ULEV Market Segmentation in Scotland

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Executive Summary

Aims and findings

Scotland has historically shown strong political commitment to tackling climate change. Scotland's new Climate Change Act commits Scotland to a target of achieving net-zero emissions by 2045. This endows Scotland with the most stringent climate targets in the world. But since 2010, emissions from Scotland's transport sector (including aviation and shipping) have been gradually rising, and contributed 37% of Scotland's total greenhouse gas emissions in 2016. Despite this, the sector offers one of the strongest potentials for decarbonisation. Scotland has consequently shown strong ambition in this area, with the Scottish Government pledging to phase out the need for petrol and diesel powertrains by 2032.

However, meeting this ambitious goal will require a rapid shift in purchasing behaviour amongst both private and company vehicle buyers. At the end of 2018, ultra-low emission vehicles (ULEVs), such as battery electric vehicles (BEVs), plug-in hybrid vehicles (PHEVs) and hydrogen fuel cell electric vehicles (FCEVs), accounted for 0.39% of Scotland's car and van stock. For Great Britain in general, ULEVs accounted for 0.52% of car and van stock at the end of 2018. The ULEV market for heavy goods vehicles (HGVs) is less developed than for cars and vans. The evolution of supportive policies will be important to ensure ULEV uptake in Scotland is sufficient to meet increasingly stringent climate targets.

To achieve a full transition to ULEVs, it is critical to understand the specific challenges and needs that different car, van and HGV buyers face to develop targeted policies. The aims of this study are therefore:

- Identify the barriers that currently exist to ULEV uptake.
- Segment Scottish car, van and HGV buyers by the specific barriers each one faces.
- Make recommendations to overcome these barriers and maximise the economic opportunity for Scotland.

Cars and Vans

The key barriers identified for ULEV adoption amongst different car and van buyers are as follows:

Cost:

New ULEVs have high upfront costs: New ULEVs are more expensive than equivalent conventional vehicles. For cars, the price premium is approximately £10,000. However, over 90% of new cars sold in the UK are purchased under a finance deal. Overall ownership costs are therefore of greater importance. Plug-in EVs have low running costs, which can partially offset their higher lease payments. Currently the Plug-in Car and Van Grants and the Scottish Government's Electric Vehicle Loan improve affordability of new ULEVs. ULEV ownership costs for buyers of new vehicles are expected to fall in future, driven by battery cost reductions and lower rates of depreciation.

Used ULEVs have high upfront costs: Used ULEVs are also more expensive than equivalent conventional vehicles. However, due to the relatively high rates of depreciation and low running costs, ownership costs of used ULEVs are very competitive with conventional vehicles. However, used vehicle buyers are less likely to purchase vehicles through finance deals and are typically lower income. This makes the higher upfront cost of used ULEVs a barrier. In future, used ULEV prices will fall along with new ULEV prices. However, this may be offset by a rise in depreciation rates of new ULEVs as the market stabilises.

Uncertainty surrounding battery lifetime: Used vehicle buyers are more exposed to battery degradation. At present, the standard battery warranty offered by most manufacturers is 8 years/160,000 km for both cars and vans. Actual battery lifetimes are uncertain, although anecdotal evidence suggests that batteries can last longer than this. But ULEVs purchased towards the end of the vehicle's life may require battery replacement, which will cost several thousand pounds for the user. This may be prohibitively expensive for used vehicle buyers, who are typically lower income.

Suitability:

ULEV concerns amongst fleet managers: Fleet managers are influential in the purchase of company owned vehicles, either because they purchase them directly or define a list from which their company's employees can choose from. Fleet managers have concerns surrounding ULEV suitability, ownership cost uncertainty, ability of employees to access charging at home, and reimbursement of electricity costs. In 2018 in Scotland, company buyers accounted for 52% of new car sales and 89% of new van sales[48]. Fleet managers are therefore critical for introducing ULEVs into the Scottish vehicle stock.

Large vans are more expensive to electrify: Electrifying large electric vans requires large batteries. High range requirements will increase the necessary battery size further. This increases vehicle cost and the weight of the battery can reduce the maximum payload volume. Van buyers are generally very sensitive to vehicle economics. Battery electric vans may therefore be prohibitively expensive for large van buyers.

Long range ULEV vans are not yet available: Latest battery electric vans have real world ranges of approximately 200km. This is suitable to complete the daily duty needs of 95% of vans. However, longer range options for the remaining higher mileage users are not yet available, and may be prohibitively expensive. For these users, H_2 fuel cell vans which offer approximately 500km of range may be more suitable. However, these remain in development and pilot stage.

Supply:

ULEVs are in short supply: Low manufacturing volumes mean automakers are prioritising the allocation of vehicles to the most profitable markets. Waiting times for many ULEV models are now over a year, and in the short term at least demand is expected to continue to outstrip supply.

Used ULEV availability lags behind new ULEV market: Used vehicle buyers cannot directly influence the number of ULEVs in the stock. They must first wait for new vehicle buyers to purchase them. Supply of used ULEVs will therefore remain constrained for longer.

Infrastructure:

Cost and delays in home charge point installation: In Scotland, 65% of cars and 58% of vans are estimated to be stored off-street at home. These drivers are well suited to plug-in EV adoption because they could charge at home, usually overnight. Ideally this would be carried out using a dedicated home charge point. Installing a home charge point incurs a cost of approximately £800 (including VAT and installation), but up to £500 is available through the UK Government's Office for Low Emission Vehicle's (OLEV) HomeCharge Scheme and a further £300 pounds from the Scottish Government's home charger grant. Costs can be higher if additional groundwork is required or the property's fuse requires upgrading. Installation can also be delayed if the local distribution network requires upgrading. However, even without a dedicated home charge point, plug-in EVs can still be charged using a domestic 3-pin socket, although this is not advised for long periods.

Installation of charge points in rented houses: In Scotland, 14% of cars/vans are parked off-street at rented accommodation. To install a home charge point permission from the landlord is likely to be required. This could delay the installation or halt it altogether. In this case, these drivers could charge their vehicles through a domestic 3-pin socket, which is not recommended, or use public or workplace charging.

Dependence on public or work charging : In Scotland, 34% of cars and 28% of vans are parked on-street. These must rely on non-home charging, such as on-street or nearby rapid charging hubs, or charging at work. This is less convenient than charging at home, and these buyers will require certainty that sufficient charging facilities are available to provide guaranteed access.

Lack of opportunity to charge at work: Workplace charge points provide a potentially convenient charging solution. But these are unavailable to drivers who do not use their vehicles to commute to work. This is a particular issue for the 21% of cars and 28% of vans that are parked on-street at home and not driven to a workplace during the day. These vehicles would rely solely on public recharging infrastructure.

Difficulties installing depot charge points: In Scotland, 0.7% of cars and 14% of vans are estimated to be kept overnight at depots. Depots provide potentially easy access to charging. However, installation of charging/refuelling infrastructure can be limited due to space constraints. Charge point installation can also incur high connection costs, particularly if vehicles need to be charged during times of peak electricity demand.

Need for rapid public charging: A dense network of rapid public charge points facilitate long distance driving amongst BEVs, and can be used as a primary source of charging for those without access to off-street parking. The coverage of rapid charge points in the existing ChargePlace Scotland network is good, but further charge points will be needed as BEV numbers increase, particularly in residential areas. Reliability of the existing network is also not good enough to guarantee charge point availability.

Lack of H2 refuelling infrastructure: Mass adoption of H_2 fuel cell vehicles requires widespread coverage of hydrogen refuelling stations. There is currently only one H_2 refuelling station open to public in Scotland (in Aberdeen). Note the public refuelling structure is not necessarily needed for transitioning captive fleets (i.e. depot-based) to H_2 vehicles, since refuelling could be carried out at the depot.

Knowledge:

Lack of knowledge: Common misconceptions surrounding ULEVs, such as range, battery degradation, and charging time, are putting off potential buyers. In the Scottish Household Survey 2017, 23% of respondents that would not consider owning a plug-in car listed lack of knowledge as a reason. In other recent surveys, 61% of consumers thought EV batteries required replacing within the first two years[1], 20% of consumers thought EVs slow as the battery is depleted[2], and 53% did not know that plug-in EVs can be charged via a normal 3-pin plug[3].

The following table shows a segmentation of Scottish car and van buyers, and the specific barriers to ULEV ownership they face. The shading represents the size of the barrier for that segment (yellow = minor barrier, red = major barrier). The share of cars and vans falling into each segment is also shown. The top 7 segments are new car and van buyers. Their shares are generally smaller than for used buyers, but they are critical for introducing ULEVs into the Scottish vehicle stock.

Segment Description	**Share of cars/vans**	**New ULEVs have high upfront costs**	**Used ULEVs have high upfront costs**	**Uncertainty surrounding battery lifetime**	**ULEV concerns amongst fleet managers**	**Large vans are more expensive to electrify**	**Long range ULEV vans are not yet available**	**ULEVs are in short supply**	**Used ULEV availability lags behind new ULEV**	**Cost and delays in home charge point installation**	**Installation of charge points in rented houses**	**Dependence on public or work charging**	**Lack of opportunity to charge at work**	**Difficulties installing depot charge points**	**Need for rapid public charging**	**Lack of H2 refuelling infrastructure**	**Lack of knowledge**
Private buyers of **new cars/vans** who park **off-street** at home	9.6%	✗				✗		✗		✗	✗				✗	✗	✗
Company cars/ vans which can park **off-street** at home	5.9%	✗			✗	✗		✗		✗	✗				✗	✗	✗
New car buyers who park **on-street** and **commute**	3.6%	✗			✗			✗				✗			✗	✗	✗
Private buyers of **new cars/vans** who park **on-street**, and **do not commute**	3.1%	✗				✗		✗				✗	✗		✗	✗	✗
Depot-based **cars/vans** with relatively **low daily mileage**	1.8%	✗			✗	✗		✗						✗		✗	✗
Company vans stored **on-street**, with **low daily mileage**	1.1%	✗			✗	✗		✗				✗	✗			✗	✗
Depot-based **vans** with **high daily mileage**	0.4%	✗			✗	✗	✗	✗						✗		✗	✗
Private buyers of **used cars/vans** who park **off-street** at home	48.8%		✗	✗		✗		✗	✗	✗	✗				✗	✗	✗
Private buyers of **used cars/vans** who park **on-street**, and **do not commute**	17.4%		✗	✗		✗		✗	✗			✗	✗		✗	✗	✗
Private buyers of **used cars** who park **on-street**, and **commute**	8.3%		✗	✗				✗	✗			✗			✗	✗	✗

[1] HPI Check (2018) Electric Vehicle Study. https://www.hpi.co.uk/content/electric-cars-the-electric-era/the-hpi-check-electric-vehicle-study/

[2] https://www.independent.co.uk/news/uk/home-news/electric-cars-misconceptions-battery-charging-safety-volkswagen-study-results-a8700536.html

[3] Encore Digital Media and Savanta (2019) EV Awareness Study. https://www.fleetpoint.org/electric-vehicles-2/automotive-brands-wont-hit-10-ev-purchase-without-education-finds-study/

Heavy Goods Vehicles

HGVs face many of the same barriers to ULEV adoption as cars and vans, as well as some specific to this vehicle type. The common barriers identified for ULEV adoption amongst HGV buyers are as follows:

Cost:

ULEVs have high capital costs: ULEV models are more expensive than equivalent conventional vehicles This is particularly an issue for HGVs as the industry operates on tight margins (HGV operators are often looking for a payback on an upfront investment of 2 years or less). The higher purchase cost is also seen as a risk due to the uncertainty in running costs, payback periods and second-hand vehicle value.

Ownership cost competitiveness: Conventionally powered HGVs currently receive low taxation rates (e.g. registration tax, annual tax, fuel VAT etc.) to help boost the economy and encourage trade. This makes it very challenging for ULEVs to compete on ownership cost as the alternative is so cheap.

Suitability:

Variation in vehicle types and operational profiles: The high variation in the HGV sector makes it very challenging to assess suitability and compare total cost of ownership between different technologies to guide fleet operators' purchasing decisions. HGVs typically drive high daily mileage and therefore require high vehicle ranges.

Supply:

Very few ULEV HGV models available: This is exacerbated by the large number of HGV variants, which means it will take longer for ULEV models to be available for all operators. Even if a ULEV in a user's required size category is available, the model may not come with the additional requirements, such as a tipper or waste crusher. Even once a ULEV model is available, fleets may face long waiting times as production lines need to be put in place to supply the vehicles.

Loyalty to existing vehicle suppliers: This limits fleets' access to ULEV models if their preferred supplier does not offer their required model as a ULEV.

Infrastructure:

Difficulties installing depot charging: As well as space constraints, HGV charge points require power levels that are an order of magnitude higher than for cars and vans. This comes with a proportionally higher cost for network upgrades which must be paid by the fleet operator. If a new high voltage cable needs to be laid, this can also lead to delays while access permission is sought from landowners along the cable route. There is currently a lack of information and support for ULEV depot refuelling infrastructure installation.

Availability of local charging/refuelling: This could be important for small businesses without in-depot infrastructure. This is especially true for hydrogen where there are more barriers to in-depot refuelling stations at small scale.

Availability of en-route charging/refuelling: This may be required to meet daily duty cycles, in which case fleets cannot adopt ULEVs until adequate availability is in place. However, with a lack of certainty around which technology (battery electric or hydrogen) fleets will choose across the country, infrastructure providers will find it challenging to create a business model for installing refuelling infrastructure.

Lack of en-route refuelling standards: There is currently a lack of standards for en-route HGV refuelling options. En-route refuelling could be provided via a range of options such as high-speed chargers, Electric Road System (ERS) or 700bar hydrogen refuelling. Without Europe wide standards it is too risky for a provider to install infrastructure ahead of wide scale vehicle rollout.

Knowledge:

Lack of information: Fleet operators currently lack up to date information about ULEV model options on which to base vehicle purchasing decisions. This is partly because as ULEV models have not been used extensively in the market there is a lack of knowledge about their reliability and maintenance requirements.

The following table shows a segmentation of the Scottish HGV fleet, and the specific barriers they face:

Segment	Description	Barriers to ULEV adoption
Small Rigid (3.5-7.5t), 24% of the fleet 	Used predominantly to deliver goods (e.g. parcels) to homes and businesses in cities. Duty cycles are low speed at typically 200-250km per day.	• Low annual mileage means low running costs of ULEVs take longer to pay back higher upfront cost • Lack of space in city depots to install charging or refuelling infrastructure
Medium & Large Rigid (7.5-25t), 22% of the fleet 	Used for both medium distance distribution of goods (e.g. food, clothes) between depots along highways, and city centre distribution from depots to shops. Daily mileage is in the range of 250-330km per day	• Very limited number of ULEV models available • High variation in usage patterns means it is difficult to assess operation suitability and total cost of ownership • Higher mileage users may depend on public refuelling/charging infrastructure
Very Large Rigid (Over 25t), 19% of the fleet 	Used for moving materials (e.g. wood, metal ore, cement, steel) from production sites to end users (e.g. construction and industrial sites). Daily mileage is in the range of 250-350km, but can be as high as 600km	• There are currently no ULEV models available in this segment • Goods moved are heavy and ULEVs typically have reduced payloads due to weight of batteries or H_2 tanks • Vehicles may be left on construction/industrial sites overnight, removing the opportunity for depot refuelling or charging. • No clear ULEV technology winner makes decision to adopt challenging
Small & Large Articulated (Over 25t), 35% of the fleet 	Primarily used to deliver products such as food, timber, steel, and chemicals over long distances, usually on motorways. Small articulated HGVs typically drive 300-375km/day and may include some urban	• Meeting the requirements of high cargo weight and distances travelled with batteries or H_2 is very challenging, particularly due to size constraints of tractor unit

	driving. Large articulated trucks will drive 350-450 km/day and sometimes up to 800km/day. These are the main method by which goods are imported/exported between Scotland the rest of UK/Europe	• Need for large batteries or hydrogen tanks makes ULEV models particularly expensive • ULEV models capable of working in the low to mid weight range of this segment are expected but there are no ULEV models able to work in 40-44 tonne range • No clear ULEV technology winner makes decision to adopt challenging • Will require public refuelling/charging network with UK and/or Europe-wide coverage
Waste collection 	Used across the medium to very large rigid segments to collect waste. Characterised by very low speeds and low daily mileage of <100km. However, regular stop-start and auxiliary power requirements (e.g. waste crushers) means they have high energy demand.	• Lack of space in city centre depots to install refuelling or charging infrastructure

Recommendations

This report has yielded the following recommendations in order to address the identified barriers to ULEV uptake:

<u>Cost</u>

- Review ULEV purchase incentives in 2020 when Plug-in Car and Van grants are due to be revised. Purchase incentives should look to close the gap in upfront cost between ULEVs and conventional vehicles, but overall value to buyers should reflect the difference in overall ownership cost
- Open up the Electric Vehicle Loan to used vehicle buyers, and extend to help HGV fleets purchase ULEV models.
- Support companies to offer ULEV specific leasing, providing low finance rates and accurate depreciation forecasts to reduce ownership costs.
- Develop battery recycling and refurbishment facilities to increase value of end of life batteries and reduce the cost of battery replacement.
- Strengthen Low Emission Zones over time to give a cost saving for ULEVs compared to any other vehicle type.

<u>Suitability</u>

- Support development of services for fleets and consumers which can show suitability for ULEV adoption and potential cost savings e.g. telematics systems.

- In the near-term help to organise and fund extended real-world vehicle trials and share the results with fleet operators across Scotland.

Supply

- Support Joint Procurement Initiatives to attract vehicle supply to Scotland, and ensure vehicles meet specifications of fleet users. This might be particularly relevant for vehicles with niche applications, such as emergency fleets. For the private sector, the Government should facilitate the aggregation of demand, from which a supply contract can be issued to one OEM. If order volumes are large enough then vehicle manufacturers can be asked to deliver a model with specific capabilities to meet the needs of Scottish fleets
- Signal to manufacturers that Scotland is primed for ULEV uptake e.g. building out public charging network, training garages in ULEV maintenance

Infrastructure

- Provide charging solutions for those without potential access to home charging. This should be led by consumer research into the preferred options for those without access to home charging. Infrastructure deployment programs should focus on areas where these consumers are located. This could be through mechanisms to allow potential plug-in EV buyers without off-street parking to lodge requests for public charging infrastructure. This could include companies who provide their employees with company cars/vans but who do not have off-street parking.
- Encourage companies with large numbers of commuters who park on-street to install workplace charge points.
- Continue to develop rapid charging network, including extending coverage to minor roads, increasing charge rates and improving reliability. Mobile charging solutions (e.g. BP FreeWire) could be used to test viability of rapid charge points in new locations.
- Incentivise landlords to allow installation of home charge points. Consider mandating Local Authorities and Housing Associations to do so.
- Support development of smart charging systems which can reduce the impact of EV charging on the grid. This can reduce the cost of charge point installation and electricity.
- Support fleets with funding (grants or zero interest loans) to help cover the upfront cost of refuelling equipment installation in the depot.
- Collect case study data from existing fleets' experience of installing depot refuelling infrastructure and share lessons learned with all fleets. This will allow fleet operators to include the needed depot upgrades in their current depot planning/maintenance.
- Develop a national plan for rollout of ULEV refuelling infrastructure for HGVs to give fleets visibility over when and where en-route refuelling infrastructure will be available in Scotland.

Knowledge

- Launch a communication campaign to combat ULEV misconceptions and provide clear advice on options for ULEV purchase.
- Encourage ULEV uptake amongst taxis and car clubs to increase consumer exposure. Aggregate and share with Scottish Local Authorities the best practices on taxi licensing rules and taxi support schemes, from where ULEV uptake has been successfully kick-started (e.g. Dundee, London, Nottingham)
- Support fleets with up to date information on ULEV models and their capabilities by encouraging fleets to use online tools such as the LoCity "Commercial Vehicle Finder".

Other recommendations

- Engage with distribution network operators to help identify network assets that are likely to require reinforcement due to charging demand in the near future e.g. provide them with the registered locations of plug-in EVs, and the charging intentions of those applying for the Electric Vehicle Loan.
- Set up a Taskforce for the case of emergency vehicles (police, fire and ambulance services) to identify fleets, their current plans for ULEV adoption, and the infrastructure they require, then develop specific support.
- Legislate local councils so that they must include vehicle emissions as a key consideration in their vehicle/contract procurement processes for public fleet vehicles
- Provide additional operational benefits to ULEV HGVs such as longer delivery hours in city centres, better parking availability, and improved access, such as allowing ULEVs to use bus lanes at certain times
- Fund research into the option to produce fuels at industrial sites for use by ULEV HGVs. For example, mining, forestry, or landfill sites could be well placed for renewable energy production and this could be used to refuel the HGVs that visit these sites without the need for major infrastructure upgrades

Contents

1 Introduction

1.1 Policy context

Scotland has historically shown strong political commitment to tackling climate change. The Climate Change (Scotland) Act 2009 set a target to reduce emissions by 80% between 1990 and 2050, and the new Climate Change (Emissions Reduction Targets) (Scotland) Act 2019 increases this target to net-zero by 2045. This is five years ahead of the UK Government's recent commitment to achieve net-zero emissions by 2050 and endows Scotland with the most stringent climate targets in the world.

In 2016, transport (including aviation and shipping) contributed 37% of Scotland's total greenhouse gas emissions, with cars, vans and heavy goods vehicles (HGVs) contributing to over two thirds of this[4]. Scottish transport sector emissions have been gradually rising since 2010, but this sector offers one of the strongest potentials for decarbonisation. Scotland has consequently shown strong ambition in this area; while the UK Government plans to end the sale of new petrol and diesel cars and vans by 2040, the Scottish Government has pledged to phase out the need for these powertrains eight years earlier, by 2032.

1.2 Challenges

However, meeting this ambitious goal will require a rapid shift in purchasing behaviour amongst car and van buyers. At the end of 2018, ultra-low emission vehicles (ULEVs)[5], such as battery electric vehicles (BEVs), plug-in hybrid vehicles (PHEVs) and hydrogen fuel cell electric vehicles (FCEVs), accounted for 0.42% and 0.16% of Scotland's car and van stocks, respectively[6,7]. This was slightly behind the Great Britain (GB) average of 0.58% for cars and 0.19% for vans. Figure 1 shows how ULEV uptake in Scotland has historically lagged behind the rest of Great Britain.

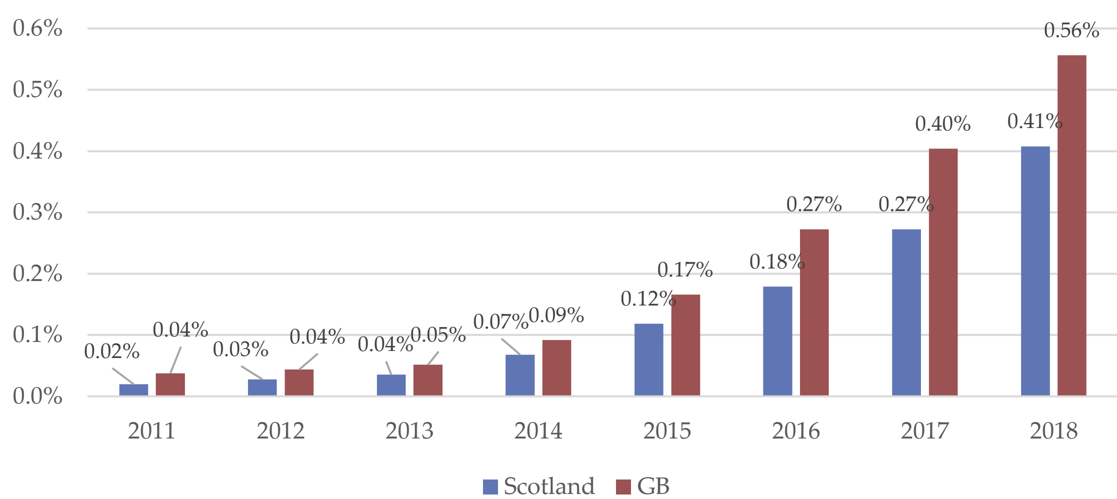

Figure 1: ULEVs as a share of total car and van stock in Scotland and GB[6,7]

As ULEV prices fall, refuelling infrastructure becomes more widespread, range increases, and choice of models grows, uptake is expected to increase. However, modelling of ULEV uptake using Element

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[4] Element Energy for Transport Scotland (2016) Greenhouse gas emissions reduction potential in the Scottish transport sector from recent advances in transport fuels and fuel technologies

[5] Defined as those with an NEDC type-approval emissions value of 75 gCO_2/km or less

[6] DfT Data Table VEH0132: Licensed ultra low emission vehicles by Local Authority: United Kingdom

[7] DfT Data Table VEH0105: Licensed vehicles by body type and Local Authority: United Kingdom

Energy's ECCo choice model[8], used by the UK Department for Transport for policy design, suggests that without further policy interventions, ULEVs will account for only 35% of new car sales and 28% of new van sales in Great Britain in 2032. With the number of policies designed to support the uptake of ULEV HGVs well behind those focused on the Light Duty Vehicle (LDV) market, ULEVs will still be a niche technology in the HGV market in 2032 without major changes in policy. Thus, driving the transition to higher ULEV uptake will require the introduction of new policies to help overcome the major barriers to widespread ULEV adoption.

1.3 Objectives of this study

To achieve a full transition to ULEVs, it is critical to understand the specific challenges and needs that different car, van and HGV buyers face to develop targeted policies. The aims of this study are therefore:

- Review the literature to identify the barriers that currently exist to ULEV uptake.
- Segment Scottish car, van and HGV buyers by the specific barriers each one faces.
- Evaluate how these barriers affect each segment, and make recommendations to overcome these barriers and maximise the economic opportunity for Scotland.

1.4 Structure of this report

This report is structured as follows:

Section 2 outlines the overarching barriers to ULEV adoption identified through a review of recent surveys.

Section 3 discusses the characteristics of vehicle buyers which influence the extent to which these barriers apply. This summarises the key barriers faced, who they apply to, and recommendations for addressing them.

Section 4 presents segmentations of cars/vans and HGVs which reflect the major differences in barriers to ULEV adoption.

Section 5 shows a number of case studies to explore specific barriers in more detail for several groups of interest.

Section 6 lists final recommendations for policymakers.

[8] http://www.element-energy.co.uk/sectors/low-carbon-transport/project-case-studies/

2 Barriers to ULEV Adoption

This chapter introduces the key barriers to ULEV adoption in the car, van and heavy-duty vehicle markets. These are summarised in Table 1.

Table 1: Summary of ULEV Barriers

Group	Barrier	Applies to Cars	Applies to Vans	Applies to HGVs
Cost	High upfront cost	x	x	x
Suitability	Lower driving range of ULEV models	x	x	x
	Uncertainty about ULEV lifetime and maintenance requirements, and lack of maintenance capability		x	x
	Impact of batteries or hydrogen storage on the amount of goods that can be transported		x	x
Supply	Lack of ULEV models across vehicle sizes	x	x	x
	Loyalty to existing vehicle suppliers can limit access to ULEVs			x
Infrastructure	Cost and ease of installing home/depot refuelling	x	x	x
	Availability of local refuelling	x	x	x
	Availability of rapid en-route refuelling	x	x	x
	Network constraints and the cost of network upgrades at depots		x	x
	Lack of en-route refuelling standards for high capacity hydrogen and electric refuelling points			x
Knowledge	Lack of knowledge and misconceptions	x		
	Lack of awareness of ULEV models		x	x
	Lack of reliable information on ULEV total cost of ownership (TCO)			x
	Uncertainty about technology winners			x

2.1 Cost

High upfront cost:

In general, ULEVs have a higher purchase price than that of comparable conventional vehicles. In the Scottish Household Survey 2017, of the 45% of respondents who would not consider owning a plug-in EV, 32% listed cost of vehicle purchase as a reason. A recent AA Populus survey found 83% of non-EV owners were concerned about their high purchase price[9]. Figure 2 shows a comparison of the purchase prices of the most popular conventional (ICE) car models in the B (supermini) and C (lower medium) segments, and similarly sized BEVs. The difference in price between these ICEs and BEVs is of the order of £10,000.

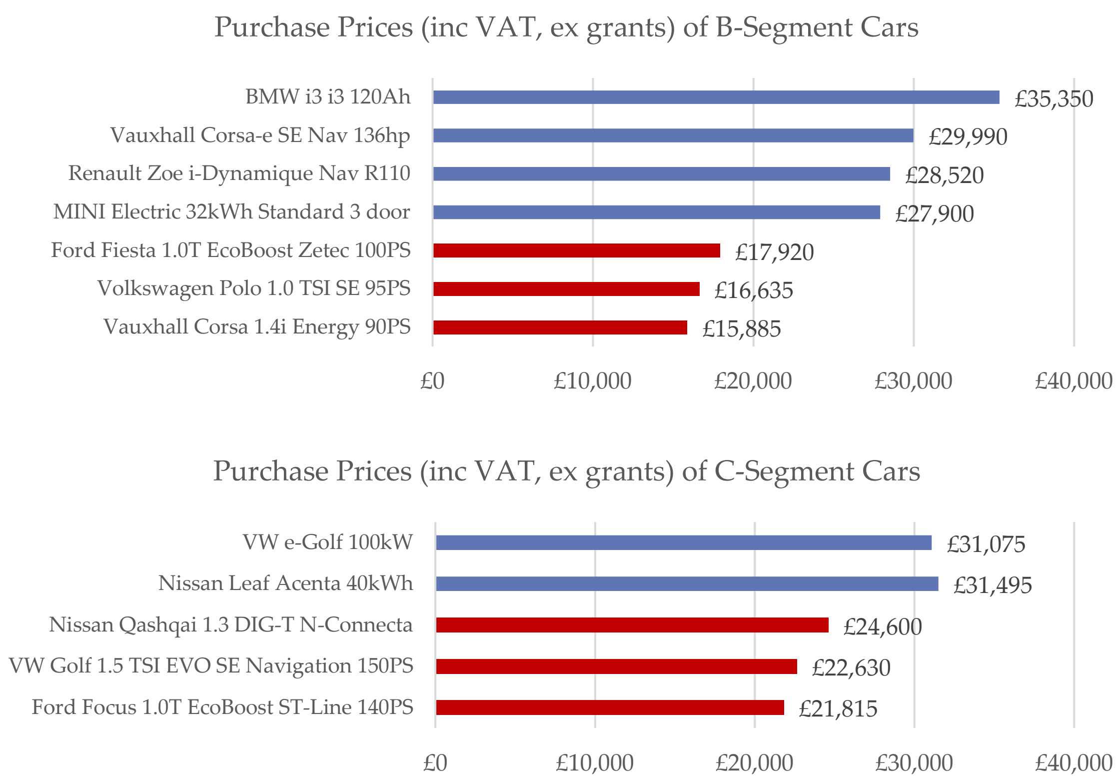

Figure 2: Purchase prices of popular B-Segment and C-Segment cars, with conventional models shown in red and battery electric models shown in blue.

