of fossil fuels with RTFO-approved renewable fuels such as biodiesel, HVO and biomethane can achieve more than 80% GHG emissions savings[2]. The most compelling longer-term opportunities were identified as sustainable low carbon 'drop-in' liquid and gaseous fuels.

HBRF were perceived to be a beneficial decarbonisation option for several HGV segments that may find switching to battery electric vehicles (BEV) and/or hydrogen fuel cell vehicles (HFC) challenging in the near term, e.g., those with the heaviest payloads and/or travelling over high mileages (responsible for the highest proportion of HGV GHG emissions). Automotive industry roadmaps, such as the Advanced

[1] www.gov.uk/government/statistical-data-sets/energy-and-environment-data-tables-env#greenhouse-gas-emissions-env02

[2] www.gov.uk/government/statistics/renewable-fuel-statistics-2019-final-report

Propulsion Centre's HGV roadmap[3], indicate that mass adoption of zero tailpipe emission technologies will not materialise until after 2040 for long-haul HGVs, and that a portfolio of vehicle propulsion technologies and sustainable low carbon fuels will play a role in achieving net zero HGVs by 2050.

In the case of public transport, strong opportunities for HBRF were identified for coach fleets. They offer a near term decarbonisation solution given the lack of zero tailpipe emission coach products on the market and immaturity of public recharging infrastructure for electric heavy-duty vehicles and low carbon hydrogen refuelling. For bus operators whose focus is on shifting to full zero emission fleets in cities, the role of HBRF was less definitive. However, some benefits could exist for small bus operators and services involving rural routes.

Biomethane

Targeting biomethane use in long-haul gas truck fleets was identified as a prime opportunity, especially as the business case for fleet operators is apparent, with investment in vehicles and public refuelling stations growing. Key opportunities include retail, logistic and road haulage fleets. Producing biomethane from manure can result in significant GHG savings due to the capture of fugitive GHG emissions (methane and nitrous oxide) which would otherwise release to the atmosphere. This can result in biomethane production being carbon negative. Subsequently, net zero biomethane fuelled HGVs could materialise in the short term. In the case of buses, biomethane could continue to provide a decarbonisation solution for some operators, particularly those with out-of-town routes and access to a local biomethane supply.

Biodiesel and Hydrotreated Vegetable Oil

Key opportunities for high blend biodiesel and HVO arise in logistics, road haulage, construction, and quarrying/mining. HVO was considered to offer the widest deployment options due to it being a drop-in diesel replacement, lacking in vehicle engine compatibility constraints. HBRF offer coach operators with high mileage journey profiles attractive GHG savings given their large fuel usage. High blend biodiesel and HVO could offer cost effective decarbonisation solutions for small bus operators with long vehicle replacement cycles and those that serve rural routes, given the high upfront costs of BEV and HFC buses. Stakeholders also mentioned roles for high blend liquid biofuels in decarbonising non-road mobile machinery and in stimulating investment in sustainable aviation fuel production. Particular interest was raised for drop-in diesel replacements such as HVO.

Estimating potential GHG emission savings from deploying HBRF in HDVs

A modelling exercise has demonstrated the cumulative WTW GHG emission savings that could be achieved from 2020 to 2050 by a diesel HDV fleet switching to electric vehicles, with and without the concurrent deployment of HBRF using scenarios agreed with industry stakeholders.

Three scenarios were used for electrifying HGVs (named slow, reference and fast), reflecting different timelines for complete transition from diesel to electric propulsion for new HGVs. Two high blend renewable fuel deployment routes were chosen focused on fleets with depot-based refuelling. For articulated HGVs it was assumed 30% of new diesel trucks would switch to gas trucks running on 100% biomethane by 2030. For the remaining (new and existing) diesel HGVs, it was assumed an average 30% blend of renewable diesel (biodiesel and HVO) was adopted by 2030, increasing over time as the number of diesel HGVs decreased. This was an optimal scenario, assuming various demand and supply-side interventions being in place. The initial modelling work revealed that between 2020 and the late 2030s, the equivalent of between 2 and 7 billion litres of diesel demand will remain in the ICE HGV fleet, depending on the rate of new vehicle electrification. This demonstrates an immense opportunity for reducing GHG emissions from the residual diesel/gas HGV fleet using HBRF over the next two decades.

For the period 2020 to 2030, based on the 'reference' EV take-up scenario combined with high blend renewable fuel deployment, an additional 15% saving in cumulative WTW GHG emissions could be achieved, compared to less than 2% with the electric HGV-only scenario. By 2030, the additional cumulative WTW GHG emission savings were estimated to be 46 million tonnes – equivalent to approximately 4% of all road transport GHG emissions; see Table 1. By 2050 this figure rises to 140 million tonnes of additional cumulative GHG emission savings.

3 www.apcuk.co.uk/product-roadmaps

Table 1: Estimated cumulative WTW GHG emissions for UK HGV transition to electric vehicle fleet, with and without HBRF deployment.

WTW GHG ($MTCO_2e$)	2030			2040			2050		
	Slow	Ref	Fast	Slow	Ref	Fast	Slow	Ref	Fast
Do nothing	308	308	308	546	546	546	820	820	820
Electrification without HBRF	307	303	298	523	468	410	593	502	430
Electrification with HBRF	260	257	253	373	342	313	408	362	328
HBRF additional savings	**47**	**46**	**44**	**150**	**126**	**97**	**186**	**140**	**102**

What interventions could help increase the adoption of HBRF in HDV fleets?

A summary of the interventions identified in the study are outlined in Table 2. The availability of wider fiscal incentives for fleet operators was identified as one the most influential policy measures.

Table 2: Summary of interventions identified by stakeholders to increase the uptake of HBRF in HDV fleets

Potential demand-side government policy interventions
Stronger recognition in policy of the role of HBRF in decarbonizing the diesel HDV fleets, especially long-haul trucks, during the transition to mass market adoption of zero tailpipe emission vehicles
Introduce a fuel duty differential between natural gas and renewable gas (biomethane and bio-SNG)
Introduce a fuel duty rebate for higher blends of renewable diesel
Reform fuel duty as a 'carbon tax' in line with the carbon and energy content of different fuels
Introduce renewable fuels rebate for truck and coach operators
Bus Service Operators Grant Low Carbon Emission Bus incentive to include renewable liquid fuels
Extend HMRC Capital Allowance Scheme for gas refueling stations to 2030
Offer grants for local authorities to support renewable fuel initiatives
HVO to be included in the BEIS GHG conversion factors for Streamlined Energy and Carbon Reporting
Run a 'know your renewable fuel' campaign targeted at the freight sector – could be linked to Government's voluntary commitment with the freight sector for 15% GHG emission reduction for HGVs by 2025
Planning policy to require construction sites to adopt GHG reduction thresholds and use of renewable fuels
Local authorities to set GHG reduction targets for road transport, including their own fleet, which include renewable fuels as an option of HGVs.
Government Buying Standards for transport to include HBRF especially for heavier truck segments

Supply-side government policy interventions
Introduce an RTFO sub-target for higher blend biofuels going to HDVs
Set an obligation for a proportion of high blend renewable diesel to be supplied to HDV fleets
Raise the existing 12.4% RTFO target to a level which pulls in higher blends
Amend the RTFO to a system rewarding fuels on the basis on their GHG emission intensity

Wider stakeholder interventions
Manufacturers to warranty higher blends of biodiesel across a wider range of heavy-duty vehicle engines
Dissemination of guidance to HGV operators demonstrating the environmental and business case for HBRF
Introduction of a Renewable Fuels Assurance Scheme to raise confidence in the GHG performance of HBRF

Further work and next steps

- Undertake wider engagement with HGV operators through the RHA, Logistics UK, CILT plus the vehicle leasing sector (BVRLA) and SMMT to explore the demand side interventions recommended in more detail. This could help identify the policy options which could deliver the most rapid HBRF take up rates and achieve the greatest GHG emission savings.
- Undertake further examination of the demand and supply-side policy interventions with different stakeholders exploring dependencies between options and ensuring no unintended consequences.
- Zemo Partnership to progress with launching the Renewable Fuels Assurance Scheme, followed by designing and piloting a recognition scheme for fleet operators using renewable fuels.

1. Introduction

The UK Government passed legislation in 2019 to make the UK a 'net zero' emitter of GHGs by 2050. The UK is currently, however, not on track to meet its previous, less ambitious, target of 80% emissions reductions by 2050. The Committee on Climate Change announced in the 6th Carbon Budget that the UK will need to ramp up GHG reduction to meet the 2050 target, lowering emissions by 68% by 2030 compared to 1990 levels. The Intergovernmental Panel on Climate Change has identified the next ten years as critically important for undertaking actions to mitigate climate change.

Road transport is responsible for 24% of UK GHG emissions, a proportion that is growing. HGVs are responsible for around 20% of these emissions, with long distance and regional trucks contributing the largest proportion[4]. Buses and coaches contribute a combined 3%. Government policy, and advice from the CCC, is heavily focused on meeting net zero through the replacement of the incumbent fossil fuel internal combustion engine (ICE) vehicle fleet, with zero tailpipe emission technologies such as battery electric and hydrogen fuel cell.

Sustainable low carbon fuels, including liquid and gaseous biofuels can play a pivotal role in decarbonising the UK road transport emissions. The RTFO has set a renewable fuel target for road transport of 12.4% by volume by 2032. Biofuels must meet a lifecycle GHG emission threshold and sustainability standards with regards to their production. In 2019 retail fuel had an average 5.1% renewable fuel content, with 2,680 million litres-equivalent of renewable fuel being supplied[5]. This achieved an average greenhouse gas saving of 83% compared to fossil fuel. High blend renewable fuels currently supplied to UK heavy-duty vehicle operators are biodiesel, biomethane and hydrotreated vegetable oil. However, the wide scale adoption of high blend renewable fuels has yet to materialise. Unlocking the potential of these low carbon fuels to decarbonise HDVs could contribute towards meeting the 2032 RTFO target and provide a highly beneficial GHG emission reduction opportunity over the next decade and beyond, a critical period for the UK in terms of achieving net zero emissions in 2050.

1.1 Aims and Objectives

This study explored the market opportunity for HBRF in lowering GHG emissions from HDVs. Focus is primarily on the next decade, with commentary on future opportunities. The study objectives:

- Determine the current HDV fleet market adoption of HBRF in the UK.
- Identify vehicle manufacturers' compatibility positions for different liquid biofuels used in HDVs.
- Identify challenges, opportunities, and interventions for wider HBRF adoption.
- Outline national and local policies, outside of the RTFO, which could stimulate both the supply and demand of HBRF.
- Highlight other measures outside of Government policy.
- Comment on the role of HBRF for HDVs in delivering GHG emissions beyond 2030.
- Determine the potential GHG emission savings for HDVs switching to high blend renewable fuels in the short to medium term (2020 – 2030) and long term (up to 2050), in combination with the transition to zero tailpipe emission vehicles.

[4] www.gov.uk/government/statistical-data-sets/energy-and-environment-data-tables-env#greenhouse-gas-emissions-env02

[5] www.gov.uk/government/statistics/renewable-fuel-statistics-2019-final-report

1.2 Methodology

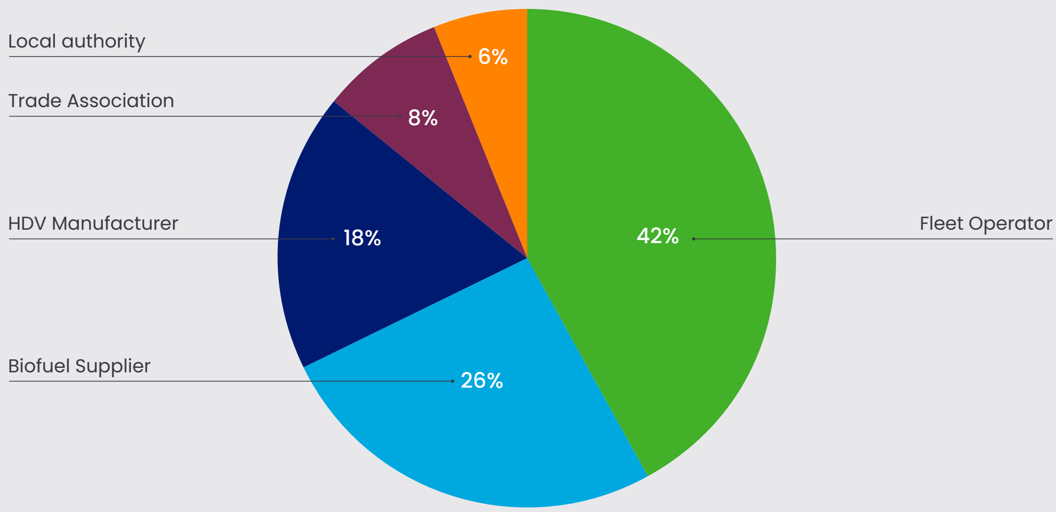
1.2.1 Scope

The study covered three HDV sectors – HGVs, buses, and coaches. For renewable fuels, this focused on liquid and gaseous biofuels above blends of 20% specifically - biodiesel (Fatty Acid Methyl Ester), hydrotreated vegetable oil (HVO) and biomethane. With regards to advanced 'second generation' biofuels such as biomass-to-liquid (BTL) and bio-syngas (BioSNG), though these renewable fuels have yet to become fully commercialised in the UK, the policy interventions (discussed in Section 7) would be applicable.

