Low CVP
Low Carbon Vehicle Partnership

energy saving trust

The Low Emission Taxi Guide

Helping Local Authorities implement low emission taxi and private hire vehicle schemes

This report is published by the Low Carbon Vehicle Partnership
and Energy Saving Trust

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1 Introduction

The low emission taxi and private hire vehicle guide has two key audiences:

1. **Local authorities** who are required to reduce road transport emissions in order to achieve compliance with legal air quality standards, and mitigate climate change. The guide outlines the latest available low emission vehicle technologies and fuels suitable for the taxi and private hire vehicle industry. In addition the guide will help taxi licensing authorities implement best practice policy measures and initiatives to accelerate the take up of clean and low carbon vehicles.

2. **Taxi and private hire vehicle drivers** who may be required to switch to low emission vehicles in order to operate in their local and neighbouring towns and cities. The guide will help them choose the most appropriate vehicle technology for their journey needs, and comply with licensing policies, and other local policy interventions, aimed at improving local air quality.

1.1 What does this guide cover?

- Background information about the profile of the taxi private hire (TPH) fleet in the UK and its impact on road transport emissions.
- An overview of the policy framework at national, regional and local level relating to air quality, climate change and specifically to TPH.
- Best practice guidance for Local Authorities (LAs) outlining policies and measures to encourage the uptake of low emission taxis, and establish charging infrastructure.
- Presents a range of low emission technologies and fuels suitable for TPH and matches these to current vehicles available and different journey patterns.
- Provides an overview of electric vehicle charging and refuelling infrastructure.
- Sets out the business, environmental and operational case for low emission TPH vehicles.
- Presents low emission taxi operator and licensing authority case studies from different regions of the UK.

The low emission technologies and fuels covered in the guide are:

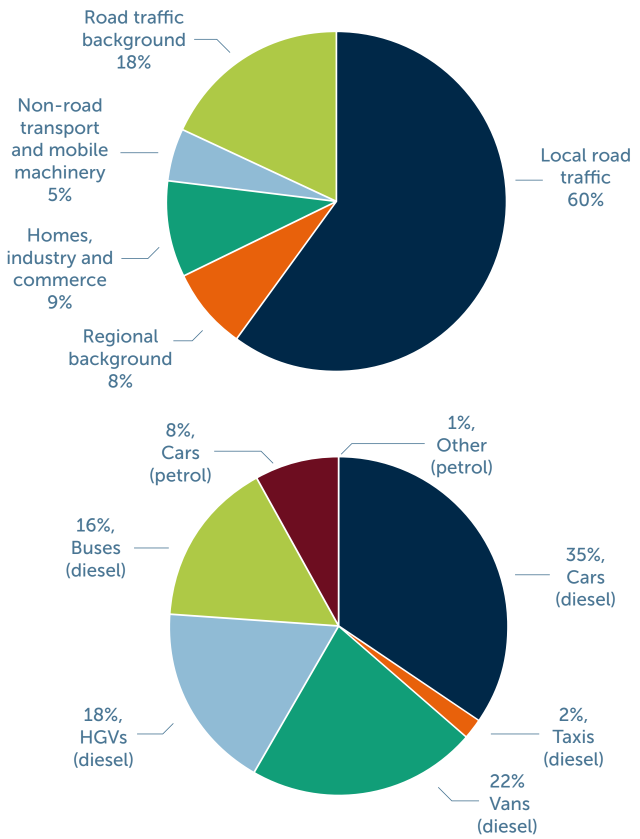
- Battery electric vehicles (BEV or pure EV)
- Plug-in hybrid electric vehicles (PHEV) and extended range electric vehicles (E-REV)
- Fuel cell electric vehicles (FCEV)
- Petrol, diesel and hybrid electric vehicles (HEV)
- Liquefied petroleum gas (LPG) - Repowering and conversion

1.2 Impacts of TPH vehicles on road transport emissions

In March 2017 there were 290,900 licensed TPH vehicles in England and Wales[1] and 23,353 in Scotland[2]. While this is a relatively small proportion of the 31.3 million licenced cars in Great Britain at the end of 2017[3], TPH vehicles have a disproportionate impact on air quality impacting human health. This is due to the relatively high mileage they cover and their concentrations in busy urban areas such as railway stations, shopping malls and supermarkets where large numbers of pedestrians are present. Emissions produced by these vehicles not only have an impact on the health of the local population (almost all taxis and many private hire vehicles are fuelled by diesel) but also on TPH drivers who may be exposed to poor air quality for 8-12 hours a day.

Road transport (including local road traffic and road traffic background) is responsible for some 80% of nitrogen oxide (NO_x) concentrations at roadside (Figure 1). Although diesel taxis are only responsible for 2% of the local road traffic NO_x emissions nationally, this rises significantly in cities[1,4] .In central London, the latest London Atmospheric Emissions Inventory (LAEI) 2013 states that the NO_x contribution from taxis is 18%[5].

Figure 1: UK national average NOx roadside concentration apportioned by source of NOx emissions, 2015



Source: PCM modelling provided by Ricardo Energy & Environment (2017) Note: 'Local road traffic' in the large pie chart is the estimate of the proportion of local NOx roadside concentrations contributed by traffic on that road and is shown in greater detail in the smaller pie chart. 'Road traffic background' is the estimate of NOx concentrations contributed by traffic on other roads. *Other (petrol) is made up of petrol vans and motorcycles. HGVs = Heavy Goods Vehicles

1.3 Defining low and ultra-low emission TPH vehicles

A **low emission vehicle (LEV)** in terms of this guide is one that complies with the minimum Euro emission standards below. These emission standards align those set in the UK Clean Air Zone Framework and London Ultra Low Emission Zone.

Figure 2: Minimum emission standards for Low Emission TPH vehicles

Euro 6	Euro 4
diesel diesel hybrid CVRAS/TfL approved LPG repower diesel black taxi	petrol petrol hybrid LPG conversion

LAs may seek to go further where appropriate and encourage TPH vehicles that are 'best in class' for CO_2 emissions. Recommendations for saloon car standards are less than 110g/km CO_2 emissions, and wheelchair accessible vehicles less than 222g/km CO_2 emission. These could be applied in the standards used for their contractor transport fleet procurement or TPH licensing rules.

Greater ambition can be delivered by transiting to ultra-low emission vehicles (ULEVs). The UK Government currently defines ULEVs as cars or vans achieving less than 75 g/km CO_2 emissions. Currently all models categorised as ULEVs have an electrified powertrain to some degree. In this guide we propose ULEV also achieve a minimum of 10 miles electric range. In 2017 53,203 ULEVs were registered in the UK which accounted for 1.7% of all new vehicle registrations.

Although ULEVs and ultimately zero tailpipe emission vehicles are the end point of this transition, due to the range of social and economic circumstances found in the TPH trade around the country, the early introduction of ULEVs is not always practical. This guide therefore covers a range of low emission vehicle technologies and fuels to help licensing authorities improve air quality emissions while reducing CO_2 emissions as much as is possible.

1.3 Why adopt low emission TPH vehicles?

Benefits for Local Authorities

Encouraging the adoption of low emission TPH vehicles can help improve local air quality and reduce greenhouse gas emissions from road transport. Diesel TPH vehicles frequently operate at transport hubs such as rail and bus stations and at other busy locations, therefore their impact on local air quality and the public's exposure to air pollution is often greater than the overall number of vehicles in operation would suggest. Therefore, the adoption of low emission TPH vehicles can potentially have a positive impact on residents' health, reducing admissions to local NHS departments.

Benefits for operators

- Drivers and operators replacing their vehicles with LEV models will not be required to pay a charge to enter a charging Clean Air Zone (CAZ), the Ultra-Low Emission Zone (ULEZ) or other regional Low Emission Zone (LEZ) that include taxis and private hire vehicles;
- Applying a whole life cost (WLC) analysis often shows that best in class vehicles are cheaper to operate than conventional and older technology vehicles;
- Existing grants offer financial support for the adoption of ULEVs as taxis;
- LAs have introduced a variety of incentives that favour low emission TPH vehicles, such as reduced parking charges and priority use of taxi ranks;
- Licensing rules may favour low emission taxis in the form of new licence availability or licence fees.

Benefits for customers

TPH vehicles serve different purposes in urban and rural areas. Compared with other modes of transport, they provide a high degree of flexibility and convenience to passengers. In rural areas in particular, TPH vehicles may be the only form of public transport available.

A low emission TPH vehicle may improve the customer experience:

- The journey in the lowest emission vehicles may be more comfortable for the passenger, as hybrids (when running in electric drive mode) and electric vehicles are quieter and smoother than conventional cars.
- The customer may consider the purchase of a LEV following the positive experience of being driven in one.
- Increased convenience if low emission TPH vehicles can access priority taxi ranks and ULEV only bus lanes.

1 Introduction

1.4 The taxi and private hire market and fleet profile

The TPH market in the UK consists of participants that provide vehicles for personal and business transport. TPH vehicles fall into two categories: taxis (also known as hackney carriages (HC)), and private hire vehicles (PHVs, also known as private hire cars in Scotland). The significant distinction between taxis and PHVs is that taxis can be hailed and pick up customers directly on the street and can also use ranks, whilst PHVs must be pre-booked through a licensed operator.

Characteristics of taxis:

Figure 3.

Maximum fares are calculated by a meter (taximeter) set by the LA.	Vehicles are often wheelchair accessible with additional accessibility features.	Maximum fares tend to be regulated by their respective licensing authority.	Can 'ply for hire' and be hailed on-street or from a taxi rank.	Can also be pre-booked.

Characteristics of PHVs:

Figure 4.

All journeys must be booked through a licensed private hire operator.	Cannot 'ply for hire' or use taxi ranks.	Fares tend to be unregulated, although fares are typically distance based and agreed before travel.	Wide range of vehicles available, including saloons, people carriers, chauffeur and executive cars and limousines.

Taxi and private hire fleet profile

Key TPH facts and figures in England and Wales[6]:

At the end of March 2017:

- 290,900 vehicles were licensed as TPH vehicles in England and Wales;
- 72% of all TPH licensed vehicles in England and Wales were private hire vehicles;
- Private hire vehicle driver licences in London increased by 78% since 2013/14[7];
- 39% of the total number of licensed TPH vehicles in England were in London;
- 56% of licensed taxis in England and Wales were wheelchair accessible vehicles (WAV);
- In 2016, a quarter (24%) of taxi or PHV trips in England were under 2 miles, and half were between 2 and 5 miles.

Key TPH facts and figures in Scotland[2]:

At October/November 2017:

- 10,393 vehicles were licensed as taxis, 4,903 were WAVs (47%)
- 12,959 vehicles were licenced as private hire cars, 294 were WAVs (2%)
- Taxi numbers have declined by 143 during the last 12 months, private hire cars have increased by 837.

Vehicle age and mileage driven:

The graphs below shows the average vehicle age and the daily mileage driven by a number of TPH fleets in the UK following a study by Energy Saving Trust (EST), commissioned by the Office for Low Emission Vehicles (OLEV) in 2016[8]. The average age of taxis ranges from under 7 to over 15 years and 12 years is common. PHVs tend to be younger and according to this study an average of 9 years old. In terms of daily mileage, taxis travel on average 91 miles while PHVs cover 128 miles.

The majority of TPH vehicles which are 13 years old will be diesel and meet the Euro 4 diesel emissions standard. However in terms of NO_x the emissions limit for these vehicles is more than three times the limit for Euro 6. Vehicles over 13 years old will be at best Euro 3, with a NO_x emissions limit six times the Euro 6 limit. The Air quality section provides more details about the harmful air pollutant NO_x.