For vans, even larger price differences are observed. For example, the Renault Master Z.E. costs from £54,985 (ex VAT, ex grants), which is over £24,000 more than an equivalent diesel Renault Master.

For HGVs the upfront cost difference is larger still as ULEV powertrains used in the HGV market require greater durability than cars and vans. This is particularly an issue for fleets as the industry operates on tight margins (HGV operators are often looking for a payback on an upfront investment of 2 years or less[10]). The higher purchase cost is also seen as a risk due to the uncertainty in running costs, payback periods and second-hand vehicle value.

[9] AA Populus Driving Survey, June 2018, https://www.theaa.com/about-us/public-affairs/aa-populus-driver-poll-summaries-2018#july2018
[10] LoCity (2016) How can LoCITY increase operator uptake of Ultra Low Emission Vehicles?

2.1.1 Policy Landscape

National policy supports the reduction of ULEV capital costs through "plug-in grants" for cars, vans and HGVs[11]:

- The Plug-in Car Grant (PiCG) currently offers consumers £3,500 (capped at 35% of the on-the-road price) for a car that can travel 70 miles with zero emissions and emits less than 50 gCO_2/km. At present, no plug-in hybrids meet this requirement, so this grant applies solely to battery electric and fuel cell electric cars. The UK Government has confirmed that the PiCG will continue in some form beyond 2020[12], although the exact grant amounts have not yet been announced.
- The Plug-in Van Grant (PiVG) offers buyers £8,000 (capped at 20% of the on-the-road price) for a van that can travel 10 miles with zero emissions and emits less than 75 gCO_2/km. This will also continue in some form beyond 2020.

At a Scottish level, the Scottish Government provides an interest-free loan of up to £35,000 to help cover the cost of a new ultra-low emission car or van[13]. This is available for any car or van model eligible for the PiCG or PiVG, as well as plug-in hybrids with an on-the-road price of less than £60,000.

For HGVs, a national-level plug-in grant is also available. This provides £8,000 (up to 20% of the vehicle purchase price) for a vehicle that has CO_2 emissions at least 50% less than an equivalent Euro VI vehicle, and has at least 10 miles of zero-emission range. In addition, the grant has been extended to £20,000 for the first 200 applications.

2.1.2 Market Trends

The key cost component of ULEVs is the power source, either the battery or fuel cell. A 40 kWh battery pack, enough to travel 270 km in a Nissan Leaf[14], is estimated to cost £5,300. But by 2030 light duty vehicle battery costs are expected to fall by 65%[15], reducing this cost to £1,900. As a result, it is estimated that the cost of owning a BEV will reach parity with conventional petrol and diesel cars on an unsubsidized basis by 2024[16]. However, this is dependent on the battery size of the vehicle, with parity being achieved earlier by vehicles with smaller batteries.

Likewise, for HGVs, power component cost reductions will have a considerable impact on vehicle capital costs. Between 2018 and 2030 the cost of heavy-duty vehicle batteries is expected to fall by 75%[17], reducing the cost of a 400 kWh HGV battery from £180,000 to £46,000. In the same period the cost of a heavy-duty fuel cell system and H_2 tank will fall by 40% from £145,000 to £60,000[18].

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[11] https://www.gov.uk/plug-in-car-van-grants
[12] https://www.gov.uk/government/news/reformed-plug-in-car-grant-extended-into-next-decade
[13] https://www.energysavingtrust.org.uk/scotland/grants-loans/electric-vehicle-loan
[14] Based on WLTP range of Nissan Leaf 40 kWh
[15] https://about.bnef.com/blog/behind-scenes-take-lithium-ion-battery-prices/
[16] Deloitte (2019) New market. New Entrants, New challenges. Battery Electric Vehicles, https://www2.deloitte.com/content/dam/Deloitte/uk/Documents/manufacturing/deloitte-uk-battery-electric-vehicles.pdf
[17] BNEF (2018) Electric Buses in Cities, https://c40-production-images.s3.amazonaws.com/other_uploads/images/1726_BNEF_C40_Electric_buses_in_cities_FINAL_APPROVED_%282%29.original.pdf?1523363881
[18] ICCT (2017) Transitioning to Zero-Emission Heavy-Duty Freight Vehicles. https://theicct.org/sites/default/files/publications/Zero-emission-freight-trucks_ICCT-white-paper_26092017_vF.pdf

2.2 Suitability

Lower range of ULEV models:

Concerns with low ranges of battery electric cars is commonly listed by consumers as a barrier to their adoption. In the Scottish Household Survey 2017, of the 45% of respondents who would not consider buying a plug-in electric car, 45% listed battery range as a reason[19]. This was the most commonly listed reason. An AA Populus survey found that respondents in Scotland were significantly more likely to be concerned about limited driving range for their day-to-day needs than the rest of the UK[20]. However, analysis of driving trips undertaken by cars and vans in Scotland show that >98% of daily mileages are less than 200 km (see Figure 3).

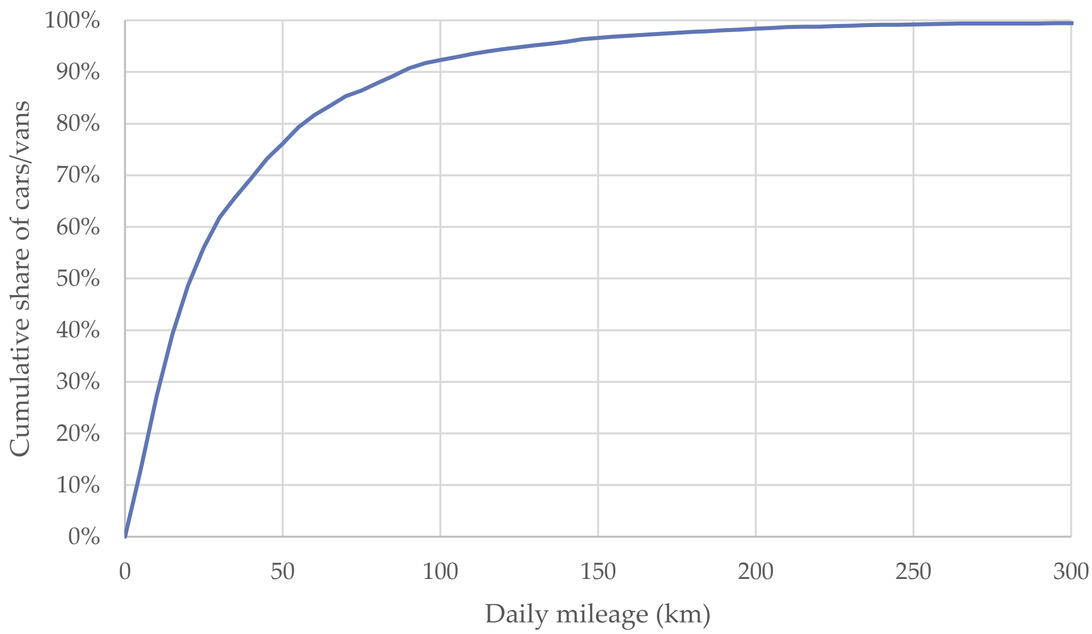

Figure 3: Share of daily mileages of cars/vans in the Scottish Household Survey 2017 Travel Diary which can be completed by a BEV with a given real-world range.

Commercial fleets tend to have specific duty cycles, which may include large distances completed in a day, end of day storage in remote locations (not in a depot or at a motorway service station) or 24/7 operation demands. These are difficult to meet with ULEVs as they require sufficient energy storage capacity (battery or hydrogen) to complete very long distances in one day. Figure 4 shows the share of vans in the UK that can be replaced by a BEV with a particular range. This assumes charging only takes place overnight outside of the vehicle's working hours. Fleets with higher mileage vehicles are therefore less able to adopt BEVs.

[19] Element Energy analysis of Scottish Household Survey 2017

[20] AA Populus Driving Survey, June 2018, https://www.theaa.com/about-us/public-affairs/aa-populus-driver-poll-summaries-2018#july2018

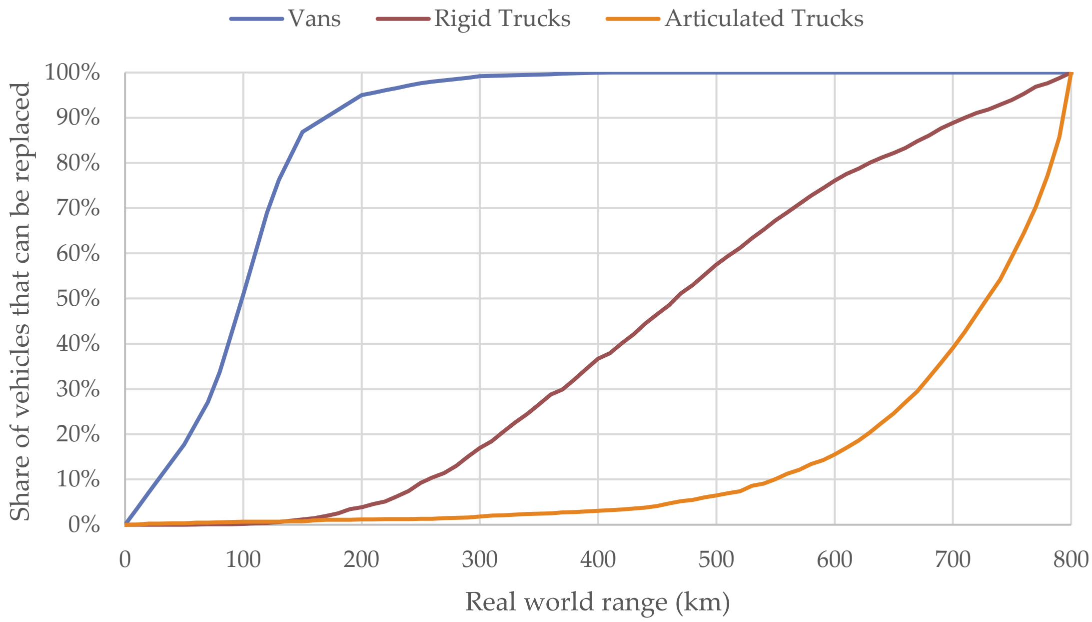

Figure 4: Share of UK van and truck fleet which can be replaced by a BEV with a given real world range[21,22].

Enabling fast refuelling can reduce the range requirement. This would allow ULEVs to recharge/refuel during their daily duty cycle. But this is a significant challenge for fleets running battery electric vehicles who may have limited time to stop and charge.

Uncertainty about vehicle reliability and maintenance:

Vehicle reliability is a major concern for fleet operators as vehicles breaking down leads to jobs unfulfilled, profit losses and disappointed clients. There is also the additional cost of having a vehicle off the road for the time it takes to repair. Conventional vehicles are very reliable and experience of using these vehicles has increasingly allowed Original Equipment Manufacturers (OEMs) to predict part failures and perform pre-emptive maintenance when the vehicle is serviced. ULEV powertrains can be equally (or more) reliable but, without the body of experience for fleet operators to learn from, fleets see taking on ULEVs as a risk. For HGVs, this issue is further exacerbated by the current lack of a maintenance and servicing sector for ULEV HGVs in Scotland.

Impact of ULEV powertrain on goods that can be transported:

ULEV powertrains take up more space and weigh more than conventional powertrains. This is especially the case for vehicles designed to travel very long distances between refuelling stops. As for vans, HGVs have a legislated size and maximum weight, and the additional size and weight of the powertrain has a knock-on effect on the amount of cargo they can carry, which will affect the profitability of the fleet.

2.2.1 Policy Landscape

Minimum zero-emission range requirements are included in the eligibility criteria of the plug-in grants (see Section 2.1.1). However, the specified ranges are intended to discourage low-range compliance vehicles rather than incentivize the consumer offering.

In 2018, the maximum weight limit for vans in the UK was increased from 3.5 tonnes to 4.25 tonnes for alternative fuel models (battery electric, hydrogen and natural gas). This makes an allowance for the

[21] Based on analysis of 18,000 light duty fleet vehicles for the ETI CVEI Project

[22] Element Energy analysis of telematics data collected from 4,400 HGVs for ETI (2018) HDV Data Analysis Optimisation Project

additional weight of the powertrain components, such as batteries, so that these vehicles can be driven by holders of a light duty vehicle driving licence.

2.2.2 Market Trends

The ranges of available BEVs have been gradually rising over the last decade (see Figure 5). The latest car models have ranges well in excess of 300km, even under real world driving conditions. As batteries decrease in cost, ranges are expected to increase to meet the needs of most mainstream consumers.

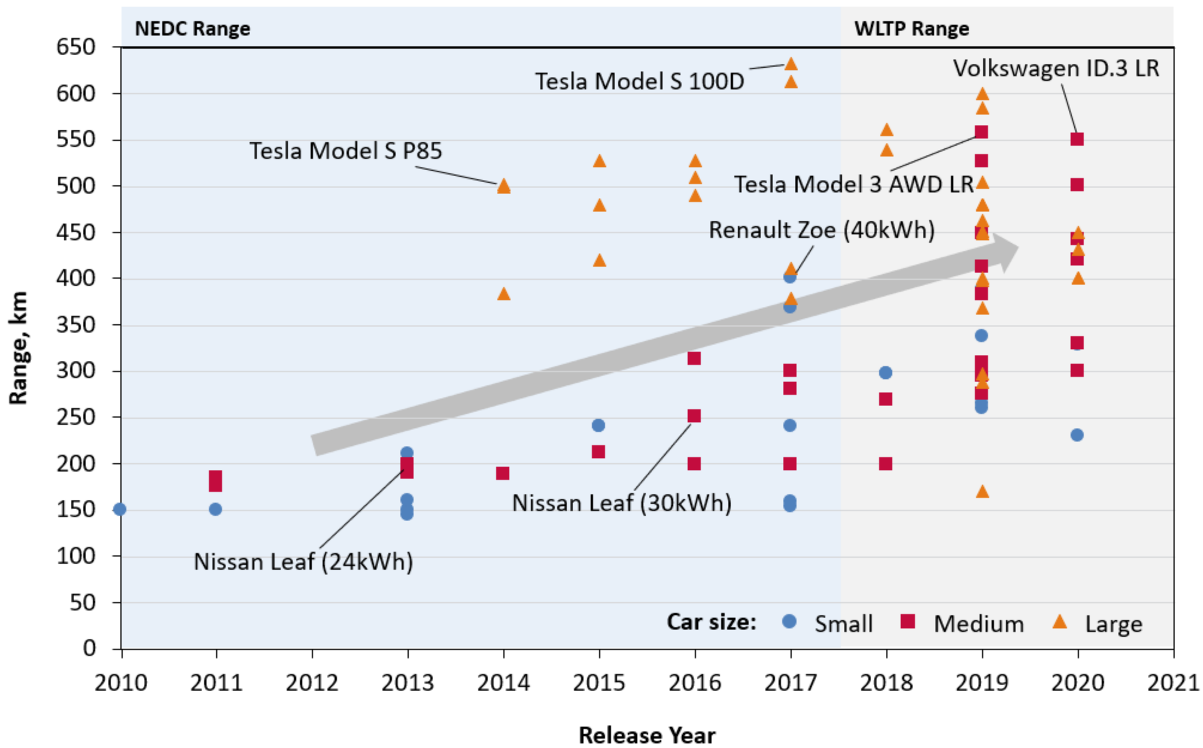

Figure 5: Official ranges of battery electric cars, both available and upcoming[23].

Battery electric vans typically have a lower electric range than cars (see Figure 6). Most ranges are still quoted under the now obsolete New European Driving Cycle (NEDC) type-approval. Ranges under real world conditions can be up to 50% lower than the NEDC figure. For example, Renault recommend their Kangoo Z.E. (33kWh) has a real-world range between 120 km and 200 km[24]. However, manufacturers are releasing vans with larger battery options in the near future. The Volkswagen eTransporter released in 2020 will have an NEDC range of 400 km, providing approximately 200 km under real world conditions. This would satisfy the range requirements of approximately 95% of van drivers (see Figure 4).

[23] The Worldwide Harmonised Light Vehicle Test Procedure (WLTP) replaced the New European Driving Cycle (NEDC) for official type approval in 2018.
[24] https://www.parkers.co.uk/vans-pickups/news/2017/renault-kangoo-ze-33-review-specs-info-driving-range/

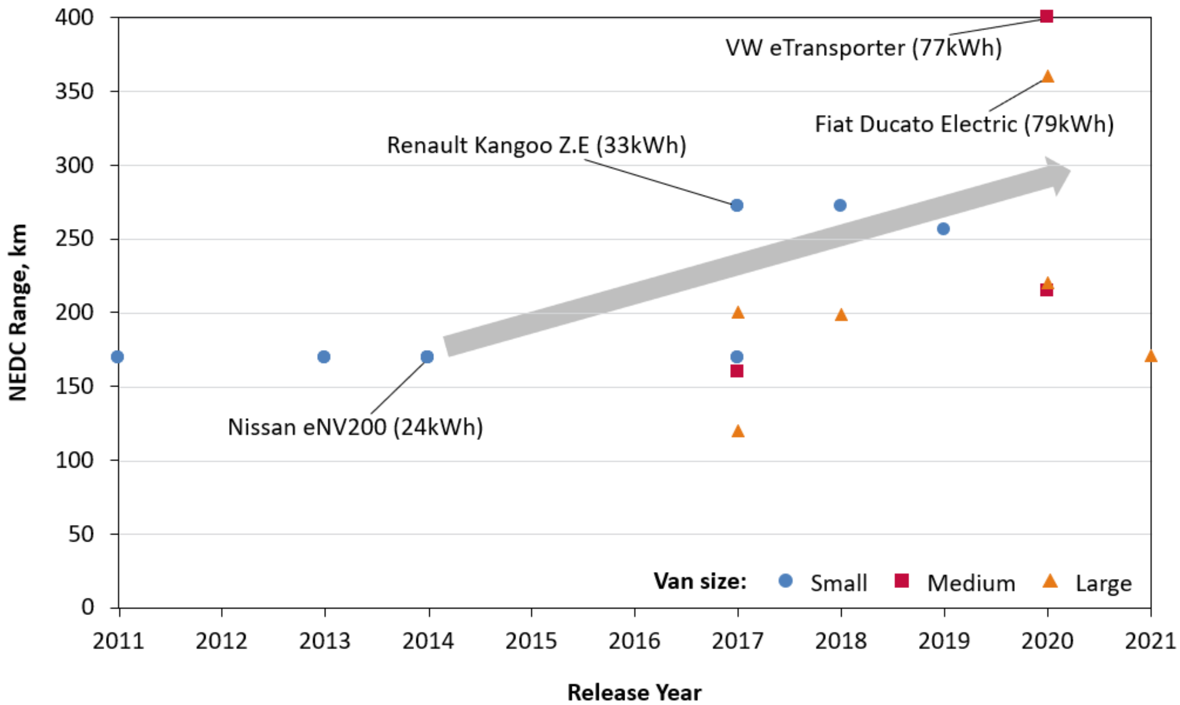

Figure 6: Official ranges (NEDC type approval only) of available and upcoming battery electric vans.

It is very challenging for ULEV models to match the daily driving profile of current HGVs (see Figure 4). Table 2 summaries the ULEV HGV models available or planned in Europe and USA. The table shows that the majority of current models planned fall below the range requirements (average daily range required 200-450km, longest daily range required 500-800km) of the average fleet operator in each vehicle size category. This suggests market developments will not overcome the suitability barriers for ULEV HGVs in the near term.

Table 2: Summary of ULEV HGV models available and announced in Europe and USA

Vehicle class	Number of ULEV models	Average range across models (km)	Longest range model (km)
Small Rigid (3.5-7.5t)	15	150	250
Medium Rigid (7.5-17t)	15	170	300
Large Rigid (17-25t)	3	360	500
Very Large Rigid (Over 25t)	7	230	500
Small Articulated (Less Than 33t)	1	200	200
Large Articulated (Over 33 t)	11	580	1200

2.3 Supply

Lack of ULEV models:

For car buyers, there are currently 26 PHEV, 23 BEV and 2 FCEV models available for sale in the UK[25]. Although this accounts for only a small portion of the estimated 387 car models available overall[26], choice is increasing rapidly. However, the limiting factor is supply of available models rather than introduction of new ones. Waiting times for many ULEV models are over a year[27]. In the short term, production volumes are expected to be limited by battery supplies and manufacturing capacity.

There are considerably fewer ULEV options for van buyers (see Table 3). At present there are 8 models available, although 3 of these are only available in very low volumes. Options for buyers of medium and large vans are therefore particularly limited.

Table 3: ULEV van models that are available or have been announced by manufacturers

Size	Model	Powertrain	Available/Upcoming
Small	Peugeot ePartner	BEV	Available
	Citroen Berlingo	BEV	Available
	Renault Kangoo Z.E.	BEV	Available
	Nissan eNV200	BEV	Available
	Volkswagen eCaddy	BEV	Upcoming (2019)
	LEVC Van	PHEV	Upcoming (2020)
Medium	BD Auto eTrafic	BEV	Available (low volume)
	Mercedes eVito	BEV	Upcoming (2019)
	Ford Transit Custom	PHEV	Upcoming (2019)
	Volkswagen eTransporter	BEV	Upcoming (2020)
Large	Renault Master Z.E.	BEV	Available
	BD Auto eDucato	BEV	Available (low volume)
	LDV EV80	BEV	Available (low volume)
	Mercedes eSprinter	BEV	Upcoming (2019)
	Fiat Ducato Electric	BEV	Upcoming (2020)
	Volkswagen eCrafter	BEV	Upcoming (2021)
	StreetScooter WORKXL	FC RE-EV	Upcoming

Likewise, there are currently very few ULEV HGV models available in the UK relative to the number of conventional models. This is exacerbated by the large number of HGV variants, which means it will take longer for ULEV models to be available for all operators. For example, a ULEV HGV of a specific size category to meet a user's needs may be available, but if the user needs a tipper or waste crusher on the back and the model offered does not come with these options, then the fleet operator cannot choose a ULEV. Even once a ULEV model is available, fleets may face long waiting times as production lines need to be put in place to supply the vehicles.

Loyalty to existing vehicle suppliers:

Many fleets have stated that they return to the same vehicle suppliers to purchase vehicles and like to stay with a supplier that they trust. However, if certain suppliers do not offer ULEVs then their

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[25] Listed on the Government's Plug-in Grants webpage, August 2019, https://www.gov.uk/plug-in-car-van-grants
[26] Based on number of generic car models which had UK sales of at least 10 during Q1 2019, as listed in DfT Data Table VEH0161 Vehicles registered for the first time by generic model Great Britain and United Kingdom
[27] https://www.thecarexpert.co.uk/electric-car-market-long-waiting-times/

customers may be less aware of ULEVs and even if they are aware, they may be less willing to risk taking on a ULEV if it means also risking using a new supplier.

2.3.1 Policy Landscape

No policies directly incentivise manufacturers to make more models available, and in greater numbers. However, manufacturers are developing more ULEVs in order to meet the EU's increasingly strict emissions standards. These set targets for the average emissions of new cars, vans and HGVs sold by each manufacturer (or pool of manufacturers)[28] within the EU. Current post-2020 targets are:

- Cars: 15% reduction in 2025, 37.5% reduction in 2030 relative to 2021
- Vans: 15% reduction in 2025, 31% reduction in 2030 relative to 2021
- HGVs: 15% reduction in 2025, 30% reduction in 2030 relative to 2019. The regulation applies only to rigid and articulated vehicles over 16 tonnes (loaded weight) used for goods deliveries (50% of the Scottish HGV fleet)

The regulations include mechanisms which encourage the sale of ULEVs, which relax these targets if more ULEVs are sold[29].

Depending on the outcome of Brexit, there is a risk that sales of cars in the UK do not contribute to these targets. Whilst the targets will still encourage the development of new ULEV models, there is a risk that manufacturers will prioritise their sale in EU Member States. Scottish consumers may therefore have more limited access to ULEVs.

2.3.2 Market Trends

By 2025, the number of ultra-low emission cars and vans offered in Europe is expected to rise to 147 PHEVs, 172 BEVs and 14 FCEVs[30]. The majority of these will be car models. Some manufacturers have shown strong ambition to electrify their offering. Volkswagen, for example, plans to offer an electric version of each of its existing 300 models by 2030[31].

Supply of ultra-low emission HGVs presents a greater barrier to uptake than for cars and vans. There are many companies interested in this space and models do exist across all vehicle sizes (see Table 2). However, many of these models are produced by start-ups and will not be available through conventional HGV suppliers in Scotland. The HGVs produced by current OEMs are in the testing phase and will only be produced in small volumes in the near future. This suggests that the growth of the ULEV market in the HGV sector will not remove many of these barriers in the near term.

2.4 Infrastructure

Cost and ease of installing home/depot refuelling.

Charging overnight at home or a depot is the easiest way to charge a plug-in electric vehicle. This can be done either through a dedicated charge point or a standard 3-pin socket with a Mode 2 charging cable. However, a dedicated charge point is recommended because 3-pin sockets may not be designed for supplying high current for extended periods. A dedicated home charge point costs approximately £800, including VAT and installation[32]. Costs can be higher if additional groundwork is required or the property's fuse box needs upgrading. Some households may need to pay to upgrade

[28] https://ec.europa.eu/clima/policies/transport/vehicles_en
[29] https://ec.europa.eu/clima/policies/transport/vehicles/regulation_en
[30] Transport & Environment (2019) Electric surge: Carmaker's electric car plans across Europe 2019-2025, https://www.transportenvironment.org/sites/te/files/publications/2019_07_TE_electric_cars_report_final.pdf
[31] https://www.reuters.com/article/us-autoshow-frankfurt-volkswagen-electri/volkswagen-spends-billions-more-on-electric-cars-in-search-for-mass-market-idUSKCN1BM296?feedType=RSS&feedName=technologyNews
[32] http://www.rolecserv.com/ev-charging/product/EV-Charging-Points-For-The-Home

their fuse boxes from 60A to 100A. Renters may also be unable to install a charge point under their rental agreement.

Introducing new refuelling technology into depots can face several barriers including: limited space to fit the infrastructure around existing hardware; meeting safety standards which may require upgrades to allow for larger electricity demands or hydrogen storage; and depot ownership which may limit the options for installing infrastructure if the land is rented.

Availability of local refuelling.

Local charging/refuelling infrastructure is required for those who cannot charge at home, or need to charge while away from home. For plug-in electric vehicles, options include charging on-street near their home, at frequently visited destinations, such as supermarkets, or nearby rapid charge points. Those who use their vehicles to commute can also potentially charge at work, if a charge point is available there.

Installation and coverage of local charging/refuelling could also be important for small businesses without in-depot infrastructure. This is especially true for hydrogen where there are more barriers to in-depot refuelling stations at small scale.

Availability of rapid en-route refuelling.

Without en-route rapid charging and refuelling, ULEVs cannot conveniently carry out trips longer than their range. This is particularly important for rural drivers who drive longer trips more frequently, and where infrastructure coverage is likely to be sparser. Reliability of existing rapid charge points is also reported to be an issue. A review of rapid charge points in Scotland on 2nd July 2019 found 105/384 (27%) were reporting a problem on at least one connector[33]. This is largely due to issues with connectivity between the charge point and cellular network.

From a fleet perspective, if en-route charging/refuelling is required to meet daily duty cycles, they cannot buy ULEVs until there is sufficient en-route infrastructure. However, with a lack of certainty around which technology fleets will choose across the country, infrastructure providers will find it challenging to create a business model for installing refuelling infrastructure.

Network constraints and the cost of network upgrades.

Distribution networks are likely to need reinforcing to meet increasing charging demands. For residential customers, the cost of these upgrades is socialised. This cost therefore does not act directly as a barrier to plug-in vehicle adoption other than potentially increasing electricity prices for all consumers in the distribution network licence area. However, the need for network upgrades has potential to slow the installation rate of residential charge points.

Installing charge points at commercial sites, such as depots and workplaces, may also trigger network upgrades. This could incur prohibitively high connection costs for the business. Scottish & Southern Electricity Networks advise that a new connection for 3-5 fast charge points (7-22kW) would cost approximately £4,000-£75,000 and take 8-16 weeks to install[34].