1.2.2 Information gathering and analysis

The study entailed a broad stakeholder engagement exercise with Zemo Partnership members, a variety of fleet operators (bus, coach, and HGV), local authorities and the biofuel supply community. Questionnaires were issued and 'one-to-one' interviews were held with forty organisations. (Further details in Appendix 1 and 2.)

Figure 1 Stakeholder engagement profile



Information gathered from stakeholders included investigations into:

- Existing HBRF deployment in HDVs
- Fleet operator experience of using HBRF
- Biofuels approval and warranty position for heavy-duty vehicle manufacturers
- Fleet operator procurement including plans for decarbonisation
- Identifying barriers for HBRF adoption
- Exploring opportunities for adopting HBRF fuel in different HDV sectors
- Identifying measures to encourage greater uptake including policy interventions and non-policy related interventions.

In addition, a simple Excel model has been built to examine the cumulative GHG emission savings that could be achieved by decarbonising diesel and gas-powered HGVs through high blend renewable fuel adoption in combination with the roll-out of new electric vehicles. The period covers 2020 to 2050. A similar analysis has been done for buses and coaches.

2. HDV Market Overview

2.1 Heavy Goods Vehicles

The UK HGV fleet comprises 499,000 rigid and artic vehicles consuming in the order of 6.5 million tonnes of diesel per year (8 billion litres)[6]. There has been a shift towards the use of larger HGVs when transporting goods across the UK; 62% were transported by artic trucks in 2019. Supply of commercial vehicles above 3.5 tonnes GVW is dominated by manufacturers DAF, Iveco, MAN, Mercedes Benz, Scania and Volvo[7].

HGVs are in active service for, on average, twelve years with fleet operators typically owning vehicles for between six to ten years. In terms of age profile, a large proportion of the HGV fleet is under fourteen years old. Approximately 50% of the fleet are Euro VI and 28% Euro V and the Road Haulage Association (RHA) forecasts that, by 2025, 80% of the truck fleet will be Euro VI[8]. New vehicle ownership profiles cover outright purchase, contract hire and leasing generally over three years. Small operators tend to favour purchasing second-hand vehicles. Approximately 80% of HGV fleets are SMEs running up to 50 vehicles; 20% are large operators with fleets > 100 vehicles. It is estimated that 60% of the fleet operate depot-based refuelling.

Presently, there is early market deployment for battery electric and range extender rigid trucks in cities, with a growing focus on last-mile logistics fleets. Less than 1% of new truck sales are zero tailpipe emission vehicles. No heavy-duty manufacturer currently offers battery electric or hydrogen fuel cell products for regional and long-haul duty cycles in the UK. Public charging infrastructure for heavy-duty vehicles, and refuelling stations for low carbon hydrogen has yet to materialise. There is a growing number of CNG and LNG trucks in operation and associated public refuelling infrastructure.

6 www.gov.uk/government/statistical-data-sets/tsgb04-freight#domestic-road-freight-transport
7 www.smmt.co.uk/vehicle-data/heavy-goods-vehicle-registrations/
8 www.rha.uk.net/getmedia/03b81d92-bade-445f-9f14-3fc066db6ae8/180508-2018-RHA-Emission-Assessment-v1.pdf.aspx

2.2 Buses and Coaches

The UK bus fleet presently comprises 44,000 vehicles[9], predominantly diesel-powered. Bus operators typically keep vehicles for fifteen years. Leading manufacturers include Volvo, Alexander Dennis, Wrightbus and Optare.

Bus fleets have a diverse range profile, with around 30% of vehicles being over twenty years old. With regards to Euro Standards, the largest proportions of the fleets outside London are Euro III and Euro IV. Most large operators purchase new vehicles outright, with smaller operators buying second-hand. Low carbon vehicle technology deployment across the UK includes 564 battery electric buses, 4536 hybrids and 20 HFC vehicles. 5% of new bus sales were electric in 2019.

The UK coach fleet comprises 27,500 diesel vehicles. Approximately 33% of the fleet are Euro VI[10], and more than 34% being more than twenty years old. The coach market is quite diverse with regards to manufacturers. The highest numbers of new vehicle registration in 2019 were associated with Mercedes, Alexander Dennis, Scania.

The coach market is made up of numerous small operators and a handful of large fleet operators; approximately 700 companies. Small operators typically buy one or two vehicles every few years, with a strong trade in second-hand vehicles. Some operators keep their vehicle for fifteen or more years. Leasing is common for smaller operators. Coach operators have various journey profiles, many regional and international, with high mileage. There is limited adoption of low carbon fuels and technologies in the coach sector, with currently only limited demonstration trials of battery electric coaches.

9 www.smmt.co.uk/vehicle-data/bus-and-coach-registrations/
10 www.zemo.org.uk/work-with-us/buses-coaches.htm

3. UK High blend renewable fuels market

3.1 Biodiesel B20 - B100

The UK's leading producers of biodiesel are Argent Energy, Greenergy Fuels and Olleco. These companies bulk supply a range of RTFO-approved high biodiesel blends - B20, B30 and B100. High blend biodiesel is produced from a variety of sustainable feedstocks such as used cooking oil, tallow oil, fats, and greases.

High blend biodiesel has been deployed in HDV fleets for over a decade, with the greatest adoption in buses. B20 and B30 is more common in HDV fleets than B100. In more recent years an increasing number of HGVs fleets have been using high blend biodiesel, in particular logistics and haulage companies. The coach industry has the lowest adoption rate, with limited take-up identified in local authority fleets. Table 3 presents a summary of high blend biodiesel adoption across UK HDV fleets in 2020.

Table 3: High blend biodiesel deployment in UK HDV fleets

HGV	Bus	Coaches
700 B20, B30, B100	8000 B20, B30, B100	250 B20
Example fleet operators: McDonalds, Alfred Hymas	Example fleet operators: First Group Stagecoach, Go Ahead, TfL, Metroline	Example fleet operators: Megabus

Engagement with fleet operators using B20, B30 and B100 revealed positive feedback. Both Hackney Council and TfL have used biodiesel B20 in truck and bus fleets reporting no operational or cost challenges. Stagecoach has benefited from the Scottish Bus Service Operator Grant (BSOG) biodiesel incentive. This motivated the company to adopt B30 in a large proportion of its bus fleet which helped cover the additional servicing costs. McDonalds has deployed B100 produced from used cooking oil across 250 vehicles for nearly a decade. The company has invested in a heated storage tank for B100 and modified its truck fleet to run this higher blend of biodiesel. Alfred Hymas, a bulk tipper haulier, has used B30 across its 77 44 tonne truck fleet for over a year. The fleet is made up of Euro V and VI vehicles from a variety of manufacturers. No alterations were required to their vehicles to run on B30, the company reports no operational or performance issues. A bulk storage tank for biodiesel was installed at their depot.

3.1.1 Deployment considerations

Heavy duty vehicle engine manufacturer compatibility

The European fuel quality standard for diesel, EN590, limits the blend of biodiesel (FAME) to a maximum 7% volume. A number of HDV manufacturers approve their engines to run on higher blends of biodiesel and warranty the vehicle engine and various components. A key condition for manufacturers is that the biodiesel supplied meets European Fuel Quality Standards specific to higher biodiesel blends such as EN16709 (for B30) and EN141214 (for B100). Conditions can additionally be set by manufacturers related to vehicle maintenance and modifications plus fuel storage. This study engaged with nine UK HDV manufacturers to determine the approval and warranty status of different heavy-duty vehicle types and engines. Table 4 shows the manufacturers which offer engine approvals for B20, B30 and B100. More detailed information can be seen in Appendix 3.

Table 4: HDV manufacturers offering high blend biodiesel compatible engines.

Blend	Manufacturer
B20	DAF, Scania, Mercedes Benz
B30	Mercedes Benz, Renault, Volvo, Scania, DAF
B100	Mercedes Benz, Scania, MAN

An estimate has been made of the market share of HDVs approved to operate on high biodiesel blends, Table 5. This has considered the market profile of UK HDV manufacturers and the latest new vehicle registration statistics, then applying knowledge of manufacturer approval information, the HDV fleets' age profile and vehicle numbers. (Further details in Appendix 3).

When looking at the entire HDV fleet it is estimated that approximately 60% would be approved to operate on high blend biodiesel, mainly B20 and B30. However, the warranty position of different manufactures needs to be considered. Given that only the latest Euro VI vehicles will be in warranty, repeating the analysis just for this set of vehicles, gives an estimate of 26% of the UK's HDV fleet being compatible for B20/30 and an additional 17% for B100.

Manufacturers typically do not offer high blend biodiesel approval for vehicles earlier than Euro III. This is more relevant to buses and coaches which have an older age profile than HGVs.

Table 5: Estimate of high blend biodiesel approval across the UK HDV fleet

HDV sector	B20/B30	B100
Buses and Coaches	40%	10%
HGVs	55%	13%

Vehicle modification, maintenance, and infrastructure

When building vehicles some manufacturers fit parts which enable them to run on high blend biodiesels. These can also be retrofitted after sale. Such modifications need to be requested by the fleet operator. For B30 this can entail a small price premium on the vehicle for some manufacturers in the order of a few hundred pounds. In the case of B100 various vehicle modifications are required incurring an on-cost of several thousand pounds. The modifications include seals, a heated fuel tank, lagged or trace-heated fuel lines. A heated fuel storage tank is also necessary to ensure cold flow requirements are fulfilled especially in the winter months. The additional vehicle and infrastructure modifications incur higher costs for a fleet operator compared with a standard diesel vehicle; approximately 10-15 pence more per litre of fuel.

Blends above B20 require increased service intervals, including more frequent engine oil and fuel filter changes. Additional cleaning is required for fuel tanks. This can result in additional maintenance costs for fleet operators.

Prior to first delivering high blend biodiesel, fleet operators are required to undertake a full tank clean to ensure there is no contamination of the new fuel from residues on the walls and in the bottom of the tank. Typically, additional in-line filtration is fitted prior to the fuel pumps.

3.2 Hydrotreated Vegetable Oil

HVO is currently imported into the UK from the Neste refinery in Finland, there is no UK domestic production. The UK's main suppliers are Green Biofuels Ltd, Crown Oil and Nationwide Fuels. It is commonly supplied in its pure form, as 100% HVO. Green Biofuels has recently started supplying synthetic diesel (GTL) blended with HVO. Recent RTFO statistics[11] identify HVO supplied in the UK being produced from sustainable waste feedstocks such as used cooking oil.

The adoption of HVO has escalated over the past two years, with approximately 800 HGVs using this biofuel. Fleet operators include Hovis which is running 580 trucks and Ceva Logistics with 85 vehicles. In the case of Ceva Logistics the switch to HVO has been motivated by the company's customer base requesting lower carbon transportation of their goods. One stakeholder mentioned increasing interest from construction and demolition companies in using HVO, considered as a route to reducing GHG emissions associated with the haulage of aggregates and other materials.

[11] DfT statistics 2020 https://www.gov.uk/government/statistics/renewable-fuel-statistics-2019-final-report

The London Borough of Hackney successfully trialled HVO and is looking to roll this out across its 450-strong HGV fleet by the end of the year. The authority has undertaken vehicle emissions testing (chassis dyno) for one of its refuse collection vehicles running on HVO. Results showed WTW GHG emission savings of 85% compared to diesel. A further demonstration trial of HVO in a Euro VI coach by Lucketts Coaches (now part of National Express) was successful. Vehicle emissions testing revealed similar WTW GHG emissions savings to the Hackney trial. In both cases the HVO was produced from used cooking oil.

HVO is also supplied to the off-highway sector for non-road mobile machinery. There is growing interest in using HVO from this sector as an alternative to red diesel. This is motivated by the planned removal of the red diesel fuel rebate in April 2022.

3.2.1 Deployment considerations

Heavy-duty vehicle manufacturers approve many of their engine ranges to run on HVO, and other renewable paraffinic diesels such as BTL[12]. There are no restrictions on blending HVO with diesel, EN590 allows blending of HVO without any limit. HVO is fully compatible with Euro VI engines, and those approved to earlier Euro Standards. No modifications are required to the vehicle or fuelling infrastructure. HVO is commonly referred to as a 'drop in' diesel replacement, although it does have slightly lower energy density than diesel. A condition that manufacturers set for using HVO is that it meets the European Fuel Quality Standard EN15940. Manufacturers' engine warranty typically covers HVO if the fuel meets EN15940.

Using the same methodology as biodiesel for estimating whole fleet compatibility, 99% of the Euro VI HDV fleet is estimated to be compatible with HVO and other drop-in paraffinic fuels such as BtL.

HVO suppliers provide bunkered storage and refuelling facilities at fleet depots and at locations like construction and demotion sites. HVO is currently more expensive than diesel, in the region of 15 pence per litre higher.

12 Mercedes Benz and Iveco each have one engine model that is not approved to run on paraffinic fuels

3.3 Biomethane

Biomethane is supplied in the UK as compressed and liquified biomethane for use in gas vehicles. Suppliers include CNG Fuels, Gasrec, Air Liquide and Flogas. The latest RTFO statistics show that the biomethane supplied is produced from sustainable waste feedstocks such as food waste, sewage, and agricultural residues[13]. The RTFO approves the mass balancing of biomethane produced at anaerobic digestion plants and distributed through UK and European gas grids. A large proportion of the biomethane supplied in transport is produced in EU Member States.

A new small-scale biomethane supply chain is emerging, involving capturing fugitive methane emissions from manure at dairy farms. A demonstration project is currently under way with Cornwall Council's contractor Cormac and biomethane producer Bennamann Ltd.