Figure 5. Average TPH vehicle age

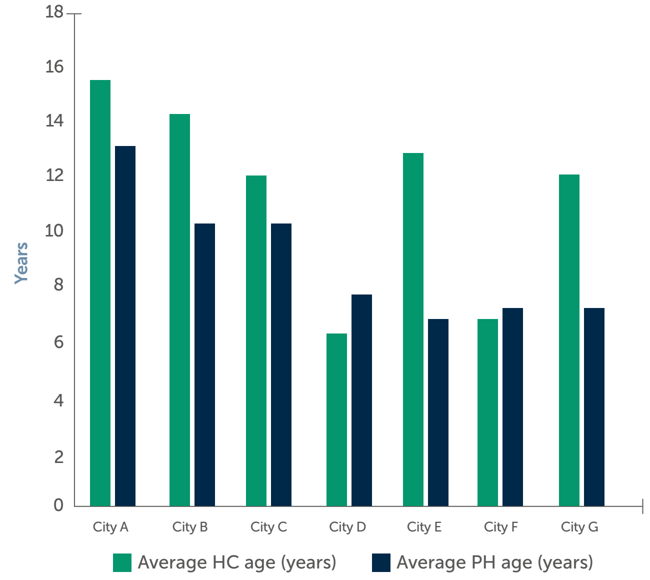
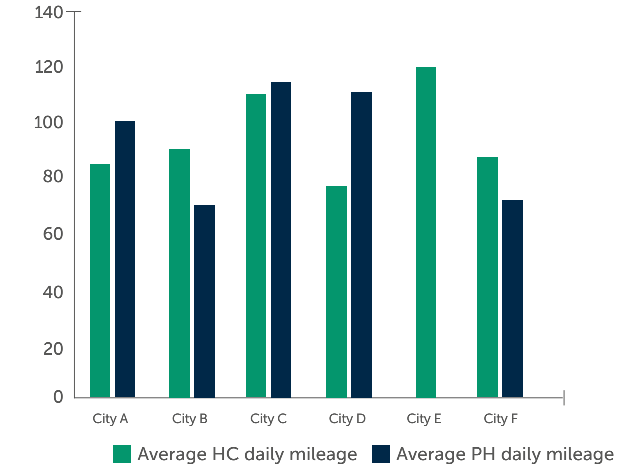


Figure 6. Average TPH daily mileage



1.5 An overview of taxi and private hire licensing

Outside London the local district council is usually the licensing authority for vehicles and drivers. In London, Transport for London (TfL) is responsible for licensing TPH vehicles and their drivers. The licensing conditions that are applied to the TPH operators, drivers and vehicles are decided by each local licensing authority, so in the case of vehicle requirements can vary considerably from area to area.

As each LA decides its licensing policy, there are many variations around the country. Taxi fleets are often required to be at least in part wheelchair accessible; policy may require kerb side access and larger vehicles, or rear access which can be achieved using a smaller base vehicle. In some areas there may be a requirement for a certain proportion of WAVs with the remainder being saloon style cars.

Taxis can be pre-booked and operate like PHVs anywhere outside of their licensed area, including cross-border. PHVs may also work outside of their own licensing area. For PHVs, the driver, vehicle and operator must be licensed with the same LA but they are able to complete jobs outside of their own licensing area as long as the booking is routed through or sub-contracted to an operator in their licensing area.

It is important to note that the cross-border operation is only allowed when vehicles are operated like PHVs and not like taxis.

The PH market is less regulated regarding vehicle specifications and although a particular licensing authority may impose strict rules on the age and type of car being licensed in their jurisdiction, PHVs licensed in other authorities are able to operate cross border[9]. PHVs are usually not required to be WAVs and smaller saloon cars usually make up the majority of the fleet in a licensing authority area.

Vehicles for use as taxis in London have to satisfy the metropolitan Conditions of Fitness[10]. A number of licensing authorities throughout England and Wales have adopted conditions of fitness similar to those imposed in London and only allow vehicles that meet them to be licensed in their areas.

The type and size of vehicles licensed by an authority should recognise local transport needs. Larger vehicles (up to eight passenger seats) may be hired for community services such as the transport of vulnerable adults or children and WAVs hired where the transport of disabled passengers is required. A range of vehicles across the TPH fleet will consider these requirements as well as the demand for competitively priced, flexible public and business transport services including more luxurious cars typically used for executive travel to and from airports or between office locations.

2 National measures to reduce road transport emissions

Launched on 9th July 2018, 'The Road to Zero'[11] outlines the Government's strategy to deliver a zero emission future for road transport for the UK.

The Government's ambition is to end sales of new conventional petrol and diesel cars and vans by 2040. As an interim target, it expects at least 50%, and as many as 70%, of new car sales to be ultra-low emission, and up to 40% of new van sales by 2030.

2.1 Air quality

Air pollution remains the most common environmental cause of preventable illness and premature deaths across the UK. In urban areas, pollutant emissions from diesel vehicles, particularly those manufactured before 2016, are frequently the cause of the majority of local air pollution.

There is an extensive body of evidence that long-term exposure to everyday air pollutants over several years contributes to the development of cardiovascular disease, lung cancer and respiratory diseases. Taxis are predominantly diesel powered, as are PHVs (although hybrids have been quite popular amongst the private hire trade over the last few years). Their high mileage and proximity to large numbers of pedestrians, particularly around transport hubs and retail centres, make their contribution to poor air quality highly significant. The two pollutants of most concern are particulate matter (PM) and nitrogen dioxide (NO_2).

In July 2017 the Government published the "UK plan for tackling roadside NO_2 concentrations"[7], which originally required local authorities in areas expected to exceed the European Union (EU) NO_2 limit values beyond the next three or four years to develop innovative local plans that will achieve statutory NO_2 limit values within the "shortest possible time'. The plan identified Clean Air Zones that include charging as the measure to achieve statutory NO_2 limit values in towns and cities in the shortest possible time.

Twenty-nine authorities have been directed by the Government to conduct feasibility studies into the best options for achieving compliance with legal limits for NO_2 in the shortest possible time, as part of the air quality plan. Five cities (Birmingham, Leeds, Nottingham, Derby and Southampton) must as part of their feasibility study, prepare a full business case for their area which were submitted to the Secretary of State before the 15th September 2018 deadline. These plans included charging Clean Air Zones for Birmingham, Leeds and Southampton, while Nottingham and Derby have submitted plans to introduce new traffic management measures to tackle air quality that they believe will not require the implementation of a CAZ. A number of other local authorities were required to submit local plans to the Secretary of State by 31 December 2018, which may include proposals to introduce CAZ.

Given the potential impacts on individuals and businesses, when considering between equally effective alternatives to deliver compliance, the Government believes that if a LA can identify measures other than charging zones that are at least as effective at reducing NO_2, those measures should be preferred – as long as the LA can demonstrate that this will deliver compliance as quickly as a charging CAZ. This, for instance, could be the introduction of emission requirements for TPH vehicles using existing licensing powers.

A CAZ defines an area where "targeted action is taken to improve air quality and resources are prioritised and coordinated in order to shape the urban environment in a way that delivers improved health benefits and supports economic growth". There are two types of CAZs:

– Non-charging CAZ, where a range of actions to improve air quality can be deployed including (but not limited to) measures to encourage the use of public transport, walking and cycling, the uptake of ULEVs or road layout changes at congestion and air pollution pinch points;
– Charging CAZ, where in addition to the above, vehicle owners are required to pay a charge to enter or move within a zone if they are driving a vehicle that does not meet the particular standard for their vehicle type in that zone. Under the CAZ Framework for England[12], charging CAZs are sub-divided into classes A - D on the basis of the types of vehicles to which the charging schemes may apply (Table 1).

Table 1. Recommended charging Clean Air Zone Classes

Charging CAZ Class	Vehicles potentially included
A	Buses, coaches, taxis and private hire vehicles
B	Buses, coaches, heavy goods vehicles (HGVs) taxis and private hire vehicles
C	Buses, coaches, HGVs, large vans, mini buses, small vans/light commercials, taxis and private hire vehicles
D	Buses, coaches, HGVs, large vans, mini buses, small vans/light commercials, taxis and private hire vehicles, cars, motorcycles and mopeds[13].

Vehicles which meet at least the minimum emission standard for the CAZ will be able to enter or move within the zone free of charge (Table 2). Fully electric or hydrogen fuel cell ULEVs will be able to enter or move within zones free of charge.

Table 2. Charging Clean Air Zone minimum emission standards

Vehicle Type	CAZ minimum emission standard
Buses and coaches	Diesel Euro VI
HGVs	Diesel Euro VI
Vans	Euro 6 (diesel) Euro 4 (petrol/LPG)
Taxis and private hire vehicles	Euro 6 (diesel) Euro 4 (petrol/LPG)
Cars	Euro 6 (diesel) Euro 4 (petrol/LPG)
Motorcycles and mopeds	Euro 3

More than £40 million from the Government's £255 million Implementation Fund has been awarded to support LAs taking action as soon as possible to improve air quality. A £220 million Clean Air Fund was launched in March 2018 to minimise the impact of local plans on individuals and businesses. The range of options LAs could consider to utilise this money includes new park and ride services, freight consolidation centres, concessionary travel schemes and improvements to bus and taxis/PHV fleets.

Working closely with EST and DfT/DEFRA's Joint Air Quality Unit (JAQU), LowCVP has developed the Clean Vehicle Retrofit Accreditation Scheme (CVRAS). Retrofit technologies can be fitted to legacy diesel vehicles to reduce NOx and PM emissions and meet CAZ emission standards. The scheme addresses the air pollution emissions from buses, coaches, heavy goods vehicles, mini-buses, black taxis and vans. The scheme provides a means of certifying the performance of retrofit technologies, and the companies supplying the equipment.

The CVRAS website[14] has a list of certified technologies and companies. Only technologies approved by the CVRAS are CAZ compliant. The scheme is also applicable to retrofit technologies fitted to diesel vehicles operating in the London Ultra-Low Emission Zone and Scotland's proposed Low Emission Zones. At present the only retrofit technology approved for black taxis is engine repowering with LPG. Transport for London have their own black taxi LPG repowering approval scheme[15] which is based on vehicle modification achieving Euro 6 emission limits.

London Ultra Low Emission Zone

London will be introducing an Ultra-Low Emission Zone (ULEZ) on 8th April 2019, which will be the same area as the current Congestion Charge zone. There will be a charge of £12.50 per day for non-compliant cars, vans and motorcycles and £100 per day for heavy vehicles to enter the zone. However, unlike the Congestion Charge and the T-charge (where the £10 a day fee to enter the zone for vehicles not compliant with at least Euro 4 emissions limits only applies Mon to Fri, 07.00-18.00) the ULEZ will apply 24 hours/365 days a year. London will not be charging taxis as revised condition of fitness will apply in order to achieve early compliance. PHVs will need to meet ULEZ standards or pay an additional daily charge when travelling within central London[16,17].

Air quality and clean air zones in Scotland

The Scottish Government has outlined plans to have four Low Emission Zones in place to address air quality in the country by 2020, with the first to be established in Glasgow by the end of 2018. Glasgow's LEZ will initially only include bus routes into the city centre though a consultation is currently underway investigating the expansion to a wider area and the inclusion of additional vehicle types. Alongside Glasgow, LEZs are also expected to be established in Edinburgh, Aberdeen and Dundee. As part of these plans, Transport Scotland launched a consultation to seek feedback from stakeholders and the general public. There was a high level of consensus among respondents with 95.5% supporting the principle of LEZs to help improve air quality in Scotland. 62% of the respondents were also supportive of a potential minimum standard of Euro 6 for diesel cars, Euro 4 for petrol cars and Euro VI for buses. This process will help inform the development of the LEZ policy, helping to shape the guiding principles that the Scottish Government will adopt to design, establish and operate Scottish LEZs[18].

Air quality and clean air zones in Wales

The Welsh Government is seeking views on its CAZ proposals, which include stopping the most polluting vehicles from entering a CAZ or charging them to enter[19]. The consultation has been launched following the announcement by the Welsh Government of a £20 million air quality fund, which will run until 2021, to support local authorities to comply with NO_2 limits and improve air quality in their areas.

There is no specific requirement on any LA in Wales to introduce a CAZ. However, LAs may choose to introduce a CAZ in order to address air quality issues locally, whether as a result of identified legal exceedances or as part of a health improvement programme to address poor air quality. Cardiff Council have decided, after being directed to develop options to bring about compliance with statutory NO_2 values, that a charging CAZ will not be necessary in the city.

2 National measures to reduce road transport emissions

2.2 Climate change

The 2008 Climate Change Act commits the UK to reducing greenhouse gas emissions by at least 80% (from the 1990 baseline) by 2050. In 2016, transport became the largest emitting sector of UK greenhouse gas emissions, accounting for 26% of UK greenhouse gas emissions . A number of EU and UK Government policies are in place to reduce these emissions:

- The EU New Car CO_2 regulation sets a mandatory targets for the fleet average gCO_2/km of cars sold by manufacturers. The target for cars is 95g CO_2/km to be achieved by 2021.
- The UK Government has introduced a range of fiscal measures to incentivise the adoption of low carbon vehicles (including ULEVs). Further details are in the Government Grants and Incentives for Low Emission Vehicles section.
- The Government is encouraging the uptake of electric vehicles through a wide range of incentive schemes covering vehicles, infrastructure and manufacturing. Following the autumn 2017 Budget, the amount invested in the period 2015-2020 will be almost £1.5 billion.