HGV charge points require power levels that are an order of magnitude higher than car charge points. This comes with a proportionally higher cost for network upgrades which must be paid by the fleet or charge point installer. If a new high voltage cable needs to be laid, this can also lead to delays while access permission is sought from landowners along the cable route.

Likewise, high connection costs can undermine the business case for public charging.

[33] As reported on https://www.zap-map.com/

[34] Scottish and Southern Electricity Networks Electric Vehicle Guide. https://www.ssen.co.uk/Connections/EVconnections/

Lack of en-route refuelling standards.

There is currently a lack of standards for en-route HGV refuelling options. En-route refuelling could be provided via a range of options such as high-speed chargers, Electric Road System (ERS) or 700bar hydrogen refuelling. Without Europe wide standards it is too risky for a provider to install infrastructure ahead of wide scale vehicle rollout.

2.4.1 Policy Landscape

There are a number of national level funding mechanisms for recharging/refuelling infrastructure:

- OLEV Homecharge Scheme: provides 75% of the cost of purchasing and installing a charge point at home, capped at £500. This will run until at least March 2020.
- OLEV Workplace Charging Scheme: provides 75% of the cost of purchasing and installing charge points at workplaces. This is capped at £500 per charging socket and is limited to 20 sockets per applicant.
- OLEV On Street Residential Chargepoint Scheme: provides Local Authorities with up to 75% of the capital cost of procuring and installing public charge points in residential areas. This is capped at £7,500 per charge point, and is backed by £5m in funding until 2020.
- Charging Infrastructure Investment Fund: £400m public-private fund that aims to enable faster expansion of the public charging network and catalyse further investment.
- Hydrogen Transport Programme: provides £23m in funding until 2020 to increase uptake of FCEVs and H_2 stations.

Additional funding is also available in Scotland:

- Home charger grant provides a further £300 on top of the OLEV Homecharge Scheme Grant.
- Workplace Charge Point funding offers businesses funding for workplace charge points. The amount of funding provided is decided on a case-by-case basis and depends on the type and owner of the plug-in vehicles to be charged. Funding is offered on one dual outlet charge point per 2 company owned BEVs, or 6 company owned PHEVs or 5 staff owned plug-in vehicles.
- Public Charge Point funding is offered to organisations installing charge points at destinations likely to see high usage by plug-in EV drivers.
- £1.9m funding was made available to Dundee to install rapid charging hubs through Go Ultra Low Cities.
- £20m funding for public charge points made available through Switched on Towns and Cities Challenge Fund and the Local Authority Installation Programme.

Free public charging is also available at many of the charge points across the Scottish Government-funded ChargePlace Scotland network. Currently, free charging is available on >90% of these charge points[35]. However, pricing is set by the Local Authorities, more of whom may choose to introduce pricing in future.

Other legislation in place will also contribute to greater installation rates of charging equipment. The EU's Energy Performance of Buildings Directive requires new and newly renovated buildings with at least 10 parking spaces to make provisions for charging infrastructure. Residential properties must have electrical wiring conduits installed to all spaces. Non-residential properties must have at least one charge point and electrical wiring conduits to 20% of spaces. The UK Government has proposed legislation to require the installation of charge points in all new houses[36].

[35] Analysis of tariff data shown on ZapMap. Weblink: https://www.zap-map.com/live/

[36] https://www.gov.uk/government/news/electric-car-chargepoints-to-be-installed-in-all-future-homes-in-world-first?utm_source=225e608b-79af-4f50-ba3d-d2e1e38881f8&utm_medium=email&utm_campaign=govuk-notifications&utm_content=immediate

Amongst other things, the UK Automated and Electric Vehicles Act also gives Government power to mandate large fuel retailers to install charging and standardise public charge point connectors and payment[37].

2.4.2 Market Trends

Public charging remains a nascent sector and several solutions for those without access to home charging are being developed. These include, for example, on-street charge points, charge points installed in lamp posts, or local rapid charging hubs. Scottish start-up, Trojan Energy, has developed an on-street charging system that sits flush with the pavement[38]. While Dundee is trialling pop-up on-street charge points[39]. However, consumers' preferred solution(s) remains uncertain and this is an area that requires further investigation.

Rapid charge points with increasingly high charging rates are now being installed. Previously, 50 kW was the default standard which provides approximately 100 miles of range for every 30-40 minutes of charging. Tesla's Supercharger network can provide up to 150 kW, reducing this time to 10-15 minutes, but these charge points are compatible with Tesla vehicles only. However, 100-350 kW rapid charge points from other providers are beginning to become available. For example, Ionity plans to install 350 kW charge points at 40 sites across the UK by the end of 2020[40]. No cars can yet accept this charging rate but vehicle charging capabilities are improving in tandem. The fastest rates are currently available only in high-end models (e.g. Tesla Model 3 and Audi e-tron) but charging rates of more affordable BEVs are also improving. Faster charging rates make long distance travel in BEVs more viable. They may also offer a convenient charging solution for BEV drivers without access to home charging.

Smart charging has been identified as a possible solution to avoiding costly network upgrades. Networks must be designed for peak capacity, but smart scheduling of charging will avoid EVs adding to this peak. Time-of-use tariffs, which discourage users from charging during certain times, are already available and more sophisticated systems are under development. Since July 2019, charge points have been required to have smart control and communication capability in order to receive OLEV's Homecharge Grant. Introducing smart charging at depots and workplaces has the potential to reduce or even remove the need for upgrading the site's connection. This can provide a significant savings in connection costs.

There is currently very little public hydrogen refuelling infrastructure. Scotland has a single public station located in Aberdeen. However, the BIG HIT Project is installing hydrogen production in the Orkney Islands for use in transportation, heat and power[41].

2.5 Knowledge

Lack of knowledge and misconceptions:

Lack of knowledge and prevalence of misconceptions are currently deterring consumers from considering ULEVs. In the Scottish Household Survey 2017, of the respondents who would not consider owning a plug-in EV:

- 23% listed lack of knowledge as one of the reasons
- 12% listed unproven technology
- 8% listed running costs, despite cost of charging and maintenance being considerably lower than running a conventional vehicle

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[37] http://www.legislation.gov.uk/ukpga/2018/18/pdfs/ukpga_20180018_en.pdf
[38] http://www.trojanenergyltd.com/
[39] https://www.electrive.com/2019/08/18/on-street-chargers-to-pop-up-on-uk-streets/
[40] https://www.drivingelectric.com/news/658/roll-out-shell-ionity-fast-charging-network-begins
[41] https://www.bighit.eu/

In other recent surveys, 61% of consumers thought EV batteries required replacing within the first two years[42], 20% of consumers thought EVs slow as the battery is depleted[43], and 53% did not know that plug-in EVs can be charged via a normal 3-pin plug[44].

Consumers also tend to overestimate their range requirements. As mentioned in Section 2.2, 45% of Scottish Household Survey respondents who would not consider owning a plug-in EV listed distance travelled on a single charge as a contributing factor. In a recent survey by the AA, consumers stated on average they required a real-world range of 400km[20]. However, 90% of car trips in Scotland are less than 34km[45], and, as observed in Figure 3, occasions where more than 200km are driven per day are very infrequent. Where BEV ranges are insufficient, adequate rapid charging infrastructure can be used to complete these longer distance trips. The ChargePlace Scotland network provides rapid charging facilities on all Scotland's highways at intervals of 50 miles. This enables extensive long-distance driving across the country.

Lack of awareness of ULEV HGV models.

New ULEV HGV models are being announced every month. Keeping track of new models announced and when they will be available for order is time consuming for fleets, especially for small fleets with no fleet manager. Many fleets order vehicles from the same suppliers. If suppliers are not up-selling ULEV technology, fleets may be unaware there is a ULEV that meets their needs.

Lack of information about ULEV HGV Total Cost of Ownership (TCO).

There are a very wide range of HGV model variants and the duty cycle of vehicles varies significantly between fleets. This makes it very challenging to produce TCO numbers that are representative of an HGV segment. Even when numbers are produced fleets are unwilling to invest based on an average TCO comparison as they are not sure this represents their business. Estimating an accurate TCO becomes more challenging for fleets that relay on en-route refuelling as the prices that will be charged by en-route refuelling stations are currently very uncertain.

Uncertainty about technology winners.

Multiple truck powertrain (battery electric or fuel cell) and refueling technologies (For BEV: depot plug-in charging, pantograph charging, rapid plug-in charging, Electric Road System (ERS). For FCEV: 350bar refuelling, 700bar refuelling, liquid refuelling) exist for HGVs. Choosing a technology winner at a company level comes with significant risk. If a fleet selects a different technology to other local fleets this could limit their options in terms of local refuelling, access to replacement vehicles and access to repair and maintenance companies. Alternatively, if HGV fleets in Scotland select a different technology winner to England or other EU members this could limit a fleet's ability to work in these countries due to a lack of suitable en-route refuelling infrastructure. This issue is exacerbated by the uncertainty associated with the medium-term option for fleet operators to transition to biofuels or natural gas. Both these options offer good short to medium term decarbonisation options for larger HGVs. However, without policy guidance fleets are unlikely to invest in biofuels or natural gas when the timeline for when these options will be superseded by electricity and hydrogen is uncertain.

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[42] HPI Check (2018) Electric Vehicle Study. https://www.hpi.co.uk/content/electric-cars-the-electric-era/the-hpi-check-electric-vehicle-study/

[43] https://www.independent.co.uk/news/uk/home-news/electric-cars-misconceptions-battery-charging-safety-volkswagen-study-results-a8700536.html

[44] Encore Digital Media and Savanta (2019) EV Awareness Study. https://www.fleetpoint.org/electric-vehicles-2/automotive-brands-wont-hit-10-ev-purchase-without-education-finds-study/

[45] Transport Scotland analysis of Scottish Household Survey 2017: Travel Diary

3 Characteristics Affecting Barriers to ULEV Adoption

3.1 Cars & Vans

This section explores the car and van buyer characteristics that influence the barriers to ULEV adoption, both positively and negatively. For each characteristic, the major barriers it imposes are summarised at the end of each section. This includes who the barrier affects, market trends which may change the barrier size over time, and a set of recommendations and new business models to address the barrier.

The characteristics considered are shown in Table 4.

Table 4: Summary of car/van owner characteristics which affect barriers to ULEV adoption.

Characteristic	Car	Van	Dimensions	Barriers to ULEV adoption
Owner	✔	✔	Private	-
			Company	Reimbursement for charging, higher mileage, choice of models may be limited by fleet manager
New/used vehicle buyer	✔	✔	New	Residual value concerns, higher mileage
			Used	No purchase subsidies, affordability more important, battery lifetime/warranty
Overnight location	✔	✔	Home	-
			On-street	Dependent on public charging infrastructure
			Depot	Possible space and connection constraints
Commuting	✔		Yes	Higher mileage
			No	No opportunity to charge at work
Vehicle size		✔	Small	-
			Large	Larger battery required, more expensive to electrify, payload and weight restrictions, low vehicle supply
Fleet utilisation		✔	Low mileage	Lower mileage means longer pay back
			High mileage	Limited short-term supply, higher mileage, more expensive to electrify, vehicle weight restrictions
Income	✔	✔	High	-
			Low	Less able to afford higher upfront cost of ULEVs
Rurality	✔		Urban	-
			Rural	Higher mileage, longer trips, lower refuelling infrastructure coverage
Home ownership	✔	✔	Owner	-
			Renter	Potentially unable to install home charge point

The following barriers are common across all car and van buyers, regardless of the characteristics listed in Table 4:

Barrier	**ULEVs are in short supply**: Low manufacturing volumes mean automakers are prioritising the allocation of vehicles to most profitable markets.
Buyers affected	All
Existing policies	-
Market trends	In the long term ULEV supply is expected to increase, but other markets with more advanced uptake may be prioritised
New business models	Garages specialising in ULEV repair to signal ULEV-ready market
Recommendations	Develop procurement framework for public fleets to signal increased ULEV demand in Scotland. Launch Joint Procurement Initiatives to encourage large volume orders. Support manufacturers to encourage local supply e.g. dealership support programmes, support training of garages to service/repair ULEVs, communicate ambition to manufacturers directly.

Barrier	**Lack of knowledge**: Significant misconceptions put car and van buyers off considering ULEVs e.g. range, battery degradation, charging time.
Buyers affected	All
Existing policies	Go Ultra Low campaign
New business models	ULEV taxis and car clubs to increase consumer exposure
Market trends	Consumer knowledge will improve over time as experience of ULEVs becomes more common e.g. through ULEV taxi rides, neighbour effect.
Recommendations	Introduce communication campaign to educate Scottish car and van buyers on benefits of ULEVs e.g. Business Breathes campaign launched by Birmingham City Council[46]. Increase exposure to ULEVs through taxis and car clubs. Support development of tools to allow consumers and fleets to assess suitability of EVs.

Barrier	**Lack of H_2 refuelling infrastructure**: There is currently only one H_2 refuelling station open to public in Scotland (in Aberdeen). Complete refuelling station coverage will be needed for widespread consumer adoption

[46] https://businessbreathes.co.uk/

	of hydrogen cars. Public refuelling infrastructure not required for captive (e.g. depot-based) fleets.
Buyers affected	All
Existing policies	Hydrogen Transport Programme provides £23m in funding until 2020 to increase uptake of FCEVs and H_2 stations. BIG HIT Project adding H2 production in Orkney Islands for use in transportation, heat and power H100 Project looking at feasibility of a 100% H_2 distribution network
Market trends	Roadmap to rolling out widespread public H_2 refuelling infrastructure is uncertain, due to the current low number of vehicles. But UK H_2Mobility states that full national coverage could be achieved by 2030 with 1,150 stations[47].
New business models	Small mobile H_2 refuelling stations could be used to kick-start areas of potential H_2 vehicle demand without investing in network of large volume stations.
Recommendations	H_2 case for light duty vehicles is currently uncertain. Therefore, prioritise support for projects to install H_2 refuelling infrastructure in high utilisation environments e.g. for captive fleets.

3.1.1 Owner

In Scotland, 93% of cars are privately owned, and 7% company owned. Whereas 53% of vans are privately owned, and 47% company owned[48]. However, company cars and vans make up a significant portion of new vehicle sales. Company buyers are therefore crucial for introducing ULEVs into the vehicle stock. In 2018 in Scotland, company buyers accounted for 52% of new car sales and 89% of new van sales[48].

Company cars tend to drive higher annual mileages and more frequent longer trips than privately-owned cars. Company cars in the UK drive an average of 28,000 km/yr compared with 11,900 km/yr for private cars[49]. Range is therefore of more significance to company car drivers. However, even if company cars were used only 5 days a week, average daily distance driven would be 107 km/day. This is well within the range of current BEVs (see Figure 5).

Company car drivers are usually reimbursed for the fuel they use for business purposes. Employers can either reimburse fuel expenditure directly, or pay 'Advisory Fuel Rates' to employees based on the mileage they drive. If an EV is primarily charged at home, direct reimbursement can be challenging as it can be difficult to identify the share of residential electricity usage which is due to charging[50]. This can dissuade potential company car buyers from considering plug-in EVs, or employers from allowing their employees to purchase plug-in EVs as company vehicles. Many companies require company

[47] UK H_2Mobility: Refuelling Infrastructure. http://www.ukh2mobility.co.uk/the-project/refuelling-infrastructure/
[48] Element Energy analysis of Scottish car and van sales and stock data provided by the Department for Transport
[49] Element Energy analysis of the National Travel Survey 2006-08
[50] Since July 2019, OLEV's Homecharge grant requires home charge points to have 'smart functionality', including the ability to meter and communicate energy consumption. This can facilitate electricity usage re-imbursement.

vehicles to be purchased from a limited list of models. Uncertainty or the need to change working practices can act as a disincentive to include ULEVs in these lists.

However, companies tend to make more economically rational purchase decisions, focussing more on ownership costs than upfront purchase price. The low running costs of ULEVs can therefore make them attractive options for company vehicle buyers. Potential tax savings can also improve the business case for ULEV adoption. Company car tax, for example, is banded by CO_2 emissions and from April 2020 zero-emission vehicles will be exempt. This can save company car drivers £1,000-£4,000/yr, depending on the income tax band of the driver, car price and CO_2 emissions. This potential saving is not available to private car buyers.

Barrier	**ULEV concerns amongst fleet managers**: these include suitability, ownership cost uncertainty, ability of employees to access charging at home, and reimbursement of electricity costs. They may also have purchase contracts in place with certain manufacturers who do not offer a suitable ULEV. Fleet managers may therefore choose not to purchase ULEVs or not include them on list of vehicles their employees can choose from.
Buyers affected	Company owned cars/vans
Existing policies	Low company car tax rates for ULEVs improves financial case. From 2020/21, zero-emission cars will pay no company car tax.
Market trends	Additional ULEV models are set to be released by a wide range of manufacturers in the near term.
New business models	Telematics services to demonstrate suitability and economic proposition of ULEVs for a company's fleet.
Recommendations	Educate companies on benefits of running ULEVs in their fleets, and if necessary, mandate them to include ULEVs on approved vehicle list.

3.1.2 New/used vehicle buyer

New vehicle buyers are responsible for introducing ULEVs into the stock. They are therefore critical for overall ULEV adoption. 21% of car owners and 58% of van owners in Scotland are estimated to purchase new vehicles[51]. Used vehicle buyers are less able to directly influence ULEV uptake, as they must first wait for new vehicle buyers to introduce them into the stock. Although used vehicle buyers in Scotland do have the option of purchasing used ULEVs from elsewhere in the UK if uptake amongst new buyers were to remain limited. However, availability of used ULEVs will remain more limited than new ULEVs, exacerbating the current supply constraint.

New vehicle buyers are less exposed to the higher upfront costs of ULEVs because most are purchased through finance contracts. In 2018, 91.2% of private new cars sold in the UK were purchased under a finance deal at point of sale[52]. Likewise, buyers of company-owned cars and vans tend to lease their vehicles, since this is more tax efficient. For a company vehicle that is also used for private journeys (including commuting), 50% of the purchase VAT can be reclaimed if the vehicle is leased. If the vehicle is purchased outright and used for private journeys, no VAT can be reclaimed.

[51] Estimated from Element Energy analysis of car and van sales and stock data in Scotland provided by DfT
[52] Finance and Leasing Association Annual Review, 2019

Conversely, financing is less common among used vehicle buyers. In the UK in 2018, only 18.4% of private used cars were purchased using finance at point of sale[53]. Higher upfront cost is therefore a greater barrier to adoption.

Because financing is more common amongst new vehicle buyers, the rate of depreciation is particularly significant. Historically, depreciation of electric vehicles has been faster than conventionally powered vehicles due to[54]:

- The plug-in grant reducing the resale value an owner is willing to accept
- Technology improvements in newer models, such as range and price
- Battery leasing, which require fixed payments to be made for the life of the vehicle
- Early ULEV adopters are generally higher income and so willing to accept low residual values upon resale
- Concerns surrounding battery life and replacement cost

This faster depreciation means that a greater share of the lifetime vehicle cost is levied on the first owner. Table 5 shows estimated ownership costs for several medium-sized petrol and battery electric cars. Ownership costs are shown both for the first owner, and a second owner purchasing the vehicle after 3 years and 30,000 miles. For the first owner, overall ownership costs for the BEVs are ~£5,000 more than for the Petrol ICEs. However, for the second owner the reverse is true and ownership costs are ~£5,000 lower for the BEVs. Currently, BEVs therefore have the potential to reduce mobility costs for used car buyers.

Table 5: Comparison of car ownership costs, assuming vehicle sold after 3 years/30,000 miles and then driven for 70,000 miles until end of life. All values sourced from https://www.fleetnews.co.uk/car-running-costs-calculator. Assumes lifetime mileage of 100,000 miles, which is the mileage limit of Nissan and Volkswagen battery warranties and average lifetime of a petrol car in the UK[55].

	Ford Focus 1.0T EcoBoost ST-Line 140PS	VW Golf 1.5 TSI EVO SE Navigation 150PS	Nissan Qashqai 1.3 DIG-T N-Connecta	Nissan Leaf Acenta 40kWh	VW e-Golf 100kW
Powertrain	Petrol ICE	Petrol ICE	Petrol ICE	BEV	BEV
Purchase price (P11D), inc. VAT, ex. plug-in car grant	£22,405	£24,375	£21,940	£31,440	£33,785
Residual value (after 3yrs/30k miles)	£9,125 (42%)	£8,600 (38%)	£10,950 (45%)	£10,250 (33%)	£11,625 (34%)
Fuel (p/mile)	11.74	12.36	14.06	5.87	3.62
Maintenance (p/mile)	2.65	2.36	2.78	1.68	1.7
New owner cost (0-30k miles)	£17,132	£18,221	£18,477	£23,455	£23,756
Used owner cost (30-100k miles)	£19,198	£18,904	£22,738	£15,535	£15,349
Lifetime cost (100k miles)	£36,330	£37,125	£41,215	£38,990	£39,105

Recently, however, high demand for used ULEVs and greater certainty of vehicle lifetimes have led to ULEV depreciation rates aligning with conventional vehicles. A 2019 study showed that electric and hybrid cars retain 47% of their value on average after 3 years and 30,000 miles. This is higher than

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[53] SMMT Used car sales report Q4 2018. https://www.smmt.co.uk/2019/02/used-car-sales-q4-2018/
[54] Regen (2019) Market insight series: Harnessing the electric vehicle revolution
[55] Ricardo-AEA (2015) Improvements to the definition of lifetime mileage of light duty vehicles

both petrol and diesel models, which retain 43% and 40%, respectively[56]. If this trend continues, more of the lifetime costs will be shifted from new ULEV owners to used, through higher purchase prices of used ULEVs. This will reduce or even remove the ownership cost advantage for used buyers currently observed. However, overall lifetime costs of conventional ICEs and ULEVs are similar (see Table 5). So, it is unlikely that adoption of ULEVs would lead to an increase in ownership costs for used vehicle buyers, relative to what they currently pay. They will, however, be exposed to higher upfront costs.

Used vehicle buyers may be more exposed to battery degradation. At present, the standard battery warranty offered by most manufacturers is 8 years/160,000 km for both cars and vans. This covers capacity loss of more than 25%. Actual battery lifetimes are uncertain, and anecdotal evidence suggests that batteries can in fact last longer than this. The Tesla Model S and Model X have been shown to lose less than 10% of their original capacity after 200,000 km[57]. However, other models, such as the Nissan Leaf 30kWh, have been shown to suffer faster degradation[58]. Although protected by warranty, the average lifetime of cars in the UK is 180,000km/14 years, and vans is 220,000 km/14 years [55]. ULEVs purchased towards the end of this period will therefore be outside of their battery warranty and may incur the cost of a battery replacement. Even if a battery replacement is not necessary, used ULEV buyers may have to contend with reduced battery ranges. However, this may not necessarily be a problem as used car and van buyers tend to drive lower mileages (see Figure 7).

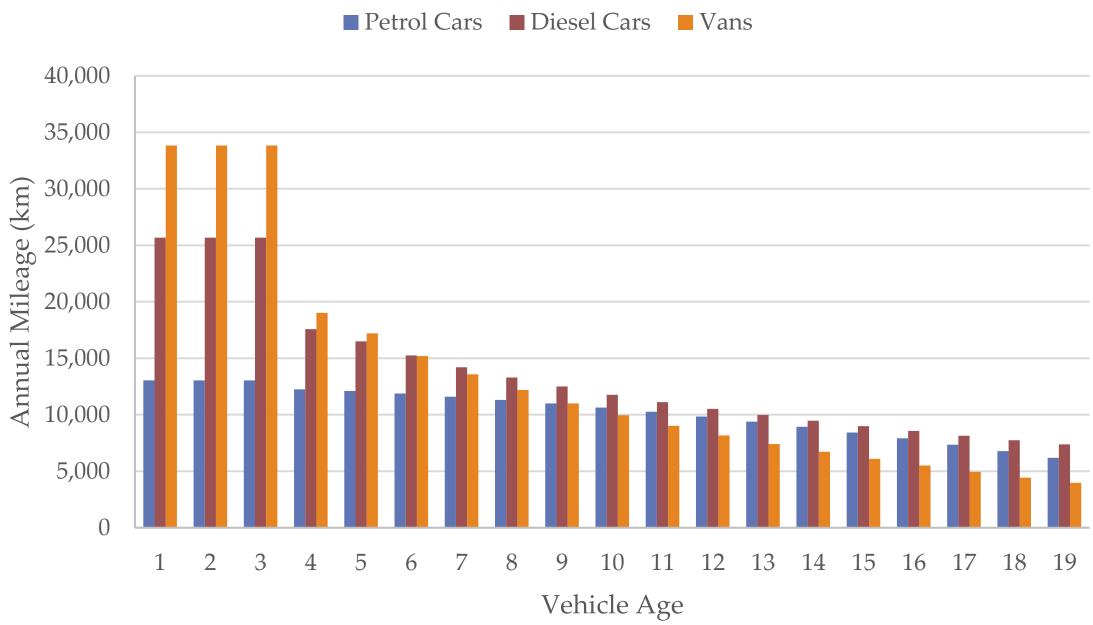


Figure 7: Annual mileage by vehicle age in UK[55]

Barrier	**New ULEVs have high upfront costs** compared with conventional vehicles. However, buyers of new cars/vans purchase their vehicles under finance deals, thus spreading the high upfront cost over the ownership period. But higher ULEV depreciation can make the cost of leasing expensive for a new car buyer.
Buyers affected	New car/van buyers

56 WhatCar, 4th April 2019, What Car? reveals Britain's best and worst depreciating cars – with electric outperforming diesel and petrol
57 https://electrek.co/2018/04/14/tesla-battery-degradation-data/
58 https://insideevs.com/news/337439/nissan-issues-statement-on-leaf-30-kwh-battery-degradation/

Existing policies	Upfront costs and thus leasing fees are reduced by the Plug-in Car and Van Grants Scottish Government provides interest free Electric Vehicle Loan
Market trends	Continued decrease in battery costs and fuel cells will reduce the upfront cost of ULEVs. Plug-in EV depreciation rates are expected to decrease, reflecting greater confidence in the technology and the lower running costs. This will reduce ownership costs for new car buyers.
New business models	Companies offering ULEV specific leasing with low finance rates and accurate depreciation forecasts can reduce ownership costs. Bundling running costs, such as electricity/fuel and maintenance, into the contracts can also help highlight to consumers possible benefits in ownership cost.
Recommendations	When plug-in car and van grants are revised in 2020, review interest free Electric Vehicle Loan to ensure terms are adequate

Barrier	**Used ULEVs have high upfront cost**s compared with conventional vehicles. Many used car buyers will be lower income, and may not have access to financing. For these buyers the upfront cost is of particular significance.
Buyers affected	User car/van buyers
Existing policies	-
Market trends	Continued decrease in battery costs and fuel cells will reduce the upfront cost of ULEVs, which should also put downward pressure on the price of used ULEVs. The expected reduction in plug-in EV depreciation rates will shift more of the lifetime ownership cost onto used vehicle buyers.
New business models	Companies offering ULEV specific leasing with low finance rates and accurate depreciation forecasts can reduce ownership costs. Bundling running costs, such as electricity/fuel and maintenance, into the contracts can also help highlight to consumers possible benefits in ownership cost.
Recommendations	Extend Scottish Government interest free Electric Vehicle Loan to used vehicles

Barrier	**Used ULEV availability lags behind new ULEV market**
Buyers affected	User car/van buyers
Existing policies	-
Market trends	Availability will remain limited until sales of new ULEVs increase.

New business models	-
Recommendations	Encourage and facilitate purchase of used ULEVs from elsewhere in the UK.

Barrier	**Uncertainty surrounding battery lifetime**, and possible costs of battery replacement
Buyers affected	User car/van buyers
Existing policies	The current European Battery Directive makes the battery manufacturer or the vehicle OEM responsible for covering any expenses related to battery collection and recycling.
Market trends	Cost of battery replacement will decrease, driven by falling costs for new batteries. Battery recycling may further decrease cost through increased value of end-of-life batteries and availability of refurbished used batteries.
New business models	Development of battery recycling facilities can be used to increase value of end-of-life batteries, thus lowering the net cost of battery replacement. Battery refurbishment (e.g. individual cell/module replacement) can extend battery lifetimes and/or provide a source of cheaper replacement batteries.
Recommendations	Consider providing funding for battery replacement to extend the life of used plug-in EVs.

3.1.3 Overnight location

Owners of cars and vans parked off-street at home are well suited to transitioning to plug-in EVs, because they can use the household electricity supply to charge, usually overnight. This can be through a dedicated charge point or a residential 3-pin socket with a Mode 2 charging cable. In Scotland, 65% of cars and 58% of vans are estimated to be stored off-street at home[59].

Likewise, cars and vans stored at depots also have potentially easy access to charging, or on-site hydrogen refuelling infrastructure. In Scotland, 0.7% of cars and 14% of vans are estimated to be kept overnight at depots[21]. However, installation of charging/refuelling infrastructure can be limited due to space constraints. Charge point installation can also incur high connection costs, particularly if vehicles need to be charged during times of peak electricity demand.

Plug-in cars and vans that do not have access to charging at home or depots, such as those parked on-street (34% of cars and 28% of vans in Scotland[59]), will rely on non-home charging. This could be public charging, such as on-street or nearby rapid charging hubs, or charging at work. This is likely to be perceived as less convenient than charging at home. These buyers will also need certainty that these charging facilities will be available before they can consider a plug-in EV. As well as having charge points installed in convenient locations, buyers will need to feel confident that the charge points will be available when needed. Charge points therefore need to be installed in large enough numbers.