Biomethane can be used in a variety of Euro VI heavy-duty gas vehicles storing gas on board in either compressed (CNG) or liquified (LNG) state. The types and manufacturers offering products in the UK are presented in Table 6. A large majority of these vehicles are based on spark ignition engine technology. The exceptions are the Volvo FH LNG and Volvo FM LNG HGVs which are powered by gas engines utilizing compression ignition technology, with a diesel pilot used to ignite the fuel mixture. Fleet operators commonly run their vehicles on 100% biomethane (via gas grid balancing mechanisms) with a small number of HGV operators running on blends of biomethane and natural gas.

Table 6. Gas heavy-duty vehicles available in the UK

HGVs	Buses	RCV	Tractor
CNG & LNG Scania, Iveco, Volvo, Mercedes	CNG Single and Double- Deck Scania, MAN	CNG Mercedes	CNG CNH Industrial

Table 7: Biomethane deployment in UK HDV fleets 2020

HGVs – CNG/LNG	Buses – CNG
600	350
Example fleet operators: John Lewis Partnership, Sainsburys, Tesco, Ocado, Asda, Hermes, Camden Council, Cornwall Council	Example fleet operators: Stagecoach, Nottingham City Transport, First Group

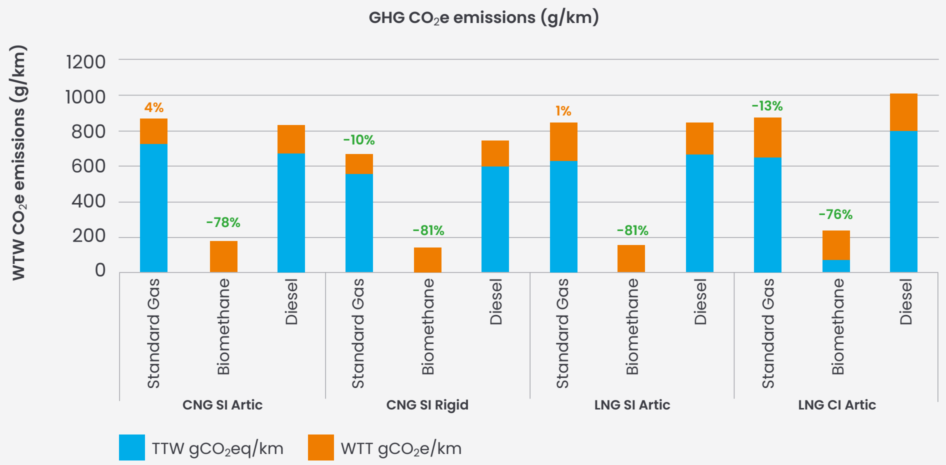
Table 7 shows that biomethane has achieved most penetration in the freight sector, with logistics and retail companies. The latest market statistics show that there are six hundred rigid and artic gas trucks running on biomethane in the UK, with this number set to rise in 2021. Stakeholders interviewed commented on positive operational performance and fuel cost savings, especially for high mileage fleets. It was highlighted that the lower fuel duty rate for natural gas and biomethane compared to diesel has improved the business case for large fleet operators investing in gas trucks.

All the companies involved had their own refuelling station and used the national gas refuelling network. The improved range of the latest Euro VI gas trucks was highlighted, encouraging greater adoption of gas vehicles. Many fleet operators interviewed are looking to expand their biomethane truck fleets, some by more than 50% over the next two years. For example, John Lewis Partnership will increase its 85 biomethane truck fleet to 143 and Asda by 200 in early 2021. John Lewis Partnership has pledged to switch its entire 600 HGV fleet to run on biomethane by 2028. This has been driven by the company's Corporate Social Responsibility strategy and mission to achieve net zero across its entire operations by 2050.

[13] www.gov.uk/government/statistics/renewable-fuel-statistics-2019-final-report

The Innovate UK Low Emission Freight Trial (LEFT)[14] has demonstrated the successful performance of gas HGVs powered by biomethane. The headline results for the four trial vehicles from John Lewis Partnership and Kuehne & Nagel's fleet is shown in Figure 2 below. The more detailed results revealed that the largest GHG emission savings were achieved over long-haul duty cycles for both the Euro VI CNG and LNG vehicles; 85% and 71% compared to a diesel Euro VI truck. The trial also demonstrated that fleet operators were achieving a payback for their gas trucks within three years due to the lower cost of biomethane and high vehicle mileages. Long-haul and regional operations were identified as being best suited to the adoption of dedicated gas technology.

Figure 2: LEFT summary WTW GHG emissions results for CNG & LNG trucks



The biomethane gas bus market has rapidly grown over the last six years, having benefited from vehicle and operational subsidy schemes such as the Low Emission Bus Grant and the BSOG LCEB incentive. First Group in Bristol and Nottingham City Transport run the largest gas-powered bus fleets in the UK.

There is niche deployment of gas vehicles running on biomethane in local authority fleets. The main examples include Camden and Islington Councils which are using biomethane minibuses to run community transport services. Camden Council has operated biomethane refuelling at its depot for over a decade, allowing third-party access for fleets.

3.3.1 Deployment Considerations

Biomethane is a drop in fuel and fully compatible in gas trucks and buses. Gas trucks and buses have a cost premium over equivalent diesel vehicles, typically offset by the lower cost of biomethane compared to diesel, especially for high mileage fleets. There is a slight premium on maintenance for gas HDVs, but this can also be offset by the fuel cost savings and the lack of a need for urea in the exhaust after-treatment system.

Refuelling infrastructure is expensive to install at fleet depots. However, this can be reduced through wet leasing. One stakeholder commented on the recent availability of new, small scale liquified gas storage and refuelling equipment. This is cheaper than conventional refuelling infrastructure.

There are currently twelve gas refuelling stations in the UK, including sites close to major motorways, at logistic parks and logistic company depots. The number of new stations is increasing each year and by the end of 2025 there are forecast to be between 45-50 open access sites located on major trunking routes.

[14] www.Zemo Partnership.org.uk/projects/commercial-vehicle-working-group/supporting-left-testing.htm

4. Challenges, interventions, and opportunities

A variety of cross-cutting issues were raised during the stakeholder engagement exercise. These are outlined below before exploring individual high blend renewable fuels.

Transition from diesel ICE to zero tailpipe emission propulsion technologies

Several fleet operators highlighted limited product availability of BEV and HFC for HGVs and coaches, especially for long-haul duty cycles. Various immediate challenges were mentioned with regards to battery electric HGVs and coaches: high vehicle capital costs; limited vehicle range to enable long distance journeys; difficulties deploying EV infrastructure at depots; immature public network for e-truck charging. Several operators foresee a future role for HFC trucks in their fleet, mentioning that public hydrogen refuelling infrastructure, and affordable vehicles, would be required to motivate fleets to adopt this technology. Subsequently, switching from incumbent diesel HDVs to zero tailpipe emission vehicles would take time and incur significant capital cost for many operators. It was emphasised that a solution was required for GHG reduction during the transition period to zero emission transport in 2050. Many stakeholders viewed sustainable low carbon fuels as having an important role.

Investment in zero emission propulsion technologies was perceived as very challenging for SME fleet operators primarily due to their high capital cost and the fact that many purchase second-hand vehicles. Such a second-hand market is unlikely to materialise for EV powertrains at scale before 2030.

Requirement for fiscal support

HDV fleet operators require a two to three-year financial payback for new, ultra-low emission vehicles, and renewable fuels. They run on tight financial margins and are currently experiencing a challenging economic environment (e.g., COVID, EU Exit and CAZ introduction). Stakeholders highlighted that fleet operators require financial support to switch to lower carbon solutions. This includes certain renewable fuels which can be more costly than diesel to deploy.

For some industry sectors, addressing air pollution emissions was seen to be a higher priority than GHG reduction, with the cost of Clean Air Zone compliance a key issue. Concerns over Euro V vehicles becoming a stranded asset were expressed, with a limited export market for these vehicles. However, there is increasing realisation that both air quality and climate change challenges need to be tackled.

Certainty and direction in Government policy

Unease was raised regarding the direction of travel of Government climate change policy, with long-term stability required to give operators confidence in decision making. Stronger visibility of the role of renewable fuels in decarbonising HGVs, in particular, was felt to be needed. The current focus was perceived to be very much on zero tailpipe emission vehicles.

Company Streamlined Energy and Carbon Reporting and Corporate GHG Targets

Company Carbon Reporting[15] and the introduction of GHG reduction targets was mentioned as driving corporate fleets to decarbonise their own transport fleets and their supply chains (contractors). Companies are looking for cost-effective solutions. Stakeholders mentioned requiring clarity and certainty of GHG performance of biofuels on the market, and confidence in their supply chain sustainability credentials.

Lack of information and awareness

Stakeholders mentioned the limited availability of independent information on various low carbon fuel and technology options available for HDVs. This includes applicability across different vehicle types and duty cycles, operational performance, clarity of manufacturer approval and warranty position related to higher blends of biodiesel, GHG emissions and whole life costs.

[15] www.gov.uk/government/publications/academy-trust-financial-management-good-practice-guides/streamlined-energy-and-carbon-reporting

4.1 Challenges identified for deploying high blend liquid fuels

4.1.1 Biodiesel B20-B100

Bus and coach sector

Engine compatibility and warranty: Manufacturers tend not to warranty B20 for older vehicles, including where the engine model has been upgraded through time. Given the broad age profile for UK bus fleets this makes adoption of high blend biodiesel across their entire fleet challenging. Lack of engine warranty moves financial risk to the operator which can be problematic. This is important as buses have a life of 15 years, coaches can be longer.

Space at depot: Difficult for some operators to have a dual fuel system on-site i.e., one for new vehicles and one for older.

Fuel procurement: Large national fleet operators can have complex procurement and contractual arrangements for the bulk supply of diesel. Moving only single or small numbers of depots to a different fuel supplier from the rest of the core business would require additional resources.

Financial: Moving to blends above B20 was identified as having cost implications. Trying to adopt a higher cost solution for reducing GHG emissions, such as high blend biodiesel, which does not improve air quality, was perceived to be difficult.

Government policy regarding decarbonising coaches: Perceived barriers include: A lack of clear direction from Government on the near to medium-term vision for coaches regarding GHG emissions reduction; no provision of funding for coach operators to adopt cleaner vehicles, zero emission technologies or low carbon fuels.

HGV sector

Engine compatibility and warranty: Truck manufacturers have varying positions regarding engine approval and warranty for B20, B30 and B100, only a few approve engines to run on B100. Many operators are risk averse and will not adopt high biodiesel blends when the vehicle engine is out of warranty. A few stakeholders mentioned that access to accurate information regarding OEMs' approvals and warranty status for different biodiesel blends made adoption difficult.

Operational: Unease regarding storage of high blend biodiesel; in particular, risk of waxing during cold weather and the need for increased servicing, for example additional oil filter changes above B30.

Financial: Increased cost due to vehicle modifications for B100, increased vehicle servicing and heated storage tanks for B100. Whilst some manufacturers offer extended warranties for B100, this would be at a cost for the operator. The absence of any kind of financial incentive for liquid renewable fuels makes moving to higher blends economically unviable for many fleet operators.

4.1.2 Hydrotreated Vegetable Oil

Financial: Cost premium of HVO relative to diesel was raised by nearly all stakeholders.

Perceptions of sustainability performance: Unease regarding the use of palm oil to produce HVO and association with negative environmental impacts. There was limited awareness that HVO can be produced from more sustainable biogenic waste feedstocks.

Availability of HVO: Perception that supply chains in the UK may struggle to accommodate increased demand in HDV fleets. Other types of advanced drop-in renewable diesel fuels are yet to be fully commercialised.

Absence of GHG conversion factors for Streamlined Energy and Carbon Reporting: The BEIS GHG conversion factors for company carbon reporting do not include Scope 1 or Scope 3 figures for HVO. This was mentioned as preventing companies from appreciating, and demonstrating, the benefits of HVO as decarbonisation option in their vehicle fleet.
Awareness: Low level of awareness of HVO amongst smaller operators and local authorities.

Depot space: Same challenges exist for HVO as with biodiesel for large bus and coach fleet operators regarding fuel procurement and deployment.

4.2 Interventions to encourage greater uptake of high blend liquid biofuels

Table 8: Stakeholder suggestions for new measures

Fiscal Subsidy	The Bus Service Operators Grant (BSOG) Low Carbon Emission Bus (LCEB) incentive in England was highlighted as an effective mechanism to encourage the adoption of renewable fuels in buses. Biodiesel and HVO, are not currently included under the LCEB incentive. It was suggested that these liquid biofuels should be included to enable a level playing field with other fuels and energy such as hydrogen, biomethane and electricity.
Fiscal Subsidy	Fleet operators perceived great value in the Government introducing a fiscal subsidy for high blend biodiesel and HVO to improve the business case and encourage greater take up. A fuel duty rebate was perceived as one of the easiest routes to achieve this.
Recognition in Government policy	Government to give stronger recognition of the role of high blend liquid biofuels in decarbonising HGVs and coaches. Clarity on Government policy position will aid procurement decisions by fleet operators.
OEMs extending warranty	For high blend biodiesel specifically: encourage manufacturers to approve a wider range of their engine on blends above B20 and offer extended vehicle warranties. A few stakeholders suggested this position could change if market demand for high blend biodiesel was apparent.
Public Sector Procurement	Introduce procurement standards for the public sector's own vehicle fleet, and in contract tendering, which stipulate use of sustainable low carbon fuels.
Education and assurance of renewable fuel GHG savings	Improve the provision of information to the fleet operators - in particular, smaller companies and local authorities - on renewable fuels options available, cost and GHG emission performance. Useful to see evidence of successful deployment of high blend biodiesel.
Education and assurance of renewable fuel GHG savings	Support for an initiative that could help give independent assurance to fleet operators of the GHG emissions performance, and feedstock sustainability, for different high blend liquid biofuels sold in the UK. This will enable more transparency in corporate carbon reporting and help procurement decisions.