Worldwide Harmonised Light Vehicle Test Procedure and Real World Driving Regulations

Currently, CO_2 figures used for reporting manufacturers' compliance with new car CO_2 targets, and Government CO_2 based car taxation are derived from the New European Drive Cycle (NEDC) test procedure. In recent years, there has been a growing gap in the fuel consumption (and therefore CO_2 emission) values obtained on the NEDC test and the figures that drivers achieve on the road. The NEDC has been in place for more than two decades and has become outdated in terms of accurately testing new vehicles.

The World Harmonised Light Vehicle Test Procedure (WLTP) is the new global test procedure for measuring new car fuel and energy consumption, air pollution and CO_2 emissions, and electric range. WLTP will replace the NEDC test procedure. WLTP introduces more realistic and robust testing conditions for new cars, based on a wide range of real driving conditions and stricter procedures. This will provide consumers with more accurate and representative fuel consumption, electric range and emission values[21]. As the test procedure is more accurate, the reported CO_2 emission values will be higher for the same car model tested under the old NEDC test.

From 1 September 2017 it became mandatory for all new car models to be type approved under WLTP. From 1 September 2018 nearly all new car registrations will be required to be type approved under WLTP. In January 2019 all consumer official fuel economy and EV range information will switch from NEDC to WLTP. However, the NEDC CO_2 figures will still be used for taxation purposes. April 2020 sees the complete transition to WLTP, when the WLTP CO_2 figures will also be used for vehicle tax, replacing the old NEDC values. Local authorities who have policies related to car CO_2 emissions are advised to continue using the NEDC CO_2 emission figure and switch to WLTP CO_2 figure in 2020. For more information about WLTP visit the LowCVP website at **www.lowcvp.org.uk/wltp**

The Real Drive Emission Regulations (RDE) came into force at the same time as WLTP and specifically affects light duty vehicle air pollution emissions. The RDE test measures the NOx and PM emission on the road, over a range of driving conditions using Portable Emission Testing (PEMS) equipment. It will be implemented over several years. RDE Stage 1, referred to as Euro 6d (Temp), applied to new car model registrations from September 2017, followed by all registered models in September 2019 . RDE Stage 2, Euro 6d (Full), will apply for new car registrations from January 2020.

At the 2017 Autumn Budget, it was announced that from 1 April 2018 purchasers of new diesel cars that do not meet the RDE Stage 2 standard will have to pay a 'diesel' supplement on the first year's Vehicle Excise Duty (VED). This increases the first year tax rate applicable by one VED band.

2.3 Government grants and incentives for low emission vehicles

At the time of writing this guide, the following grants are available and confirmed until at least October 2018.:

Grants and incentives available across the UK

OLEV funding for taxi charging infrastructure[22]

A second round of funding for local authorities to install charging infrastructure for ultra low emission taxis was held in 2018 by the Office for Low Emission Vehicles as part of the Government's Road to Zero strategy. Energy Saving Trust provided support to local authorities to help plan their bids to access this funding.

Winners of this funding round were announced in February 2019. The full list of successful bids can be found at https://www.gov.uk/government/publications/ultra-low-emission-taxi-infrastructure-scheme-round-2

Plug-in vehicle grant[23]

Grants towards the cost of eligible vehicles are based on emissions and zero emission driving range.

OLEV maintains the list of eligible vehicles as well as full details of categories and the grants available at **www.gov.uk/plug-in-car-van-grants**.

The grant is automatically deducted from the retail price when an eligible vehicle is purchased, so there is no additional paperwork to complete, and there's no need to pay the full retail price and then reclaim the benefit.

The Plug-in Taxi Grants (Category 1&2 Taxis) are only available for new purpose built ULEV taxis that meet the eligibility criteria specified in the OLEV guidance[24]. Please note, criteria for grants are subject to change and applicants should refer to the OLEV Guidance for more details.

On-street Residential Chargepoint Scheme[25]

The On-street Residential Chargepoint Scheme (ORCS) managed by EST provides grant funding for LAs towards the cost of installing on-street residential chargepoints for plug-in electric vehicles. LAs can receive 75% of funding for the installation and procurement costs of chargepoints for residents without access to off street parking. OLEV will provide up to £7,500 per chargepoint installation and each project should not exceed more than £100k of OLEV funding.

Although this funding cannot be used to support the installation of chargepoints for the primary use of taxi fleets, installations near individual taxi drivers' homes, where no off street parking is available, are eligible.

EV Homecharge Scheme[26]

EV users can receive funding from OLEV to install a home chargepoint for their plug-in vehicle through the Electric Vehicle Homecharge Scheme (EVHS). This provides a grant of up to 75%of the eligible costs of a chargepoint and its installation (capped at £500, inc. VAT) for the registered keeper, lessee or nominated primary user of a new or second-hand eligible electric vehicle from 1st October 2016.

Find out more about eligibility criteria and a list of approved installers at **www.gov.uk/government/publications/electric-vehicle-homecharge-scheme-guidance-for-customers-version-22**

Workplace Charge Scheme[27]

The Workplace Charging Scheme (WCS) is a voucher-based scheme that provides support towards the up-front costs of the purchase and installation of electric vehicle charge-points, for eligible businesses, charities and public sector organisations. The contribution is limited to £300 for each socket up to a maximum of 20 sockets across all sites for each application.

Additional grants and incentives available in Scotland[28]

Additional grant funding is available in Scotland:

Grant funding for workplace electric vehicle charge point installations

On top of OLEV's Workplace Charging Scheme, grant funding is available to help organisations to install EV chargepoints on their premises.

Switched On @Work

Switched On @Work supports organisations interested in helping their employees to identify the benefits of switching to ULEVs. ULEVs range from pure EVs, PHEVs and E-REVs.

Low carbon transport business loan

Interest-free loans of up to £100,000 are available to Scottish businesses to help lower their transport and travel costs. These loans have a repayment term of up to 6 years and can be used to meet the cost of a wide range of sustainable measures including pure EVs and PHEVs.

EV loan

The interest-free EV loan currently offers drivers in Scotland loans of up to £35,000 to cover the cost of purchasing a new pure EV/ PHEV. The loan has a repayment term of up to six years. The purchased EV should be the only plug-in vehicle owned by the applicant and must be eligible for the 'plug-in car grant' funded by OLEV. Second hand vehicles are not eligible.

Low carbon hackney cab loan

Interest-free loans of up to £120,000 are available from EST, funded by Transport Scotland, to enable owners and operators of HCs to replace conventional internal combustion engine hackney cabs, regardless of age, with newer, more efficient Euro 6 models. Please note that the loan cannot be used for PH or saloon vehicles.

Domestic chargepoint funding

Funding is currently available towards the cost of home charge points for EVs from EST and OLEV. EST will provide up to £300 further funding on top of the OLEV grant (EVHS).

2 National measures to reduce road transport emissions

Other national and regional incentives for low emission TPH vehicles

Table 4 lists a range of other national and regional fiscal incentives for low and ultra low emission vehicles.

3 Best practice guidance for local authorities

LAs have the powers to deliver clean and low carbon TPH schemes in their local areas through implementing a range of local policy measures and initiatives. A number of cities are demonstrating best practice in terms of delivering a variety of measures to encourage their local TPH companies to switch to low emission vehicles. These range from introducing new conditions in taxi licensing, establishing emission based road access restrictions, offering fiscal incentives, running awareness raising and promotional activities, to introducing electric vehicle infrastructure.

Taxi licensing and vehicle emission based road access restrictions (such as charging CAZ) are regulatory interventions that can deliver the quickest fleet turnover and emission reductions. It is recommended that before the introduction of such policies proactive engagement is made with the local taxi trade.

The establishment of communication channels will help ensure that licencing authorities understand the trade's requirements, the challenges they face switching to / purchasing low emission vehicles and the most effective approach to support them. Given the variety of local authority regions across the country, socio-economic differences and taxi journey profiles, not all TPH companies will be able to adopt ULEVs in the near term. A pragmatic approach should therefore be taken and a range of low emission vehicles promoted.

Table 4. Other fiscal incentives low emission TPH vehicles

Incentive	Description
CAZ or ULEZ access	Vehicles meeting the LEV definition will not be charged to enter 'charging' CAZ or the ULEZ.
VED for ultra low emission vehicles	Most ULEVs registered before April 2017 are exempt from VED. However, following changes to how VED is calculated from April 2017, some ULEVs are brought into a charging band[29] but they pay a lower first year rate.
VED rates for electric taxis	In March 2018 HM Treasury confirmed that all taxis eligible for the Plug-in Taxi Grant (PITG) are exempt from the VED charging band for cars over £40,000 list price. This is worth £1,550 over the first six years of the vehicle's life.
Corporation tax	Businesses buying cars can write down 100% of the purchase price against their corporation tax liability if the vehicle emits no more than 50g/km CO_2 emissions.
Parking	Free parking and/or reduced cost of resident parking permits may also be available to further encourage the uptake of low emission vehicles in some urban areas.
Clean Air Fund	Local authoritiess can apply for funding for low emission taxi and PHV initiatives such as offering drivers grants or loans to purchase ULEVs or repowered LPG diesel black taxis (CVRAS approved).
Fuel duty	Electricity and hydrogen benefit from zero fuel duty. Fuel duty for LPG is lower than petrol and diesel.

3 Best practice guidance for local authorities

3.1 What to consider before making any policy changes

Set the scene

In the first instance LAs need to have a good understanding of the profile of their TPH fleet. Some key indicators of the fleet's profile are average age, CO_2 emissions, mileage driven and Euro Standard. On board technology, such as telematics, can be installed to provide accurate information about the journeys a vehicle has made, the mileage, the time and duration of break to assess the feasibility of these journeys being operated in electric vehicles. This information will shape the level of intervention an authority can make, especially with regards to setting appropriate timescales to requesting fleet renewals. For instance, a more drastic approach will be required for a very old, polluting fleet while different interventions will be required for a relatively modern fleet that can become even cleaner.

Engagement with the trade

The introduction of charging CAZs, or other restricted access schemes, and stricter licencing requirements has the potential to significantly impact TPH companies financially, due to the need to invest in cleaner vehicles. Smaller organisations will face greater challenges.

It is of paramount importance for licencing authorities to hold regular meetings with the trade and understand how they can support the industry with this transition. This engagement should be used to establish an open, honest and constructive relationship between the authorities and the trade as drivers and operators will have an opportunity to share their views on the technology proposed and suggest support measures to make the transition smoother and easier.

Drivers and operators of TPH vehicles will need to make some important decisions when it comes to compliance of their fleet with new proposed standards. These decisions may have a significant impact on their businesses' finances. It is important that LAs consult with TPH operators and give advanced warning of any policy changes and associated timelines. LA should seek feedback from the trade on the proposed changes. Clear lines of communication should be opened and maintained between LAs and the TPH trade to provide opportunities for a constructive dialogue. Vehicle demonstrations and opportunities for drivers to test the vehicles should be provided.

Consider socio-economic factors

The operation of TPH vehicles includes social dimensions which should be considered by LAs before any policy measures are introduced. These include TPH driver working conditions, job insecurity, income and occupational health which have an impact on affordability issues faced by TPH fleets, especially outside London.

Taxis and PHVs help to connect low income groups with employment opportunities and access to vital services, particularly in areas where public transport is not readily available. In addition, the TPH market creates employment opportunities across communities which might not otherwise exist[8].

Council departmental engagement

Engagement with different departments across the Council will ensure all stakeholders are aware of the issues the trade faces, proposed solutions and how these solutions are going to be delivered. Key departments are: planning, estates, taxi licensing, parking, air quality as well as colleagues from outside bodies such as a County Council which may have responsibility for roads. All should be consulted and kept up to date with any proposed changes. Low emission taxi policies should be embedded across Council plans and strategies to galvanise change and encourage collaboration. A number of cities have produced a taxi and PHV strategy that covers specific measures and initiatives related to low and ultra low emission vehicles.

3.2 Local policy measures and initiatives

Outlined below are a range of policy measures and initiatives local authorities can introduce to encourage the adoption of low and ultra low emission vehicles. These are followed by best practice city case studies.

Southampton City Council and Eastleigh Borough Council have introduced Low Emission Taxi Incentive Scheme offers cash back for replacement of a more polluting TPH vehicle with a low emission alternative. The amount of cash back varies between £1,500 and £3,000 depending on the alternative. More details can be found on the Southampton City Council's website[30].

Regulatory Measures

Restricted vehicle access
Introduce access restriction schemes, based on Euro standards, where compliant vehicles can enter for free while non-compliant vehicles are charged, eg charging CAZ and London ULEZ where LEVs and ULEVs enter free of charge. More ambitious 'zero emission' zones could be considered as the market for zero emission capable TPH vehicles expands.