[59] Element Energy analysis of Scottish car and van stock data, and Scottish housing stock data

Barrier	**Cost and delays in home charge point installation**: Installing a home charge point incurs a cost, usually on the vehicle buyer, particularly if the household's fuse requires upgrading. Installation of home charge point may also be delayed if network upgrade is triggered.
Buyers affected	Car/van drivers who park at home off-street
Existing policies	OLEV Homecharge Scheme plus additional grant from Scottish Government. But total funding for home charge points in Scotland is capped at £800 per property. This may not be enough for some installations if significant groundwork is required, or household fuse needs upgrading. Distribution network operators (DNOs) are informed when a home charge point is installed. However, if a plug-in EV is purchased and no home charge point is installed because the user intends to use a 3-pin socket, the DNO is not made aware.
Market trends	-
New business models	Smart charging systems can shift charging outside of peak demand to potentially avoid household fuse upgrades.
Recommendations	Maintain grant for home charging and consider providing additional funding for cases where installations are particularly costly Engage with Scottish DNOs to help identify network assets that are likely to require reinforcement due to charging demand in the near future. This could include providing them with the registered locations of plug-in EVs, to a level of detail that allows the identification of the distribution assets concerned. Information on their intentions for charging, such as where and with what equipment, could be collected as part of the application for the interest-free ULEV loan. This could be shared with the DNOs.

Barrier	**Dependence on public or work charging** as a primary means of charging
Buyers affected	Car/van drivers who park at home on-street
Existing policies	OLEV On-Street Residential Chargepoint Scheme OLEV Workplace Charging Scheme Scottish Government's Public Charge Point funding Scottish Government workplace charge point funding ChargePlace Scotland network
Market trends	On-street and workplace charging is expected to be become more common, but the business case of slow public charging is currently very challenging.
New business models	Novel on-street charging solutions, e.g. Trojan Energy charge connector which is flush with the pavement

Recommendations	Survey car drivers without off-street parking to explore their preferred option for charging. Virtually no formal research has been conducted on this topic yet. Identify areas where plug-in EVs parked on-street are likely to be located. Introduce mechanism to allow potential plug-in EV buyers without off-street parking to lodge request for nearby public charge point, or charge point at work. Maintain Scottish workplace charging scheme. Consider measures to incentivise businesses with large numbers of commuting employees who park on-street to install workplace charge points.

Barrier	**Need for rapid public charging**: Coverage of existing network is good, but further charge points will be needed as BEV numbers increase, particularly in residential areas. Reliability of existing network is also not good enough to guarantee charge point availability.
Buyers affected	Car/van drivers who park on-street – rapid charging can be used as the primary source of charging Car/van drivers who require long-distance driving
Existing policies	Automated and Electric Vehicles Act gives UK Government power to mandate: • large fuel retailers to install charge points • data on location and availability of all public charge points to be made freely available • standardisation of public charge point connectors and payment. UK Government's £400m Charging Infrastructure Investment Fund ChargePlace Scotland network offers a rapid charge point every 50 miles on highways.
Market trends	Rapid charging rates are increasing, with the latest charge points and cars capable of charging at 100-150kW Private companies are building out their own rapid charging networks
New business models	Mobile rapid charging solutions (e.g. BP FreeWire) can be used to test viability of rapid charge points at potential sites ahead of permanent installation.
Recommendations	Model number of rapid charging points that are likely to be needed to keep up with demand, and track progress against this. Improve reliability of rapid charging network e.g. add availability targets to maintenance contracts. Require contactless payment on all rapid charge points to ensure all charge points are accessible. Upgrade charging rate of ChargePlace Scotland charge points to improve convenience of BEV ownership. Prioritise the most utilised points.

Barrier	**Difficulties installing depot charge points**: This may be due to space constraints, or high cost of connection charged by the DNO.
Buyers affected	Commercial cars/vans kept at depots
Existing policies	OLEV Workplace Charging Scheme Scottish Government workplace charge point funding
Market trends	-
New business models	Smart charging systems or local energy storage to reduce peak charging loads
Recommendations	Incentivise installation of smart charging solutions to reduce connection costs e.g. add to eligibility criteria of workplace charge point funding. Engage businesses and fleets to ensure they understand the cost benefits of smart charging when requesting connection upgrades from DNOs for charge points. This information could be added the DNO's guidance on charge point installation.

3.1.4 Commuting

In Scotland, 38% of cars are estimated to be used for commuting to a workplace[60]. People who travel to work by car generally drive higher annual mileages than non-commuters. In the UK, commuters drive on average 22,600km/yr, compared with 12,700km/yr for non-commuters[61]. Range is therefore of greater significance to commuters. However, the average car commute in Scotland is only 13 km each way, and 94% are less than 50km (see Figure 8). Even a round trip of 100km is well within the range of a modern BEV.

[60] Element Energy estimate based on analysis of data from DfT's National Trip End Model
[61] Element Energy analysis of the National Travel Survey 2006-08

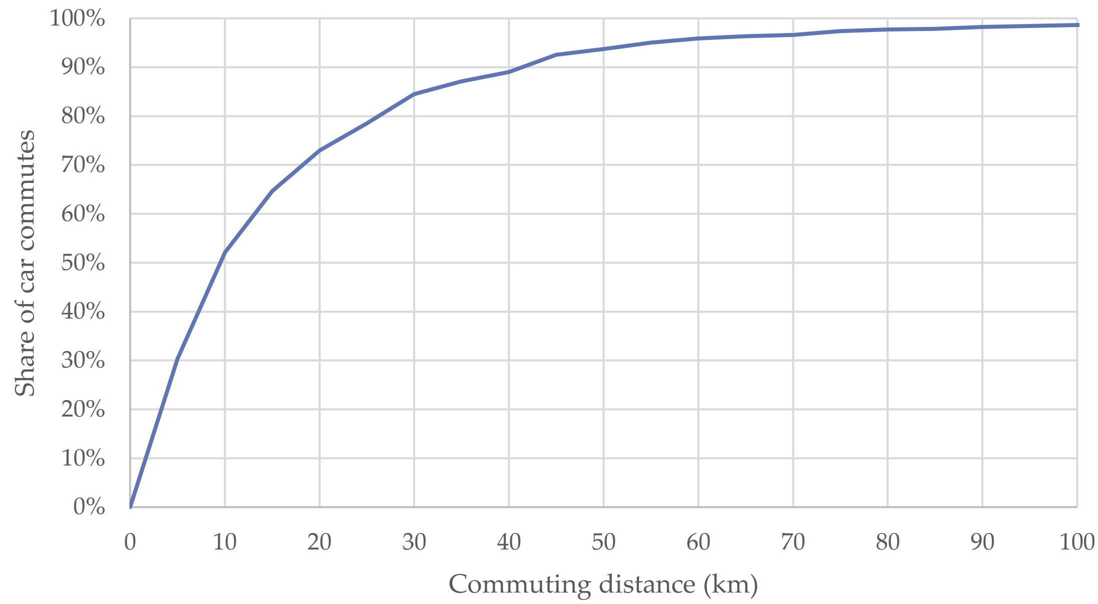


Figure 8: Share of car driving commutes in Scotland which could be satisfied by a car with a given range[62]

Commuters also have the potential to charge at work, if a charge point is installed. This provides a charging solution for car commuters without home charging. Workplace charging is obviously not available for non-commuters.

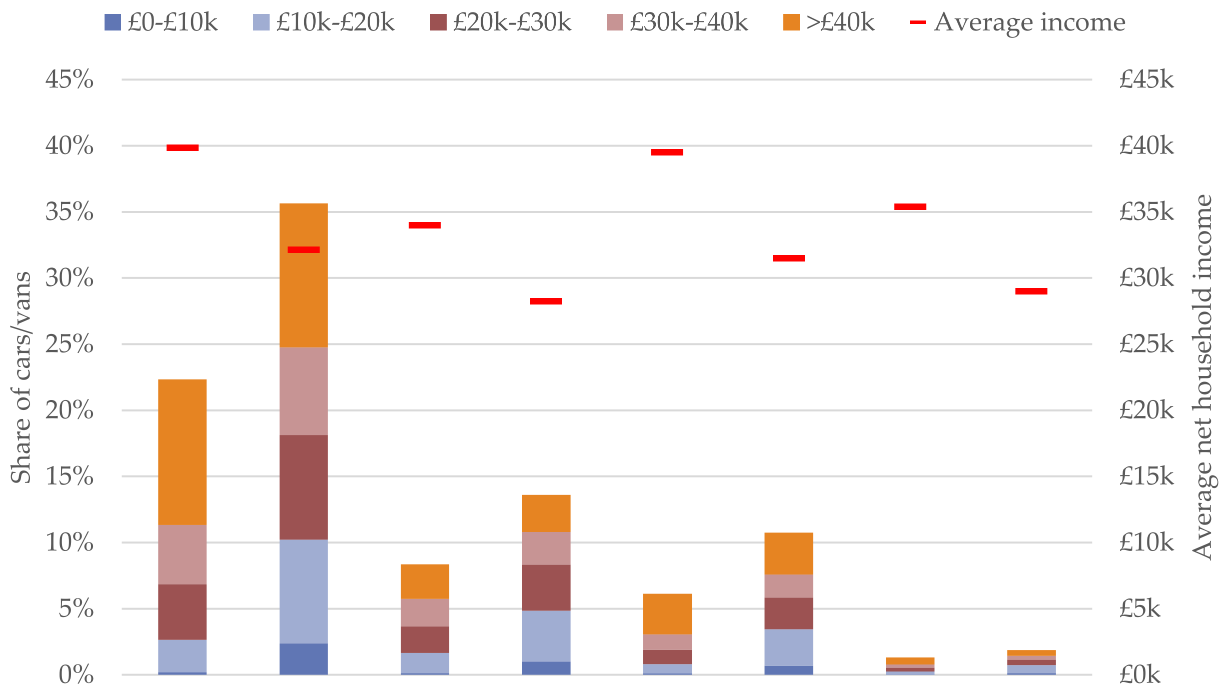
Barrier	**Lack of opportunity to charge at work**
Buyers affected	Buyers who do not use their car for commuting, particularly those who park at home on-street
Existing policies	OLEV On-Street Residential Chargepoint Scheme Scottish Government's Public Charge Point funding ChargePlace Scotland network
Market trends	-
New business models	Novel on-street charging solutions, e.g. Trojan Energy charge connector which is flush with the pavement.
Recommendations	Survey car drivers without off-street parking to explore their preferred option for charging. Virtually no formal research has been conducted on this topic yet. Identify areas where plug-in EVs parked on-street are likely to be located, particularly those where cars are not used for commuting. Introduce mechanism to allow potential plug-in EV buyers without off-street parking to lodge request for nearby public charge point.

[62] Element Energy analysis of Scottish Household Survey 2017

3.1.5 Income

The higher purchase price of ULEVs compared with conventional petrol and diesel vehicles makes their adoption amongst lower income buyers potentially challenging. However, lower income groups are unlikely to purchase new vehicles, and instead purchase second or third hand. Therefore, it is the price of used electric vehicles which is more relevant. As discussed in Section 3.1.2, used ULEVs currently offer potential cost savings on an ownership basis. However, upfront costs remain higher and these may rise as ULEV depreciation rates decrease.

Figure 9 shows the income distribution for different types of car/van owners. The characteristics of the owners considered are commuter vs non-commuter, overnight location of vehicle (home/on-street) and urban/rural.



Commuter	Yes	No	Yes	No	Yes	No	Yes	No
Overnight location	Home		On-Street		Home		On-Street	
Urbanity	Urban				Rural			

Figure 9: Distribution of net household income for different Scottish car/van owner groups, defined by whether they commute, overnight location of vehicle and urban/rural[63].

Amongst the eight groups shown in Figure 9, the largest share of lower income car/van owners, with a net household income of <£20k per year, are urban non-commuters who park at home (10% of car owners). But 5.6% of car owners have a net household income of <£20k and are also non-commuters who park on-street. ULEV purchase is particularly challenging for this group as they are not able to charge at work so would rely solely on public charging infrastructure.

3.1.6 Rurality

This section considers the differences in urban vs rural drivers, and how this affects some of the characteristics that influence ULEV barriers, including:

- Income: differences in income between car/van owners in urban and rural locations is small

[63] Element Energy analysis of the Scottish Household Survey 2017

- Driving behaviour: Annual mileages and trip distances tend to increase with increasing rurality but remain within the capabilities for existing BEVs. Remote island locations show relatively low mileages, suggesting ULEVs are suitable for a large share of drivers here.
- Access to off-street parking: the share of cars/vans with access to off-street parking is >80% in rural areas, demonstrating that a large number of plug-in cars/vans could charge at home.

Income

The income distributions of car/van owners shown in Figure 9 suggest there is little difference between urban and rural car owners. However, this distinction is based on the Scottish Government's 2-point urbanity classification. Here, rural is defined as an area with fewer than 3,000 people. But this ranges from Accessible Rural Areas within a 30 minutes drive of a settlement with 10,000 people, to Very Remote Rural Areas at least 60 minutes' drive from a 10,000 person settlement (see Table 6). A simple urban/rural distinction therefore does not capture the variation within rural car/van owners.

Table 6: Definition of each level in the 8-point urbanity scale used by the Scottish Government

8-point Urbanity	Urban / Rural	Name	Population	Drive time to settlement with >10,000 people
1	Urban	Large Urban Areas	> 125,000	-
2	Urban	Other Urban Areas	10,000-125,000	-
3	Urban	Accessible Small Towns	3,000-10,000	< 30 minutes
4	Urban	Remote Small Towns	3,000-10,000	30-60 minutes
5	Urban	Very Remote Small Towns	3,000-10,000	> 60 minutes
6	Rural	Accessible Rural Areas	< 3,000	< 30 minutes
7	Rural	Remote Rural Areas	< 3,000	30-60 minutes
8	Rural	Very Remote Rural Areas	< 3,000	> 60 minutes

Figure 10 shows how gross household income of car/van owners varies across each of the 8-point urbanity levels. Income in Levels 4 & 5 (Remote and Very Remote Small Towns) is slightly lower than for more urban locations. For rural Levels 6-8, average income gradually decreases with increasing rurality. But the data show only minor variations between the urbanity levels. Income is therefore not expected to impose a significant barrier to ULEV adoption amongst rural car/van owners.

Annual Mileage

Figure 11 presents an estimate for the average annual mileage of cars in each Local Authority. In general, the more rural the Local Authority, the higher the annual mileage. For example, cars in the most urban locations drive on average 12,300 km/yr (34 km/day) and this increases by nearly 1,000 km/yr (2.7km/day) for each 8-point urbanity level. However, annual mileages in the most remote Local Authorities (Shetland Islands, Eilean Siar and Orkney Islands) do not follow this trend and are relatively low. These three Local Authorities are islands and so this reflects that these car/van owners have fewer places to travel to. Longer trips likely involve them travelling to the mainland, however, for this they must pass through ferry ports. These provide ideal locations for situating recharging infrastructure to help these ULEV drivers complete their onward journeys.

Perth & Kinross shows a particularly high annual mileage, but this is an artefact of the approach used to estimate these figures. This assumes that all mileage driven in each Local Authority is carried out by cars registered in that Local Authority. Perth & Kinross includes the A9, the main route from Edinburgh/Glasgow to Inverness, and so a large share of mileage recorded here is due to through-traffic registered elsewhere.

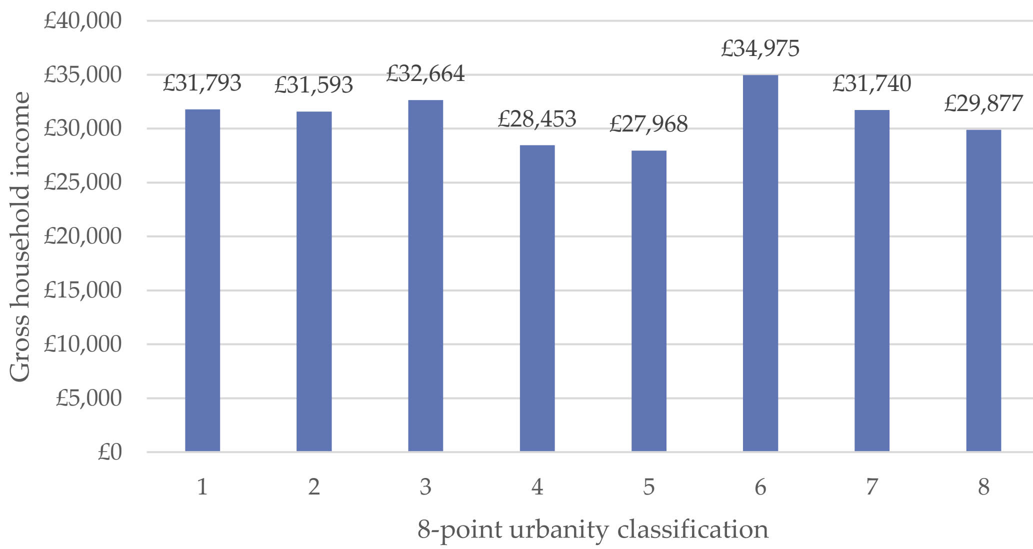


Figure 10: Average gross household income of Scottish car/van owners by 8-point urbanity classification[64].

[64] Element Energy Analysis of Scottish Income Estimates 2014 (updated 2017): https://www.gov.scot/publications/chma-small-area-income-estimates/

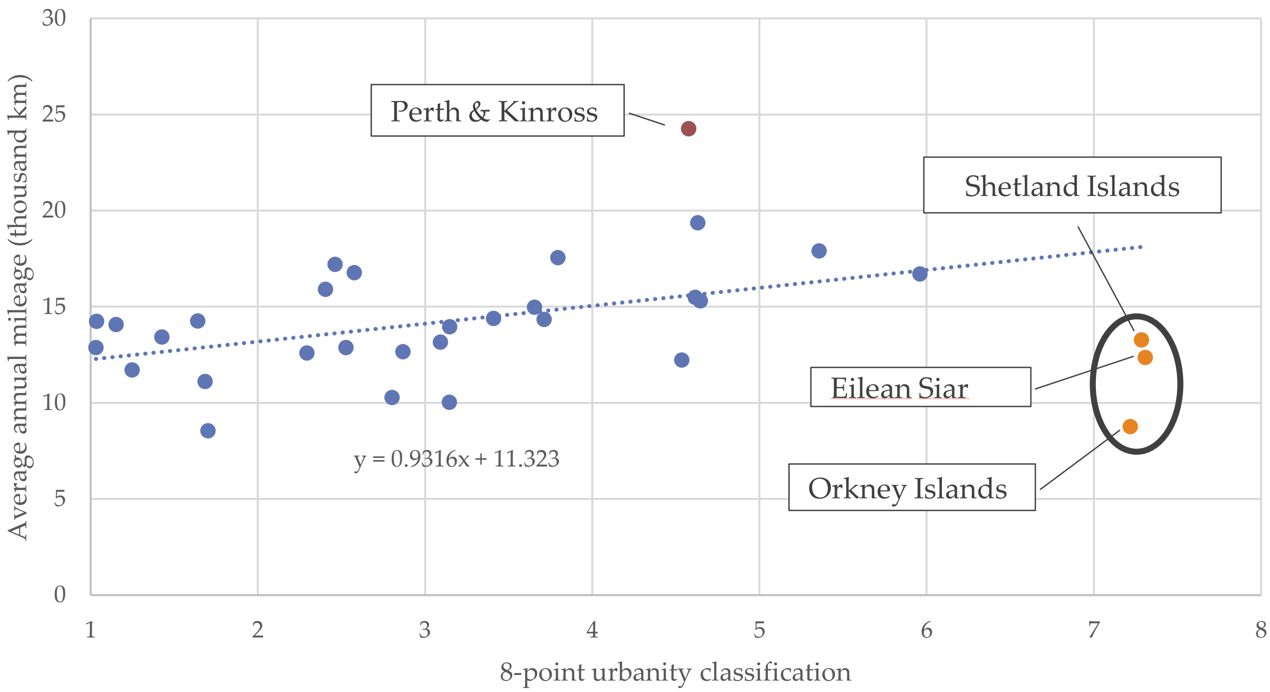


Figure 11: Estimated average annual mileage of each Scottish Local Authority[65], by average urbanity of constituent Output Areas.

[65] Estimated by dividing total car kilometres travelled in each Local Authority (DfT Vehicle Statistics TRA8902) by the number of cars in Local Authority (DfT Vehicle Statistics VEH0105)

Trip Distances

As well as having higher annual mileage, trip distances for car owners tend to increase with greater rurality (see Figure 12). This remains the case for Remote Rural locations where annual mileages appears to be lower. However, even for Remote Rural locations, 90% of trips are less than 50km which is well within the range of a battery electric vehicle. Even a round trip of 100km will not pose a problem.

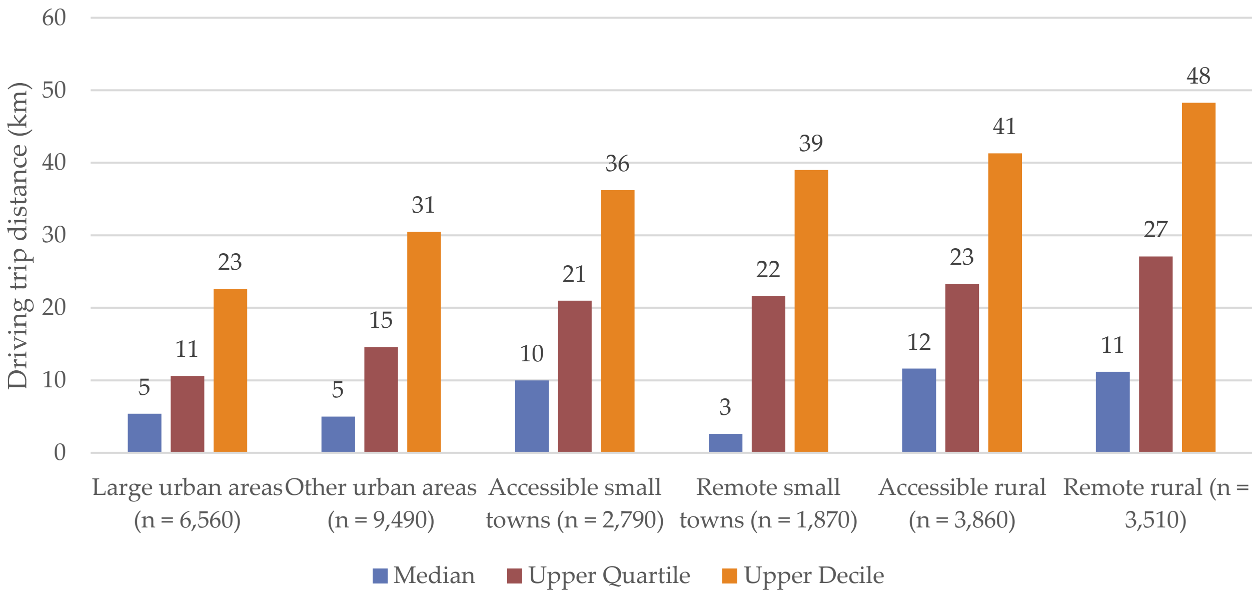


Figure 12: Median, Upper Quartile and Upper Decile distances of driving trips carried out by Scottish car owners across 6-point urbanity classification[66]. n = sample size

The trend in trip distances is less clear for vans (see Figure 13). Remote Small Towns show a tail of considerably longer trips than the other categories. However, the sample size for this group is small, meaning this upper decile figure of 87km may be due to a very small number of vans. In any case, a round trip of 180 km remains just about within the range of battery electric vans available today (see Figure 6).

It is worth considering, however, that ULEV ranges in rural areas may be reduced due to mountainous terrain. Vehicle energy consumption rises considerably whilst climbing. Much of this energy is regained whilst driving back downhill but some will be lost under braking to regulate speed. The overall impact is an increase in energy consumption and reduction in range. However, due to the presence of regenerative braking, the impact on energy consumption for ULEVs is much less than for conventionally powered vehicles[67]. The magnitude of the impact is dependent on the specific road travelled and hence there is little relevant evidence for the case of Scotland. It is recommended that this is explored in more detail in a dedicated study. Even if the overall effect on electricity consumption is low, rapid loss of range whilst climbing could serve to heighten range anxiety and spread further misconceptions of ULEV capabilities.

Access to Off-street Parking

Figure 14 shows an estimate for the share of cars/vans in Scotland that have off-street parking available. The analysis reveals availability of off-street parking increases with greater rurality. For rural Levels 6-8, more than 80% of cars/vans have access to off-street parking. This is likely to be a

[66] Analysis of travel diary data from Scottish Household Survey 2015-17

[67] O. Travesset-Baro, M. Rosas-Casals & E. Jover (2015) Transport energy consumption in mountainous roads. A comparative case study for internal combustion engines and electric vehicles in Andorra. DOI: https://doi.org/10.1016/j.trd.2014.09.006

conservative estimate. Rural plug-in electric cars/vans are therefore far more likely to be able to charge at home. Urban cars/vans, however, are less likely to have access to off-street parking. A larger share of urban plug-in electric cars/vans will therefore rely on non-home charging, such as public or work.

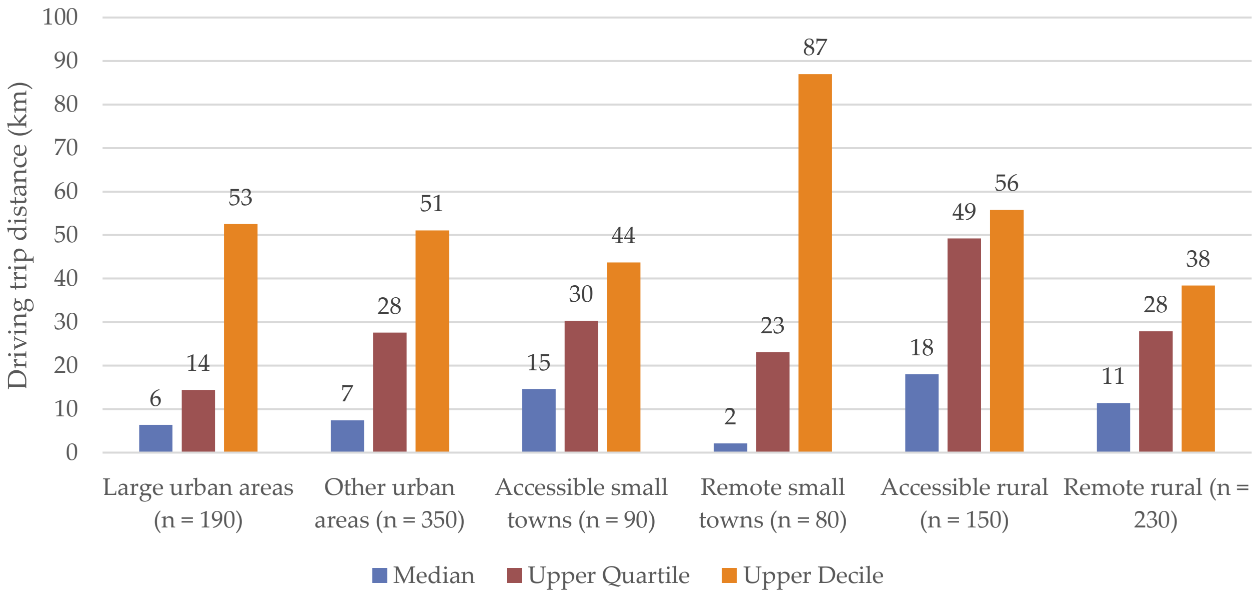


Figure 13: Median, Upper Quartile and Upper Decile distances of driving trips carried out by Scottish van owners across 6-point urbanity classification[68]. n = sample size

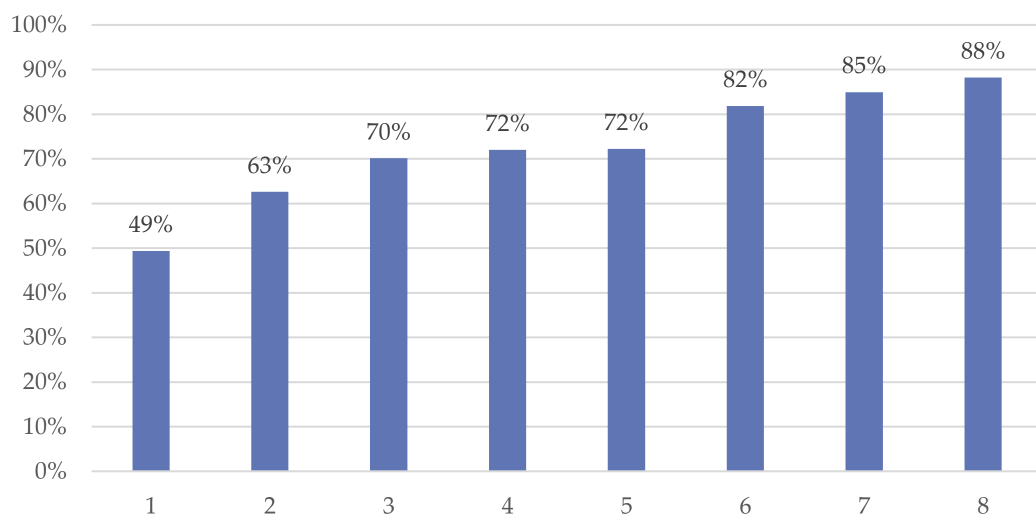


Figure 14: Estimated share of Scottish cars/vans with off-street parking by 8-point urbanity classification[69].