4.3 Opportunities for deploying high blend liquid biofuels in HDVs

HGV fleets which have depot-based refuelling were considered the most suitable candidates for high blend liquid biofuels. Examples mentioned by stakeholders included logistics, construction, haulage, and quarry industry fleets. Stakeholders mentioned that heavy payload HGVs, and those with regional and long-haul duty cycles, are the more challenging to decarbonise in the near to medium term using battery electric and HFC technologies. High blend liquid biofuels could provide a readily deployable low carbon solution. The use of 'drop-in' renewable diesel, such as HVO, was considered to offer the widest range of opportunities given the absence of engine compatibility challenges.

One stakeholder mentioned the potential role of paraffinic biofuels in improving the performance of Euro VI diesel HDVs in cities and in reducing tailpipe particulate matter emissions. This was due to aiding the regeneration of diesel particulate filters during congested urban driving conditions.

Local authority HGV fleets such as refuse disposal vehicles, street cleaning and tipper lorries were also mentioned as worthwhile candidates for high blend liquid biofuels. One local authority stakeholder mentioned a variety of challenges in terms of installing EV charging infrastructure at their depots. Using HVO in this case was considered a simple route for achieving GHG emissions reduction across their whole fleet during the transition to a fully electric fleet.

One bus operator stakeholder was open to undertaking further trials of high blend biodiesel and was considering HVO. However, others mentioned reluctance to expanding their current use of biodiesel B20. Given the strong focus for large bus operators to switch to electric buses in towns and cities, it appears that wider adoption of high blend liquid biofuels to decarbonise existing diesel vehicles is limited unless a financial incentive is introduced.

Coach and small bus operators with high mileage journey profiles and lengthy vehicle replacement cycles could benefit from adopting high blend liquid biofuels. Moving to battery electric coaches will be challenging for these types of operators, especially as Government funding for these types of operators does not exist. Those most suitable for HBRF are probably operators with a fleet of more than twenty vehicles to justify a bunkered fuel supply at their depot. Coach operators who offer regional day trips would be especially able to benefit from high blend liquid biofuels, even if at a blend of 20%. Given the wide age profile of some coach and bus fleets, drop-in renewable fuels would offer more flexibility and ease of adoption.

Over the next ten years several renewable synthetic diesels were identified by stakeholders as promising new market entrants, potentially offering a broader range of 'drop in' fuels including: dimethyl ether, oxymethylene dimethyl ether and biomass to liquid/Fischer-Tropschs diesel. HDV manufacturers already approve a variety of advanced renewable fuels.

Stakeholders mentioned that the production of high blend renewable diesel for HGVs in the short-term could provide a platform, and investor confidence in producing sustainable, low carbon Jet 1 fuel in the future. For example, biorefineries operating the hydro-processing conversion process could begin with supplying HVO for HGV fleets, then move to HEFA production (bio-kerosene) for the aviation industry. Concurrently renewable diesel would be a middle distillate produced during the manufacture of sustainable aviation fuel, improving the long-term financial resilience, and business case for such biorefineries. By-products that would help decarbonise the existing fossil supply chain include bio-naptha and bio-propane. This could serve as an important opportunity for strengthening the UKs bioeconomy. The introduction of a demand-side fiscal incentive for high blend liquid biofuels was suggested that could stimulate an expansion of drop-in renewable diesel supply chains and encourage investment in a UK production plant for HVO and advanced biofuels.

Several stakeholders mentioned the important role high blend liquid biofuels could have in decarbonising non-road mobile machinery used at construction sites. Primarily due to the significant volumes of diesel this sector consumes and associated GHG emissions, plus the absence of alternative zero and low carbon technological options in the near term.

4.4 Challenges identified for deploying biomethane

Public refuelling stations: Lack of wide-scale public gas refuelling infrastructure for HGV fleets.

Financial: High cost of installing refuelling infrastructure at depots. For local authority's absence of Government funding for refuelling infrastructure, prevents them offering open-access refuelling hubs.

Immature second-hand gas vehicle market: For small fleet operators, absence of second-hand market for gas trucks hinders adoption.

4.5 Interventions to encourage greater uptake of biomethane

Table 9: Stakeholder suggestions for new measures

Fiscal Subsidy	More long-term fiscal support for installing gas refuelling infrastructure. Funding for local authorities for establishing open-access refuelling stations. Dis-incentivising use of 'fossil' natural gas and encouraging greater use of 'renewable' gaseous fuels notably biomethane and bio-SNG.
Recognition in government policy	Government recognising the important role of biomethane for decarbonising regional and long-haul HGVs over next decade; alongside the gradual transition to BEV or HFC trucks.

4.6 Opportunities for deploying biomethane in HDV fleets

The fuel duty differential between diesel and biomethane/natural gas was highlighted by stakeholders as being highly valuable. Lower fuel costs, combined with corporate GHG emission reduction targets, are motivating truck fleets operating over long haul duty cycles to invest in CNG and LNG trucks running on biomethane. Biomethane was perceived to be a key opportunity for decarbonising artic truck fleets which are responsible for the largest proportion of HGV miles and GHG emissions. These fleets typically use back-to-base refuelling. Stakeholders mentioned the important role of biomethane in gas trucks as a transition solution for the heavier truck segments, given that it would take some time before zero tailpipe emission HGVs >32 tonne GVW to become established in the market.

The growing number of bio-CNG and bio-LNG refuelling stations across the UK supplying biomethane, including 3rd party access sites, was considered a key enabler for the greater adoption of biomethane trucks. Biomethane suppliers forecast station numbers will increase approximately ten-fold by 2030. More rapid adoption would materialise if financial support were available for installing refuelling stations, and for small operators, capital support for vehicles would provide a further incentive, even if time limited. Two stakeholders mentioned the opportunity for public gas refuelling stations to evolve into hydrogen refuelling stations in the future. Given their strategic location for serving logistics and haulage fleets, these would be well placed to support the roll-out of HFC truck fleets. Further uptake could be encouraged by making the business case for using biomethane in gas trucks more attractive by differentiating the fuel duty rate between natural gas and biomethane.

There is likely to be a second-hand gas truck market opening up over the next few years. This will encourage small fleet operators to switch to biomethane, further encouraged by the expansion of public gas refuelling stations.

For the bus sector, while focus is on moving to electric bus fleets, several operators are likely to continue purchasing biomethane buses, in particular where there are more out-of-town bus routes and access to locally produced biomethane.

The production of biomethane from manure waste can achieve net zero, or better, GHG emission performance, following the recent revision of the Renewable Energy Directive (Recast to 2030). This arises as the biomethane production process involves capturing fugitive methane and nitrous oxide emissions released by manure stored in the open environment. Given the high mileage of regional and long-haul HGV operators, a proportion of manure in the biogenic waste feedstock mix used to produce biomethane would result in significantly increased GHG savings. These vehicles could be considered net zero HGVs. This would also be the case for biomethane buses. The level of GHG emission savings would be predicated on the proportion of manure making up the biomethane feedstock mix. One company in the UK, Bennaman Ltd, is producing small volumes of biomethane from 100% manure for use in road vehicles. Other biomethane suppliers are looking to introduce increase proportion of manure into the biomass feedstock mix.

Rural communities producing biomethane from farm slurry wastes could reap benefits from developing a circular economy, turning waste into energy, and supplying renewable fuel to local hauliers. Farmers could additionally use biomethane tractors thereby reducing the need for red diesel. More wide-scale environmental benefits would be gained through mitigating methane, and nitrous oxide emissions, both of which are powerful greenhouse gases associated with the agricultural sector. Air quality benefits could also be achieved as manure is a key source of ammonia emissions.

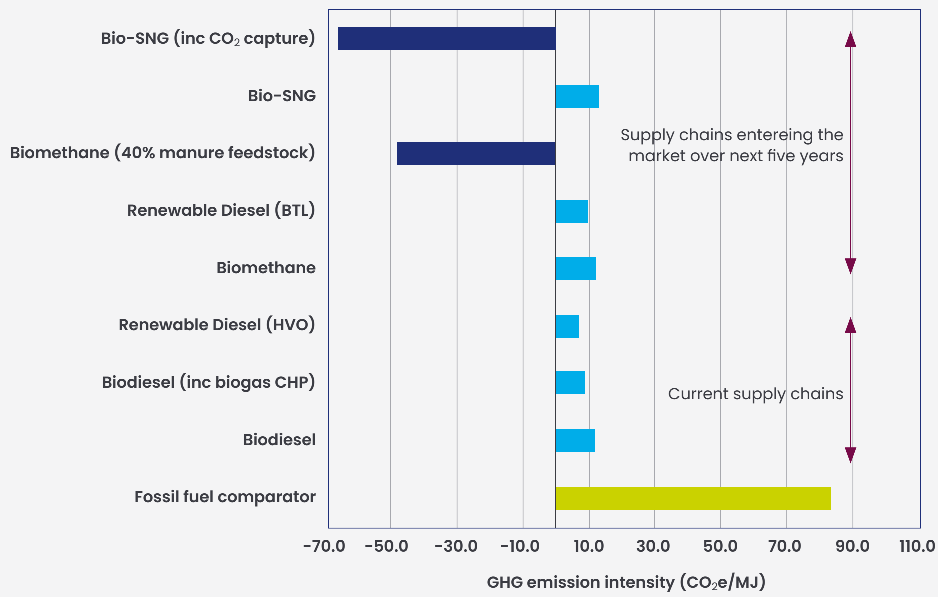
Scania has recently brought an LNG coach to market in Europe. This could be an opportunity for coach operators making long-distance journeys, especially as biomethane refuelling stations are expanding across the UK. This would be predicated on Scania bringing this product to the UK market and the Government offering vehicle capital grants for coach operators.

4.7 Opportunities for life cycle GHG emissions reduction

The chart in Figure 3 illustrates the fuel life cycle GHG emission intensities of high blend renewable fuel supplied to fleet operators today and for new supply chains which are likely to come to market over the next five years. These include advanced production pathways; renewable diesel (BTL) produced via the Fischer-Tropsch process, and bio-synthetic natural gas (bio-SNG) produced from gasification. At present, liquid and gaseous biofuel pathways achieve GHG emission savings of more than 80% compared to fossil fuel. New supply chains for biomethane could result in negative GHG emissions, depending on the proportion of manure in the biogenic feedstock mix. California[16] has for the first time reported this year renewable natural gas achieving a negative carbon intensity under the state's Low Carbon Fuel Standard programme. This is due to an increasing volume of dairy farm waste, such as manure and slurry, being used to produce biomethane.

For renewable diesel and bio-SNG GHG savings range from 88% to more than 100%, when CO_2 capture is included with bio-SNG production. Biofuel producers are exploring various methods to reduce the carbon intensity of their existing supply chain. These include for example, installing on-site biogas CHP, using lower carbon process chemicals such as renewable hydrogen in producing HVO, capturing waste CO_2 for secondary markets, replacing CO_2 produced from fossil fuel powered industrial processes, and securing new biogenic waste feedstocks.

Figure 3: Fuel life cycle GHG emission (CO_2e/MJ) of high blend renewable fuel supply chains



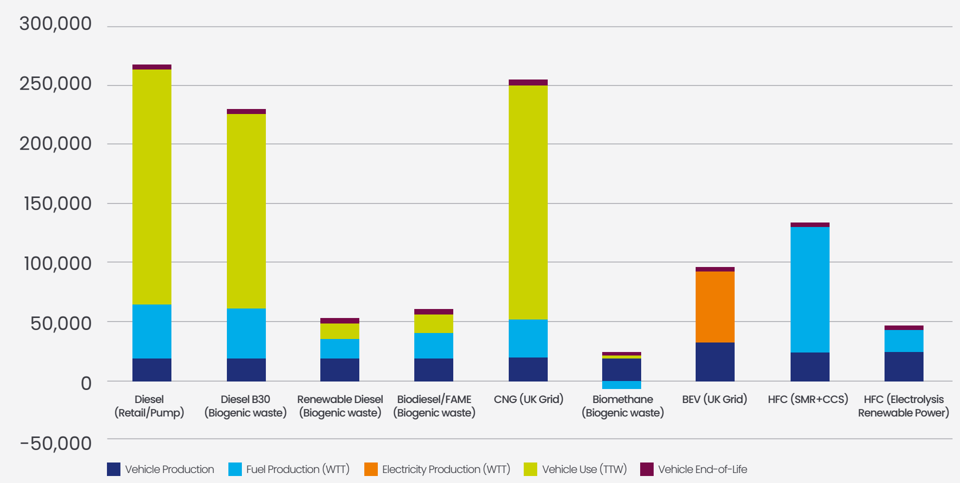
Source of WTT and TTW GHG emission intensities described in Appendix 3.

In order to fully appreciate the opportunity for high blend renewable fuels to decarbonise HDVs a rudimentary vehicle life cycle GHG emission analysis has been undertaken. Figure 4 illustrates the estimated vehicle life cycle GHG emissions for an HGV manufactured in the UK in 2020 and operated over a ten-year lifetime. The operation of the vehicle takes into consideration 'well-to-wheel' GHG emissions. The analysis has assumed a change in well-to-tank carbon intensity of liquid and gaseous fuels, electricity, and hydrogen, for the period 2020 to 2030. This includes decreasing the carbon intensity of the electricity grid, introduction of advanced biofuel supply chains and changes in biomass waste feedstocks. The analysis is focused on fuel and energy supply chains which are available today and likely to achieve commercial potential over the next ten years.