Revise conditions of fitness
Revise 'conditions of fitness' for newly licensed vehicles to state that they must meet LEV emission standards as a minimum. More ambition could be encouraged through requiring 'best in class' CO_2 emission vehicles and ULEVs.

Vehicle age limits for new vehicles
Revise the age restrictions for newly licensed vehicles – including the age at which vehicles can first be licensed (for example Euro 6) and a total age limit. Consider higher age limits for ULEVs.

Vehicle age limits for existing vehicles
Phase in a more ambitious age restriction on existing vehicles. Compliance with any access restriction zones may require this process to be accelerated.

TPH emission standards
Regulate that all or a proportion of TPH vehicles in a licencing authority must be LEV and/or ULEV by a certain date.

Flexible licensing caps
Implement flexible licensing caps to give LEV/ULEV drivers priority in accessing a new license.

Dedicated ULEV-only taxi ranks
Introduce ULEV-only taxi ranks or spaces at the head of ranks in prime locations.

Introduce concessions to address trade issues
Issues aired by the trade may be resolved alongside a commitment to operate LEVs. An example could be by creating "green licences" enabling those restricted from joining the trade being able to do so by operating a LEV.

Planning policy to encourage adoption of ULEVs
Set planning conditions, and use s106 agreements, to require charging infrastructure in new developments, ULEV only parking bays and taxi ranks.

Financial Measures

Reduced fees for TPH licences and renewals
TPH operators pay less for LEV/ULEV TPH licenses.

Stipulate the use of LEVs/ULEVs as part of LA procurement guidelines
Include criteria in TPH contract tenders to make these more favourable to operators with LEV or ULEV fleets. Work with local NHS Trust(s) and education authorities to modify criteria of patient/pupil transport contract tenders to require TPH operators to utilise a certain number of LEVs/ULEVs.

Provide competitive advantages
Work with local land owners, larger businesses and station operators to provide a package of benefits to LEV/ULEV drivers, which allow them to be more competitive.

Rebates and other financial incentives
Offer grants or loans to encourage purchase of ULEV taxis and CVRAS approved retrofit technologies. Consideration should also be given to incentivising uptake of second hand ULEVs.
LA could purchase a range of LEV/ULEVs and lease to local drivers.
ULEV drivers have access to charging infrastructure either at a reduce cost or for free.
Offer grants or local incentives for local business to support installation of charging infrastructure

Financial incentives to encourage old vehicle replacement – taxi scrappage scheme
Offer cash back to drivers who replace older polluting vehicles with LEV/ULEVs.

Parking restrictions/permits
Allow free or discounted parking for ULEVs in certain locations, restrict parking of internal combustion engine vehicles in EV-only bays and impose parking fines.
Allow free access to car parks where dedicated TPH charging infrastructure is located.

Install public charging infrastructure
Fund the installation and operation of rapid charging infrastructure on-street and in car parks.

3 Best practice guidance for local authorities

In Bristol taxi drivers are being offered subsidies of more than £3,000 if they purchase an electric car to help improve air quality in Bristol. The package of incentives on offer includes five year subsidies to cover the costs for: licencing fees at £187 per year, certificate of conformity fee at £50 per year, permit to operate at Temple Meads Railway Station at £490 per year.

Promotional Measures

Awareness raising campaigns for Low Emission Vehicles Conduct analysis and produce case studies illustrating the local, real-life business case for taxi drivers and operators. Promote on the Council's website and events. Raise awareness of existing grants and other financial incentives for ULEVs, highlighting the business case and cost saving benefits for operators.. Inform drivers of the location of charging infrastructure, show these on the Council's website, create a local charging phone app. Organise local road shows with industry representatives and organisations (such as EST) to promote practical and business benefits of LEVs/ULEVs.
Local taxi fleet demonstrations and trials of ULEVs Work in partnership with vehicle manufacturers to offer drivers the opportunity to test ULEVs in their fleet.

Nottingham City Council will be running an Ultra Low Emission Vehicle Experience project that forms part of the Council's Workplace Travel Service. The project is about supporting local businesses in Nottingham to adopt ULEVs through offering fully funded fleet reviews, try before you buy vehicle loans and organising staff engagement events with ride and drive events.

3.3 Policy case studies

Oxford City Council

OXFORD CITY COUNCIL

Oxford City Council and Oxfordshire County Council are proposing to introduce the world's first 'Zero Emission Zone' (ZEZ) in Oxford city centre in an effort to reduce air pollution. The proposal will see diesel and petrol vehicles banned from Oxford city centre in phases, starting with some vehicle types and a small number of streets in 2020, and - as vehicle technology develops - moving to all vehicle types across the whole city centre in 2035.

The City Council plans to install £500,000 of EV charging points for taxis and to phase out older, high-emitting hackney cabs from the city in another effort to reduce air pollution. The charging points will be 'rapid' and 'fast' chargers to enable drivers to quickly charge batteries during breaks. The City Council won £370,000 of funding from OLEV for the project. The aim is to seek the remaining funding from private investment.

The Council is working closely with hackney carriage drivers trying to understand the hurdles they face and ways to support them before any policy changes are introduced. A number of engagement events will take place where drivers can test drive zero emission capable (ZEC) taxis, ask questions and share their feedback with the authorities. Oxford is also involved in a project alongside Cenex and other LAs using computer modelling to identify cost efficient options for taxi drivers to operate ZEC taxis, based upon information from local drivers and real world Oxford duty cycles.

The low emission taxi scheme also sets out, for the first time, the City Council's intention to require all newly-licenced taxis to be ULEVS (by the end of 2020 - subject to vehicle availability).

Oxford City Council officers have pledged to provide a range of support to taxi drivers and owners, for example supporting drivers to seek additional income from on-cab advertising and other sources, helping operators apply for grants to install charging points at their homes or businesses, and producing detailed business cases to help drivers plan their purchases.

Case study

Dundee City Council

Dundee City Council

Dundee is one of four cities identified by the Scottish Government as being required to set up a LEZ. The adoption of EVs is a central approach to improving air quality in Dundee. The Council is leading by example, having 87 electric vehicles in its fleet, ranging from Nissan eNV200 electric vans to Kia Souls and Peugeot Ion cars. Since first introducing electric vehicless in 2011, the council have realised maintenance cost reductions of up to 30% and fleet running costs of approximately 2/3 pence per mile.

Before they implemented any policy measures to clean the TPH fleet, council officers spent some time to understand the trades' requirements. They organised quarterly meetings with the trade to improve communications and understand the issues drivers were concerned about. Council officers and officials then presented a variety of initiatives which resulted in the following new policy measures:

1. As of September 2016, all new PH vehicles had to be pure EVs.
2. Hackney carriage vehicles wanting to have company plates can only do so as long as the new vehicle they use is an EV.
3. The drivers of pure electric or a plug-in hybrid vehicles do not pay electricity costs to charge the vehicle when using public fchargepoints.
4. Electric taxis in Dundee are very popular and a few factors that supported this switch to electric are:

– an EV only taxi rank outside a recently refurbished hotel near the train station in Dundee
– a £10 discount off the cost taxi drivers pay for their regular vehicle test
– fully functioning integrated EV charging infrastructure supported by one back office provider
– 4 new rapid charging hubs located across the city that will provide priority EV taxi charging

A catalyst for all these measures was the installation of 5 rapid charging points and the introduction of 30 Nissan Leafs by the Dundee Taxi firm 203020 back in 2015.These taxis have now completed over 3 million miles between them.

Dundee now has 82 pure electric TPH vehicles operating in the city. At 11%, Dundee very close to its target to see 15% of taxis become electric by the end of 2018.

Transport for London

Transport for London

TfL are responsible for delivering the Mayor of London's transport strategy. As part of his strategy to tackle air pollution, the Mayor has already introduced the T-Charge in central London and brought forward the start date of the ULEZ. TfL is deploying a range of measures to ensure that the emissions from taxis and private hire vehicles are reduced as quickly as possible.

3 Best practice guidance for local authorities

For Taxis:

- 15-year age limit (introduced 2012. Consultation currently underway looking at a phased reduction to 12 years by 2022.)
- A requirement for all newly licenced vehicles from 1st January 2018 to be ZEC; this requires a minimum zero emissions driving range of 30 miles and CO_2 emissions no higher than 50g/km.
- An additional five years is allowed if the taxi is fitted with an approved TfL modification to reduce emissions. This allows some vehicles to qualify if retrofitted with Euro 6 compliant petrol engines, which includes LPG repowered black taxis.
- A £2.5 million fund to help drivers of relatively new Euro 5 taxis to be converted to LPG fuel.
- Taxi delicensing scheme.

The taxi delicensing scheme[31] is offered to the owners of the oldest and most polluting taxis in London to remove their vehicles from the fleet and help to make the switch to ZEC vehicles sooner than through the "natural" replacement rate. Top payments of £10,000 are available to the first 1,250 applicants, with tiered payment levels available to subsequent applicants on a first come, first saved basis:

Eligible Vehicles	No. of payments available	Payment (£)
Taxis younger than 13 years	1,250	10,000
	1,100	9,000
	850	8,000
	500	7,000
	400	6,000
15 or older	1,000	1,000

For PHV:

From the introduction of the ULEZ in 2019 all PHVs will need to meet the ULEZ emission standards or pay the daily charge. ZEC licensing standards are being introduced for PHVs. These require a zero emission range of at least 20 miles and CO_2 emissions no higher than 75g/km. The requirements for PHVs are being introduced in three phases to ensure that by the 1st January 2023 all PHVs licensed for the first time will be ZEC vehicles.

Phase 1: 1st January 2018 to 31st December 2019

- PHVs licensed for the first time must be Euro 6 petrol or diesel or Euro 4 petrol hybrid

Phase 2: 1st January 2020 to 31st December 2022

- All new (less than 18 months old) PHVs licensed for the first time will be required to be ZEC
- PHVs > 18 months old will need to be Euro 6 compliant to be registered for the first time

Phase 3: 1st January 2023

- All PHVs of any age will need to be ZEC when licensed for the first time.

Policies to ensure that adequate rapid charging infrastructure will be available for drivers are being introduced in parallel which are detailed in chapter 4 of this guide.

Case study

Nottingham City Council

As a unitary authority, Nottingham City Council is the taxi licensing authority within its boundary. The council published a Hackney Carriage and Private Hire Vehicle Strategy in 2017, which includes a set of policies and strategies to respond to air quality and climate change challenges. Examples of these policies are:

- A minimum of 40% of taxis to be ULEVs by 2020
- All newly licenced taxis from 31/12/2019 to be ultra-low emission, Euro 6 diesel or Euro 4 petrol
- A maximum age of 10 years for conventional vehicles in operation and 12 years for ULEVs
- A target for 25% of the Private Hire fleet to be ULEV by 2020 and 50% of fleet by 2025

The council recognises that taxi drivers and operators need time to investigate the business models so their chosen vehicles comply with the new age and emissions limits. The council is assisting local taxi drivers by having regular meetings with the taxi trade, sending regular newsletters, holding roadshows and through continued driver engagement.

The council is also trying to increase income opportunities for the taxi trade through a partnership with 'Mytaxi', a smartphone application that allows users to book, pay and log their journey on their smartphone. The project was launched in March 2018, with more than 300 drivers signed up to the app. Drivers will also be allowed to advertise outside, inside and on the roof of the vehicle, which the council is supporting through the Cabzy Ads initiative.

As part of the council's strategy to incentivise the adoption of low emission taxis, 32 charging points will be installed from late 2018 at key locations across the city following a successful £700,000 OLEV taxi bid and a £100,000 DEFRA bid to make sure that one in three taxis in the city are 'green' by the year 2020. The council is exploring locations for siting the charge points based on common routes drivers take. These charging points are on top of the 230 points that will be for public as well as taxi use, which the council has received £2m of separate Government funding through the Go Ultra Low City scheme. As part of the scheme, a discounted tariff will be introduced allowing all residents and taxi drivers to use the local units at 20p/kwh.

Recognising the high capital costs of ULEV taxis and following feedback from drivers, the council investigated the opportunities around purchasing the taxis and leasing them back to drivers. To pilot this concept, the council has secured £270,000 from the DEFRA Early Measures Fund to purchase electric taxis – initially up to six.

The scheme is currently in development but early thinking includes a proportion of vehicles to be offered on long term leases (6 months +) and some vehicles to be held and offered on a 'try before you buy' basis to give more drivers the opportunity to trial the vehicles for a period of one week to one month so that they can fully understand how the vehicle operates and undertake a real world comparison between their usual vehicle and the ULEV option.