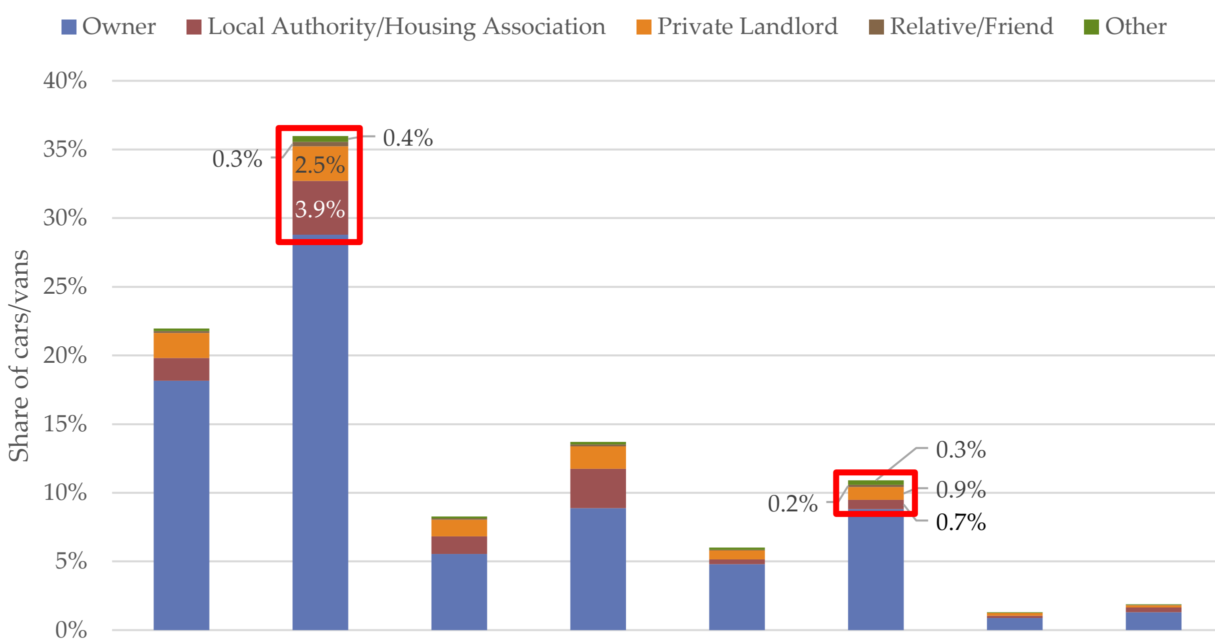
Remote rural car/van owners tend to drive lower mileages, have similar incomes to the rest of Scotland, have greater access to off-street parking and drive trips that are well within the range of

68 Analysis of travel diary data from Scottish Household Survey 2015-17
69 Estimated from analysis of households by dwelling type in each Output Area

current battery electric vehicles. They therefore appear well suited to adopting battery electric vehicles. This is discussed in more detail in Section 5.2.

3.1.7 Home ownership

Cars and vans parked off-street at home are ideally charged via a dedicated home charge point. However, those living in rented accommodation are likely to require permission from their landlord to install a charge point. Figure 15 shows the share of car/vans by whether their owner owns their house or who they rent their house from. This is shown for eight groups, characterised by whether they are commuters, the overnight location of the vehicle (home/on-street) and urban/rural (as also shown in Figure 9 for income).



Commuter	Yes	No	Yes	No	Yes	No	Yes	No
Overnight location	Home		On-Street		Home		On-Street	
Urbanity	Urban				Rural			

Figure 15: Home ownership/landlord for different Scottish car/van owner groups, defined by whether they commute, overnight location of vehicle and urban/rural[70].

In Scotland, 14% of cars/vans are parked off-street at rented accommodation, for whom installation of a home charge point could pose a problem. If this is the case, they can either charge in non-home locations, such as at work or public charge points, or use a domestic 3-pin socket. However, the latter requires there to be a suitably located socket and is not recommended as a permanent charging solution (see Section 2.4). Work charging is only available to commuters. Figure 15 highlights (in red boxes) the 9% of cars/vans which are owned by non-commuters who park off-street in rented accommodation. Difficulties with persuading landlords to permit installation of a home charge point are particularly acute for this group. Legislation may be needed to incentivise or mandate landlords to allow home charge points to be installed. Note that just over half of this 9% are in Local Authority/Housing Association properties, where regulation may be easier to impose.

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[70] Element Energy analysis of the Scottish Household Survey 2017

Barrier	Installation of charge points in rented houses
Buyers affected	Home renters who park their vehicles off-street
Existing policies	New buildings directive requiring charge points to be installed in new homes. However, this does not affect existing homes unless newly renovated.
Market trends	-
New business models	-
Recommendations	Mandate landlords to accept requests to install home charge points

3.1.8 Van size

Van models can be divided up into five distinct groups, based on vehicle size, payload and body type. Figure 16 shows the market share of each. Current ULEV options are focussed in the smaller sizes. There are very few options in the medium and large classes, although several models are due to be released before the end of 2020 (see Table 3).

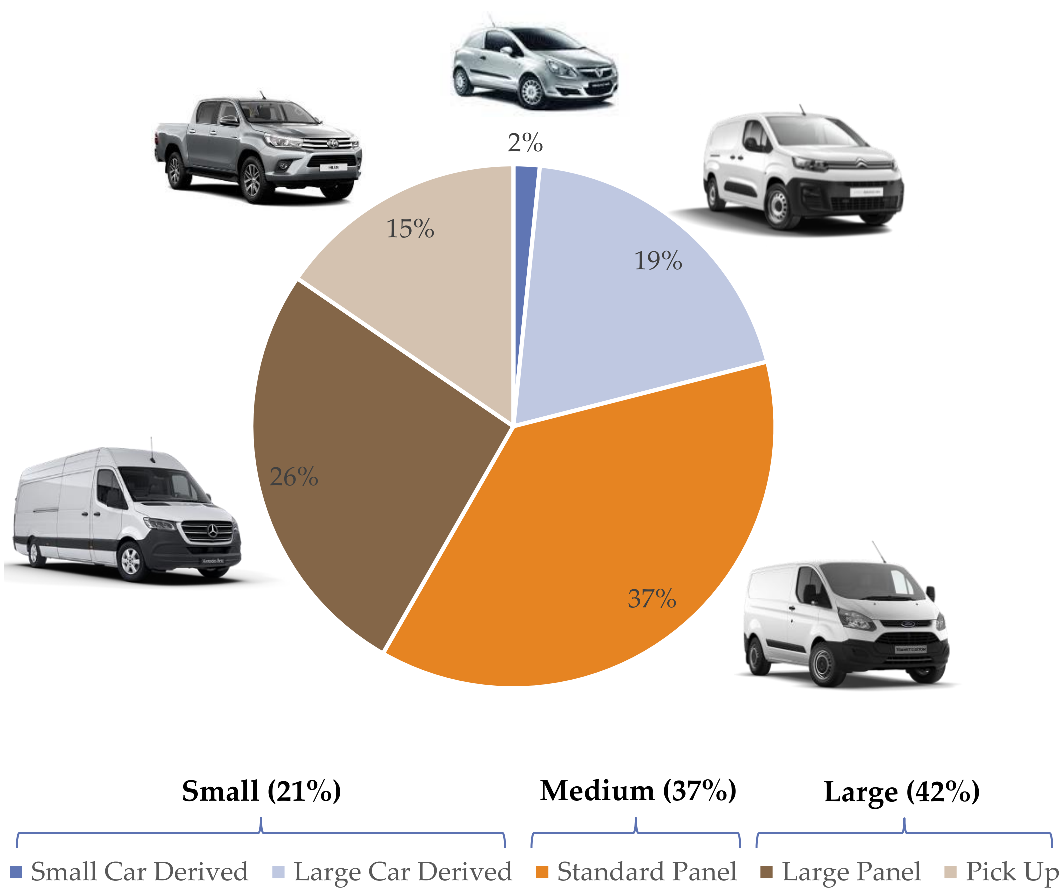


Figure 16: Share of vans sold in 2018 in Great Britain by size segment[71]

[71] Van sales data provided by the Society of Motor Manufacturers and Traders

Large battery electric vans require large batteries to provide adequate range. Figure 17 presents the official range (NEDC) and battery capacities for a number of different available and upcoming battery electric vans. To provide an official range of 200km, large vans require ~20kWh more than small vans. This additional battery capacity costs ~£3,000 in today's battery prices[15]. Cheaper, short range variants of battery electric vans are likely to be made available. But these may not be suitable for users of large vans with high range requirements.

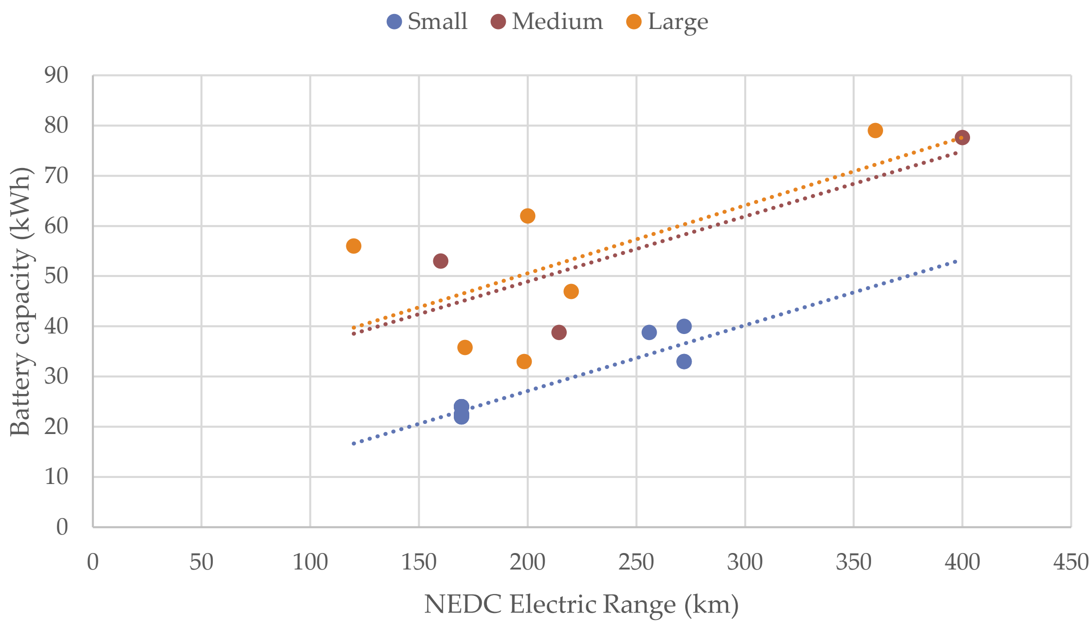


Figure 17: NEDC electric range vs battery capacity for released and upcoming battery electric vans.

The need for large batteries also reduces available payload. For example, the upcoming Mercedes eSprinter is a large panel BEV. The 41 kWh option will provide a maximum payload weight of 1,040 kg. A 55 kWh battery option will also be offered but this reduces the payload to 900 kg[72]. Both versions have a lighter payload than the >1,200kg offered by the equivalent diesel version. Larger batteries will reduce the payload weight further, thus creating a trade-off between range, payload and vehicle price. However, all variants of the eSprinter have a gross vehicle weight of 3.5 tonnes. The recent change in licencing laws allows battery electric vehicles to have a gross vehicle weight of 4.25 tonnes, thereby allowing larger batteries and/or payloads.

Barrier	**Large vans are more expensive to electrify**: This is due to the need for a larger battery. High range requirements will increase this upfront cost. Although, most company-owned cars/vans are leased, thus spreading the high upfront cost over the ownership period.
Buyers affected	Buyers of large and/or high range vans
Existing policies	Upfront costs are reduced by the Plug-in Car and Van Grants Scottish Government provides interest free Electric Vehicle Loan

[72] https://www.coolkit.co.uk/blog/mercedes-benz-esprinter-van/

Market trends	Battery prices are falling and battery weight decreasing making it cheaper to electrify large vans and offer higher range
New business models	Companies offering ULEV specific leasing with low finance rates and accurate depreciation forecasts can reduce ownership costs. Bundling running costs, such as electricity/fuel and maintenance, into the contracts can also help highlight to consumers possible benefits in ownership cost.
Recommendations	When plug-in car and van grants are revised in 2020, review interest free Electric Vehicle Loan to ensure terms are adequate. Increase funding available for long range van fleets.

3.1.9 Van utilisation

Analysis of company owned vans in the UK, based on their mileage requirement and storage location, reveals three distinct groups[73] (see Figure 18). 31% of these vans are stored at depots and the remainder are driven back to employees' homes when not in use. Some of these will be parked on-street.

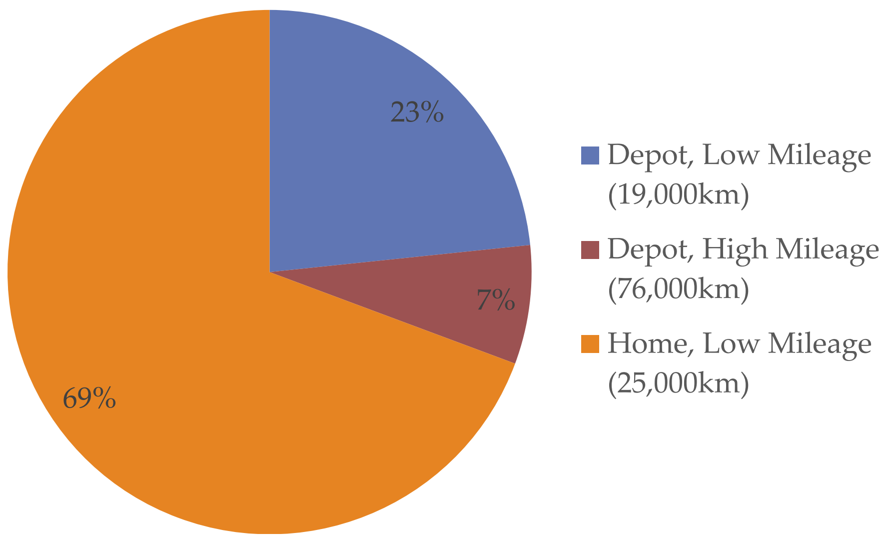


Figure 18: Share of company-owned vans, grouped by their storage location and mileage requirements. Average annual mileage shown in brackets.

Analysis of the duty cycles shows a clear distinction between those driving low mileages, and those driving high mileages. Figure 19 shows the share of each group which can be replaced by a BEV with a given real-world range. For the depot-based and home-based low mileage vans, a real-world range of 200km is adequate to replace all of them. This is within the capabilities of upcoming battery electric vans. For the 7% of company-owned vans that are depot-based and high mileage, a range of 400km is required to satisfy the daily duty requirements of all of them. This is beyond the real-world ranges of high range vans set to be released in 2020 (see Figure 6). These have large batteries of >75 kWh, and larger capacities will add significant upfront cost and weight, thereby limiting payload. For the very highest mileage vans, hydrogen fuel cell powertrains may be more appropriate. DHL and

[73] Analysis of duty cycles of 18,000 vehicles across 300 fleets, carried out by RouteMonkey and Element Energy for the Energy Technologies Institute, Consumers Vehicles and Energy Integration Project 2015-19. https://www.eti.co.uk/programmes/transport-ldv/consumers-vehicles-and-energy-integration-cvei

StreetScooter have developed a large panel van with a battery and hydrogen fuel cell range extender[74]. This has an advertised range of 500km.

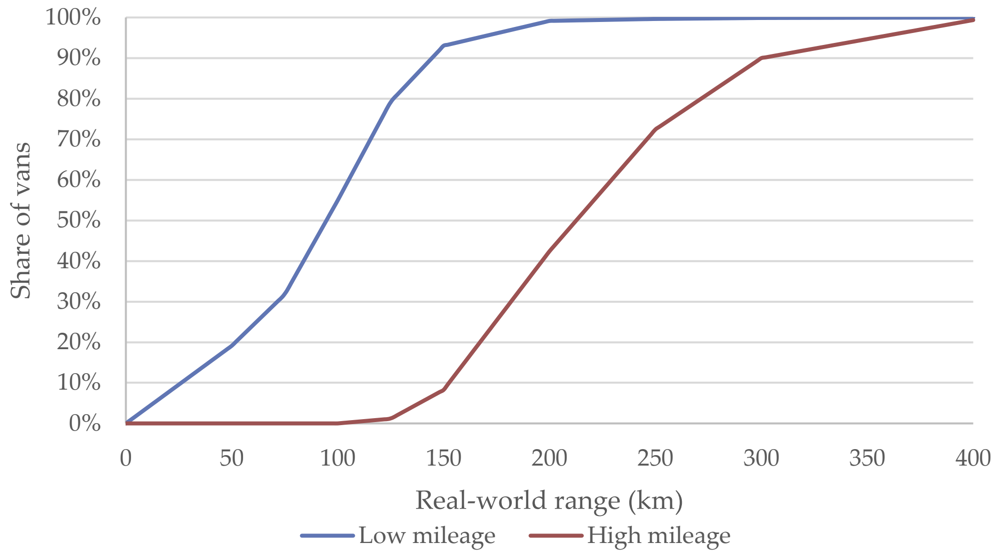


Figure 19: Share of low mileage and high mileage vans which can be replaced by BEV with a given real-world range[73]

Barrier	**Long range ULEV vans are not yet available**
Buyers affected	Van drivers with high daily mileages
Existing policies	-
Market trends	Ranges of battery electric vans are increasing, with upcoming models offering 200-300 km real world range Longer range zero emission vans employing hydrogen are under development
New business models	-
Recommendations	Develop procurement framework for public fleets to define specifications OEMs must meet. Launch Joint Procurement Initiatives to define vehicle specifications required. Manufacturers incentivised to meet specification due to large volume order. Install rapid charging network with adequate coverage and speed to reduce BEV range requirements

[74] https://www.dpdhl.com/content/dam/dpdhl/en/media-center/media-relations/documents/2019/factsheet-h2-panel-van.pdf

3.2 HGVs

There are a number of company level factors that will impact on ULEV HGV uptake. Three key factors are:

- Understanding of and views towards ULEV technologies
- The number of HGVs in an operator's fleet. Fleet operators in Scotland have HGV fleets ranging from 1-2 vehicles to over 200 vehicles.
- Fleets moving their own goods versus fleets contracted out to work for other companies.

LoCity conducted research on freight operators' views on ULEVs by interviewing 200 operators, making this the most comprehensive study on this subject in the UK. Figure 20 summaries the findings and shows that 26% of operators are positive (green) towards the change, 34% are neutral (blue) and 40% are negative (red). These results suggest that there are currently more fleets with a positive outlook on using ULEVs than there are ULEVs being supplied by current HGV manufacturers. This suggests supply constraints are a major issue. The results also show that only 43% (the positive groups in green and the "sceptic having done research group" in pale red) of fleets have conducted enough research to understand if ULEVs are a viable option for them. This suggests a strong need for reliable information and education to increase the number of fleets considering ULEVs.

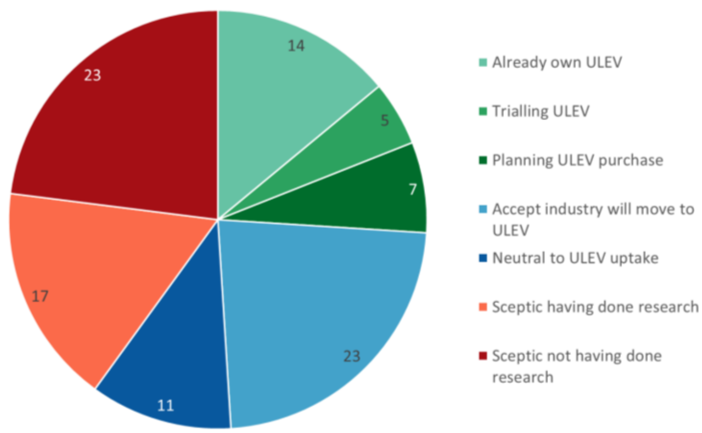


Figure 20: Freight operators stated views to ULEVs

The size of an HGV fleet is a good indicator of the company size. In Scotland, very small fleets (fleets that own less than 10 vehicles) represent 86% of operator license holders (pie chart on the left) but own 32% of vehicles (pie chart on the right). Medium sized fleets (fleets that own between 10-50 vehicles) represent 12% of operator license holders and own 30% of vehicles. Large fleets (fleets that own more than 50 vehicles) represent 3% of operator license holders and own 39% of vehicles. Company size is important in terms of barriers to ULEV uptake as the company's resources (capital and time) are restricted and this can lead to several barriers that are specific to these smaller companies. These issues are explored in more detail in the case studies in Section 5.

HGV operators using a restricted license are only allowed to carry their own goods. These companies are likely to have a non-transport focus and own HGVs only to move their own goods to clients. Whereas companies with an unrestricted license can earn an income by offering the carriage of goods as a service to other companies. Figure 22 shows the distribution of licence types across the Scottish HGV fleet.

Restricted licenses represent 48% of companies (left hand pie chart) but only 24% of vehicles (pie chart on the right) in the Scottish fleet. Unrestricted licenses represent 52% of companies and 76% of vehicles in the Scottish fleet. License types are important in terms of barriers to ULEV uptake because they are linked to differences in vehicle size and utilisation rates (restricted license holders are expected to own smaller vehicles and utilise them less compared to unrestricted licensed logistics operators who will own larger vehicles and maximise their utilisation), which impact ULEV uptake. These issues are explored in more detail in the case studies in Section 5.

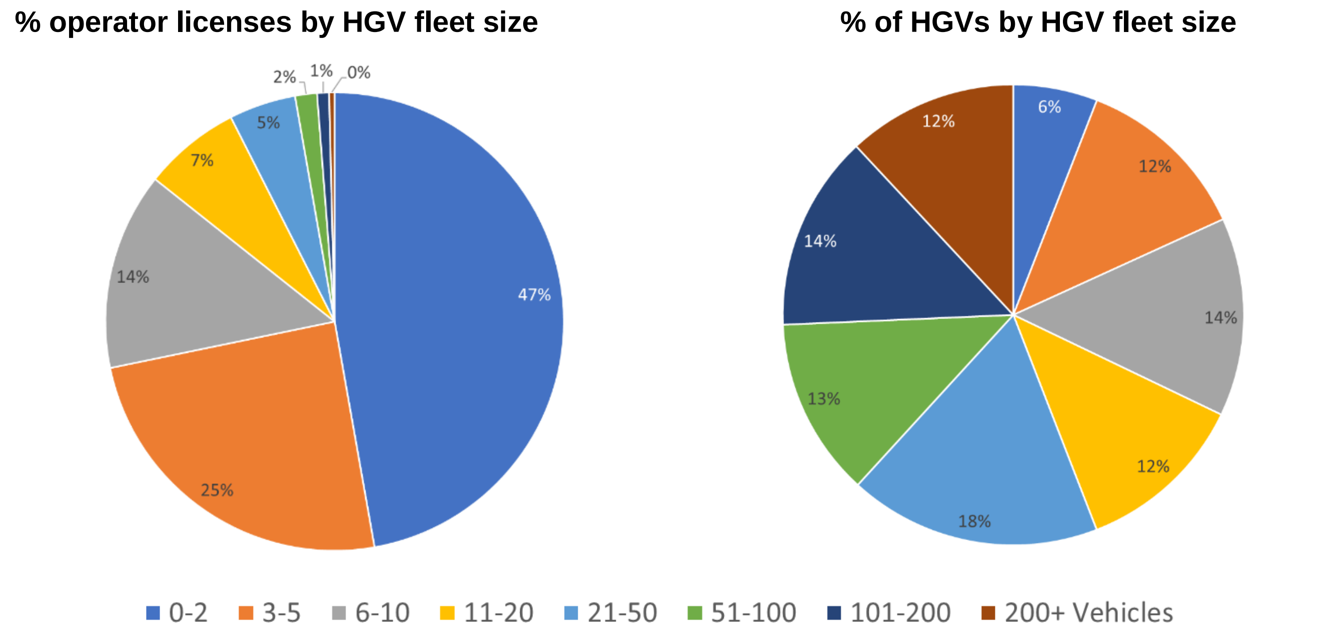


Figure 21: Left: The number of HGV operator license holders by the size of their fleet. Right: The number of HGVs in Scotland by the size of the fleet

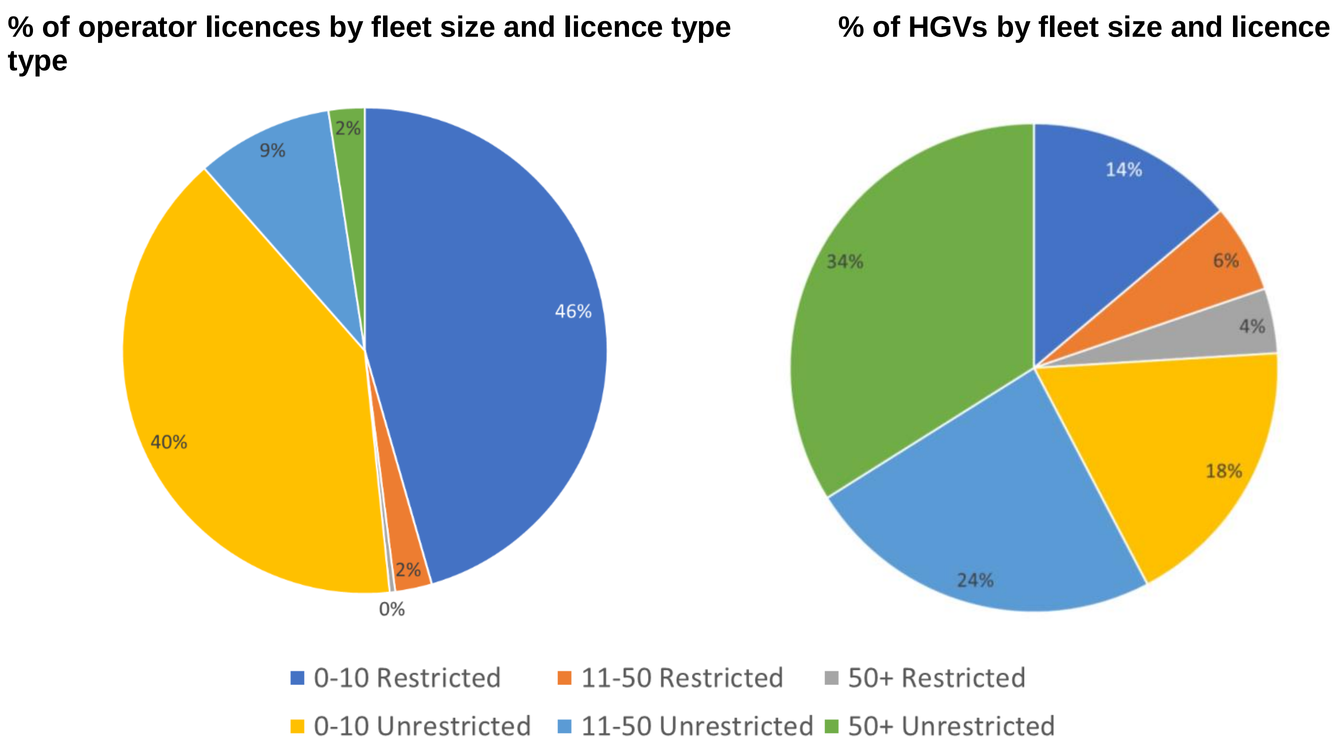


Figure 22: Left: The number of HGV operator license holders by the size of their fleet and the type of license. Right: The number of HGVs in Scotland by the size of the fleet and the type of license (Restricted licenses allow operators to move their own goods. Unrestricted licenses allow operators to move goods for other companies)

4 Segmentation

4.1 Cars & Vans

Scottish car and van buyers have been grouped into 10 segments, based on the several of the characteristics discussed in Section 3.1. This segmentation scheme attempts to capture the major barriers to ULEV adoption faced by different car and van buyers. However, due to limitations in data availability, not all characteristics are considered in the segmentation scheme (e.g. income, home ownership, rurality). Some of these are explored in more detail in a series of case studies in Section 5. A detailed description of the segmentation process is shown in the Appendix.

Note that the share of vehicles falling into the new buyer segments are considerably smaller than the used buyer segments. However, as discussed in Section 3.1.2, new buyers are responsible for introducing ULEVs into the vehicle stock. They are therefore of particular significance for overall ULEV adoption.

Table 7: Description of car and van segments, and the specific barriers to ULEV adoption they face. Yellow shading = minor barrier, red shading = major barrier.