[16] www.bioenergy-news.com/news/californias-natural-gas-vehicles-achieve-first-carbon-negative-milestone/

Figure 3 demonstrates that a portfolio of low carbon technologies and fuels capable of delivering high life cycle GHG savings over the next decade when compared to their fossil fuel counterparts. A combination of these low carbon solutions will be required to deliver deep cuts in HGV emissions, with different options being more suitable, and readily deployable, for different sectors of the HGV market. The chart also demonstrates that when considering WTW GHG emissions, high blend renewable fuels can have a critical role in delivering net zero HGV fleets, and in the right vehicle applications could achieve negative GHG emissions – biomethane in the example below. Given that GHG emissions associated with vehicle operation dominate the vehicle life cycle for HGVs, the use of low carbon fuels in incumbent ICE diesel and gas vehicles is a key decarbonisation solution. The increasing decarbonisation of the electricity grid will benefit both BEV and HFC in terms of WTW GHG emission performance.

Figure 4: Estimated vehicle life cycle GHG emissions (gCO_2e/km) for HGV using different vehicle propulsion technologies and fuels.



- Analysis has been undertaken using Zemo Partnership's in-house life cycle GHG emission tool.
- B30: blend of 30% biofuel combination of biodiesel and HVO
- Biodiesel: assumes 100% blend
- Renewable Diesel: 'Drop in' – paraffinic fuels such as BtL and HVO, assumes 100% blend
- Biomethane: 40% manure feedstock, remaining biogenic waste, assumes 100% blend
- Hydrogen: electrolysis: electrolyser off site powered by wind turbines
- Hydrogen: SMR+CCS, UK natural gas supply – indicative value
- Appendix 4 outlines the sources of data for this analysis.

5. UK policy landscape and perspectives on new interventions

5.1 National policy landscape

Eight existing national policy measures were perceived by stakeholders as being relevant for renewable fuel deployment in HDVs. Fiscal incentives that improve the economic case for investing in low carbon fuels, and vehicles, have the most influence on fleet operator purchase behaviour. This is evident through the growing market for gas trucks using biomethane. There is however an absence of incentives for high blend renewable liquid fuels. Streamlined energy and carbon reporting and internal carbon targets are becoming more important for large companies, stimulating actions to decarbonise existing diesel fleets and their supply chains. However, for smaller companies making investments in lower carbon solutions will be more costly and challenging. The DfT's voluntary GHG emissions reduction commitment with the freight industry could be an important lever for motivating the adoption of high blend renewable fuels. Closer engagement and collaboration with the logistics and road haulage industry could provide a route to raising awareness of the applicability of high blend renewable fuels in this sector and understanding how key challenges can be alleviated.

National policy intervention presently pertaining to high blend renewable fuels –

- HMRC fuel duty discount for biomethane and natural gas.
- Transport Scotland's BSOG Low Carbon Vehicle incentive for biodiesel. A rebate is received by bus operators based on the percentage of biodiesel to standard diesel used, starting at 15%. 100% biodiesel receives 17 pence/kilometre.
- DfT BSOG LCEB incentive offers bus operators 6p/km subsidy for biomethane used in CNG buses. This incentive scheme does not include renewable liquid fuels.
- HMRC Capital Allowance Scheme - applicable for gas refuelling stations, due to expire in 2025.
- Streamlined Energy and Carbon Reporting – mandates Scope 1 and Scope 2 GHG reporting for large companies, Scope 3 is voluntary – this includes contracted transport services such as logistics and haulage companies, as well accounting for 'upstream' fuel production emissions.
- DfT has set a voluntary commitment with freight industry to reduce GHG emissions by 15% by 2025, based on 2015 level.
- Government Buying Standards – public sector authorities can use their purchasing power to promote the use of clean, low carbon and energy efficient vehicles (buy and lease) through setting product standards. There are best practise guidelines related to using sustainable low carbon fuels.
- The Renewable Transport Fuel Obligation was identified as the only renewable supply side policy measure relevant for high blend renewable fuels.

5.2 Recommendations for national policy interventions

A variety of policy interventions were identified and discussed with stakeholders.

5.2.1 Fiscal incentives

Reforming fuel duty to serve as a 'carbon tax' in line with the carbon and energy content of the fuel.
Fuel duty could be priced against the carbon and energy intensity of different fossil and low carbon fuels/energy vectors. Such a taxation scheme is in place in Finland and proving to be effective. Scaling fuel duty in line with fuel carbon intensity was considered the most effective, equitable and beneficial mechanism to stimulate more rapid adoption of high blend renewable fuels. This would provide fleet operators with a greater fiscal incentive to purchase HBRF and stimulate renewable fuel suppliers to decarbonise their production processes. The initiative would require assurance of the carbon intensity of renewable fuel supplied to fleet operators, this could be evidenced, and verified, through Zemo Partnership's Renewable Fuels Assurance Scheme, outlined on page 33.

Stakeholders recommended a review of taxation should take a holistic approach and consider the entire transport sector. Combining this with road user charging was highlighted by one stakeholder as an interesting area to explore.

Duty differential introduced between natural gas and biomethane
This could encourage the greater adoption of biomethane if priced lower than natural gas, thereby giving a fleet operator a better financial incentive to switch to renewable gas. This would also benefit future advanced low carbon gaseous fuels such as bio-SNG.

Fuel duty rebate for higher blend renewable diesel (biodiesel and HVO)
This could work by allocating a pence-per-litre rebate based on the volume of renewable diesel, supplied above the current 7% biodiesel mandate. The rebate could be time limited. This would translate into lower priced renewable diesel for fleet operators. The process would require a fully audited administrative process from the biofuel suppliers to ensure RTFO verified renewable fuel was being supplied to fleet operators at different blends (Zemo Partnership's forthcoming Renewable Fuels Assurance Scheme could provide this evidence).

This intervention was perceived as being a very effective near-term intervention that could achieve quick reaction rates with fleet operators, both small and large. Countries such as Austria and Germany have introduced renewable diesel fuel rebates which are driving the adopting for both biodiesel (up to B100) and HVO.

Truck and coach operator renewable fuel incentive
Similar in approach to the BSOG LCEB incentive, this could entail truck and coach operators receive a rebate in relation to using renewable liquid fuels. The level of subsidy awarded could be associated with GHG savings of the renewable fuel supplied, which would be influence by the blend of renewable fuel adopted by the fleet operator. This would require truck and coach operators to provide evidence of sustainable low carbon usage to Government in order to receive a rebate, akin to how the English and Scottish BSOG schemes operate.

BSOG LCEB incentive to include renewable liquid fuels
Incorporate high blend biodiesel and HVO into the DfT's BSOG LCEB incentive scheme to provide a more level playing field with other low carbon fuels and energy vectors. The payment could be scaled relative to the GHG savings of the biofuel blend supplied.

Extend HMRC Capital Allowance Scheme
Allow more long-term support for gas refueling infrastructure to 2030.

Grants for local authorities to support low carbon fuel initiatives.
This could cover installing refuelling equipment for high blend liquid biofuels and gas refuelling infrastructure at council depots and strategic locations in towns and cities. Local authorities could be awarded funding to establish open access local refuelling hubs. Grants could be competitive and focus on areas with strategic benefits.

5.2.2 RTFO-related mechanisms

Introduce an RTFO sub-target for higher blend biofuels going to HDVs
This could provide mechanism through the RTFO dedicated to supplying high blend renewable fuel to captive HDV fleets. A positive aspect of this approach would be in safeguarding against drop in fuels being absorbed in the fungible diesel pool. Exploring how the benefits of RTFCs could be translated into a stronger monetary value for fleet operators was raised by one stakeholder.

Introduce an obligation for a proportion of high blend renewable diesel to be supplied to HDV fleets
This could, for example, be set at 0.5% from 2025. Alternatively, start with a fuel duty rebate for higher blends then phase this out, introducing an RTFO obligation to supply a percentage of higher blend renewable diesel to HDVs.

Raising the existing target level of the RTFO to a level which pulls in higher blends
This would be highly important to prevent any potential cannibalisation of the target resulting from a successful High blend renewable fuel intervention programme. This was considered a priority for many renewable fuel industry stakeholders with regards to: a) to fully cover impact of E10 so that biodiesel is not impacted negatively, b) to take account of the growth in biomethane consumption, c) to take account of electrification and vehicle efficiency gains, but it must also go beyond that, so that it creates a demand for the remaining fuel to be decarbonised using higher blends.

This measure alone will not necessarily encourage fleet operators to invest in running their fleets on B100 or B30, additional financial incentives would be required.

Amend the RTFO to a system rewarding fuels on the basis on their GHG emission intensity
This could entail RTFCs being allocated in-line with renewable fuel GHG emission intensity. This could stimulate greater GHG emissions reduction in renewable fuel production and help the commercialisation of advanced renewable fuels.

5.2.3 Further policy measures

Run a 'know your renewable fuel' campaign targeted at the freight sector
This was perceived as a very useful marketing mechanism by Government to raise awareness about renewable fuels and the associated GHG benefits to the freight sector. This could be tied to the Government's commitment with the freight sector to reduce HGV GHG emissions by 15% by 2025.

Stronger recognition of renewable fuels in decarbonising HGVs in policy and WTW GHG emission performance
Greater recognition in Government strategies and plans of the role of renewable fuels in decarbonising HGV was considered valuable, in conjunction with recognition of positive WTW GHG emission performance. This was considered important for demonstrating the variety of options available to fleet operators for fleet decarbonisation, especially for certain HGV sectors which will find it challenging to switch to zero tail-pipe emission vehicles prior to 2030.

An innovative approach raised by one stakeholder was introducing an additional compliance option under the heavy-duty vehicle CO_2 standard by allowing heavy duty vehicle manufacturers to earn credits for supporting investments in specific fuel decarbonisation technologies, including advanced renewable fuels. This would consider WTW GHG emission performance rather than just tail-pipe emissions[17].

Government buying standards to take account of renewable fuels for HGVs.
Best practise standards could promote the use of high blend renewable fuels for HGVs, in particular for heavier HGV segments. This could specify the use of RTFO-verified, sustainable low carbon fuels.

[17] www.fuelseurope.eu/wp-content/uploads/Cerulogy_Truckin-on_March2019.pdf

5.3 Recommendation for local policy interventions

Local authority environmental policy is presently quite focused on improving air quality, with emphasis on tailpipe emissions reduction. This means that there are limited interventions in place specifically related to low carbon fuels and broader WTW GHG emission reduction. A small number of local authorities have vehicle procurement policies which includes the use of clean vehicles in combination with renewable fuels. A few local authorities have policies related to climate change and economic development encouraging 'waste to bioenergy' projects; this includes the production of biomethane from agricultural waste and use in local fleet vehicles; Cornwall Council is one example. A growing number of local authorities have introduced Climate Change Strategies which typically include GHG emissions reduction targets for road transport. This could be an effective platform for introducing local policies which encourage the adoption of high blend renewable fuels in HDV fleets.

Planning policy - this could entail requiring construction management plans to include the use of high blend renewable fuels in Euro VI vehicles. Vehicle GHG emission-based performance criteria could be created for construction vehicles and machinery or an overall construction site GHG emission target. Construction companies could provide evidence during the planning process. (Construction companies could also see this as an opportunity to meet corporate social responsibility – CSR – requirements.) Performance criteria could be set to ensure RTFO verified low carbon fuels are deployed, with evidence required to demonstrate supply chain GHG and sustainability performance.

Public procurement standards (Government Buying Standards) - local authorities could set procurement standards for their own vehicle fleets and their contractors vehicles based on vehicle emissions standards and the use of renewable fuels. This could specify the use of high blend renewable fuels for HDV fleets, in particular those associated regional and long-haul duty cycles. Central Government could also set requirements for Euro VI HGVs using renewable fuels in their own procurement standards, in particularly for heaviest truck segments. These specifications could be adjusted over time as the availability, and affordability, of zero emission tailpipe HGV vehicles improves.

Fleet emission reduction targets and strategy - embedding GHG emission targets into a council's own transport services and preparing a strategy for adopting clean vehicles and low carbon fuels over the next decade, which includes HDVs. The use of an internal carbon price could help fleet managers compare different solutions and demonstrate the benefits renewable fuels could bring in terms of GHG emissions reduction.

HDV upgrade grant – targeted at SME (smaller operators) to help support the cost of moving to Euro VI diesel and gas trucks or Euro VI diesel buses and coaches, either through purchasing or leasing a new vehicle or retrofitting with NOx abatement technologies to older diesel vehicles. A condition of a grant could be for the vehicle to run on high blend renewable diesel or biomethane – Low Emission Vehicle criteria could be established. This can serve as an interim solution until market conditions for adopting zero tailpipe emission HDV improve, and they become affordable for SMEs.

5.4 Additional measures to help accelerate the adoption of high blend renewable fuels

Heavy duty vehicle manufacturers to warranty a wider range of engines for high blend biodiesel
This was perceived as a highly important intervention to encourage further adoption of high blend biodiesel. Encouraging HD manufacturers to offer an extension to vehicle warranties was considered a key priority. If funding were available from Government a wider range of biodiesel blends could undergo vehicle engine testing and be approved by manufacturers, thereby giving assurance of operational performance.