3 Best practice guidance for local authorities

3.4 Guidance for installation of EV charging infrastructure

Drivers who take their cars home between shifts will find it very hard to use a BEV if they don't have access to off street parking and a chargepoint, as evidenced in the Uber case study described in the BEV section.

LAs can help overcome this barrier by the provision of on-street charging facilities and by encouraging the installation of rapid charging equipment in areas where the drivers live and work. Engagement with the industry can help with the planning of charging provision, which may include allowing infrastructure to be installed on land owned by the LA.

Installing charging points to support TPH trade to switch to EVs can be challenging. When planning the installation EV chargepoints, LAs will need to take into account factors like land availability, constraints on the supply of electricity as well as planning guidelines that could potentially restrict the primary sites that could be used.

Choosing the right equipment

TPH drivers need to be able to recharge their vehicles quickly, ideally without being off the road for longer than they would in a conventionally fuelled taxi. Therefore, the majority of the chargepoints for taxis during the shift should be rapid or fast (22kW). Compatibility with both CHAdeMO and the CCS is recommended. For home charging, standard (3.7kW) or fast (7kW) chargepoints are recommended.

Chargepoints should be capable of communication with a back office system through the Open Charge Point Protocol (OCPP).

Back office software should provide the functionality needed to reliably maintain and operate the network including:

- Detailed information on chargepoint activity including real-time status;
- Charging start and finish times;
- Electricity consumption by chargepoint per hour/day and energy provided to each vehicle by charge event;
- Management of power demand to avoid network overload;
- Remote software updates and maintenance;
- Support for customer service and chargepoint maintenance staff;
- Provision of a live map to show available chargepoints and facilitate booking;

Deciding ideal chargepoint locations

Correctly locating rapid chargepoints for taxis is crucial to facilitate the shift from conventional to LEV technology. Chargepoints should be sited at or close to where taxis are stationary in large numbers, such as key ranks and drivers' break locations. Strategically locating chargepoints is also necessary to maximise chargepoint utilisation rates. It should enable those using the infrastructure to do so with minimal impact on their daily routine and allow them to benefit from the lower operating costs while not being compromised in terms of business turnover.

Drivers who have off street parking may install dedicated home charging points so they start each shift with a fully charged battery. These drivers can at the time of writing benefit from OLEV's EVHS. If they don't have access to off street parking, their LA might decide to take advantage of the ORCS funding to install a chargepoint on street near their property.

Other considerations

Other factors LAs should consider is the level of Service Level Agreement (SLA) which ideally will include 24/7 remote reaction time within 10 minutes and a site visit within two hours with issues resolved within 24 hours in order to guarantee high uptime.

LAs have different options when it comes to how drivers can pay to charge their vehicle. This means that drivers could either be charged on a pay as you go (PAYG) basis or alternatively through a membership or a combination of both.

The cost of installing two chargepoints does not necessarily double compared to the cost of installing one, as installation costs have an economy of scale when more chargepoints are installed at a location.

LAs can refer to the UK Electric Vehicle Supply Equipment (EVSE) Association guide which provides more information about EV chargepoint technology, installation, pricing and procurement[32].

State aid

LAs are responsible for ensuring their policy measures and projects comply with state aid rules. This is particularly relevant where chargepoints are installed on private property. State aid should be considered early in the process advice sought to avoid problems and save time. More information about state aid rules can be found on the Government's website[33].

Traffic regulation order

Where the infrastructure is on-street and access will be enforced under Highway Regulations it is necessary to create a Traffic Regulation Order (TRO), or in London a Traffic Management Order (TMO). A TRO provides the means by which consultation is carried out with statutory consultees as well as the general public. It provides details of the parking restrictions, kerbside location of the bay and other information relevant to enforcement.

Partnerships and stakeholder engagement

It is vital that LAs collaborate with all the relevant stakeholders as part of their chargepoint installation projects to ensure successful delivery of the schemes. The communications are important within the different teams of the Council as well as with the chargepoint network operator and the Distribution Network Operator (DNO).

3 Best practice guidance for local authorities

Working with Local Distribution Operator

One of the major potential issues when selecting locations is the constrained supply of electricity from the grid. Installing multiple chargepoints at a given site will add significant demand to the grid. Therefore, network reinforcement may be required to provide sufficient power.

DNOs distribute electricity to charge points and provide new power supplies to connect them to the network. A site survey will be required from the DNO at each location to determine whether sufficient capacity exists in the network. For a small installation, such as a single chargepoint, it is less likely that upgrades to the grid supply will be required. However, with several rapid chargepoint installations in a localised area, investment such as transformer or substation upgrades or even a new substation may be needed[34].

The cost of upgrading the electricity network could well be the greatest cost to developing rapid charge infrastructure. This will become even more of an issue as higher powered chargepoints enter the market.

Investigating potential electricity supply constraints early in the process of assessing locations should allow the selection of sites with lower upgrade costs.

It is critical that LAs, the network operator(s) and the relevant DNOs work closely together from the outset to manage rapid chargepoint installations and any necessary supply upgrades as these organisations all share responsibility to manage the provision of sufficient chargepoints.

Case studies

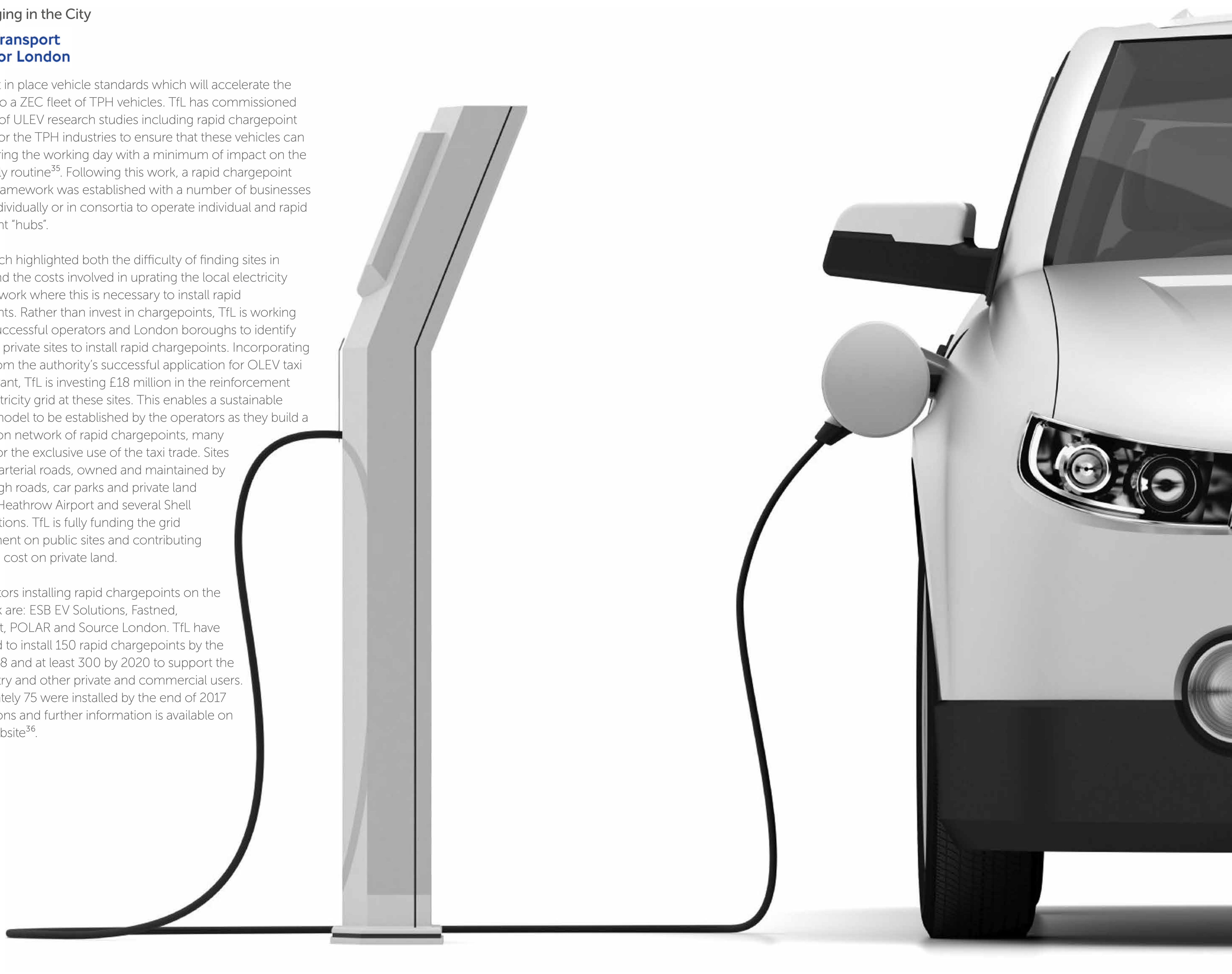
Tfl, Charging in the City

Transport for London

TfL has put in place vehicle standards which will accelerate the transition to a ZEC fleet of TPH vehicles. TfL has commissioned a number of ULEV research studies including rapid chargepoint mapping for the TPH industries to ensure that these vehicles can charge during the working day with a minimum of impact on the drivers' daily routine[35]. Following this work, a rapid chargepoint operator framework was established with a number of businesses bidding individually or in consortia to operate individual and rapid chargepoint "hubs".

The research highlighted both the difficulty of finding sites in London and the costs involved in uprating the local electricity supply network where this is necessary to install rapid chargepoints. Rather than invest in chargepoints, TfL is working with the successful operators and London boroughs to identify public and private sites to install rapid chargepoints. Incorporating funding from the authority's successful application for OLEV taxi scheme grant, TfL is investing £18 million in the reinforcement of the electricity grid at these sites. This enables a sustainable business model to be established by the operators as they build a pan-London network of rapid chargepoints, many reserved for the exclusive use of the taxi trade. Sites will be on arterial roads, owned and maintained by TfL, borough roads, car parks and private land including Heathrow Airport and several Shell service stations. TfL is fully funding the grid reinforcement on public sites and contributing 50% of the cost on private land.

The operators installing rapid chargepoints on the framework are: ESB EV Solutions, Fastned, GeniePoint, POLAR and Source London. TfL have committed to install 150 rapid chargepoints by the end of 2018 and at least 300 by 2020 to support the TPH industry and other private and commercial users. Approximately 75 were installed by the end of 2017 and locations and further information is available on the TfL website[36].



4 Technology chapters

4.1 Battery electric taxi and private hire vehicles

Technology introduction

BEVs otherwise known as "pure EVs" are wholly driven by an electric motor, powered by a battery that can be recharged from mains electricity.

BEVs emit zero tailpipe emissions, making them the ideal solution to reduce TPH vehicles' impact on air quality. BEVs are a type of ULEV and will not be charged to enter a charging CAZ or ULEZ. Lifecycle CO_2 emissions can be further reduced by using low carbon electricity and renewable energy tariffs.

Taxi and private hire vehicles' duty cycles make them ideal for utilising plug-in technology. Here are a number of reasons why BEVs are especially suitable for TPH use:

Operational use

- BEVs suit driving in a predominantly urban, stop-start environment, where they operate most efficiently.
- Pure EVs can meet the needs of drivers who carry out predominantly urban driving. Longer journeys, typically airport runs will often require charging infrastructure, preferably rapid charging, to ensure that return journeys can be completed.
- Duty cycles usually include periods of downtime, for example quiet periods of the day, waiting for a passenger or during breaks, so charging events can be incorporated into working patterns.
- BEVs are smooth and quiet and drivers report that they are more relaxing to drive than a conventional car. The smooth quiet environment is appreciated by customers too.
- The use of electric vehicles by the trade increases the visibility of the technology potentially encouraging wider adoption.
- The uptake of BEVs could support tourism, enhancing the image of a town or city as the customer travels in a clean and quiet vehicle.

Vehicle specification

Taxis
Depending on the local licensing policy, a number of BEVs may be suitable for adoption as hackney carriages. Where saloon cars are allowed, the Nissan Leaf is a popular choice and additional models providing the interior and boot space required by the trade are becoming available including the Hyundai Ioniq. The Nissan e-NV200 can provide up to seven seats or be converted to provide a rear loading WAV.

Where a full size side door WAV is required, Dynamo are converting the e-NV200 into a vehicle which will comply with the London conditions of fitness although not officially approved by TfL yet. Nottingham City Council has recently included Dynamo into their list of eligible HCs.