Segment Description	Share of cars/vans	New ULEVs have high upfront costs	Used ULEVs have high upfront costs	Uncertainty surrounding battery lifetime	ULEV concerns amongst fleet managers	Large vans are more expensive to electrify	Long range ULEV vans are not yet available	ULEVs are in short supply	Used ULEV availability lags behind new ULEV	Cost and delays in home charge point installation	Installation of charge points in rented houses	Dependence on public or work charging	Lack of opportunity to charge at work	Difficulties installing depot charge points	Need for rapid public charging	Lack of H2 refuelling infrastructure	Lack of knowledge
Private buyers of **new cars/vans** who park **off-street** at home	9.6%	✗ (yellow)				✗ (yellow)		✗ (red)		✗ (yellow)	✗ (yellow)				✗ (yellow)	✗ (red)	✗ (red)
Company cars/ vans which can park **off-street** at home	5.9%	✗ (yellow)			✗ (yellow)	✗ (yellow)		✗ (red)		✗ (yellow)	✗ (yellow)				✗ (yellow)	✗ (red)	✗ (red)
New car buyers who park **on-street** and **commute**	3.6%	✗ (yellow)			✗ (red)			✗ (red)				✗ (red)			✗ (red)	✗ (red)	✗ (red)
Private buyers of **new cars/vans** who park **on-street**, and **do not commute**	3.1%	✗ (yellow)				✗ (yellow)		✗ (red)				✗ (red)	✗ (red)		✗ (red)	✗ (red)	✗ (red)
Depot-based **cars/vans** with relatively **low daily mileage**	1.8%	✗ (yellow)			✗ (yellow)	✗ (yellow)		✗ (red)						✗ (red)		✗ (yellow)	✗ (red)
Company vans stored **on-street**, with **low daily mileage**	1.1%	✗ (yellow)			✗ (red)	✗ (yellow)		✗ (red)				✗ (red)	✗ (red)			✗ (red)	✗ (red)
Depot-based **vans** with **high daily mileage**	0.4%	✗ (yellow)			✗ (yellow)	✗ (red)	✗ (red)	✗ (red)						✗ (red)		✗ (yellow)	✗ (red)
Private buyers of **used cars/vans** who park **off-street** at home	48.8%		✗ (red)	✗ (yellow)		✗ (yellow)		✗ (red)	✗ (red)	✗ (yellow)	✗ (red)				✗ (yellow)	✗ (red)	✗ (red)
Private buyers of **used cars/vans** who park **on-street**, and **do not commute**	17.4%		✗ (red)	✗ (yellow)		✗ (yellow)		✗ (red)	✗ (red)			✗ (red)	✗ (red)		✗ (red)	✗ (red)	✗ (red)

Private buyers of **used cars** who park **on-street**, and **commute**	8.3%		✗	✗				✗	✗			✗			✗	✗	✗

The following section provides a brief description of each segment and outlines the individual barriers that each segment face towards ULEV uptake.

4.1.1 Private buyers of new cars and vans who can park off-street at home

This segment represents 9.6% of car and van buyers in Scotland. This segment is generally well-suited to early ULEV adoption. Private buyers of new cars and vans are generally higher income and usually purchase their vehicles through a finance package. This spreads the higher upfront cost of ULEVs over the ownership period, during which the higher leasing cost is at least partially offset by the lower running costs. Buyers in this segment also have the potential to charge at home. Since they are generally higher income, they are more likely to be homeowners, so would not need a landlord's permission to install a charge point.

Barriers to ULEV adoption:

New ULEVs have high upfront costs

Large vans are more expensive to electrify

ULEVs are in short supply

Cost and delays in home charge point installation

Installation of charge points in rented houses

Need for rapid public charging

Lack of H2 refuelling infrastructure

Lack of knowledge

4.1.2 Company cars and vans which can park off-street at home

This segment represents 5.9% of Scottish car and van buyers. Like private new car buyers with off-street parking, this segment is also well suited to early ULEV adoption. Company cars are typically purchased through a finance package, and companies may be attracted to the low running costs of ULEVs and tax benefits. Although charging can be carried out at home, many of these vehicles will be used to commute to a workplace. Workplace charge points can be used to provide supplementary charging, or as a primary charging location in cases where a charge point cannot be installed at home. Since the users' company will be involved in the purchase, encouraging these companies to support ULEV adoption offers a key pathway to introduce ULEVs into the vehicle stock.

Barriers to ULEV adoption:

New ULEVs have high upfront costs

ULEV concerns amongst fleet managers

Large vans are more expensive to electrify

ULEVs are in short supply

Cost and delays in home charge point installation

Installation of charge points in rented houses

Need for rapid public charging

Lack of H2 refuelling infrastructure

Lack of knowledge

4.1.3 New car buyers who park on-street and use their car to commute

This segment represents 3.6% of Scottish car and van buyers. This segment includes both private and company buyers. This segment would rely on non-home charging infrastructure, such as slow on-street or rapid charging points. However, because they commute to a workplace, charging at work could provide their primary charging needs. This would lower their dependence on public charging infrastructure. It is recommended that companies with large numbers of commuters without off-street parking are encouraged to install workplace charge points.

Barriers to ULEV adoption:

New ULEVs have high upfront costs

ULEVs are in short supply

ULEV concerns amongst fleet managers

Dependence on public or work charging

Need for rapid public charging

Lack of H2 refuelling infrastructure

Lack of knowledge

4.1.4 Private buyers of new cars and vans who park on-street, and do not use their vehicle to commute

This segment represents 3.1% of Scottish car and van buyers. The barriers to ULEV adoption for this segment are large. These buyers do not use their vehicles to commute to a workplace and so have no opportunity to charge at work. They therefore rely solely on public charging infrastructure. Measures to deploy public charging infrastructure should target areas with large numbers of these buyers.

Barriers to ULEV adoption:

New ULEVs have high upfront costs

Large vans are more expensive to electrify

ULEVs are in short supply

Dependence on public or work charging

Lack of opportunity to charge at work

Need for rapid public charging

Lack of H2 refuelling infrastructure

Lack of knowledge

4.1.5 Depot-based cars and vans with relatively low daily mileage

This segment represents 1.8% of Scottish car and van buyers. These vehicles will be company-owned and purchased new. Buyers of plug-in EVs in this segment would generally look to charge them outside of working hours (i.e. overnight). They would therefore be required to complete a full day's mileage on a single charge. But daily mileage is low, so they are well suited to ULEV operation. Charging would ideally be carried out at the depot to guarantee charging access, and they would not be expected to require public charging. Depot-based operations also provide an early opportunity to adopt H_2 vehicles, with H_2 refuelling infrastructure installed at the depot.

Barriers to ULEV adoption:

New ULEVs have high upfront costs

ULEV concerns amongst fleet managers

ULEVs are in short supply

Difficulties installing depot charge points

Lack of H2 refuelling infrastructure

Lack of knowledge

4.1.6 Company vans which are stored on-street, with relatively low daily mileage

This segment represents 1.1% of Scottish car and van buyers. These vehicles are purchased new by companies but parked on-street at employees' homes. Company fleet managers will therefore have major concerns over the availability of charging infrastructure and may restrict their adoption. Since these are vans, they will not be used for commuting, and so users will rely solely on public charging infrastructure. Like depot-based vans, these would be expected to carry out a full day's mileage between charging. Their low daily mileage makes them well suited to plug-in EV adoption, with charging taking place overnight. They are therefore better suited to slow on-street charging. Measures to install on-street charging infrastructure should target areas where this segment is located. Charge points need to be installed in high enough numbers that the users perceive guaranteed access, as they will probably need to charge every night.

Barriers to ULEV adoption:

New ULEVs have high upfront costs

ULEV concerns amongst fleet managers

ULEVs are in short supply

Dependence on public or work charging

Lack of opportunity to charge at work

Lack of H2 refuelling infrastructure

Lack of knowledge

4.1.7 Depot-based vans with relatively high daily mileage

This segment represents 0.4% of Scottish car and van buyers. These vans are company-owned and purchased new. They would be primarily charged overnight at the depot. But their high daily mileage and preference to complete this under a single charge is beyond the capability of current plug-in vans. While longer range plug-in vans are being released in the near term, these have large batteries so are likely to be expensive, and will not provide sufficient range for the highest mileage users. In addition, these vans will require longer or higher powered charging overnight. This may incur prohibitively high connection costs to install depot charging infrastructure. Use of rapid charging during the day can alleviate the need for depot charging, but there is limited opportunity to do this during the daily duty cycle. H_2 powered ULEVs may therefore be a better option for this segment, particularly if H_2 refuelling infrastructure can be installed at the depot.

Barriers to ULEV adoption:

New ULEVs have high upfront costs

ULEV concerns amongst fleet managers

Large vans are more expensive to electrify

Long range ULEV vans are not yet available

ULEVs are in short supply

Difficulties installing depot charge points

Lack of H2 refuelling infrastructure

Lack of knowledge

4.1.8 Private buyers of used cars and vans who can park off-street at home

This segment represents 48.8% of Scottish car and van buyers. This is by far the largest buyer segment. However, this includes only used vehicle buyers who cannot directly influence uptake of ULEVs (unless they purchase used ULEVs from outside Scotland). This segment is well suited to ULEV adoption as they can charge at home. However, used vehicle buyers tend to include lower income groups, who are more likely to rent their houses. They may therefore face issues with installing home charge points.

Barriers to ULEV adoption:

Used ULEVs have high upfront costs

Uncertainty surrounding battery lifetime

Large vans are more expensive to electrify

ULEVs are in short supply

Used ULEV availability lags behind new ULEV market

Cost and delays in home charge point installation

Installation of charge points in rented houses

Need for rapid public charging

Lack of knowledge

Lack of H2 refuelling infrastructure

4.1.9 Private buyers of used cars and vans who park on-street, and do not use their vehicle to commute

This segment represents 17.4% of Scottish car and van buyers. This segment includes only used vehicle buyers. They do not have access to home charging or use their vehicles to commute, and so would rely solely on public charging infrastructure. Public charge points on the ChargePlace Scotland network provide free public charging in many areas. However, the network is increasingly transitioning to a paid model. Public charging is generally more expensive than charging at home. This will remain the case whilst public charge point utilisation is low. This could pose an issue for this segment which will include low income groups.

Barriers to ULEV adoption:

Used ULEVs have high upfront costs

Uncertainty surrounding battery lifetime

Large vans are more expensive to electrify

ULEVs are in short supply

Used ULEV availability lags behind new ULEV market

Dependence on public or work charging

Lack of opportunity to charge at work

Need for rapid public charging

4.1.10 Private buyers of used cars who park on-street, and use their vehicle to commute

This segment represents 8.3% of Scottish car and van buyers. This segment includes only used vehicle buyers. Although they do not have access to charging at home, they use their cars to commute. They can therefore charge primarily whilst parked at work, as long as their employer makes charge points available. This will reduce their dependence on public charging infrastructure.

Barriers to ULEV adoption:

Used ULEVs have high upfront costs

Uncertainty surrounding battery lifetime

ULEVs are in short supply

Used ULEV availability lags behind new ULEV market

Dependence on public or work charging

Need for rapid public charging

Lack of H2 refuelling infrastructure

Lack of knowledge

4.2 HGVs

Unlike the car and van market where there are a relatively small number of variants of each vehicle make and model, in the Heavy Goods Vehicle (HGV) market many different variants exist; this is to allow a single base chassis to perform many tasks from refrigerated food deliveries to waste collection. This variability makes the classification and segmentation of the HGV sector challenging and leads to a greater spread of vehicles within each segment. The most important segmentation criteria, for which data are available, are:

- The Gross Combination Vehicle Weight (GCVW) limit, which represents the maximum laden weight of the truck plus trailer and goods.
- The daily mileage, which is a function of the HGV weight and the sector the truck is operating in (e.g. food deliveries or waste collection).

There are approximately 36,800 HGVs registered in Scotland with close to 4,000 (11%) new units added to the fleet each year. The fleet is dominated by the smallest (<7.5t) and largest (>33t) vehicles, with the smallest vehicles providing urban distribution and the largest inter-urban distribution.

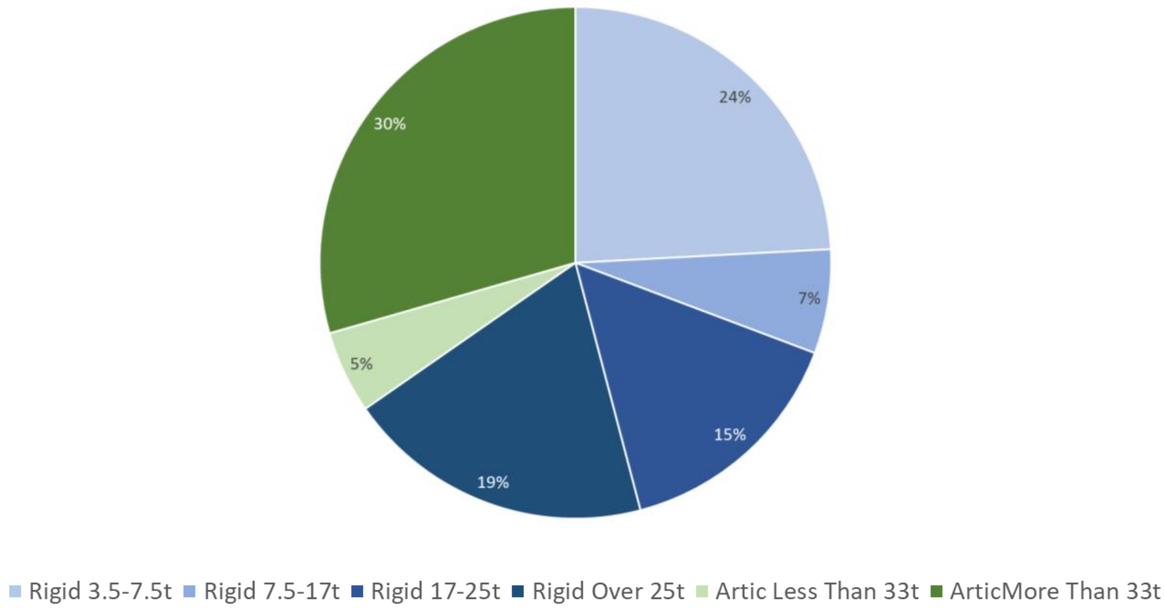


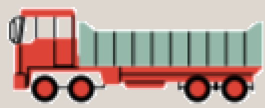
Figure 23: Scottish HGV fleet broken down by vehicle weight band[75]

Table 8 summaries the six vehicle weight segments. The daily mileage is for new vehicles, not a fleet average, reflecting the fact that ULEVs will be new trucks and operators will want to use them intensively to get a return on their investment. Vehicle weight has been used as the key segmentation criterion as the weight/size of a vehicle strongly dictates the type of use it is put to. For example, the vehicle size influences the sector the vehicle is used in, the use in urban, rural, and motorway settings, and the number of kilometres driven each day.

Table 8: Summary of HGV Segments

Vehicle Class	% of the Fleet (%)	Most Common Cargo (% of Vehicle km)	Common Usage Location	Average Daily Mileage (km/day)	Maximum Daily Mileage (km/day)
Small Rigid (3.5-7.5t) 	24	Mail (>30%) Machinery (>10%) Food (>10%)	Urban	200-250	400-500
Medium Rigid (7.5-17t) 	7	Food (>20%) Waste (>20%) Clothes (>10%) Machinery (>10%)	Urban & Motorway	250-300 (except waste = 100)	500-600
Large Rigid (17-25t)	15	Waste (>20%)	Urban & Motorway	250-330	500-600

[75] Transport Scotland, 2017, https://www.transport.gov.scot/publication/scottish-transport-statistics-no-36-2017-edition/chapter-1-road-transport-vehicles/. Categories have been adjusted to match UK Department for Transport categories so that Scottish and UK data can be directly used and compared

		Machinery (>10%) Food (>10%) Clothes (>10%)		(except waste = 100)	
Very Large Rigid (Over 25t) 	19	Waste (>30%) Raw Materials (>10%) Materials & Minerals (>10%) Food (>10%)	Urban for waste collection, Motorway & Industrial sites	250-350 (except waste = 100)	500-600
Small Articulated (Less Than 33t) 	5	Mail (>40%) Food (>30%) Clothes (>10%)	Urban, Motorway	300-375	550-700
Large Articulated (Over 33 t) 	30	Food (>30%) Materials & Minerals (>10%) Waste (>10%)	Motorway	350-450	600-800

4.2.1 Sector Wide Barriers and Recommendations

There are a number of barriers faced by the HGV market as a whole that are not related to vehicle segments. These are presented first to provide the reader with a sector wide view before the segment specific analysis in the next sub-section. The sector wide barriers and recommendations for HGVs are as follows:

Barrier	Fleet operators lack up to date information about ULEV model options on which to base vehicle purchasing decisions
Recommendations	In the near term, interview fleets about their interest in ULEVs and act as a facilitator to aggregate demand. Once demand for ULEVs in Scotland reaches approximately 100 vehicles in one size category supply can be drawn to Scotland by offering the supply contract to one OEM Support fleets with up to date information on ULEV models and their capabilities by encouraging fleets to use online tools such as the LoCity "Commercial Vehicle Finder"

Barrier	There are many different HGV vehicle types and operational profiles, this makes it very challenging to produce vehicle Total Cost of Ownership (TCO) comparisons between different technologies that fleet operators trust to guide their purchasing decisions

Recommendations	Once more ULEV models are on the market, support fleets to analyse their vehicle operating profile using telematics data and supply a simple tool to convert this into a TCO figure for conventional and ULEV models. This could involve contracting a telematics provider to develop a new ULEV suitability tool for HGVs. This project could be co-financed by government and industry.

Barrier	As ULEV models have not been used extensively in the market there is a lack of knowledge about their reliability and maintenance requirements
Recommendations	In the near-term help to organise and fund extended real-world vehicle trials and share the results with fleet operators across Scotland

Barrier	Lack of information and support for ULEV depot refuelling infrastructure installation
Recommendations	Collect case study data from existing fleets experience of installing depot refuelling infrastructure and share lessons learned with all fleets Support fleets with funding (grants or zero interest loans) to help cover the upfront cost of refuelling equipment installation in the depot

Barrier	Low taxation rates for current conventionally powered HGVs. To help boost the economy and encourage trade diesel HGVs currently benefit from low taxation (registration tax, annual tax, fuel VAT etc.). This makes it very challenging of ULEV HGVs to compete on cost as the alternative is so cheap
Recommendations	Once ULEV alternatives are available follow a well sign posted strategy of increasing the taxation on diesel HGVs over the next decade

Barrier	The capital cost of ULEV models is higher than that of conventional vehicles
Recommendations	Support fleets to purchase ULEV models with capital grants or no/low interest loans

Barrier	Loyalty to existing vehicle suppliers limits fleets' access to ULEV models if suppliers do not offer ULEV models
Recommendations	Share information with vehicle suppliers about the number of ULEV models available and the number of fleets interested in ULEVs to encourage them to interact with the ULEV market Provide information to fleet operators about suppliers who offer ULEV models

These recommendations offer several business model opportunities in Scotland. These are focused on the vehicle supply where there are opportunities to support fleets with information, vehicles and infrastructure.

HGV suppliers are currently a barrier to the uptake of ULEV HGVs: the number of situations where a supplier offering ULEVs and a fleet wanting ULEVs are matched up is likely to be less than the number of fleets wanting ULEVs. As fleets are expected to be loyal to current suppliers this poses a major challenge. However, there is an opportunity for new supplier business models to overcome this barrier and increase the income of the supplier. The list below shows the services offered by various companies to support ULEV car uptake. Offering a similar range of services to HGV fleets could be a new business opportunity. In the extreme case some business models currently offered provide vehicles and infrastructure to fleets with a per km fee, helping fleets avoid the high upfront costs associated with a switch to ULEVs.

1. <u>EV Suitability Analysis</u>. Vehicle telematics data can be used to check that an EV can meet the duty requirements of the fleet.
2. <u>Personalised Fleet TCO Analysis</u>. The telematics data can also be used to calculate a fleet specific total cost of ownership comparison between conventional and electric vehicles, taking into account all policy support mechanisms.
3. <u>Planning and Installation of Charge Points</u>. The telematics data provides information on where vehicles are parked for extended periods of time and therefore where charge points should be located. Once planned the supplier can also organise the supply and installation of charge points.
4. <u>Supply of Electric Vehicles</u>. Supply of electric vehicles and disposal of current vehicles onto the second-hand market.
5. <u>Offer of Green Tariffs or On-Site Renewables</u>. Offer customers a green electric tariff or offer a service that designs an on-site renewable plus battery storage system to help the fleet reduce fuel costs through on-site production.

Three of the leading examples of HGV ULEV uptake are UPS electric delivery trucks, DHL electric delivery trucks and H2 Energy and Hyundai hydrogen truck project in Switzerland. In all three cases the production of ULEV HGVs was driven by active fleet demand as vehicle manufacturers were not offering the vehicles fleets wanted. In the case of DHL they purchased a small ULEV HGV manufacturer “Street Scooter” in 2014 so that they could ensure the supply of ULEV HGVs that met their needs. UPS has worked closely with several electric HGV startups including Arrival, Thor and Workhorse to shape the supply of electric HGVs (they also commissioned the conversion of old UPS diesel trucks to electric). In Switzerland the “H2 Mobility Switzerland Association”, which represents several key logistics companies, wanted a ULEV HGV that met its members’ needs. Unable to find anything on the market the group, represented by H2 Energy, sought to find a vehicle manufacturer who would develop a new ULEV HGV for this market. This resulted in H2 Energy forming an agreement with Hyundai to supply 1,600 hydrogen HGVs in Switzerland. The joint venture between H2 Energy and Hyundai will organise or supply hydrogen production, stations and vehicles offering fleet user’s vehicles at a fixed per km charge with no high capital cost investments.

The ULEV HGV market is clearly still at an early stage of development and there is plenty of room for ULEV HGV start-ups and infrastructure providers to partner with major vehicle manufacturers and HGV fleet users to offer new ULEV HGVs, helping to overcome the current ULEV HGV supply barriers.

4.2.2 Small Rigid Segment Barriers and Recommendations

The small rigid segment is made up of HGVs that can carry up to 7.5t when fully loaded and represents 24% of all HGVs in Scotland. This segment is predominantly used to deliver goods such as parcels to homes and businesses within cities. The city centre routes completed by these vehicles are predominantly speed restricted to 30 or 40 miles per hour and delivery is only allowed during the day to avoid disturbances. This limits the daily mileage that can be completed by these vehicles to 200-250km/day on an average day and 400-500km/day in an extreme case.

Segment Barriers

- It is challenging for fleets in this segment to see a return on the higher ULEV purchase costs from lower fuel costs, because of the low annual mileage completed by these vehicles
- There is a lack of space in city centre depots to install refuelling infrastructure
- Early BEV adopters are likely to be in this segment due to the smaller daily distance driven. Being an early adopter presents its own challenges regarding lack of information about vehicle models, vehicle reliability, and refuelling infrastructure installation procedures

Policy Gaps

- Low Emission Zones (LEZs) do not provide specific incentives for the uptake of ULEVs, reflecting the higher barriers for these vehicles compared to low emission vehicles
- This vehicle segment is outside of the EU emission standards meaning there are no policy incentives for vehicle manufacturers to produce more efficient models (this segment will be captured in the super credits scheme which may encourage manufactures to produce ULEVs in this segment as it is easier than producing them in the larger segments)

Recommendations

- Provide additional operational benefits to ULEV HGVs such as longer delivery hours in city centres, better parking availability and improved access such as allowing ULEVs to use bus lanes at certain times
- Draw early ULEV supply into the Scottish market by aggregating demand across several fleets to increase order volumes
- Engage fleet operators now with information about future ULEV refuelling needs to allow fleet operators to include the needed depot upgrades in their current depot planning/maintenance
- Strengthen the LEZs over time to give a cost saving for ULEVs compared to any other vehicle types

New Business Models

- Autonomous last mile delivery vehicles could reduce the mileage of these HGVs by completing the end of the journey from the local area to a specific house or business

4.2.3 Medium & Large Rigid Segment Barriers and Recommendations

The medium rigid segment is made up of HGVs that can carry between 7.5 and 17t when fully loaded and represents 7% of all HGVs in Scotland. The large rigid segment is made up of HGVs that can carry between 17 and 25t when fully loaded and represents 15% of all HGVs in Scotland. Both segments are used for a wide range of operations from medium distance distribution of goods (food, clothes, waste etc.), between depots along motorway routes, to city centre distribution from depots to shops for goods and from homes to depots for waste. With their mixed driving pattern most vehicles in this category will only achieve 250-330km/day on average but routes that include predominantly motorway driving are not uncommon and this could lead to a maximum daily distance of 500-600km/day.

The exception to the description given above is waste collection vehicles which are often driven less than 100km/day. These vehicles are covered separately in section 4.2.6.

Segment Barriers

- The large variation in the way HGVs in these vehicle segments are used means that for many, current ULEV models do not match the operational requirements in terms of range and refuelling times
- There are currently very few ULEV models available, especially in the large rigid segment
- Vehicles in these segments are likely to use depot, local, and motorway refuelling. The planning and installation of this infrastructure is often outside of the fleet operators' control
- The variability in vehicle use means calculating vehicle TCO comparisons between different technologies, that are representative of each fleet's usage patterns, is very challenging

Policy Gaps

- Low Emission Zones (LEZs) do not provide specific incentives for the uptake of ULEVs, reflecting the higher barriers for these vehicles compared to low emission vehicles
- The medium rigid segment is outside of the EU emission standards meaning there are no policy incentives for vehicle manufacturers to produce more efficient models

Recommendations

- Draw early ULEV supply into the Scottish market by aggregating demand across several fleets to increase order volumes. If order volumes are large enough then vehicle manufacturers can be asked to deliver a model with specific range capabilities to meet the needs of Scottish fleets
- A national plan for ULEV refuelling infrastructure rollout is needed for Scotland and the UK to give fleets visibility over when en-route refuelling infrastructure will be available
- Strengthen the LEZs over time to give a cost saving for ULEVs compared to other vehicle types

4.2.4 Very Large Rigid Segment Barriers and Recommendations

The very large rigid segment is made up of HGVs that can carry over 25t when fully loaded and represents 19% of all HGVs in Scotland. This segment is predominantly used for two distinctly different operations. The first is waste collection in city centres, which will be covered in section 4.2.6. The second is for moving raw materials (wood, metal ore, aggregates etc.) and construction materials (cement, steel, bricks etc.) from extraction and production sites to end users including construction and industrial sites. The location of these sites is very varied meaning these vehicles operate on urban, rural, and motorway routes. The average daily mileage in this sector is 250-350km/day but the variability in routes means vehicles could be regularly used for 500-600km/day.

Segment Barriers

- The ULEV models available in this segment are focused on the waste collection market. There are no ULEV models designed to work in the materials distribution market
- The goods moved by the segment are all heavy and vehicles are often likely to meet their legal weight limit. The addition of hydrogen tanks or batteries would increase the weight of the vehicle and reduce payload
- Vehicles used on construction or industrial sites may be kept there overnight rather than in a depot removing the opportunity for depot based refuelling/recharging overnight. This leads to the need for local refuelling which may not be installed in the near term as the refuelling demand in these locations will be limited
- All low carbon fuels struggle to meet the demands of this segment. There is, therefore, no clear technology winner making it very challenging for the decision about which technology to use to be made on a fleet basis

Policy Gaps

- This vehicle segment is outside of the EU emission standards meaning there are no policy incentives for vehicle manufacturers to produce more efficient models or greater numbers of ULEV models

Recommendations

- Change vehicle length and weight restrictions for ULEVs to allow for the additional size and weight of the powertrain
- A national plan for ULEV refuelling infrastructure rollout is needed for Scotland and the UK to give fleets visibility over when en-route refuelling infrastructure will be available
- Fund research into the option to produce fuels at rural industrial sites for use by these vehicles. For example, mining or forestry sites could be well placed for renewable energy production and this could be used to refuel HGVs that visit these sites without the need for major infrastructure upgrades

4.2.5 Small & Large Articulated Segment Barriers and Recommendations

The small articulated segment is made up of HGVs that can carry up to 33t when fully loaded and represents 5% of all HGVs in Scotland. This segment is predominantly used to deliver goods such as mail and some food products which can be large but not very heavy. Most of the routes covered by these vehicles are along motorways between depots but they are also used on some urban routes, for example to deliver food to large city centre supermarkets. The average daily mileage in this sector is 300-375km/day but the variability in the routes means the vehicles could be used for 550-700km/day.

The large articulated segment is made up of HGVs that can carry over 33t when fully loaded and represents 30% of all HGVs in Scotland. This segment is used to transport a very wide range of products including food, materials (timber, steel, chemicals, etc.), and waste over long distances. This segment is predominantly used to move goods over long distances along motorway corridors and is the main method by which goods are importuned and exported from Scotland to the UK and the rest of Europe. The average daily mileage in this sector is 350-450km/day but the variability in routes means that vehicles could be regularly used for up to 600-800km/day.

Segment Barriers

- The large weights of cargo moved and long distances covered by these vehicles means that they require a very large amount of energy to drive their daily routes. Meeting this daily demand with batteries or hydrogen without reducing the payload of the vehicle is very challenging, especially given the size constraints of an articulated tractor unit (the front of the truck that pulls the trailer)
- The large number of batteries or hydrogen tanks needed to move these vehicles makes ULEV models very expensive to purchase
- There are currently ULEV models proposed capable of working in the low to mid weight range of this segment but there are no ULEV models able to work in 40-44 tonne range
- All low carbon fuels struggle to meet the demands of this segment. There is, therefore, no clear technology winner making it very challenging to decide which technology should be used on a fleet basis
- To meet their daily driving profile these vehicles will need access to refuelling sites across the UK and Europe. Delivering this refuelling network and ensuring compatibility between all vehicles and infrastructure requires government level coordination across countries

Policy Gaps

- There is no allowance in the vehicle weight and size limits for the extra space and weight needed to install ULEV powertrains

Recommendations

- Change vehicle length and weight restrictions for ULEVs to allow for the additional size and weight of the powertrain
- Provide interest free loans to help operators afford the high upfront costs of ULEVs
- A UK wide rollout strategy for ULEV HGV refuelling that sets out where and when refuelling sites will be installed is needed before fleets can choose the right technology for them

New Business Models

- Electric Road Systems (ERS) where trucks are charged as they drive along motorways and pay a per km change is a potential new refuelling model for fuel providers that could overcome current range issues

4.2.6 Waste Collection Vehicles Barriers and Recommendations

Waste collection vehicles exist in the medium rigid, large rigid, and very large rigid vehicle segments. Waste collection vehicles are characterised by very low driving speeds, regular stops and starts (needed to pick up waste in residential areas), and significant additional energy demand from on-board loads such as waste crushers. The regular accelerations and additional on-board loads mean that these vehicles have very high energy demands for their routes even though their slow speeds mean that daily routes are often on average only 100km/day.