Improved dissemination of guidance and engagement of fleet operators

The wider dissemination of guidance regarding biofuels availability, GHG performance, whole life costs and performance were identified as important information requirements. This would help companies understand the business case for adopting higher blend biofuels. More case studies demonstrating success stories; in particular, high blend biodiesel deployment. Clearer information regarding OEMs' approvals and warranty position for different biodiesel blends was highlighted as useful to communicate.

Key stakeholder groups mentioned to target in terms of awareness raising were local authorities and business involved in construction, haulage, and logistics. Zemo Partnership has produced a Renewable Fuels Guide which provides a good starting point for fleet operators. Further dissemination and direct engagement with organisation such as RHA and Logistics UK was suggested. A central on-line information source for low carbon fuels and technologies was also suggested. This is being delivered through Energy Saving Trust's Freight Portal in association with Zemo Partnership.

Zemo Partnership Renewable Fuels Assurance Scheme

Zemo Partnership has established a Renewable Fuels Assurance scheme to address uncertainties raised by fleet operators regarding GHG emission performance and feedstock sustainability of different biofuel supply chains. The scheme aims to improve the credibility of renewable fuel amongst commercial vehicle operators and provide assurance that operators are purchasing sustainable low carbon fuels that have been approved under the Government's RTFO scheme. This scheme will essentially serve to guarantee the origin and 'well-to-tank' (Scope 3) GHG emission performance of a variety of renewable fuels, including blends of biofuels; specific to a fleet operator's supply chain. Claims of GHG emission savings and feedstock sustainability performance will verified through an independent audit process. The scheme aspires to raise confidence in fleet managers in terms of understanding the business case for adopting high blend renewable fuels, and for disclosing their transport fleet GHG emissions performance in corporate carbon reporting and CSR plans. The scheme will be launched in Q1 2021.

Recognition scheme for fleet operators using renewable fuels

Zemo Partnership proposes that an initiative is established which recognises fleet operators who are using renewable fuels, including high blend renewable fuels. This would raise the profile of companies decarbonising their vehicle fleets using sustainable low carbon fuels and could encourage a company's contractors to adopt high blend renewable fuels. The scheme would have further impact if was recognised within public and corporate vehicle procurement standards. This scheme could link to Zemo Partnership's Renewable Fuels Assurance scheme by enabling fleet operators to demonstrate they are purchasing sustainable low carbon fuel from an approved supplier.

Low Emission Freight Trial – Part Two

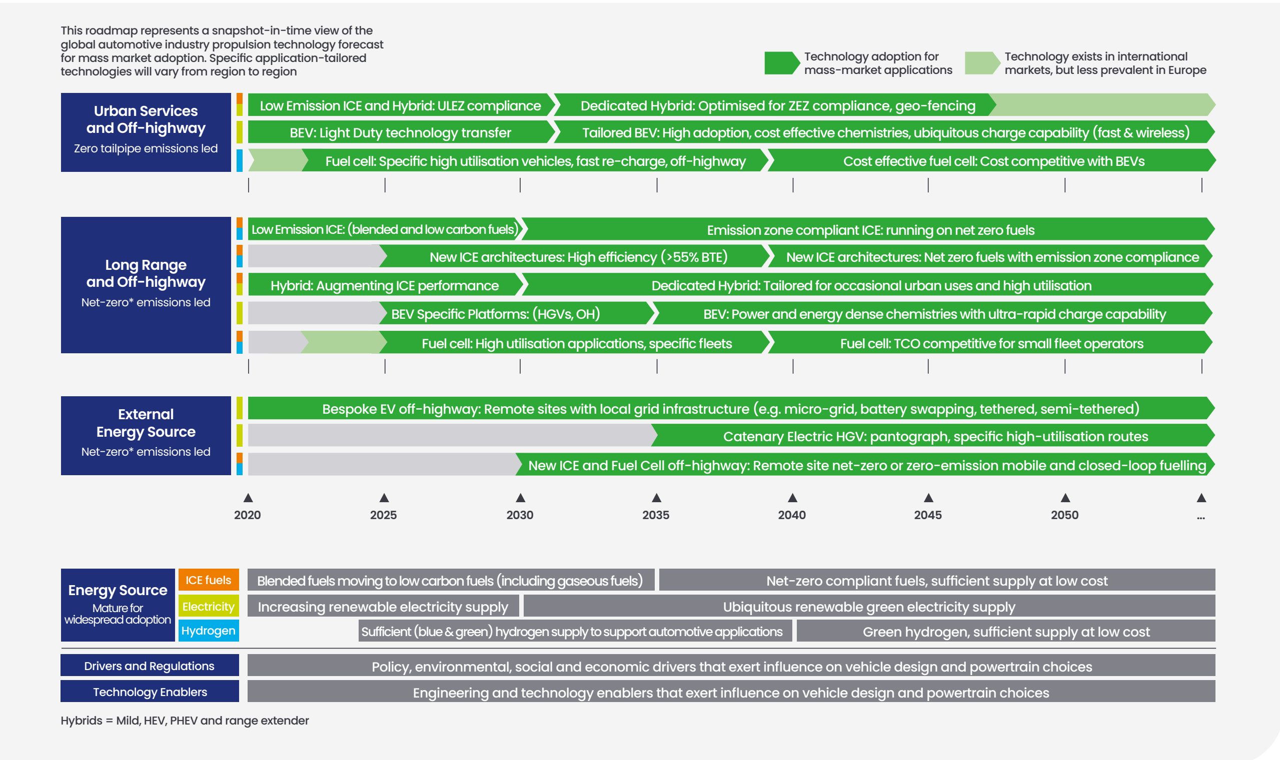
It could be useful to undertake a demonstration trial, like the LEFT programme, focused on high blend biodiesel (B30/B100) and HVO deployed in Euro VI trucks and coaches. This could also include new types of thermally efficient heavy-duty engines which may enter the market over the next few years. This could provide data to raise fleet operator confidence in the operational and economic performance of HDVs using high blend renewable fuels in different applications and duty cycles. It could provide robust and representative GHG emission and air pollution emission performance data.

6. The long-term role for high blend renewable fuels in decarbonising HDVs

The Advanced Propulsion Centre (APC) HGV product roadmap[18], Figure 4, indicates that mass market adoption of zero tailpipe emission HGV technologies for long range applications may not materialise until after 2035. The roadmap shows the role for high blend renewable fuels in HGVs to 2050 in low emission internal combustion engine vehicles. The roadmap suggests that from 2035 net zero fuels will be increasingly utilised.

Low carbon fuels such as high blend renewable fuels could bring additional GHG savings when used in hybrid and range extender vehicles. For long-haul buses and coaches, the mass market roll-out of zero emission tailpipe technologies is also anticipated after 2035; this suggests that there is an opportunity to decarbonise the residual diesel bus and coach fleet in the interim period. For buses and coaches the APC's product roadmap identifies a role for low carbon fuels for 'long range mobility', in internal combustion engine zero emission-capable vehicles.

Figure 4: APC HGV roadmap



[18] www.apcuk.co.uk/product-roadmaps

The APC's HGV thermal propulsion systems roadmap[19] identifies an on-going role for internal combustion engines to 2050, complemented by sustainable fuels, including biofuels. From 2025, reductions in tailpipe HGV CO_2 emissions will result from progressive improvements in vehicle efficiency through new EU heavy-duty vehicle CO_2 regulations – driving a 15% improvement in fuel efficiency by 2025 and 30% by 2030. This will be achieved through the introduction of new types of high efficiency power units such split-cycle engines. When combined with high blend renewable fuels the opportunities for net zero HGVs could begin to materialise from 2025 onwards, resulting in ultra-low WTW GHG emissions. This will be complemented over the next decade by the introduction of Euro VII air quality emission standards.

The Transport Energy Network report[20] highlights that regional and long-haul HGVs will be one of the most challenging of the heavy-duty sectors to decarbonise, requiring a portfolio of solutions including sustainable low carbon fuels. The report emphasises the importance of commercialising and scaling-up supply chains for advanced sustainable biofuels, as well electro-fuels, and low carbon hydrogen after 2030.

19 www.apcuk.co.uk/technology-roadmaps/
20 www.apcuk.co.uk/planning-future-automotive/spokes/transport-energy-network/

7. Estimating GHG savings for HDVs adopting high blend renewable fuelss

An Excel model has been built to demonstrate the potential GHG savings HDV fleets could achieve through the introduction of high blend renewable fuels in the near-term 2020 to 2030, then long-term from 2030 to 2050. Scenarios were based on forecasting the transition of HGVs from diesel ICE to zero emission propulsion over the next three decades with and without contributing GHG abatement from high blend renewable fuels. The focus of the analysis has been on HGVs given their significant diesel usage and as they provide the greatest opportunity for GHG emission reduction using high blend renewable fuels. A limited additional analysis has been undertaken for buses and coaches. The analysis assumes that a variety of policy interventions will be introduced over the next decade to accelerate High blend renewable fuel deployment. This would be augmented by various 'softer' measures, outlined in the previous chapter.

The methodology entailed sourcing data on registered UK HGVs by age and type (N2 Rigids, N3 Rigids and N3 Artics)[21] plus annual mileage of HGVs by age and type[22]. Overall (diesel) fuel use by HGV age and type[23] was then determined.

The 2019 HGV parc profile has been maintained to 2050. No overall change in total energy requirement at the wheels has been assumed – HGV traffic growth being offset by efficiency improvements has been the general trend since 1990 (emissions have flatlined). Current pump-average diesel fuel WTW GHG emissions factors have been held constant as the baseline scenario. Further details of GHG emission factors can be found in Appendix 4.

[21] Data for UK parc obtained from DfT Stats Team, as at end 2019

[22] Data from TRACCS project (2010), correlated to published DfT overall HGV mileage statistics (3/5/10 bn veh-miles)

[23] Typical average mpg's assumed for each HGV type (13/9/10), correlated against CO_2e (fuel) data from NAEI gives overall diesel fuel use for each type of HGV (1/2.5/4.5 bn litres)

7.1 Electrification scenarios

Three electrification scenarios were modelled (fast, reference, slow), Table 10. The Fast EV uptake scenario is modelled on Daimler's commitment to fully electrify all their HGVs by 2040, although note that the commitment probably assumes a high proportion of fuel cell-powered vehicles. A 2040 date has also been suggested by the National Infrastructure Commission. The slow EV uptake scenario assumes full ZE new sales of all HGV types no later than 2050. (So, all scenarios have very low demand for ICE fuels - excluding H2 - after 2050. Growth rates have been modelled to be realistic based on those already achieved for electrified cars in Norway).

Table 10: EV adoption scenarios

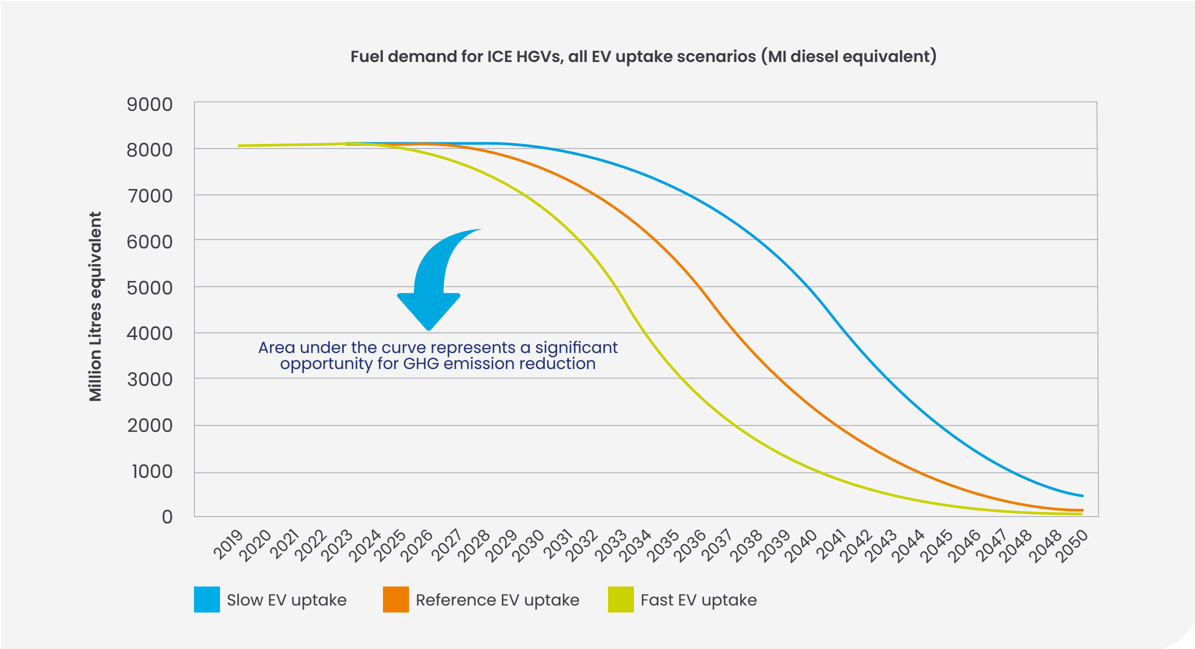
EV Scenario	100% of new N2R	100% of new N3R	100% of new N3A
Slow	2040	2045	2050
Reference	2035	2040	2045
Fast	2035	2035	2040

The electrification scenarios are based on electrified miles as a proportion of all HGV miles (of the same type) from new HGVs each year from 2020. Electrification is based on direct electrification only (battery and/or ERS). The projected future grid carbon intensities have been used, regardless of overall demand for electricity and were taken from BEIS electricity grid carbon intensity projections to 2050[24].