To date vehicle range has matched the average daily mileage of a typical hackney carriage but leaves little leeway for longer working days or journeys. The new Nissan Leaf, available from spring 2018 allows a real world driving range in the order of 170 miles. A revised e-NV200 with a real world range of c.130 miles also becomes available in April 2018.

Private hire vehicles
The most popular BEV in use in the private hire industry is the Nissan Leaf. Phoenix Taxis in Blyth, Northumberland have run the car since 2013. The e-NV200 has also been adopted where more carrying capacity is required including rear access wheelchair conversions.

.Available models

A number of BEVs are currently available, suitable for use in the taxi (where saloon cars are allowed) and private hire industry. In addition to the Nissan Leaf, the BYD e6, Hyundai Ioniq and Volkswagen e-Golf are also available. Where executive cars are required, the Tesla model S and X and the Jaguar i-Pace provide a choice of long range (240+ miles) vehicles. Smaller models such as the KIA Soul and Renault Zoe may be allowed by some licensing authorities.

The electric vehicle market is in its infancy, in Q1 2018 c.2% of new car sales were eligible for the plug-in car grant it is however growing quickly[37]. The vehicles in Table 5 below are examples of a medium saloon, people carrier and executive car which are suitable for the TPH market where conditions of fitness allow. The choice of vehicles and their range capabilities is increasing rapidly and where approved vehicle lists are in place, they should be updated regularly as more models become available.

Table 5. Examples of BEVs suitable for use as taxi and private hire vehicles

	Dynamo Taxi (WAV 	Nissan Leaf Acenta 40kW 	Nissan eNV200 Evalia Tekna Rapid Plus 	Tesla Model S 75D 
Battery size kWh	40	40	40	75
NEDC Range (miles)	170 (est)	217	174	304
Estimated real world range (miles)	134	171	137	240
No. of passenger seats	5	4	5/7 optional	4

4 Technology chapters

An overview of electric vehicle charging infrastructure

The availability of charging infrastructure is key to the successful introduction of BEVs. Ideally, drivers should be able to charge at or close to home when not working and at rapid charging infrastructure in locations where drivers typically take breaks or are stationary for a period of time as required during the working day, should a top up of range be necessary.

EV chargepoints are primarily defined by the power (in kW) they can deliver and therefore how fast they are capable of charging an EV (including BEV, PHEV and E-REV in this context).

The speed of charging is dependent on the technology built into the vehicle and into the charging infrastructure. For example, when the charging capability of the vehicle is less than that of the charger then the vehicle will charge only at the maximum speed allowed by the vehicle. Charging rates as shown in Table 6, vary from slow chargers - which can take more than 12 hours to completely replenish a battery in a BEV - to rapid chargers which can provide 80% of charge in 20-30 minutes.

Table 6 – EV charging speeds

	Slow	Fast	Rapid
Power Rating	3.5 - 7kW	7 - 22kW	43 - 50kW
Electrical Supply type	AC	Usually AC, DC available at higher rates	AC & DC
Charge time	4 to 8 hours	2 to 4 hours	25 - 40 minutes (80% charge)
Vehicle range added in 15 minutes	3 - 6 miles	6 - 20 miles	35 - 40 miles
Cost per chargepoint* (approximate)	£500 -£1,000	£2-3k (AC), £19k (DC)	£20-£40k
Comments	Chargepoints are usually Type 2 sockets, however Type 1 or 2 tethered cables are available. Popular method of charging at home overnight. For home charging a dedicated chargepoint is recommended OLEV grant available providing 75% of the cost of the chargepoint and installation up to £500.	Majority of chargers are untethered Type 2 sockets. Tend to be found on street and at destinations such as car parks, supermarkets or shopping centres. Fast chargepoints are approximately half the cost of rapid units. They are less likely to require expensive electricity supply upgrades.	Rapid units have tethered cables. Found at most motorway and main road service areas, increasingly found at supermarkets and on-street.

* Costs are an approximation provided by a chargepoint provider and do not include installation costs.

There have been significant recent advances in the speed at which EVs can be charged. Chargepoints as powerful as 150 kW have recently become available and rapid chargepoints delivering up to 50kW are a common sight at motorway and main road service stations throughout the UK. Chargers as powerful as 350kW will be available in the next few years which will dramatically reduce recharging times for future generations of vehicles.

For TPH operators, one of the most significant considerations when operating electric vehicles is the time required to charge. Also of great importance is daily mileage, downtime during the day and vehicle compatibility with the different types and speeds of charging equipment. The most common chargepoint connectors are outlined in Table 7 below.

Table 7- Chargepoint connector types

Connector Type	Typical charge speed and current	Associated manufacturers
Type 2 (Mennekes)	3.5kW, 7kW, 22kW, 43kW AC	Compatible with most vehicles, but not all will be capable of utilising the higher rates of charge (charge speed dependent on vehicle on-board charger)
Combined Charging System (CCS)	50kW DC (150kW DC being trialled[38])	BMW, Audi, Volkswagen, Porsche, Ford, Hyundai
CHAdeMO	50kW DC	Nissan, Kia, Citroën, Tesla (via adapter), Mitsubishi, Peugeot

Most TPH companies who have successfully adopted BEVs have invested in their own rapid charging infrastructure, providing drivers with the opportunity to top up or fully charge their vehicles during the working day. Where vehicles are kept overnight on the operator's premises, standard or fast charging will allow vehicles to start the working day fully charged.

Please refer to the EST Guide to chargepoint infrastructure for business users for more information about charging infrastructure[39].

4 Technology chapters

Financial information

Vehicle running costs of BEVs are usually much lower than PHEVs or conventional cars, as the electricity price is low in comparison with petrol/diesel prices, and experience has demonstrated that vehicle maintenance costs are also lower. Recharging BEVs at home or at an operator's premises is likely to be the lowest cost option providing running costs of 3-5 pence per mile, a third of that of a conventional car at 12-15 pence per mile. Using rapid chargepoints or other public infrastructure could increase the pence per mile cost of using a BEV, a 30p/kWh rate would mean that the operator was paying an equivalent fuel rate of around 7-9 pence per mile.

Some energy companies offer tariffs that reward charging ULEVs at off-peak times, such as overnight. Find more tips on how to save money whilst charging at home[40].

Table 8 provides an example of total fuel and VED costs for two BEVs operated as taxi or private hire vehicles, compared to diesel equivalents and assuming 30,000 miles driven per year over a period of four years.

Table 8. BEV – fuel and VED cost comparisons

	Nissan Leaf Acenta 40kW 	Skoda Octavia 1.6 TDi S 	Tesla Model S 75D 	Mercedes E350d SE 
Fuel cost (4 yrs)	£5,020	£11,744	£7,032	£16,616
VED cost (4 yrs)	0	£585	£930	£2,180
Total cost	£5,020	£12,329	£7,962	£18,796
Pence per mile	4.2	10.3	6.6	15.7
CO_2(g/km) (tailpipe, NEDC)	0	106	0	153
Vehicle price (OTR)	£25,190*	£19,810	£62,900	£48,940

*Including Category 1 OLEV Grant

The table above clearly shows the reduction in fuel and VED costs when a BEV is operated in comparison to a diesel equivalent. In these examples the Nissan Leaf more than makes up for the list price difference between it and the Skoda Octavia (best in class). The Tesla S is likely to be a similar cost to run compared to the Mercedes E class when the lower maintenance costs of the BEV are factored into a whole life cost calculation, or should the vehicles be operated for a longer period.

The electricity costs used are assumed to be at domestic levels [see assumptions section in Appendix], it should be noted that if the BEVs were charged at a commercial rapid charger, the electricity costs would be higher (for that proportion of driving) depending on the supplier. This would not be the case for a Tesla using a Tesla Supercharger as there would be no charge for the electricity.

Case study

Phoenix Taxis

Phoenix Taxis is a family run business that operates from a central office in Blyth, Northumberland to provide taxi, private hire, minibus, and coach services across Northumberland, Tyneside and Newcastle. Phoenix, operate around 230 vehicles and was one of the first taxi companies in the UK to offer an electric taxi service, investing £250K and introducing nine Nissan LEAFs into their fleet in 2013. Phoenix now operate only hybrid or electric saloon cars including 15 Nissan Leafs, 4 Teslas, 2 Nissan eNV200s and 150 Toyota Prius, with another 15 40kWh Nissan Leafs in place.

Two main challenges in relation to operating EVs are recognised by Alex Hurst, Managing Director of Phoenix. The first is the charging infrastructure; the company has installed three rapid chargers - two on site and one at Newcastle University with whom they have a partnership. Drivers, typically travelling 75 to 100 miles a day in a mixture of rural and urban driving, do not pay to use these chargepoints, further reducing their running costs. Secondly Phoenix believes that licencing authorities should use their powers to reward operators or drivers running EVs to encourage the adoption of electric taxi and private hire vehicles.

The company appreciate that electric vehicles are more expensive to buy compared to Internal Combustion Engine (ICE) vehicles but emphasises the high quality service offered to customers as well as the vehicles' zero tailpipe emissions. Commitment to the environment is an integral part of the business, but Alex also finds that the Leafs have very low maintenance costs and are very easy to sell second hand, a bonus in a highly competitive industry.

Alex and his colleagues at Phoenix are wholeheartedly supporting the transition to EVs and believe that as well as the competitive advantage these vehicles offer, they also play their part in improving air quality in the North East.

4 Technology chapters

Case study

eConnect cars – GLH

GLH are a private hire, chauffeur drive and courier company established in 1967. GLH became the first private hire company in London to switch its fleet of Ford Mondeos to Toyota Prius hybrids in 2004, saving its drivers around £35 a week in fuel. The company has recently acquired eConnect cars adding 20 Nissan Leafs to its fleet of 380 vehicles. For the moment the Leafs are driving up to 500 miles a week, compared to their hybrid cars which travel about 750 miles over five shifts. Zoe Walsh, Sales and Customer Relations Director at GLH, finds that charging the cars during the day remains a challenge in London as is recruiting drivers who don't suffer from range anxiety, although the experienced Leaf drivers love their cars. The Leafs are frequently allocated for runs to and from Heathrow, as there is a charging infrastructure in place at the airport.

Zoe believes that local authorities could do more to support the use of electric private hire cars and taxis. On street charging for drivers who do not have a driveway and contracts that specify a requirement for operators to use electric cars is important, also a reasonable cost of electricity from rapid charging during the day.

The company is also trialling technology being developed by EV Technology Limited which monitors the cars' battery state of charge and the drivers' driving style to their job allocation software, optimising the use of the cars. Zoe is looking forward to longer range cars being available and a wider choice of vehicles including people carriers so that their electric fleet can grow just as the Prius fleet grew 14 years ago.

Case study

Uber

Following an electric vehicle trial of 50 cars in London in 2016[41], Uber now have over 100 electric vehicle drivers working on their app, 70 of which are London based. The main challenge for drivers participating in the trial was the lack of charging infrastructure; on street charging for those drivers without off street parking, but also a lack of rapid chargepoints for quick recharges in advance of, or during, the working day. As a result of this, at the time of writing, Uber have already installed rapid chargers in 3 central locations in London (Tower Bridge, Chinatown and Knightsbridge) and plan to build further rapid infrastructure in underserved areas where a vast majority of Uber drivers reside. These chargepoints are currently for Uber drivers' use only, but it is planned that they will be opened up to other users once established.

More than 200,000 passengers have travelled more than a million miles in these electric vehicles so far and the company plans to take all non-hybrid cars off the road in London by 2020, operate petrol six seaters and operate only electric vehicles in London by 2025. In the rest of the country this policy will start to be implemented in 2023, with electric vehicles only by 2028. Uber recognise that the cost of the vehicles is a sticking point for drivers and plan to launch a "Clean Air Fund" which will provide drivers with a financial incentive, up to £5,000, to help them adopt the technology.

4 Technology chapters

4.2 Extended range and plug-in hybrid taxi and private hire vehicles

Technology introduction

Extended range electric vehicles (E-REV) and plug-in hybrid electric vehicles (PHEV) have a battery, electric drive motor and a petrol or diesel ICE as in a conventional hybrid, however the battery can be recharged from a chargepoint. Regenerative braking is provided to help increase the battery driving range. The ICE allows the vehicle to be driven for an increased number of miles when the battery is depleted.

Both of these vehicle types are ULEVs and often referred to as plug-in hybrid; however, there are key differences which impact their use:

E-REVs usually have a large battery, similar or identical in storage capacity to an equivalent BEV equivalent. The vehicle's ICE acts as a generator which provides electricity to drive the wheels when the battery is depleted. The wheels are always driven by electricity.