Segment Barriers

- There is often a lack of space in city centre depots to install refuelling infrastructure
- Early BEV adopters are likely to be in this segment due to the smaller daily distance driven. Being an early adopter presents its own challenges regarding lack of information about vehicle models, vehicle reliability, and refuelling infrastructure installation procedures

Policy Gaps

- This vehicle segment is outside of the EU emission standards meaning there are no policy incentives for vehicle manufacturers to produce more efficient models or greater numbers of ULEV models

Recommendations

- Support local council with information regarding the ULEV models available and the process of transitioning depot refuelling over to ULEV fuel so that they can create their own strategy and timeline for ULEV infrastructure rollout
- Legislate local councils so that they must include vehicle emissions as a key consideration in their vehicle/contract procurement process for waste collection vehicles
- Provide funding to local councils to purchase ULEV waste collection vehicles
- Fund research into the option to produce fuels at waste collection sites for use by these vehicles. For example, landfill and waste incineration can both lead to on-site energy production that could be used to refuel these vehicles when they visit to drop off waste

New Business Models

- Manufacturing of vehicle components for use in specialised application ULEVs (e.g. waste collection)
- On-site fuel-from-waste production to power vehicles

5 Case Studies

5.1 Urban commuters and non-commuters without off-street parking

This case study covers those in the most urban areas who do not have access to off-street parking. Urban in this case is defined as areas that have >10,000 people (Levels 1 and 2 on the 8-point urbanity scale). This group covers 14.2% of all Scottish car/van buyers. There is a particular need for ULEV adoption here to improve urban air quality. However, off-street parking is more limited in urban areas (see Figure 14), and installation of public charging can be difficult due to network and space constraints.

Approximately a third of this group use their vehicles for commuting. Figure 24 shows the income distribution of both car commuters and non-commuters. In general, the commuters have higher net household income of £34,000, compared with £29,000 for non-commuters. They are also more likely to be provided with company cars. The average driving commute distance is short at only 11.2km[76]. If they park at work this provides a potential opportunity to charge. This group may therefore be well suited to plug-in electric vehicles. However, urban commuters will not necessarily have access to parking at work, and may instead have to park on-street. Like the non-commuters, they will depend exclusively on public charging.

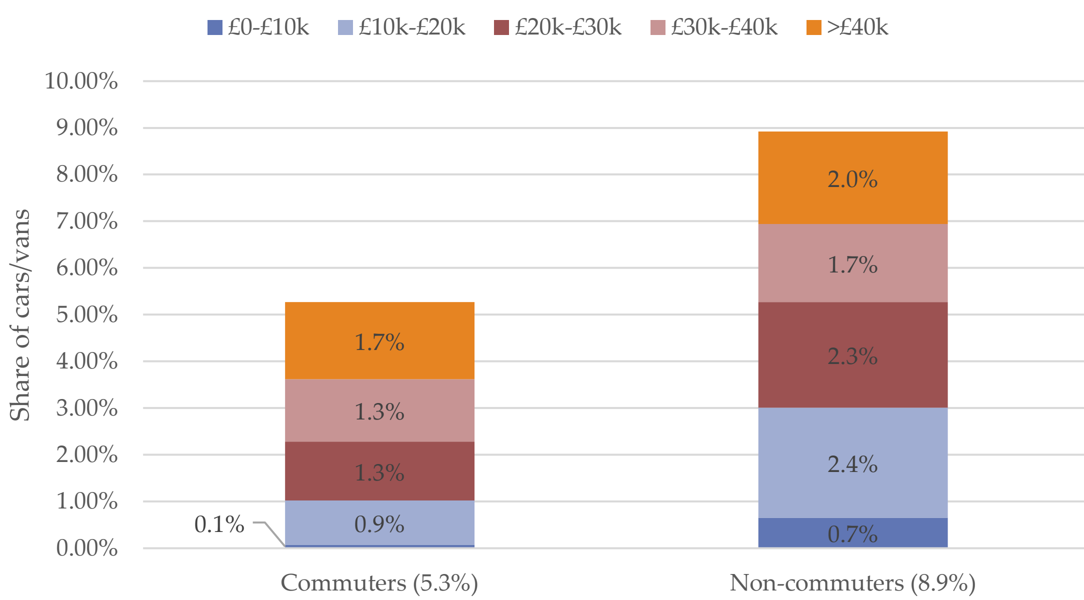


Figure 24: Distributions of net household income for urban commuters/non-commuters without off-street parking in Scotland[77].

Providing public charging in urban areas leads to several specific challenges:

- Suitable space is in short supply, particularly on pavements which will have a higher density of pedestrians than more rural areas.
- Competition for parking is higher, which creates issues with assigning dedicated parking bays to EVs that using on-street charge points.

[76] Element Energy analysis of Scottish Household Survey 2017
[77] Element Energy analysis of Scottish Household Survey 2017

- The business case for on-street charge points is currently challenging. Without dedicated bays, large numbers of charge points are required to guarantee access. Until there are large numbers of plug-in EVs using them, utilisation will remain low.

Recommendations:

- Urban commuters are likely to be making daily trips into (or out of) city centres. Their exposure to city centre clean air zones will therefore be high. This can act as a powerful incentive to encourage ULEV adoption amongst this group. However, care must be taken not to unfairly penalise those who cannot switch to a plug-in vehicle due to a lack of access to charging.
- Identify the extent to which urban car commuters cannot charge at work. As well as installing charge points in areas where access to off-street parking is low, charging infrastructure could also be installed in areas with high numbers of commuter destinations. This can serve those who commute but park on-street.
- An alternative to ULEV adoption is use of low emission Mobility-as-a-Service, such as car sharing. Supporting roll-out of these Mobility-as-a-Service platforms can provide a low-cost option for low mileage drivers i.e. urban non-commuters. Mobility-as-a-service is best suited to urban environments. Dense populations mean that vehicle utilisation is higher, spreading the cost of the service over a larger number of users.

5.2 Remote rural and island car and van buyers

This case study covers car and van owners in the most remote rural areas: the most rural mainland Local Authorities of Highland and Argyll & Bute, and the island Local Authorities of Eilean Siar, the Shetland Islands and the Orkney Islands. Highland and Argyll & Bute account for 5.7% of cars and vans in Scotland. The three island groups cover 1.6% of Scotland's cars and vans. These are the most car dependent areas in Scotland and therefore potentially the most negatively affected by barriers to ULEV adoption. However, in-depth analysis of these areas reveals that they would not be dispropotionatly affected compared with the rest of Scotland:

- Daily mileages are well within the range of ULEVs. Figure 25 shows what share of daily mileages travelled in these areas could be met by a given real-world range. The distribution of daily mileages is not markedly different from the rest of Scotland (see Figure 3).
- Incomes of car and van owners are similar to the rest of Scotland in both the island and mainland rural areas (see Figure 26). The islands show a marginally higher share of the lowest income group. However, the difference is small and so the higher upfront cost of ULEVs will not pose a significantly greater barrier here than elsewhere.
- Nearly all car and van owners have access to off-street parking, allowing charging to be carried out at home. This is conservatively estimated to be >85% of cars and vans in these areas (see Figure 14).
- These regions suffer so called 'fuel station poverty', whereby the long-term trend of fuel station closures has left some remote areas poorly served[78]. Charging plug-in EVs at home would alleviate the need for fuel stations.

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[78] BBC, 18th January 2011, Warnings of a rural 'fuel desert' in Scotland: https://www.bbc.co.uk/news/uk-scotland-highlands-islands-12214674

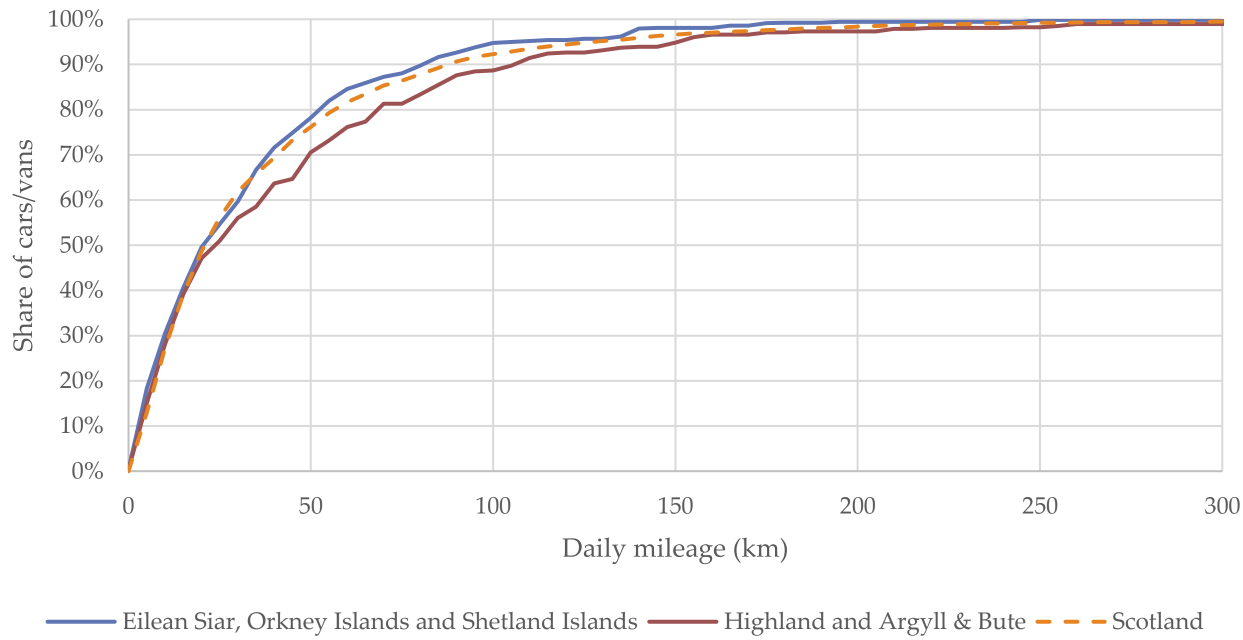

Figure 25: Share of car/van daily mileages in Eilean Siar, the Shetland Islands and the Orkney Islands, and Highland and Argyll & Bute, which could be satisfied by a car/van with a given range[79]

The island groups of Eilean Siar, the Orkney Islands, and Shetland Islands also show other characteristics which make them well suited to ULEVs:

- Any long-distance trips are likely to be to the mainland, which will involve travelling by ferry. Ferry ports therefore provide an ideal location to install rapid charge points to enable these trips to be completed. 50kW rapid charge points have already been installed at many ferry ports across these islands.
- These regions have access to considerable wind, tidal, and wave energy resources. However, existing generation assets are often curtailed due to insufficient capacity in the interconnectors which transport excess electricity to the mainland[80]. Smart charging and hydrogen production via electrolysers can be used to better integrate renewable energy generation and will reduce the need to export excess energy to the mainland. The Orkney Islands is already running several ULEV projects. BIG HIT is exploring the benefits of using hydrogen production to reduce curtailment of wind generation[81]. The ReFLEX (Responsive Flexibility) project is demonstrating a smart grid system and aims to deploy 600 new plug-in EVs as well as a host of other technologies[82].

[79] Element Energy analysis of the Scottish Household Survey 2017: Journey Diary
[80] https://www.desmog.co.uk/2019/03/10/Orkney-Energy-Islands-Penalised-Too-Clean-Too-Soon
[81] https://www.bighit.eu/about
[82] http://www.emec.org.uk/press-release-energy-system-of-the-future-to-be-demonstrated-in-orkney/

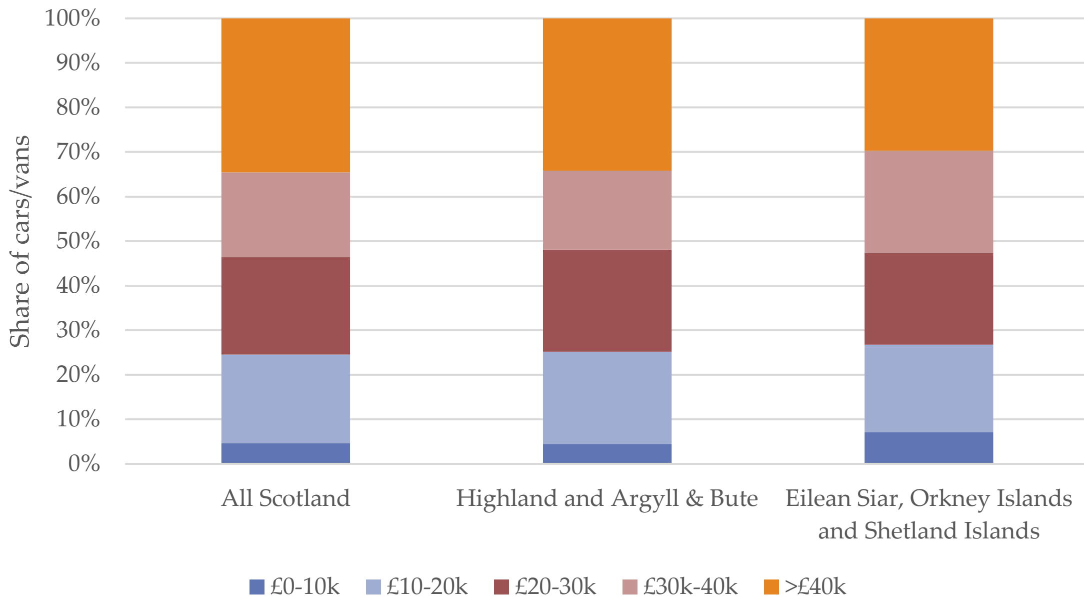

Figure 26: Distribution of net household income of car and van owners in all Scotland, and remote Scottish islands[83]

At the end of 2018, the stock shares of plug-in cars and vans in these three Local Authorities currently stood at 1.57% in the Orkney Islands, 0.31% in Shetland Islands, 0.15% in Eilean Siar, 0.30% in Argyll & Bute, and 0.22% in Highland. The relatively high share in the Orkney Islands is largely due to the various smart grid projects that have been carried out in recent years. The shares in the other regions remain behind the overall Scottish average (0.41%). Despite appearing well suited to ULEV adoption, there remain several barriers specific to both sets of regions:

- The share of new car/van buyers is relatively low (see Table 9), compared with the rest of Scotland. Unless buyers can be incentivised to purchase new vehicles, adoption of ULEVs will be limited by their availability in the used vehicle market.

Table 9: Estimated share of cars/vans purchased new in Scotland and the Scottish islands[84].

	Scotland	Eilean Siar	Orkney Islands	Shetland Islands	Highland	Argyll & Bute
Cars	30%	11%	12%	29%	22%	15%
Vans	53%	12%	28%	28%	34%	19%

- These five Local Authorities have the lowest population densities in Scotland which makes the business case of any public charging/refuelling infrastructure challenging. This is particularly significant for the small number of car/van owners without access to off-street parking. A public charging/refuelling infrastructure must balance utilisation with adequate coverage.
- In rural locations, there is greater demand for more rugged vehicles which are capable of driving off-road. Electric vehicles are, in principle, well suited to off-road driving due to their high torque, reliability, and 4-wheel drive capability. However, there are currently few options

[83] Element Energy analysis of Scottish Household Survey 2017
[84] Element Energy analysis of DfT sales and stock data for Scotland. Assumes new cars are owned for 4 years, and new vans for 5.5 years.

available to purchase. For example, no electric pick-up trucks are available in the UK, although both Ford and Tesla have announced plans to develop them.
- The populations of the three island Local Authorities are the smallest in Scotland. The authorities may therefore lack the scale and capacity to cover the risk of launching large scale initiatives to increase ULEV adoption.

Due to the islands' unique situation, it is recommended that a specific study is carried out to explore their potential for ULEV adoption. This should:

- Analyse the current ULEV uptake and types of buyers in detail.
- Map out the current refuelling (all fuels) and recharging infrastructure, and project the future recharging and H_2 refuelling networks needed to support the targeted level of uptake.
- Investigate the supply of renewable energy and robustness of the electricity grid. The objective would be to identify opportunities for local production of electricity and hydrogen as well as evaluate the network reinforcement and connection cost corresponding to the targeted ULEV uptake.

Upon completion of this study, a dedicated funding programme might be put in place, depending on the findings.

5.3 Taxi and Private Hire Vehicles

There are 10,356 taxis and 13,843 private hire vehicles (PHVs) registered in Scotland. These make up a very small proportion of the overall vehicle stock. PHVs make up 0.6% of the total car stock, but taxis and PHVs account for 2.4% of all journeys made by car or van[86]. These vehicles are mostly concentrated in the major cities of Glasgow, Edinburgh, Aberdeen, and surrounding areas (see Figure 27).

Although they account for only a small share of vehicles, transitioning taxis and PHVs to ULEVs is important to increase consumer exposure to the technologies and improve air quality in cities. But they currently face a range of specific barriers:

- Taxis must meet strict licencing conditions, such as a minimum passenger capacity or wheelchair accessibility. At present, the TX eCity is the only ultra-low emission 'black cab' model. This uses a battery with a petrol range-extender. ULEV options for taxi and PHV buyers are therefore limited. It is recommended that licencing conditions in each Local Authority are reviewed to ensure they do not unnecessarily preclude the adoption of ULEVs.
- In Scotland, taxis and PHVs drive approximately 43,000 km/yr[85]. Assuming a 5-day working week, this corresponds to 300 km per day. Although BEVs are available which can meet this, they require large batteries and are therefore expensive.
- If daily mileage exceeds range, particularly in the case where drivers 'double-shift' on a single vehicle, fast refuelling will be needed. For these use cases, hydrogen vehicles may be more suitable. Green Tomato Cars, for example, have deployed 27 Toyota Mirai H_2 fuel cell cars within their PHV fleet in London.

[85] Insure Taxi (2016) Taxi Driver Survey. https://www.insuretaxi.com/2016/08/taxi-driver-survey-2016/

- For drivers that prefer to purchase their taxis or PHVs outright, the high upfront costs of ULEVs can be challenging. This is somewhat offset by OLEV's Plug-in Taxi Grant which subsidises 20% of the purchase price of the vehicle, up to a maximum of £7,500. PHVs can apply to Plug-in Car Grant. Their higher mileages also mean that payback periods for ULEVs can be relatively short.

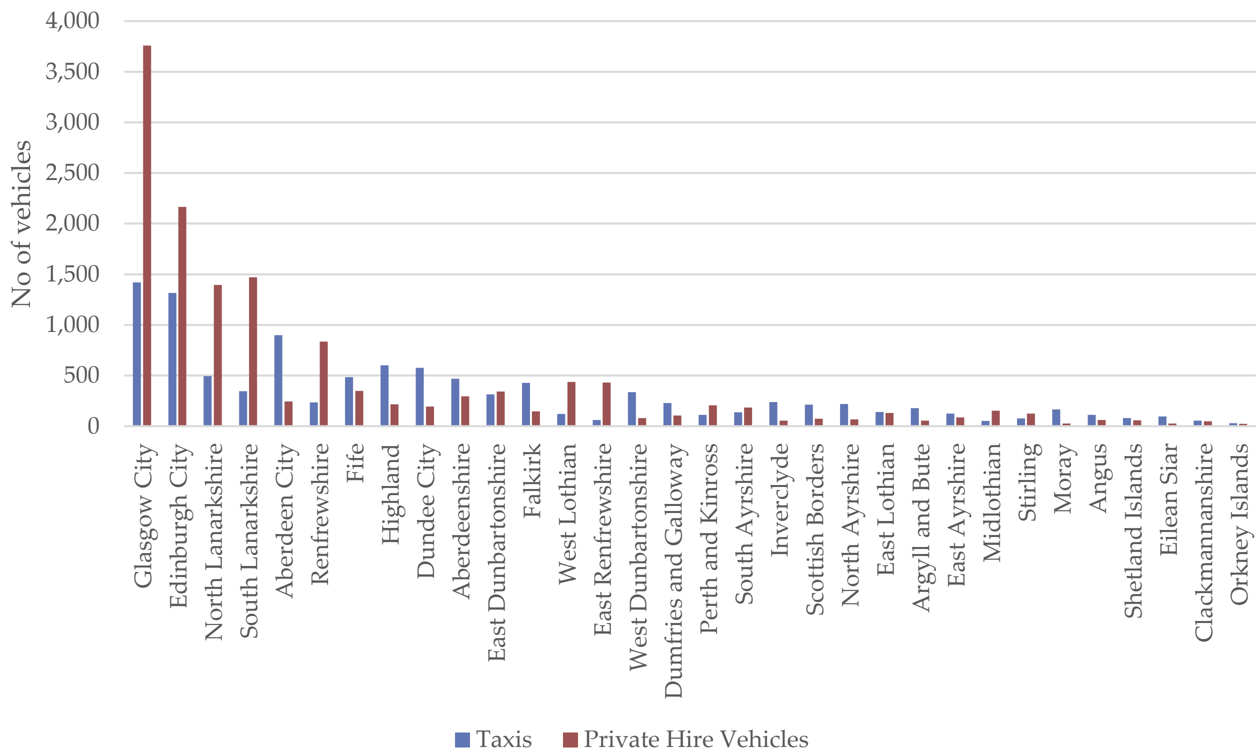

Figure 27: Stock of taxis and private hire vehicles in each Local Authority in 2018[86]

To overcome these barriers, the following measures are recommended:

- Aggregate and share with Scottish Local Authorities the best practices on taxi licensing rules and taxi support schemes, from where ULEV uptake has been successfully kick-started (e.g. Dundee, London, Nottingham). Existing licencing conditions should be reviewed to ensure they effectively incentivise ULEV uptake, or at least do not unnecessarily preclude the adoption of ULEVs.
- Support taxi and PHV drivers in understanding the potential financial benefits of ULEV adoption and their suitability. This could be through a communication campaign or telematics services.

[86] Scottish Transport Statistics, No 37, 2018 Edition. https://www.transport.gov.scot/media/44025/scottish-transport-statistics-no-37-2018-edition.pdf

5.4 Public Fleets and Emergency Vehicles

Public sector fleets, such as Local Authority, NHS, and emergency service vehicles, offer several opportunities to support ULEV uptake:

- Increase ULEV exposure amongst general public
- Place large vehicle orders or establish supply contracts to drive down ULEV costs
- Visibly signal public sector support to encourage manufacturers to increase ULEV supply to Scotland
- Introduce ULEVs into the general vehicle stock

ULEV uptake within public fleets can be encouraged or mandated by adding this as a condition into procurement rules. Public sector bodies in Scotland already have a legal duty under the Procurement Reform (Scotland) Act 2014 to consider the environment and use whole life costing when carrying out procurement of goods, services, and works. The public sector, in general, can therefore encourage further ULEV uptake by adding ULEV requirements when tendering for services from private companies. This is most effective for services that involve significant levels of transport, such as delivery services.

Several developments have already been initiated to transition public fleets in Scotland to ULEVs:

- Scottish Government has announced a plan to phase out the need for new petrol and diesel vehicles in Scotland's public sector fleet by 2030[87].
- Transport Scotland has introduced the Switched On Fleets initiative which offers free, evidence-based analysis identifying new opportunities for the cost effective deployment of plug-in vehicles in each of Scotland's 32 Community Planning Partnerships. This programme will continue into 2020.

- Police Scotland have announced a plan to make its entire fleet of 3,500 vehicles 'close to zero-carbon'[88]. The force has 2,500 cars, 800 vans and 100 motorcycles. However, police vehicles are usually purchased through joint procurement processes with other police forces to drive down costs. Large orders of ULEVs would therefore likely require buy-in from other forces. Furthermore, emergency vehicles (e.g. ambulances, fire services, police) have greater availability requirements (need to be charged quickly) and may need to operate across other jurisdictions.

Recommendations to encourage widespread uptake of ULEVs amongst public sector fleets:

- Set up a Task force for the case of emergency vehicles (police, fire and ambulance services) to identify fleets, their current plans for ULEV adoption, and the infrastructure they require, then develop specific support.
- Legislate local councils so that they must include vehicle emissions as a key consideration in their vehicle/contract procurement processes for public fleet vehicles

[87] Protecting Scotland's Future: the Government's Programme for Scotland 2019-2020: https://www.gov.scot/publications/protecting-scotlands-future-governments-programme-scotland-2019-20/pages/5/

[88] https://www.thetimes.co.uk/article/police-scotland-leads-charge-to-turn-every-vehicle-electric-cd057c6bk

5.5 Small HGV Fleet with a Non-Transport Business Focus

In the first HGV case study we look at small businesses that own HGVs to move their own products. These companies' focus will not be haulage, but they own HGVs to keep control of the movement of their goods in-house and to save money. This company archetype represents 46% of all HGV fleet owners but they own only 14% of the HGVs in the Scottish fleet.

Vehicle Size	As these companies are only moving their own goods and only require a small fleet to achieve this, they are likely to operate smaller vehicles (small and medium sized rigids)
Vehicle Purchasing	These companies are more likely to purchase second-hand vehicles because the core business will struggle to raise the capital to buy news vehicles. Companies who prefer not to buy second-hand vehicles due to the higher risk of maintenance issues may have to lease new vehicles rather than buying them outright
Vehicle Utilisation	The HGVs used by these companies are likely to operate less km/day than the average for their vehicle size as these companies are not in a position to optimise the utilisation of the fleet to the same extent as logistics companies
Refuelling	These vehicles are likely to be refuelled on an ad hoc basis at a public refuelling stations as organized depot based refuelling is an unnecessary complexity for a company whose focus is not on operating HGVs

Small operators face the full list of barriers presented in the previous section, but there are several barriers that effect small business to a greater degree. These include:

1. Small businesses with a business focus outside of transport will find it especially challenging to raise the capital to buy more expensive ULEV HGVs
2. As these vehicles are used less intensively the benefit of lower ULEV fuel costs will not be fully realised and the payback times will be longer
3. It will take a long time before ULEVs are available on the second-hand market for these companies to buy
4. These companies will not have a fleet manager who has the time to research and consider ULEV HGVs and refuelling options
5. Local refuelling stations will be behind motorway refuelling stations in introducing ULEV refuelling infrastructure, limiting these companies' ability to refuel a ULEV locally. The cost benefit of refuelling BEVs on-site could encourage these companies to consider on-site refuelling. This may not be a process they have a good understanding of, and they may not be well placed in terms of resources and space to move to on-site refuelling

These companies can be supported through a range of initiatives including:

1. Support fleets to analyse their vehicle operating profile using telematics data and supply a simple tool to convert this into a TCO figure for conventional and ULEV models. This could involve contracting a telematics provider to develop a new ULEV suitability tool for HGVs. This project could be co-financed by government and industry.
2. Support fleets with up to date information on ULEV models and their capabilities by encouraging fleets to use online tools such as the LoCity "Commercial Vehicle Finder"
3. Information and support to choose and install on-site refuelling, including information about planning requirements and grid connections and fees
4. Low interest loans to support the higher upfront cost of ULEV purchase

5.6 Medium to Large HGV Fleet Focused on Providing Logistic Services

In the second HGV case study we look at medium and large businesses that own HGVs to offer logistics services to other companies. This company type represents only 11% of all HGV fleet owners but they own 58% of the HGVs in the Scottish fleet. Companies of this type will make decisions purely on a cost basis as the cost of owning and operating the vehicles represent the full profitability of the company.

Vehicle Size	HGVs in this archetype are likely to be medium or large vehicles as the cost to move a tonne of freight goes down the larger the vehicle. It is therefore in the companies' interest to use larger vehicles and to move goods for multiple clients to ensure these vehicles are fully loaded for as many trips as possible
Vehicle Purchasing	For these companies there are significant cost penalties for a vehicle being un-operational. This makes it more likely that these companies will want new vehicles with some companies choosing to purchase and some to lease
Vehicle Utilisation	These HGVs will be utilised as much as possible to maximise the economic return on investment in the vehicles, meaning the vehicles will travel more km/day than the average vehicle
Refuelling	The larger size of these fleets makes it more cost effective to refuel in depot with occasional refuelling at public refuelling sites using a company refuelling card. This flexibility is needed as these companies will deliver goods to locations in Scotland, England and the wider EU

Large operators face the full list of barriers presented in the previous section, but there are several barriers that affect large logistics business to a greater degree. These include:

1. These companies make a profit by utilising their vehicles as much as possible. To achieve this, these vehicles must be large and drive long distances each day. Larger vehicles travelling longer distances require more energy storage which is particularly challenging to provide with ULEV fuels. This has meant that there are very few ULEV models aimed at these companies
2. These companies may rely on public refuelling for some routes in Scotland and in other countries. However, these companies are not in a good position to direct the rollout of this infrastructure and may therefore not be in control of when they can move to ULEV vehicles for a proportion of their fleet
3. These companies are very focused on the TCO of their vehicles, with an expected payback time of just 2 years. Higher purchase costs for ULEVs and uncertain TCOs mean these companies will find it hard to invest in ULEVs

These companies can be supported through a range of initiatives including:

1. These companies are likely to already have telematics systems but are less likely to have used this databank to explore how ULEVs could fit in their duty cycle. Support for companies to do this type of analysis will help them to have an evidence based view on when ULEV models are right for them. This could involve contracting a telematics provider to develop a new ULEV suitability tool for HGVs. This project could be co-financed by government and industry.
2. A refuelling network strategy for Scotland and England that provides basic coverage for ULEV fuels is needed for HGV operators to be confident that the ULEV technology they choose will be supported with infrastructure over their full operating territory

6 Conclusions and Recommendations

This work analysed buyers of cars, vans, and HGVs to identify the barriers to ULEV adoption faced by different market segments in Scotland. This yielded a series of recommendations to overcome these barriers. These are summarised in the following sections:

6.1 Cars and vans

Cost

- Allow buyers of used ULEVs to apply for the Electric Vehicle Loan
- Review ULEV purchase incentives in 2020 when Plug-in Car and Van grants are due to be revised. Purchase incentives should look to close gap in upfront cost between ULEVs and conventional vehicles, but overall value to buyers should reflect difference in overall ownership cost.