Figure 5 illustrates the modelled equivalent ICE HGV diesel demand across each of the slow, reference and fast uptake scenarios. Demand for combustion fuel remains at or around 8 billion litres-equivalent throughout the 2020s under all scenarios. Demand falls to <1 billion litres equivalent in the 2040s under all scenarios. Demand in the 2030s is highly dependent on the specific EV uptake scenario used. The 2038 range is from 2-7 billion litres, for example. From 2020 – 2032 irrespective of the EV uptake scenario, there remains a significant volume of diesel in the HGV fleet that could be decarbonised. This demonstrates the key opportunity for deploying high blend renewable fuels in both rigid and articulated HGVs.

24 BEIS projections https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal

Figure 5: Modelled HGV diesel demand across all EV scenarios



7.2 High blend renewable fuel scenario

The High blend renewable fuel scenario covers partial displacement of diesel-powered vehicles with gas powered vehicles running on biomethane, and partial displacement of diesel in existing and new HGVs with FAME and HVO. The analysis has focused on back-to-base HGV fleets, assumed to account for 60% of the overall fleet. The modelled scenarios adopted were:

- 30% adoption of gas vehicles using biomethane (100%) for new ICE artic HGVs by 2030
- 30% (B30) liquid biofuel adoption for remaining HGVs by 2030

New gas-powered vehicles applied only to the articulated vehicle segment (N3A), and for new vehicle sales they reach 30% ICE market penetration (or, more accurately, 30% of new, non-electrified vehicle miles) by 2030, and stabilise at 30% thereafter (until all new artics are electrified). All gas vehicles run on certified 100% biomethane. The artic fleet was chosen as evidence to date demonstrates this HGV sector is best suited to running on biomethane, achieving the highest GHG emission savings due to high mileage and long-haul duty cycles.

Renewable fuels use ramps up in the 2020s so that by 2030, 30% of the diesel fuel demand is met by some combination of biodiesel and drop-in fuel such as HVO. The exact mix is not relevant to the modelling (it can be all diesel trucks running on B30, or 30% running on HVO, or any combination in between). The analysis has assumed this rises to 60% by 2050 as the volume of diesel in the residual fleet reduces. At the same time, renewable diesel becomes available due to the electrification of the LDV fleet and concurrent reduction in fuel demand.

All biofuels are modelled to produce 85% WTW GHG savings compared with current pump average diesel at 100% blend; this is considered reasonable given the current WTW GHG emission performance of current high blend renewable fuels used in HDV fleets. For a 30% (B30) renewable fuel blend the WTW GHG benefits reduce to around 25% less than the current pump average.

7.3 Modelling outcomes

Table 11 presents the modelling results for 2030, 2040 and 2050. The modelling work has revealed that the wider adoption of high blend renewable fuels in rigid and artic HGV fleets from 2020 – 2030, during the very early transition to electric vehicles, could be significant. For the electric vehicle-only scenarios ranging from slow to rapid adoption rates, cumulative WTW GHG emissions are estimated at 298 – 307 $MtCO_2e$ by 2030. The concurrent adoption of high blend renewable fuels (combination of biomethane and B30 renewable diesel) could reduce these by an additional 44-47 $MtCO_2e$ emissions by 2030.

From a 2019 baseline, cumulative HGV GHG emissions could fall by an estimated 16% by 2030 for the reference EV scenario combined with High blend renewable fuel adoption, compared to less than 2% for the new vehicle electrification-only pathway. By 2040, the combined savings rise to 39% and 17% respectively. This would subsequently give rise to significant benefits in reducing wider road transport GHG reduction.

In the event of slow EV adoption rates by HGV operators, high blend renewable fuels could enable continued GHG emissions savings to be realised and provide a supportive, risk mitigating GHG abatement solution. This is evident in Table 11 which shows the largest GHG emissions savings associated with high blend renewable fuels for the slow EV take-up scenario.

Between 2040 and 2050, as the EV HGV fleet increases, the volume of diesel in the residual ICE fleet lessens, and this enables a larger proportion of renewable biofuel to be blended, enabling continued GHG emissions savings. Zemo Partnership modelling has shown this could bring about an additional 140 Mt cumulative CO_2e savings by 2050 based on the reference scenario.

Table 11: Estimate of cumulative WTW GHG emissions 2030, 2040 and 2050 of HGV electrification with and without high blend renewable fuel uptake

WTW GHG ($MTCO_2e$)	2030			2040			2050		
	Slow EV	Ref	Fast EV	Slow EV	Ref	Fast EV	Slow EV	Ref	Fast EV
Do nothing scenario	308	308	308	564	564	564	820	820	820
Electrification without HBRF	307	303	298	523	468	410	593	502	430
Electrification with HBRF	260	257	253	373	342	313	408	362	328
HBRF additional savings	**47**	**46**	**44**	**150**	**126**	**97**	**186**	**140**	**102**
Electrification savings %	0.3%	1.4%	3%	7%	17%	27%	28%	39%	48%
Further HBRF savings %	15%	15%	14%	27%	22%	17%	23%	17%	12%
Combined savings %	**16%**	**16%**	**18%**	**34%**	**39%**	**44%**	**50%**	**56%**	**60%**

7.4 Factors influencing high blend renewable fuel adoption rates

The analysis has adopted a pragmatic perspective in terms of uptake rates for gas vehicles using biomethane and high blend liquid biofuels. A variety of factors were considered relevant for further discussion.

Introduction of a Government fiscal incentive would be necessary to encourage the wider take-up of liquid biofuels thereby making the switch more affordable to vehicle operator. Engagement with stakeholders suggested this could start to materialise within twelve months of the Treasury introducing an intervention. Obviously, the time taken for Government to introduce such an incentive is a key variable. Large operators would likely react first, with smaller operators following shortly with the right awareness-raising interventions in place. Improving the warranty position manufacturers take regarding high blend biodiesel would have greater influence on the speed of adoption. Company Carbon Reporting and GHG reduction targets will increasingly influence companies, and their suppliers to adopt lower carbon transport solutions. Indeed, this is happening now. However, this will only materialise more quickly, and across a larger number of fleet operators, with additional fiscal subsidies in place, especially for high blend liquid biofuels.

In the case of gas trucks using biomethane, a fuel duty differential between natural gas and biomethane, could quicken the adoption rate of gas trucks. It is assumed that by 2025 the second-hand market for gas trucks will have developed and that public and open-access gas refuelling stations will have increased, growing further to 2030. An increasing number of both large and small operators would, by then, have adopted gas trucks using biomethane.

In terms of demand for biomethane in road transport, consideration needs to be given to potential competing demand for decarbonising heat. Our analysis has indicated that biomethane demand would be no higher than 1,200 kt per annum – this is less than 50% of the estimated overall UK supply potential (100 PJ) - or as low as 800 kt. Biomethane demand peaks in the early to mid-2030s, depending on the EV uptake scenario. Engagement with biomethane suppliers has indicated this will not present a challenge for various reasons.

Firstly, the RTFO's approval of cross-border mass balancing is enabling wider supply chain opportunities for biomethane, arising from Europe. This will reduce pressure on domestic biomethane supplies. New Ofgem rules are enabling AD operators in the UK to allocate some of their biomethane to the heat sector (RHI) and some to transport (RTFO), which is increasing the availability of biomethane going to transport. The new Green Gas Support scheme will stimulate the building of new AD plant, enabling biomethane to be shared between the heat and transport sectors. New supply chains for bio-SNG, produced from biomass gasification, will also start to contribute renewable gas for HGVs over the next decade. One company, Advanced Biofuel Solutions Ltd, now has a plant operating in the UK. More detailed work is required to evidence the likely availability of biomethane for road transport over the next decade.

With regards to factors influencing liquid biofuel supply chains competing factors include increasing demand for HVO in the NRMM sector, and potential competition for biomass feedstocks from other sectors. Further work is required to fully understand biofuel feedstock and supply chain dynamics over the next decade. Stakeholders interviewed in this study identified opportunities to stimulate supply chains for 'drop-in' liquid biofuels in the production of sustainable aviation fuel.

Two stakeholders mentioned near- term opportunities for expanding HVO supply in the UK due to a growing international market. This includes a commitment to increasing plant capacity by Neste Oil and new supply chains from Europe. Over the next two years it has been suggested that up to a billion litres of HVO could be supplied in the UK. With regards to biodiesel, increasing volumes are likely to become available as the LDV market is increasingly electrified. This will open opportunities to decarbonise HGVs using high blend renewable fuels. A critical policy intervention that will need to materialise is the expansion of the current RTFO target in 2032. Our modelling work indicates that beyond 2030, the total supply of biodiesel/HVO into the HGV market will continue to rise, as renewable fuel use by cars and vans falls, by 150 Ml per annum.

7.5 Further analysis - buses and coaches

Modelling was based on similar methodology to HGVs: 44,000 buses and 27,500 coaches. High blend renewable fuel assumptions are in line with the scenario for HGVs but restricted to liquid biofuel (FAME/HVO). One reference scenario for EV uptake assumed the electrification of 100% of buses by 2035, coaches by 2040. As can be seen from Table 12, greater cumulative WTW GHG emission savings are achieved between 2020 and 2050 with the deployment of high blend liquid biofuels.

Table 12: Cumulative WTW GHG emissions for buses and coaches with and without high blend renewable fuel adoption

WTW GHG ($MTCO_2e$)	2030	2040	2050
Do nothing baseline	47	87	126
Electrification without HBRF	45	66	72
Electrification with HBRF	42	52	54
HBRF savings	**3**	**14**	**17**
Electrification savings %	5%	24%	43%
Further HBRF savings %	**7%**	**16%**	**14%**
Combined savings %	12%	40%	57%

8. Conclusion

The study has revealed that to date, the greatest adoption of high blend biodiesel has been in the bus market, being deployed in approximately 17% of the bus fleet. For biomethane and HVO, the highest adoption rates have taken place in HGV fleets, representing less than 1% of the vehicle parc.

One of the key findings was that HGV fleets with back-to-base operations offer the greatest opportunities for deploying high blend renewable fuels and delivering substantial GHG emission savings. High blend renewable fuels were considered to offer an immediate solution for mitigating GHG emissions during the transition to zero tailpipe emission HGV technologies. They are also likely to provide benefits as they can provide a decarbonisation solution for a variety of challenging diesel HGV applications. These are vehicles with the heaviest payloads, and those travelling over high mileages, in particular regional and long-haul duty cycles. High blend renewable fuels were identified as having a long-term role in decarbonising HGVs, serving as a complimentary pathway to zero tailpipe emission technologies. The greatest long-term opportunities can be seen for low carbon 'drop-in' liquid and gaseous fuels in highly efficient ICEs, potentially resulting in net zero HGV fleets when considering WTW GHG emissions.

The study has demonstrated that significant GHG emission savings could be achieved over the next decade from the HGV fleet adopting a 30% renewable fuel blend taking into account diesel and gas HGVs. This would be helpful in meeting the RTFO's 2032 target, and potentially delivering sizable GHG emissions savings that could contribute to achieving the Fourth Carbon Budget. Decarbonising the legacy diesel HGV fleet using high blend renewable fuels, in combination with the roll-out of zero tailpipe emission technologies could facilitate much greater, and rapid, GHG emissions reductions from 2030 onwards, than an electric-only pathway.

For the bus sector, the definitive role for high blend renewable fuels was more difficult to determine given the strong focus on moving to e-mobility in towns and cities. For buses operating out of town and rural routes, high blend renewable fuels could be a more suitable GHG emission reduction option. As a large proportion of the coach sector has high mileage journey profiles, there could be a key role for high blend liquid biofuels given the slower pace of shifting to e-mobility for the sector.

A variety of barriers to the wide scale adoption of high blend biodiesel, HVO and biomethane were identified. These related to financial, operational, and information-related issues. A range of interventions were recommended by stakeholders which could increase the adoption of these fuels. These covered national and local policy measures, as well as non-Government enablers. The measures recommended where primarily focused demand-side measures, though several supply side enablers were also raised. The introduction of a Government fiscal incentive for high blend liquid biofuels was considered to be a particularly important measure of increasing adoption rates in the near-term, with a more ambitious recommendation of restructuring fuel duty based on the carbon and energy intensity of different fuels and energy vectors. Increasing the current 2032 RTFO target beyond 12.4% by volume was highlighted as a critical supply side intervention.

Recommendations for further work

- Undertake wider engagement with HGV operators through the RHA, Logistics UK, CILT plus the vehicle leasing sector (BVRLA) and SMMT to explore the demand side interventions recommended in the study in more detail. This could help identify policy options capable of delivering the most rapid High blend renewable fuel take-up rates and achieve the highest GHG emission savings. The engagement could also take into account the non-government lead interventions recommended.

- Undertake further examination of the demand and supply side policy interventions with different stakeholders to understand various dependencies between options and ensuring no unintended consequences. Further work should also explore the practical and financial implications of delivering the interventions proposed.

- Zemo Partnership to progress with the launch of the Renewable Fuels Assurance Scheme, followed by designing and piloting a scheme which gives recognition to fleet operator using sustainable low carbon fuels in their vehicle fleets.

Appendix 1 – Stakeholders who participated in the study

Table A: Stakeholders who participated in this studytailpipe emission technologies could facilitate much greater, and rapid, GHG emissions reductions from 2030 onwards, than an electric-only pathway.