PHEVs usually have a larger battery than a conventional hybrid but smaller than an E-REV. The vehicle can be driven by the ICE, the electric drive motor or both together and will operate as a conventional hybrid when the battery is depleted.

E-REVs and PHEVs emit no tailpipe emissions while driving in ZEC mode (powered solely by the battery), making them a flexible solution with low or zero emissions in an urban environment but with the ability to travel longer distances when the need arises. However, when the ICE is in use, CO_2 and NOx emissions will be similar or in some cases worse than an equivalent petrol or diesel vehicle.

Operational use

- When operated in electric drive mode the vehicles are zero emission and suitable for driving in a predominantly urban, stop-start environment, where they operate most efficiently.
- The vehicles meet the needs of drivers who carry out predominantly urban driving but are often required to undertake longer journeys, such as when a fare originates at a major airport, or when access to rapid charging en-route may not be available or desirable.
- Duty cycles usually include periods of downtime, for example quiet periods of the day, waiting for a passenger or during breaks, so charging events can be incorporated into working patterns as in the case of BEVs.
- Vehicle running costs, in particular electricity, are much lower than for a conventional car, but only when the vehicle is operated in electric drive mode. Operating the vehicles without charging them will result in far higher running costs, at least as much as a petrol or diesel equivalent.
- The vehicles drive like a BEV when in electric drive mode, with a smooth, quiet power delivery. There is a low level of engine noise when the ICE comes into operation in urban driving. At higher vehicle speeds, the ICE in an E-REV operates at a higher engine speed to generate the increased electricity demand of the electric drive motor. In a PHEV the ICE will drive the vehicle through a gearbox
- It will be possible to use geofencing, a technology that ensures the vehicles only operate in ZEC mode in future zero emission zones. This ensures that emissions impacting on air quality are minimised in the areas most prone to road traffic pollution.

Vehicle specification

Taxis
There are no wheelchair accessible PHEVs available in the UK, however where saloon cars are allowed, there are many cars available from a number of manufacturers.

In terms of E-REVs, the Metrocab has undergone testing in London and is expected to be available; however as of April 2018 the vehicle isn't available to order. No detailed technical information is available at this time.

The LEVC TX is on sale and replaces the LTI/LTC TX4 Euro 6 black cab. The new vehicle is a fully accessible, six seat hackney carriage with many features which increase comfort and convenience for both driver and passengers. The vehicle has a 31kWh battery which provides for an NEDC official range of 80.6 miles. The company states that the range in real world operating conditions is around 64 miles. A 1.5 litre petrol engine operates as a range extender to provide a total quoted range of 377 miles. The 40 litre petrol tank therefore provides the flexibility which allows long journeys, to be undertaken without the need for charging.

Private hire vehicles
Only one saloon car E-REV (the BMW i3 Rex) is available. The vehicle has an unusual door mechanism which requires that the corresponding front door has to be opened before the rear passenger door can be opened. This feature, alongside limited boot capacity, makes the vehicle unsuitable as a PHV and is unlikely to be granted a license for the carriage of more than one passenger by licensing authorities.

Table 9. Examples of PHEVs and E-REVs suitable for use as taxi and private hire vehicles

	LEVC TX (WAV) 	Hyundai Ionic 1.6h GDi PiH PHEV 	BMW 530 2.0e SE PHEV 
Battery size (kWh)	31	8.9	9.2
NEDC electric range (miles)	81	39	29
Estimated real world range (miles)	64	31	23
CO_2 g/km (tailpipe, NEDC)	29	26	46
PICG/PITG category	1	2	2
No. of passenger seats	6	4	4

Available models

A wide range and growing number of PHEVs are available, in addition to those in the Table 10, examples in include:
- Audi A3 1.4TFSi PiH e-tron
- BMW 225xe Active Tourer, 330saloon 2.0ePHEV, 740 2.0e PHEV
- Kia Niro 1.6GDi PHEV, Optima saloon and estate 2.0h GDI
- Mercedes C350e 2.0 PiH saloon and estate, E 350e 2.0 PiH saloon and estate
- Toyota Prius PiH
- VW Golf 1.4 TSi PiH, Passat 1.4 TSi PiH saloon and estate
- Volvo V60 PiH 2.4 D6 (Diesel PHEV), S90 PiH 2.0 saloon and V90 PiH 2.0 Estate

4 Technology chapters

Charging Infrastructure

For further details, see the BEV section on page 26.
It is important to be noted that with a few noticeable exceptions such as the Mitsubishi Outlander, the majority of PHEVs are not capable of rapid charging. Though they can use the chargepoints, the power will be limited by the vehicles internal charger. Many rapid charging networks will discourage PHEVs using their infrastructure as it reduces the availability for BEV drivers who can fully utilise the chargepoints. The LEVC TX is also capable of rapid charging.

Table 10. PHEVs - fuel and VED cost comparisons

	LEVC TX 	LTI/LTC TX4 	Hyundai Ionic 1.6h GDi Premium PHEV 	Ford Mondeo 2.0 TDCi 180 T Ed 
Fuel cost (4 yrs)	£10,852	£24,376	£10,380	£12,888
VED cost (4 yrs)	£390	£3,110	£390	£625
Total cost	£11,242	£27,486	£10,770	£13,513
Pence per mile	9.4	22.9	9.0	11.3
CO_2 g/km (tailpipe, NEDC)	29	222	26	119
Vehicle price (OTR)	£55,599*	£45,955	£25,345**	£26,440

* Including Category 1 OLEV grant ** Including Category 2 OLEV grant

Financial information

Vehicle running costs when driving in electricity mode are lower than for a petrol or diesel vehicle. E-REVs and PHEVs are only cost efficient when running in full electric mode, otherwise they can be more expensive to run than a conventional petrol, diesel or hybrid, particularly on higher speed motorway journeys. Some elements of the engine associated maintenance costs, such as brakes, should last longer than in a petrol or diesel due to regenerative braking and the fact that the engine runs for less time overall. As with BEVs, charging at home or at an operator's premises is likely to be the lowest cost option.

The reduction in fuel and VED costs for the new LEVC TX compared with the LTI/LTC TX4 is a powerful argument and that the trade should consider the WLCs for this vehicle. After the PITG the list price is around £10,000 higher but this has been more than compensated after four years as can be seen in this example. Comparing Hyundai and Ford examples demonstrates the savings that can be made by moving to a "best in class" PHEV vehicle.
If the Hyundai was driven for a higher proportion of time using electric propulsion, this would result in an even greater saving [see Assumptions section in Appendix about share of miles driven in electric mode during a shift].

Case study

EV TECHNOLOGY

EV Technology
With the continued roll-out of hardware, from EVs to charging posts, the market is now starting to see the emergence of service based companies offering products that will help accelerate the adoption of this new technology. Such products and services are seeking to make it as easy for consumers to use electric cars as it is to use the traditional diesel and petrol variants.

One such company is EV Technology which has developed data algorithm and telematic devices adopted for the EV market to provide vehicle operators with real time insights. The company already has data from over 250,000 kms of recorded EV driving, and this is being used to constantly improve the understanding of EV range and battery utilisation, based on numerous parameters including driver behaviour, route selection, topography, weather conditions, etc. By integrating this data with charging infrastructure location and utilisation, fleets can drive improvements in their key performance indicators.

Outputs from EV Technology systems can be integrated with existing booking and dispatch systems via Application Programming Interfaces (APIs) to enable the auto-dispatch capabilities of modern systems to work with EVs. The provision of tools and products from companies like EV Technology are expected to be critical to the adoption of EVs by taxi fleets, especially in large cities and areas where relevant charging infrastructure is limited.

4 Technology chapters

4.3 Hydrogen fuel cell taxi and private hire vehicles

Technology introduction

Fuel cell electric vehicles (FCEV) use hydrogen as a fuel. The hydrogen reacts with oxygen from the atmosphere in a fuel cell, generating electricity to drive the vehicle. A battery stores energy from regenerative braking, improving efficiency and provides instantaneous power for acceleration. Combining hydrogen and oxygen in the fuel cell produces water which is the only waste product and therefore zero emission at the tailpipe. In terms of CO_2 emissions associated with hydrogen production, this is highly dependant on the method of manufacturing hydrogen gas. CO_2 emissions can be lower or higher than diesel and by generating renewable hydrogen greatly reduces production related CO_2 emissions.

Operational use

- FCEVs currently have a driving range of 300 miles or more that enables them to easily drive a typical TPH shift. The vehicles can be refuelled in three to five minutes at a hydrogen refuelling station and the process is straightforward and not unlike fuelling with LPG.
- FCEVs use an electric motor for propulsion and are therefore quiet and smooth in operation, making them comfortable for both driver and passengers.
- Limited refuelling infrastructure and expensive vehicles in limited supply mean the technology isn't ready for wide scale deployment in the taxi and private hire industry.

Vehicle specification

Taxis

Only three models are available in the UK in limited numbers. It is a niche market with vehicles currently in use being funded through OLEV trials. All are ULEVs.

Private hire vehicles

The saloon models would be suitable for use in the private hire trade, in an "executive" car capacity, Green Tomato cars in London are using the cars successfully in this role.

Available models

The models available are the Toyota Mirai, Honda Clarity FCV and the Hyundai iX35. The Toyota and the Honda are large saloon cars and the Hyundai a crossover.

Hydrogen infrastructure

As of early 2018 there are 13 publicly accessible hydrogen filling stations in the UK and the network is expanding. Shell are adding hydrogen refuelling to a small number of stations in partnership with ITM Power. Charging infrastructure information provider Zap map provides a list of available FCEV refuelling stations.

In March 2017 the Government launched a £23 million funding scheme to accelerate the uptake of hydrogen-powered vehicles and infrastructure.

Refuelling a FCEV is almost as simple and quick as using a petrol pump. The driver attaches the refuelling station's nozzle to the car which locks it in place creating a sealed system.

Financial information

The technology has been in development for many years; currently the cost of certain components means that vehicles are expensive. However, costs, particularly the fuel cell, are falling and it has been reported that Toyota plans to reduce the cost of the key components of a new model on sale around 2020 by half and by a further three-quarters by 2025. The cost of hydrogen is also high at £9-£10/kg; the fuel cost per mile is therefore equivalent to a petrol or diesel car achieving around 35 mpg.

With the current high cost of the vehicles and the fuel, the technology is unlikely to be adopted across the taxi and private hire industry in the short term; however, as costs fall this could change in the next few years. The WLC of FCEVs is not favourable for TPH operators at the moment, however trials in progress in the trade and in wider commercial use are investigating actual operating costs, including the leasing of vehicles.

Case study

Green tomato cars

Green Tomato Cars are recognised for introducing the Toyota Prius into the private hire industry over ten years ago and this model still accounts for 80% of their cars to date. Where larger cars are required, a number of Mercedes E class plug-in hybrids and diesel powered VW CCs, VW Sharans and Ford Tourneos are operated, but a "no diesel" purchase policy is currently being implemented, with the removal of all diesels to be achieved by the end of 2018.

The company's innovative approach to vehicle technology continues in the shape of two Toyota Mirai Fuel Cell Electric Vehicles on trial in London. These cars are fuelled by Hydrogen and can travel around 300 miles between refills, potentially every other day, based on the 100 to 150 miles they travel each day. There are five hydrogen refuelling stations in the London area which provide refuelling in the same speed as for conventional petrol or diesel cars, and the vehicles themselves are proving extremely popular with both customers and their drivers.

Green Tomato Cars acknowledge that the refuelling costs and the current high cost of the FCEVs make their use across the fleet uneconomical at the moment without funding support. However, in view of support from the European Fuel Cells and Hydrogen Joint Undertaking (FCH-JU's) ZEFER programme and OLEV in the UK[42], the company expects to take on 50 Mirai to replace their fleet of VW CCs this year, as their self-imposed diesel ban comes into effect. It's clear that Green Tomato Cars see hydrogen FCEVs as an important technology alongside electric cars as they work towards their goal of being a zero tailpipe emission fleet by 2023.

4 Technology chapters

4.4 Petrol, diesel and hybrid electric taxi and private hire vehicles

Technology introduction

Petrol, diesel and hybrid electric vehicles (HEV)

It is appreciated that there are areas where the trade would struggle to afford BEVs, E-REVs and PHEVs. Encouraging the use of "best in class" CO_2 emission petrol, diesel and hybrid vehicles, which comply with the LEV emission standards proposed in this guide, can help reduce emissions and benefit drivers through lower running costs.