Supply

- Support Joint Procurement Initiatives to attract vehicle supply to Scotland, and ensure vehicles meet specifications of fleet users. This might be particularly relevant for vehicles with niche applications, such as emergency fleets.

Infrastructure

- Provide charging solutions for those without potential access to home charging
- Research preferred charging options for those without access to home charging e.g. through consumer surveys
- Identify areas with demand for public charging:
    - Identify areas with large numbers of potential plug-in EV buyers without off-street parking
    - Introduce a mechanism to allow potential plug-in EV buyers without off-street parking to lodge requests for public charging infrastructure. This includes companies who provide their employees with company cars/vans but who don't have off-street parking
    - Target public charging infrastructure investment at these locations
- Encourage companies with large numbers of commuters who park on-street to install charge points.
- Continue to develop rapid charging network, including extending coverage to minor roads, increasing charge rates and improving reliability.
- Develop a target for number of public charge points (both slow and rapid) required to meet demands of increasing numbers of plug-in EVs. Track progress of public charge point installations against target.
- Incentivise landlords to allow installation of home charge points. Consider mandating Local Authorities and Housing Associations to do so.

Knowledge

- Launch communication campaign to combat ULEV misconceptions and provide clear advice on options for ULEV purchase
- Support development of services for fleets and consumers which can show suitability for ULEV adoption e.g. telematics systems

Other recommendations

- Investigate suitability of plug-in EVs on Scottish islands e.g. through feasibility study and/or trial
- Engage with distribution network operators to help identify network assets that are likely to require reinforcement due to charging demand in the near future e.g. provide them with the registered locations of plug-in EVs, and the charging intentions of those applying for the Electric Vehicle Loan.
- Add questions to the Scottish Household Survey on availability of off-street parking, and whether vehicles were purchased new or used. This will allow better cross referencing of ULEV suitability characteristics with perceived barriers to ULEV uptake listed by respondents.

- Aggregate and share with Scottish Local Authorities the best practices on taxi licensing rules and taxi support schemes from areas where ULEV uptake has been successfully kick-started (e.g. Dundee, London, Nottingham)
- Set up a Taskforce for the case of emergency vehicles (police, fire and ambulance services) to identify fleets, their current plans for ULEV adoption, and the infrastructure they require, then develop specific support.
- Legislate local councils so that they must include vehicle emissions as a key consideration in their vehicle/contract procurement processes for public fleet vehicles

6.2 HGVs

Cost

- Support fleets to purchase ULEV models with capital grants or no/low interest loans
- Strengthen Low Emission Zones over time to give a cost saving for ULEVs compared to any other vehicle type

Suitability

- In the near-term help to organise and fund extended real-world vehicle trials and share the results with fleet operators across Scotland
- Once more ULEV models are on the market, support fleets to analyse their vehicle operating profile using telematics data and supply a simple tool to convert this into a TCO figure for conventional and ULEV models

Supply

- In the near term, interview fleets about their interest in ULEVs and act as a facilitator to aggregate demand. Once demand for ULEVs in Scotland reaches approximately 100 vehicles in one size category, supply can be drawn to Scotland by offering the supply contract to one OEM. If order volumes are large enough then vehicle manufacturers can be asked to deliver a model with specific range capabilities to meet the needs of Scottish fleets

Infrastructure

- Collect case study data from existing fleets' experience of installing depot refuelling infrastructure and share lessons learned with all fleets
- Support fleets with funding (grants or zero interest loans) to help cover the upfront cost of refuelling equipment installation in the depot
- Engage fleet operators now with information about future ULEV refuelling needs to allow fleet operators to include the needed depot upgrades in their current depot planning/maintenance
- Develop a national plan for ULEV refuelling infrastructure rollout to give fleets visibility over when and where en-route refuelling infrastructure will be available in Scotland

Knowledge

- Support fleets with up to date information on ULEV models and their capabilities by encouraging fleets to use online tools such as the LoCity "Commercial Vehicle Finder"

Other recommendations

- Provide additional operational benefits to ULEV HGVs such as longer delivery hours in city centres, better parking availability, and improved access, such as allowing ULEV to use bus lanes at certain times
- Fund research into the option to produce fuels at industrial sites for use by ULEV HGVs. For example, mining, forestry, or landfill sites could be well placed for renewable energy production and this could be used to refuel the HGVs that visit these sites without the need for major infrastructure upgrades
- Legislate local councils so that they must include vehicle emissions as a key consideration in their vehicle/contract procurement processes for public fleet vehicles

6.3 New Business Models

This work also identified several new business models which could be developed to help address barriers to ULEV uptake:

- ULEV specific leasing offering low finance rates and accurate depreciation forecasts to reduce ownership costs.

- Garages specialising in ULEV repair to signal ULEV-ready market
- Telematics services to demonstrate suitability and economic proposition of ULEVs for a company's fleet.
- Development of battery recycling and refurbishment facilities to increase value of end-of-life batteries and lower cost of battery replacement.
- ULEV-only taxis and car clubs to increase consumer exposure
- Smart charging systems to shift charging outside of peak demand and provide services to the electricity network. This can avoid potentially costly household fuse upgrades for home charging, and connection costs for depot charging. Smart charging and vehicle-to-grid can also reduce electricity costs or even provide a revenue stream through provision of flexibility services.
- Novel on-street charging solutions
- Mobile rapid charging solutions to test viability of rapid charge points at potential sites ahead of permanent installation.
- Small mobile H2 refuelling stations to kick-start areas of potential H_2 vehicle demand without investing in network of large volume stations.

8 Appendix

8.1 Development of car and van segments

This document outlines the process through which the long list of segments of Scottish car and van buyers has been aggregated to arrive at a final shortlist. Development of the long list has been carried out by combining the car and van buyer characteristics shown in Table 10. Note that this includes fewer characteristics that shown earlier in Table 4. This was due to limitations in data availability, and the requirement that it must be possible to cross-tabulate each characteristic with all others in order to estimate segment size.

Table 10: Characteristics of Scottish car and van buyers considered in the development of the long list of segments

Characteristic	Car	Van	Dimensions	Possible ULEV barriers/opportunities
Owner	✔	✔	Private	Buyer has free choice.
			Company	Reimbursement for charging, higher mileage, choice of models may be limited by fleet manager; discounted company car tax, company led transition, more economically rational
Overnight Location	✔	✔	Home	Renters not always allowed EVCP installation; Potential to charge at home;
			On-street	Dependent on public charging infrastructure
			Depot	Possible space and connection constraints; on-site H2 refuelling
Urbanity	✔		Urban	Low mileage, suitable for MaaS; potential access/parking privileges
			Rural	Higher mileage, sparse refuelling infrastructure
Commuter	✔		Yes	Higher mileage; potential to charge at work
			No	No opportunity to charge at work; lower mileage
New/used vehicle buyer	✔	✔	New	Residual value concerns, higher mileage; new car ULEV subsidies
			Used	No purchase subsidies, affordability more important, battery lifetime/warranty; potentially lower ownership costs; lower mileage
Utilisation		✔	Low Mileage	Low daily mileage; require all van sizes
			Low Mileage Core	Low daily mileage; transport is core to business so require large payloads, tend to use larger vans
			Mid Mileage	Higher daily mileage, require all van sizes
			High Mileage	Tend to use smaller vans; higher daily mileage

The long list includes 33 combinations of these characteristics, shown in Table 11, and the share of buyers falling into each. These were estimated through analysing the make-up of the Scottish car and van stock in each Intermediate Data Zone. Each combination has a Group number assigned.

Table 11: Long list of segments of Scottish car and van buyers

Gp #	Veh	Commuter	Owner	Overnight Location	New/used buyer	Urbanity	Utilisation	Vehs	Total share	Share in cars/vans	Share in new/used
1	Car	Non-commuter	Private	Home	New	Urban	-	125,367	4.5%	5.0%	23.4%
2	Car	Commuter	Company	Home	New	Urban	-	78,762	2.8%	3.2%	14.7%
3	Car	Commuter	Private	Home	New	Urban	-	69,110	2.5%	2.8%	12.9%
4	Car	Non-commuter	Private	On-Street	New	Urban	-	68,726	2.5%	2.8%	12.8%
5	Car	Commuter	Company	On-Street	New	Urban	-	52,594	1.9%	2.1%	9.8%
6	Car	Commuter	Private	On-Street	New	Urban	-	37,328	1.3%	1.5%	7.0%
7	Car	Non-commuter	Private	Home	New	Rural	-	32,276	1.2%	1.3%	6.0%
8	Car	Commuter	Company	Home	New	Rural	-	21,445	0.8%	0.9%	4.0%
9	Car	-	Company	Depot	New	-	-	17,052	0.6%	0.7%	3.2%
10	Car	Commuter	Private	Home	New	Rural	-	16,444	0.6%	0.7%	3.1%
11	Car	Non-commuter	Private	On-Street	New	Rural	-	7,691	0.3%	0.3%	1.4%
12	Car	Commuter	Company	On-Street	New	Rural	-	5,343	0.2%	0.2%	1.0%
13	Car	Commuter	Private	On-Street	New	Rural	-	3,876	0.1%	0.2%	0.7%
14	Car	Non-commuter	Private	Home	Used	Urban	-	646,205	23.3%	26.0%	33.2%
15	Car	Non-commuter	Private	On-Street	Used	Urban	-	397,655	14.3%	16.0%	20.4%
16	Car	Commuter	Private	Home	Used	Urban	-	342,580	12.3%	13.8%	17.6%
17	Car	Commuter	Private	On-Street	Used	Urban	-	209,549	7.5%	8.4%	10.8%
18	Car	Non-commuter	Private	Home	Used	Rural	-	189,420	6.8%	7.6%	9.7%
19	Car	Commuter	Private	Home	Used	Rural	-	94,337	3.4%	3.8%	4.8%
20	Car	Non-commuter	Private	On-Street	Used	Rural	-	45,106	1.6%	1.8%	2.3%
21	Car	Commuter	Private	On-Street	Used	Rural	-	22,265	0.8%	0.9%	1.1%
22	Van	-	Company	Home	New	-	Home, Mid Mileage	61,802	2.2%	20.9%	35.8%
23	Van	-	Company	On-street	New	-	Home, Mid Mileage	29,885	1.1%	10.1%	17.3%
24	Van	-	Company	Depot	New	-	Depot, Low Mileage Core	27,219	1.0%	9.2%	15.7%
25	Van	-	Private	Home	New	-	Home	22,595	0.8%	7.6%	13.1%
26	Van	-	Private	On-street	New	-	Home	10,926	0.4%	3.7%	6.3%
27	Van	-	Company	Depot	New	-	Depot, Mid Mileage	5,915	0.2%	2.0%	3.4%
28	Van	-	Company	Depot	New	-	Depot, Low Mileage	5,318	0.2%	1.8%	3.1%
29	Van	-	Company	Depot	New	-	Depot, High Mileage	4,287	0.2%	1.5%	2.5%
30	Van	-	Company	Home	New	-	Home, Low Mileage	3,301	0.1%	1.1%	1.9%
31	Van	-	Company	On-street	New	-	Home, Low Mileage	1,596	0.1%	0.5%	0.9%
32	Van	-	Private	Home	Used	-	Home	82,723	3.0%	28.0%	67.4%

33	Van	-	Private	On-street	Used	-	Home	40,002	1.4%	13.5%	32.6%
							Total	2,778,700	100%	200%	400%

The following sections describe the steps taken to merge the Groups to create a final segmentation scheme. In each step, the merger is justified and the resulting dilution of characteristics and thus barriers to ULEV adoption are presented. In the final report, the relevant differences in barriers faced by each segment's constituent Groups will be discussed, but the relative size of these Groups will not be quantified.

Merger 1: Combine equivalent urban and rural groups

Urbanity is of particular importance in Scotland, with drivers covering a much wider range of circumstances than in the UK generally. For example, Scotland's 8-point urbanity scale includes a range from densely populated urban areas to very remote islands (see Table 6).

There is a danger therefore that considering urbanity across only 6-8 car buyer segments will not capture the full range of challenges buyers will face, particularly those in very rural communities. Instead, therefore, this has been explored in the focussed case studies in Sections 5.1 and 5.2.

It is worth noting, however, that urbanity in this case primarily affects the typical trip lengths and annual mileages of cars. Other features linked with urbanity, such as availability of off-street parking and likelihood of purchasing new vehicles, are accounted for in the other characteristics.

Table 12: Segmentation scheme after Merger 1

Gp #	Veh	Commuter	Owner	Overnight Location	New/used buyer	Utilisation	Vehs	Total share	Share in cars/vans	Share in new/used
1,7	Car	Non-commuter	Private	Home	New	-	157,643	5.7%	6.3%	29.4%
2,8	Car	Commuter	Company	Home	New	-	100,206	3.6%	4.0%	18.7%
3,10	Car	Commuter	Private	Home	New	-	85,554	3.1%	3.4%	16.0%
4,11	Car	Non-commuter	Private	On-Street	New	-	76,417	2.8%	3.1%	14.3%
5,12	Car	Commuter	Company	On-Street	New	-	57,938	2.1%	2.3%	10.8%
6,13	Car	Commuter	Private	On-Street	New	-	41,204	1.5%	1.7%	7.7%
9	Car	-	Company	Depot	New	-	17,052	0.6%	0.7%	3.2%
14,18	Car	Non-commuter	Private	Home	Used	-	835,624	30.1%	33.7%	42.9%
15,20	Car	Non-commuter	Private	On-Street	Used	-	442,761	15.9%	17.8%	22.7%
16,19	Car	Commuter	Private	Home	Used	-	436,917	15.7%	17.6%	22.4%
17,21	Car	Commuter	Private	On-Street	Used	-	231,814	8.3%	9.3%	11.9%
22	Van	-	Company	Home	New	Home, Mid Mileage	61,802	2.2%	20.9%	35.8%
23	Van	-	Company	On-street	New	Home, Mid Mileage	29,885	1.1%	10.1%	17.3%

24	Van	-	Company	Depot	New	Depot, Low Mileage Core	27,219	1.0%	9.2%	15.7%
25	Van	-	Private	Home	New	Home	22,595	0.8%	7.6%	13.1%
26	Van	-	Private	On-street	New	Home	10,926	0.4%	3.7%	6.3%
27	Van	-	Company	Depot	New	Depot, Mid Mileage	5,915	0.2%	2.0%	3.4%
28	Van	-	Company	Depot	New	Depot, Low Mileage	5,318	0.2%	1.8%	3.1%
29	Van	-	Company	Depot	New	Depot, High Mileage	4,287	0.2%	1.5%	2.5%
30	Van	-	Company	Home	New	Home, Low Mileage	3,301	0.1%	1.1%	1.9%
31	Van	-	Company	On-street	New	Home, Low Mileage	1,596	0.1%	0.5%	0.9%
32	Van	-	Private	Home	Used	Home	82,723	3.0%	28.0%	67.4%
33	Van	-	Private	On-street	Used	Home	40,002	1.4%	13.5%	32.6%
						Total	2,778,700	100%	200%	400%

Merger 2: Combine non-commuters and commuters with access to home charging

Charging infrastructure availability is a key barrier to plug-in ULEV uptake, and in the case of commuters, can be addressed by providing charging at their workplace. However, if both commuters and non-commuters have access to charging at home, then this barrier is less important and the ability to charge at work offers only a small marginal benefit.

Distinctions diluted:

- Commuters typically drive higher mileages and so may be more affected by ULEV range. However, the average distance of commutes by cars in Scotland is only 13 km each way, and so with the latest generation of plug-in electric vehicles this barrier is less likely to become a distinguishing factor between commuters and non-commuters.

Table 13: Segmentation scheme after Merger 2

Gp #	Veh	Commuter	Owner	Overnight Location	New/used buyer	Utilisation	Vehs	Total share	Share in cars/vans	Share in new/used
1,7,3,10	Car	-	Private	Home	New	-	243,197	8.8%	9.8%	45.4%
2,8	Car	Commuter	Company	Home	New	-	100,206	3.6%	4.0%	18.7%
4,11	Car	Non-commuter	Private	On-Street	New	-	76,417	2.8%	3.1%	14.3%
5,12	Car	Commuter	Company	On-Street	New	-	57,938	2.1%	2.3%	10.8%
6,13	Car	Commuter	Private	On-Street	New	-	41,204	1.5%	1.7%	7.7%
9	Car	-	Company	Depot	New	-	17,052	0.6%	0.7%	3.2%
14,18,16,19	Car	-	Private	Home	Used	-	1,272,542	45.8%	51.2%	65.4%
15,20	Car	Non-commuter	Private	On-Street	Used	-	442,761	15.9%	17.8%	22.7%

17,21	Car	Commuter	Private	On-Street	Used	-	231,814	8.3%	9.3%	11.9%
22	Van	-	Company	Home	New	Home, Other	61,802	2.2%	20.9%	35.8%
23	Van	-	Company	On-street	New	Home, Other	29,885	1.1%	10.1%	17.3%
24	Van	-	Company	Depot	New	Depot, Low Mileage Core	27,219	1.0%	9.2%	15.7%
25	Van	-	Private	Home	New	Home	22,595	0.8%	7.6%	13.1%
26	Van	-	Private	On-street	New	Home	10,926	0.4%	3.7%	6.3%
27	Van	-	Company	Depot	New	Depot, Mid Mileage	5,915	0.2%	2.0%	3.4%
28	Van	-	Company	Depot	New	Depot, Low Mileage	5,318	0.2%	1.8%	3.1%
29	Van	-	Company	Depot	New	Depot, High Mileage	4,287	0.2%	1.5%	2.5%
30	Van	-	Company	Home	New	Home, Low Mileage	3,301	0.1%	1.1%	1.9%
31	Van	-	Company	On-street	New	Home, Low Mileage	1,596	0.1%	0.5%	0.9%
32	Van	-	Private	Home	Used	Home	82,723	3.0%	28.0%	67.4%
33	Van	-	Private	On-street	Used	Home	40,002	1.4%	13.5%	32.6%
						Total	2,778,700	100%	200%	400%

Merger 3: Combine van segments with similar mileages and duty cycles

Van mileage and duty cycles are considered with the Utilisation characteristic. The Utilisation levels are derived from an analysis of 18,000 fleet vehicles across 300 fleets, and is used within Element Energy's ULEV uptake model, ECCo. Figure 28 shows the duty cycle suitability curves for each of the 'utilisation' levels, which quantify the share of vehicles in each level that can be replaced by a BEV with a particular range. There is a clear distinction between Low mileage/Low mileage core and Medium/High mileage, with range acting as a more significant consideration for the latter group.

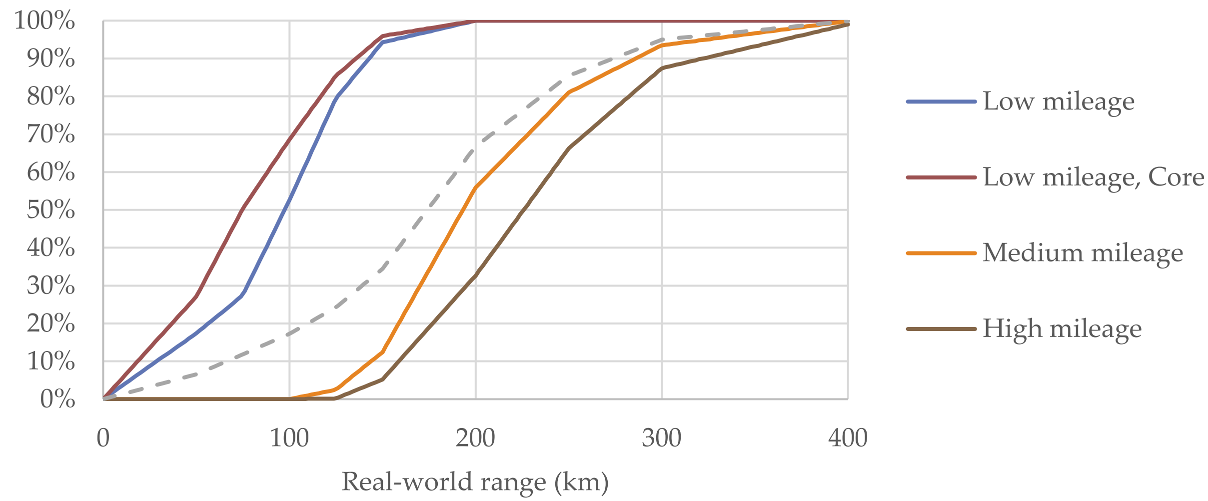

Figure 28: Share of vans which can be replaced by a BEV with a given real world range

Distinctions diluted:

- As well as duty cycles, these utilisation levels also describe the required van size, and these are not aligned in the same way as the daily duty requirements (see Table 14). "Depot, Mid mileage" and "Depot, High mileage" both have high daily duty requirements, however, the latter purchase only small vans and pick-ups. At present, the availability of ULEVs in the medium and large vans segments is more limited and so this barrier is somewhat diluted in combining these two utilisation levels. The same is true of the "Home, Low mileage" and "Home, Other" utilisation levels.

Table 14: Attributes of the van utilisation levels

Utilisation	Annual mileage (km)	Daily duty requirements	Overnight Location	Vehicle Size
Home, Other	25,000	Low	Employee's Home	Small vans and Pick-ups
Home, Low mileage	23,800	Low	Employee's Home	All
Depot, Mid mileage	69,500	High	Depot	All

Depot, High mileage	80,700	High	Depot	Small vans and Pick-ups
Depot, Low mileage core	17,900	Low	Depot	Medium and Large vans
Depot, Low mileage	24,700	Low	Depot	Medium and Large vans

- "Depot, Low mileage core" differs from "Depot, Low mileage" in that for the former transport is a core part of the vehicle owners' business. Note that for all other utilisation levels no correlation was found between business type and duty cycle requirements. In combining these two levels, the only distinct difference in business types is lost.

Table 15: Segmentation scheme after Merger 3

Gp #	Veh	Commuter	Owner	Overnight Location	New/used buyer	Utilisation	Vehs	Total share	Share in cars/vans	Share in new/used
1,7,3,10	Car	-	Private	Home	New	-	243,197	8.8%	9.8%	45.4%
2,8	Car	Commuter	Company	Home	New	-	100,206	3.6%	4.0%	18.7%
4,11	Car	Non-commuter	Private	On-Street	New	-	76,417	2.8%	3.1%	14.3%
5,12	Car	Commuter	Company	On-Street	New	-	57,938	2.1%	2.3%	10.8%
6,13	Car	Commuter	Private	On-Street	New	-	41,204	1.5%	1.7%	7.7%
9	Car	-	Company	Depot	New	-	17,052	0.6%	0.7%	3.2%
14,18,16,19	Car	-	Private	Home	Used	-	1,272,542	45.8%	51.2%	65.4%
15,20	Car	Non-commuter	Private	On-Street	Used	-	442,761	15.9%	17.8%	22.7%
17,21	Car	Commuter	Private	On-Street	Used	-	231,814	8.3%	9.3%	11.9%
22,30	Van	-	Company	Home	New	Home, Low Mileage	65,103	2.3%	22.0%	37.7%
23,31	Van	-	Company	On-street	New	Home, Low Mileage	31,481	1.1%	10.7%	18.2%
24,28	Van	-	Company	Depot	New	Depot, Low Mileage	32,537	1.2%	11.0%	18.8%
25	Van	-	Private	Home	New	Home	22,595	0.8%	7.6%	13.1%
26	Van	-	Private	On-street	New	Home	10,926	0.4%	3.7%	6.3%
27,29	Van	-	Company	Depot	New	Depot, Mid Mileage	10,202	0.4%	3.5%	5.9%
32	Van	-	Private	Home	Used	Home	82,723	3.0%	28.0%	67.4%
33	Van	-	Private	On-street	Used	Home	40,002	1.4%	13.5%	32.6%
						Total	2,778,700	100%	200%	400%

Merger 4: Combine company-owned and privately-owned commuter cars

Commuter cars will have similar mileage requirements, regardless of whether they are company or privately owned, and thus the extent to which ULEV range acts as a barrier is likely to be similar

Distinctions diluted:

- Some company cars are owned by drivers with mileages that are considerably higher than the average, for example, travelling salespeople. For these drivers ULEV range is likely to be of greater importance.
- Buyers of company cars may have a more limited choice, as some companies will choose vehicles from a pre-approved list. This can either restrict company car buyers' ability to choose a ULEV, or can be used to encourage ULEV adoption through a company led transition.
- Additional policy options exist to encourage ULEV adoption amongst company car buyers, for example, company car tax.
- Buyers of company cars usually receive reimbursement for the fuel they use for business purposes. Reimbursement for charging a plug-in electric car at home is more challenging since the electricity usage must be differentiated from the general household consumption.

Table 16: Segmentation scheme after Merger 4

Gp #	Veh	Commuter	Owner	Overnight Location	New/used buyer	Utilisation	Vehs	Total share	Share in cars/vans	Share in new/used
1,7,3,10	Car	-	Private	Home	New	-	243,197	8.8%	9.8%	45.4%
2,8	Car	Commuter	Company	Home	New	-	100,206	3.6%	4.0%	18.7%
5,12,6,13	Car	Commuter	-	On-Street	New	-	99,142	3.6%	4.0%	18.5%
4,11	Car	Non-commuter	Private	On-Street	New	-	76,417	2.8%	3.1%	14.3%
9	Car	-	Company	Depot	New	-	17,052	0.6%	0.7%	3.2%
14,18,16,19	Car	-	Private	Home	Used	-	1,272,542	45.8%	51.2%	65.4%
15,20	Car	Non-commuter	Private	On-Street	Used	-	442,761	15.9%	17.8%	22.7%
17,21	Car	Commuter	Private	On-Street	Used	-	231,814	8.3%	9.3%	11.9%
22,30	Van	-	Company	Home	New	Home, Low Mileage	65,103	2.3%	22.0%	37.7%
23,31	Van	-	Company	On-street	New	Home, Low Mileage	31,481	1.1%	10.7%	18.2%
24,28	Van	-	Company	Depot	New	Depot, Low Mileage	32,537	1.2%	11.0%	18.8%
25	Van	-	Private	Home	New	Home	22,595	0.8%	7.6%	13.1%
26	Van	-	Private	On-street	New	Home	10,926	0.4%	3.7%	6.3%
27,29	Van	-	Company	Depot	New	Depot, High Mileage	10,202	0.4%	3.5%	5.9%
32	Van	-	Private	Home	Used	Home	82,723	3.0%	28.0%	67.4%
33	Van	-	Private	On-street	Used	Home	40,002	1.4%	13.5%	32.6%
						Total	2,778,700	100%	200%	400%

Merger 5: Combine similar car and van segments

- Combine home-based company cars and home-based company vans. These groups have very similar annual mileages of ~25,000 km each and are both stored at home. Home-based company cars are more likely to commute to a work place, where charging could be provided, however, this is of less significance if home charging is available.
- Combine depot-based cars and Low mileage depot-based vans. These have reasonably similar annual mileages of 30,000 km and 19,000 km, respectively, and are purchased by fleet managers who base their decision on suitability and total cost of ownership. Depot-based cars also make up only 3.2% of all new car sales, and 0.6% of all light duty vehicle sales overall. Since depot-based cars and vans are not used for any private mileage, the policy handles available are similar. For example, there is no company car tax or van benefit charge.
- Combine Non-commuter private cars and private vans with equivalent overnight locations. Both will be unable to charge at workplaces and so will rely on either home or public charging infrastructure.

Distinctions diluted:

- The supply of suitable ULEVs is a more significant issue for vans, particularly for Low mileage depot-based vans which favour medium and large sized vehicles. This will be made apparent in the report by showing the number of ULEV models available on the market.
- Van buyers generally drive higher mileages, so have greater range requirements, whilst battery electric van ranges are in general lower than for cars.

Table 17: Segmentation scheme after Merger 5

Segment	Gp #	Veh	Commuter	Owner	Overnight Location	New/used buyer	Utilisation	Vehs	Total share	Share in new/used
1	1,7,3,10,25	Car/Van	-	Private	Home	New	-	265,792	9.6%	37.6%
2	2,8,22,30	Car/Van	-	Company	Home	New	-	165,310	5.9%	23.4%
3	5,12,6,13	Car	Commuter	-	On-Street	New	-	99,142	3.6%	14.0%
4	4,11,26	Car/Van	Non-commuter	Private	On-Street	New	-	87,342	3.1%	12.3%
5	9,24,28	Car/Van	-	Company	Depot	New	Depot, Low Mileage	49,589	1.8%	7.0%
6	23,31	Van	-	Company	On-street	New	Home, Low Mileage	29,885	1.1%	4.2%
7	27,29	Van	-	Company	Depot	New	Depot, High Mileage	10,202	0.4%	1.4%
8	14,18,16,19,32	Car/Van	-	Private	Home	Used	-	1,355,265	48.8%	65.4%
9	15,20,33	Car/Van	Non-commuter	Private	On-Street	Used	-	484,359	17.4%	23.4%
10	17,21	Car	Commuter	Private	On-Street	Used	-	231,814	8.3%	11.2%
							Total	2,778,700	100%	200%