Fleet Operators	Biofuel Industry	Trade Bodies	OEMs
John Lewis Partnership	CNG Fuels	Renewable Transport Fuel Association	Scania
Sainsburys	Air Liquide	Logistics UK	Leyland/DAF
Asda	Gasrec	Road Haulage Association	ADL
Howard Tenens	Greenergy	UKPIA	Volvo
Kuehne & Nagel	Argent Energy Ltd		Mercedez Benz
London Borough of Camden	Nova Pangaea		Iveco
London Borough of Hackney	Crown Oil		Renault
Cornwall Council	Green Biofuels		MAN
UPS	Neste		
Coca Cola	Velocys		
Wincanton	Portland Fuels		
First Group	Calor		
Alfred Hymas	Corytons		
Go Ahead	Olleco		
TfL	Air Liquide		
National Express			
Wolseley UK			
Hayton Coulthard			
CEVA logistics			
DDC Fuel Services			

Appendix 2 – Stakeholder interview and survey questions

Fleet operators and local authorities

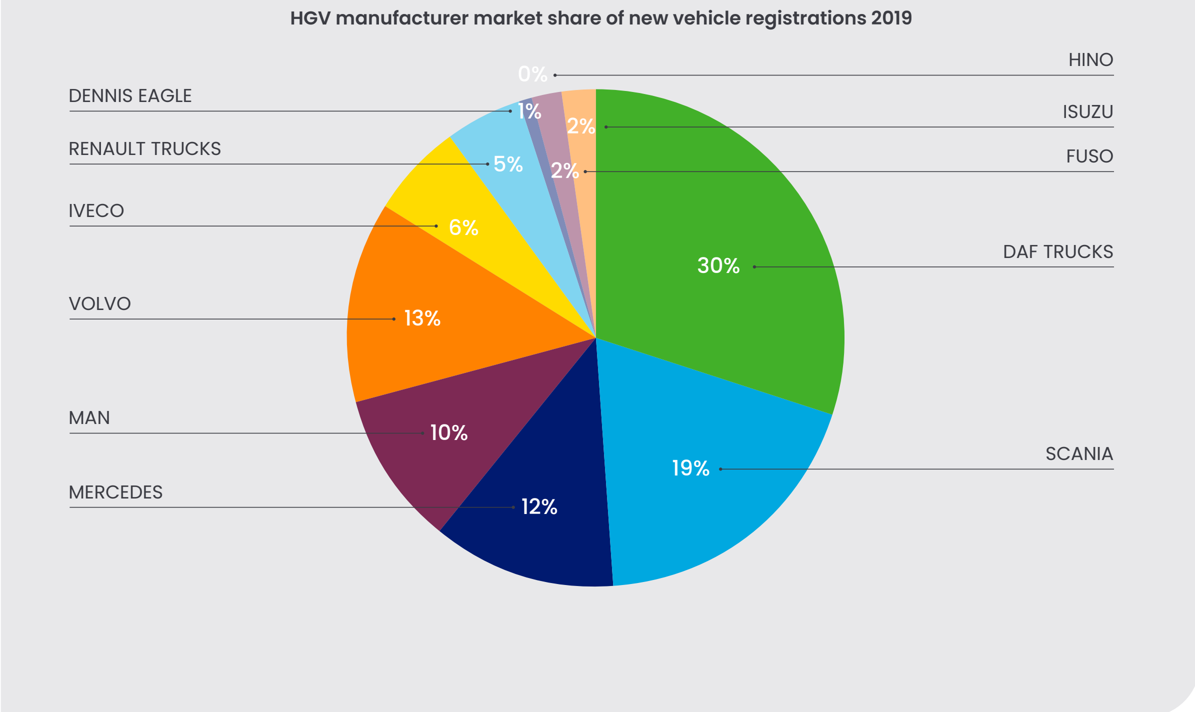
1. How many HGVs do you operate in your fleet?
2. What proportion of your fleet are Euro VI?
3. What category of trucks do you run? Rigid 7.5-18t, Rigid 18t-36, Artic 26t - 36t, Artic 40t - 44t
4. What is your typical journey profile (duty cycle)?
5. How do you purchase your vehicles?
6. How long do you keep your vehicles?
7. Do you have refuelling facilities at your depot?
8. Where do you source information regarding new vehicle purchases including low carbon vehicles and renewable fuels?
9. Are you aware of any of the following renewable fuels that are currently on sale in the UK Biodiesel FAME – B20/30, Biodiesel FAME – B100, HVO, Biomethane, BioLPG
10. Does your vehicle fleet run on biofuels? Which biofuels do you use?
11. What factors influenced your decision to adopt biofuels?
    For example: improved whole life costs than diesel, reducing your fleet GHG emissions, improving corporate image / CSR, contract required use of low carbon fuels
12. How important was access to public refuelling infrastructure for your deployment of biofuel?
13. How do you perceive the GHG emissions and sustainability performance of biofuels?
14. If you are not using biofuels in your fleet why not? For example:
    - Unaware of the options available
    - Vehicle purchase and operational cost too high
    - Lack of confidence of vehicle performance
    - Unaware of whole life costs compared to diesel
    - No commercial reasons to adopt them
    - Lack of OEM compatibility and warranty eg FAME B20/100
    - Difficult to install refuelling infrastructure at your depot eg CNG/LNG
    - Other practical/cost barriers
15. What Government interventions might encourage more operators to adopt renewable fuels?
16. If GHG emissions reduction is important to your business what is driving this?

Renewable fuel supply chain stakeholders

1. Where do you see the greatest opportunities in the UK HDV fleet in terms of High blend renewable fuel deployment over the next 15years?
2. What key challenges do you believe are preventing more rapid take up of high blend renewable fuels?
3. What supply and demand policy interventions do you believe would encourage the wider take-up of high blend renewable fuels in HDVs?
4. Have you any other additional suggestions for policy interventions not considered above?
5. Do you foresee any refuelling challenges for deploying 30% blend of renewable liquid biofuel?
6. How could refuelling challenges be overcome?
7. Do you foresee any supply chain challenges if demand of high blend renewable fuels significantly increased over the next decade and long term?
8. What role could HDV manufacturers take in helping to accelerate the adoption of high blend renewable fuels?

Appendix 3 – Heavy duty vehicle manufacturer approval and warranty

For the UK fleet the share of the market controlled by each of the heavy-duty engine manufacturers were determined using SMMT new vehicle registration statistics, 2019, for HGVs, buses, and coaches[25]. An example of HGV data is presented below. The age profile of UK trucks, buses and coaches was determined through statistics on vehicle Euro Standards data from RHA[26], DfT[27] and Zemo Partnership[28]. This was then apportioned to different manufacturers biodiesel approval and warranty position across vehicle types and ages. Further details on the following page. This was repeated for HVO.



HGV manufacturer market share of new vehicle registrations 2019

Euro Standard	Number of HGVs
Euro VI	244853
Euro V	136367
Euro IV	43169
Euro III	32046
Pre Euro III	33565

25 www.smmt.co.uk/vehicle-data/heavy-goods-vehicle-registrations/ www.smmt.co.uk/vehicle-data/bus-and-coach-registrations/
26 www.rha.uk.net/getmedia/03b81d92-bade-445f-9f14-3fc066db6ae8/180508-2018-RHA-Emission-Assessment-v1.pdf.aspx
27 www.gov.uk/government/statistical-data-sets/veh05-licensed-heavy-goods-vehicles
28 Zemo Partnership 2020 Coach Market Report - https://www.Zemo Partnership.org.uk/Hubs/lec.htm

Heavy duty vehicle engine manufacturers were contacted and provided valuable information about their position on biodiesel compatibility and warranty.

DAF	Euro III LF & CF65 models can use B20 (EN14214) without modification of the vehicle or change to service requirements • All DAF CF75, CF85 & XF95 & XF105 vehicles produced from 2001 can operate subject to certain specifications & service limitations (1) can be operated on blends up to B100 including Euro VI Euro VI - MX-11, MX-13, XF and CF B30 Euro VI PX-4, PX-5, PX-7. B20
Daimler/ Mercedes Benz	All Euro III, IV and V engines fitted with unit injectors can be operated on B20/30 and B100 biodiesel (specified only as FAME, EN16709 & EN14214), given a range of precautions and increased service frequency. Some parts may need changing for B100 compatibility (2). Euro VI Actros 4, only if fitted with Code M0W, B100
Iveco	All engines compatible only with current pump diesel (B7)
MAN	All Euro III, IV, V engines can be operated on B100 biodiesel (specified only as FAME, EN14214) but an additional warranty would need to be purchased, and currently MAN only provide this for vehicles that are on contract. (3) Euro VI OBD-D truck range only for B20, B30 and B100 (but no fleets are these vehicles operating in the UK) Service intervals must be more frequent then EN 590 and the vehicle is supplied with an extended warranty.
Renault Trucks	Renault Trucks gives a manufacturer's guarantee of two years for the use of biodiesel mixed with diesel up to 30% for all engines in its trucks (Euro III, IV, V, VI). The warranty is subject to two conditions: the intervals for the change of oil should be increased to twice normal rate; and if rape seed biodiesel is used, it should comply with the European norm EN 14214. Some Euro VI engines run on B30 and B100.
Scania	All Euro III, I, V and VI engines with unit injectors can operated on B20, B30 & B100 biodiesel (specified only as FAME, EN14214 and EN16709) but there are additional servicing requirements. For Euro V trucks, all can be B100 compatible, but this should be specified at the time of ordering so that vehicle is built with appropriate gaskets and hoses, etc. again there are additional servicing requirements. All engines also run on B20 and B30. Euro VI DC09 108 & 112, DC09 133 & 134, DC09 320, DC13 124/125, DC16 106. B20 – B100
Volvo	Volvo permit the use of B30 in Euro III, IV, V engines using unit injectors. Plus there are other servicing requirements (4). Euro VI engines are only compatible with blends up to B10

1) The specification items include fuel line water separator, replacement fuel hoses. Service requirements include half the normal oil drain intervals, fuel filter replacement and fuel tank checks- this can significantly increase annual operating costs. Warranty on the SCR catalyst fitted to Euro 4/5/6 vehicles is limited to 12 months instead of 24 months. Requirements for biodiesel storage at B100 - 4 weeks in fuel tanks on vehicles that are temporarily out of service, 6 months when stored in storage tanks and supply systems.
2) Reduced service intervals (50%). Separate fuel tank for Night Heater required
3).MAN Vehicles with NOx control (OBD1b and OBD2) must be ordered with the sales group 'Biodiesel" Vehicles with CRT filters can only be operated after approval with FAME.
4) The additional servicing requirements specified by Volvo are more frequent fuel filters changes, plus cleaning of the fuel tank once a year

- Two further bus and engine manufactures ADL and Cummins were contacted. ADL approve Euro V and Euro VI for B20, Cummins B20 and B100, biofuels must meet relevant fuel quality standards.

Appendix 4 – WTW GHG Emission Factor Sources

WTW GHG emissions data sources[29]

Fuel/Energy	Reference and comments
Diesel	WTT/TTW - BEIS GHG conversion factors 2020 Scope 1 and Scope 3
CNG (UK natural gas grid)	WTT - BEIS GHG conversion factors 2020 Scope 3 TTW - BEIS GHG conversion factors 2020 Scope 1
Biodiesel	WTT - RTFO statistic 2019 – biogenic waste TTW - BEIS GHG conversion factors 2020 Scope 3
Renewable Diesel	WTT - RTFO statistics 2019 -HVO feedstock UCO and JEC WTT report v5 default factor for synthetic diesel (BTL) feedstock wood waste TTW - BEIS GHG conversion factors 2020 Scope 1
Biomethane	WTT - RTFO statistics 2019, biogenic waste feedstocks and JEC WTT report v5 compressed biomethane default factor value with manure feedstock TTW – BEIS GHG conversion factors 2030 Scope 1
Bio-SNG	WTT – Go GreenGas, BioSNG Demonstration Plant 2018 TTW – Assumes identical to biomethane
Electricity (UK Grid)	WTT - BEIS GHG conversion factors 2020 Scope 1 and 2 WTT - BEIS Green Book 2020 future electricity grid GHG emissions
Hydrogen - electrolysis	WTT - Zemo Partnership calculation - energy consumption data for each element of the fuel lifecycle pathway sourced from industry. Pathway assumes large scale electrolyser, connected to wind tubes, compressed H2 transported by road tanker to depot refuelling station.
Hydrogen – SMR+CCS	WTT - Zemo Partnership calculation energy consumption data for SMR plant sourced from industry, estimated value for CCS assumed 85% capture rate. Assume natural gas feedstock for SMR plant, compressed H2 transported by road tanker to depot refuelling station

Vehicle life cycle analysis

Vehicle production - GHG emission associated with vehicle manufacturing based on BEIS GHG conversion factors 2020 for electricity and natural gas.

Vehicle operational phase (WTW GHG emissions) - Fuel and electricity consumption values for each of the propulsion systems have been sourced from a variety of data sources including: Zemo Partnership members, LEFT programme. Diesel and gas trucks are assumed to be Euro VI.

- Vehicle lifetime milage: 500,000km
- Diesel fuel consumption: 26l/100km
- CNG fuel consumption: 21kg/100km
- BEV electricity consumption: 0.6 kwh/km (85 kwh lithium battery ion battery)
- HFC fuel consumption: 3.5kg/100km (50 kw fuel cell, 30 kwh lithium ion battery)

29 www.gov.uk/government/statistics/renewable-fuel-statistics-2019-final-report
www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2020
ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/jec-well-tank-report-v5
www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal

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