A HEV has a petrol or diesel ICE, a battery used to store energy recovered through regenerative braking and an electric motor. The wheels can be driven by the ICE, the electric motor or both together. The electric motor is used to accelerate the vehicle from standstill or power it altogether for short distances (up to a mile) at low speed. The harvesting of energy which would usually be lost as heat when braking and using it to drive the vehicle means that HEVs are particularly fuel efficient in urban driving conditions. Additionally, the engine always stops when the vehicle is at rest; these features combined make them a fuel efficient choice particularly in urban driving conditions. HEV are therefore beneficial in reducing both air pollution and CO_2 emissions.

Operational use

- There is a large choice of new petrol, diesel and hybrid vehicles, choosing "best in class" models for CO_2 emissions will reduce drivers' fuel bills.
- If opportunities are limited for the trade to adopt newer, cleaner technologies; petrol hybrids (minimum Euro 4) will reduce emissions and fuel costs particularly in urban driving conditions.
- Petrol, diesel and hybrid vehicles are better suited to longer distance journeys than electric vehicles, for example airport runs in many parts of the country feature long motorway journeys.
- HEVs operate for short distances (usually no more than a mile) in electric drive (zero emission) mode and are particularly suitable for and fuel efficient when driving in a predominantly urban, stop-start environment.
- HEVs operate for short periods without the engine running and the engine always stops when the car is at rest. This makes for a relaxing drive for the driver and passenger in stop start driving conditions.

Vehicle specification

Taxis

Diesel taxis are by far the most common, particularly when fully accessible vehicles are required by a licensing authority. The LTI/LTC TX models has only been available with a diesel engine until the launch of the LEVC TX model and the base vehicles used for competitors' models are also diesel powered. The majority of the smaller rear access WAVs and many saloon cars, particularly outside London, are diesel powered as well. Where saloon cars are licenced as a taxis a wide range of HEVs are available.

Private hire vehicles

Diesel is the most common technology in use in the private hire industry. Licensing authorities should encourage the use of best in class models, which includes hybrid for saloon models, however there are currently no larger multi-seat hybrids on the UK market. The Toyota Prius is very popular with drivers in many areas and larger hybrid models are in use in the chauffer drive sector.

Available models

There are several full size and smaller (rear access) WAVs on the market. It is important that the trade is encouraged to adopt Euro 6 diesel and the fuel economy and CO_2 emissions of the vehicles should be borne in mind when the best in class vehicles are being selected. For larger multi-seat vehicles in use in the private hire industry, best in class diesel should be the preferred option in the absence of HEV technologies in this sector.

Where taxi conditions of fitness allow saloon cars for the private hire industry, a wide range of diesel and petrol cars are available. Similar models, even from the same manufacturer, can have significantly different fuel economy and CO_2 emissions. A best in class approach can significantly reduce emissions and fuel consumption of vehicles in these sectors. The choice of vehicles also includes HEVs. The Toyota Prius and larger (occasional 7 seat) Prius + are the most established model in the industry, however other petrol HEVs include the Ford Mondeo 2.0HEV saloon, Hyundai Ionic 1.6hGDI hatchback, Lexus CT 200 hatchback and Lexus IS 300. Larger and premium brand cars include the Mercedes C300 diesel hybrid saloon and estate models, the Lexus LS 500 saloon, Infiniti Q50 and Q70 saloons.

Table 11. Examples of best in class and HEVs models for use as taxi and private hire vehicles

	KIA CEE'D 1.6 CRDi 2 	Toyota Prius 1.8VVT-h Active HEV 	VW Passat Estate 1.6TDi S 	Mercedes C300 AMG Estate HEV 
Fuel	Diesel	Petrol/Electric	Diesel	Diesel/Electric
CO_2g/km(tailpipe, NEDC)	99	78	107	104
mpg (NEDC)	74.3	83.1	68.9	68.9
No. of passenger seats	4	4	4	4

Financial Information

Choosing best in class diesel models can significantly reduce vehicle running costs and HEVs can reduce costs further, particularly in urban driving when the hybrid system improves overall fuel efficiency. Aspects of vehicle maintenance should also be lower, for example, brake wear is reduced due to regenerative braking.

Table 12. Best in class petrol, diesel, HEV-fuel and VED cost comparisons

	KIA CEE'D 1.6 CRDi 2 	Toyota Prius 1.8VVT-h Active HEV 	VW Passat Estate 1.6TDi S 	Mercedes C300 AMG Estate HEV 
Fuel cost (4yrs)	£10,892	£9,508	£11,784	£11,784
VED cost (4yrs)	£565	£485	£585	£1,455
Total cost	£11,457	£9,993	£12,369	£13,239
Pence per mile	9.5	8.3	10.3	11.0
CO_2 g/km (tailpipe, NEDC)	99	78	107	104
Vehicle price (OTR)	£19,740	£24,245	£25,605	£41,475

When the lowest emission and therefore most fuel efficient vehicles are selected there is little difference in the overall fuel and VED costs, except in this instance for the Mercedes diesel hybrid estate which has a list price of over £40,000 and is therefore subject to the diesel supplement for cars over this price.

4 Technology chapters

4.5 Liquefied petroleum gas taxi and private hire vehicles

Technology introduction

LPG has been in use as a transport fuel for many years. LPG produces less CO_2 per litre burnt than diesel, and vehicles running on LPG emit significantly lower levels of NO_x and PM compared with a diesel vehicle.

BioLPG is produced from wastes, residues and renewable vegetable oils and has recently been made available in the UK. It can be blended and used for all existing LPG applications reducing lifecycle CO_2 emissions by up to 80%.

The use of LPG as a fuel for the TPH industry should be considered in two parts:

Black taxi repowering

This involves replacing the diesel engine in a TX series black taxi with a new petrol engine, converted to run on LPG and achieving the Euro 6 emission standard. This solution is especially useful for cleaning up older diesel taxis.

Taxi/private hire vehicle conversion

This involves the conversion of a petrol engine car to run on LPG. It is important to note that the Euro emissions standard of converted vehicle will not be changed, therefore vehicles will have to be Euro 4 before conversion to comply with charging CAZ Framework criteria.

Operational use

- LPG vehicles, whether repowering or conversions, can be operated just as normal petrol or diesel vehicles; the only inconvenience is that not all petrol stations sell LPG.

- Both TX taxis repowering and car conversions retain a petrol tank so the vehicle can be driven on petrol as a reserve fuel if LPG refuelling is not available. However, due to the lower fuel duty on LPG, fuel costs will be almost twice as high running on petrol instead of LPG, it is important that drivers are aware of this.

Vehicle specification

Taxis

A repowering technology (GasCab) for the TX1, TX2 and TX4 taxi is available which involves replacing the diesel engine with a petrol engine adapted to run on LPG. The conversion when applied to the TX2 and TX4 has been authorised for use by TfL. These vehicles are granted a five-year extension to the London age limit of 15 years. In addition to London, the cities of Birmingham, Edinburgh and Glasgow have also approved the use of LPG repowering technology by TX drivers. The LPG repowering technology has been approved by CVRAS, and Vehicle Repowering Solutions (VRS) the company supplying the technology is currently going through the CVRAS accreditation process. The CVRAS[14] website shows a list of certified companies and technologies.

The GasCab repowering technology comprises of a 2.0L Turbo Ecotec Opel engine adapted for running on LPG by Kronenburg Management Systems (KMS). The KMS engine control unit (ECU) is optimised to work with a Vogels LPG system to achieve optimal power and emissions performance. The engine is mapped to follow the original diesel power output as closely as possible and produces 80 – 100 HP depending on the diesel engine being replaced. The original output of the engine is 280HP (as installed in the Vauxhall Astra VXR) therefore it is operating well within its limitations which should mean a long service life. The original fuel tank is replaced by a 100 litre LPG tank and a 12 litre petrol tank for cold starting and as a reserve.

Where saloon cars are licensed as taxis, many petrol engine cars are suitable for conversion. A gas injection system, a controller and a pressurised LPG tank is fitted to the vehicle. The tank is often located in the spare wheel well. A network of converters across the country is approved by UKLPG, to ensure safe and satisfactory conversions; their consumer website DriveLPG has further details.

Private hire vehicles

An approved LPG installer should be used for Euro 4,5 and 6 petrol or hybrid car conversions. In addition the DriveLPG website enables used car buyers to check, by typing in the registration number, if a vehicle they are proposing to buy is on the UKLPG register. This means it has been converted and inspected by an approved converter on the UKLPG scheme.

4 Technology chapters

Available models

In terms of the repowering solution, one WAV is available based on the TX series of taxis. In addition many Euro 4,5 & 6 petrol and hybrid cars are also suitable for LPG retrofit conversion.

LPG infrastructure

There are over 1,300 outlets selling LPG across the UK. For locations of LPG refuelling points in the UK view the DriveLPG refuelling map[43]. Autogas Ltd, the country's largest supplier of automotive LPG, has a search function for their refuelling sites on their website.

Refuelling at an LPG pump is straightforward; the refuelling nozzle is locked into place to create a sealed pressurised system. Refuelling takes around the same time as refuelling with petrol or diesel.

Financial information

Running vehicles on LPG enables drivers to benefit from the lower rate of fuel duty applied to LPG making it almost half the cost of petrol or diesel. When petrol cars are converted, fuel consumption usually increases and drivers should expect an engine to use around 20% more fuel when running on LPG. Overall, fuel costs can be up to 40% lower than for an equivalent petrol car and slightly lower than an equivalent diesel.

LPG conversions on petrol saloon cars are usually in the region of £1,500 to £2,000 -, this cost would be borne by the driver or operator. There is a small increase in maintenance costs as a "gas service" is required periodically.

The cost of the repowering technology on the TX diesel taxi is between £9,800 and £10,800 ex VAT, dependant on model and options on the vehicle. i.e. air conditioning. The CVRAS accreditation may mean that funds become available to support taxi operators repowering their vehicles[44]. A comparison of fuel and VED costs for a diesel TX4 and a TX4 repowered LPG vehicle for four years is shown below.

Table 13. LTC TX4, LTI/LTC TX Repower LPG - fuel and VED cost comparisons

	LTC TX4 Diesel 	LTC TX4 Repowered LPG 
Fuel cost (4 yrs)	£24,376	£18,985
VED cost (4 yrs)	£1,260	£1,260
Total cost	£25,636	£20,245
Pence per mile	21.4	16.9
CO_2 g/km (tailpipe, NEDC)	222	c.203*

*estimated from fuel consumption **conversion price incl' VAT for TX4

It can be seen in the table above a significant fuel saving comes from the lower cost of LPG even though the fuel consumption is somewhat higher than the diesel (27.4 mpg diesel, 17-18 mpg LPG). Over 4 years, the running costs for the repowered vehicle are reduced by more than £5,000 in comparison with a diesel TX4.

Case study

Birmingham City Council

Birmingham City Council

In September 2014, Birmingham City Council (BCC) received £500,000 from DfT's Clean Vehicle Retrofit Technology fund to repower 65 diesel TX1 and TX2 black taxis with petrol engines using LPG. The work is part of BCC's NO_x Reduction Champion project, a partnership between approved converter Harborne Garage in Selly Oak, engine manufacturer Kronenberg Management Systems (KMS), European LPG conversion kit experts Vogels Autogas Systems and BCC. The partnership is further supported through collaboration with LPG supplier Autogas Ltd.

There are approximately 1,200 taxis and 4,000 private hire vehicles licensed by BCC. Birmingham has an ageing fleet of taxis that means the provision of cleaner vehicle in the city is a priority for BCC addressing air quality, whilst delivering CAZ compliant taxi fleet.

The repowering technology cost around £9,000+VAT. Drivers were only required to pay the associated VAT, the repowering was covered by DfT fund. The participating Birmingham drivers have driven more than 80,000 miles to date and feedback has been very positive with 97% stating they would recommend the conversion to other drivers

Vehicle emission testing demonstrated the repowered TX1 and TX2 black cabs running on LPG emitted 80% less NOx emissions (post conversion) compared with a diesel powered version. The repowered taxis achieved the Euro 6 petrol emission limits for PM and NO_x. In addition, a 7% reduction in CO_2 was also achieved.

As a result of the success of this project, BCC have submitted an application for Clean Air Zone funding to run a larger LPG taxi retrofit programme.

Appendix 1 – Assumptions

A list of assumptions used throughout the document are described below:

1. The electricity cost figures are derived from EST's database and are based on average costs over the previous 12 months[45]. Electricity costs are assumed to be domestic.

Electricity costs	14.33p/kWh (unit)

2. Fuel and LPG cost figures are derived from the Automobile Association's (AA) March 2018 report[46].

Fuel cost	
Petrol	119.7 p/litre
Diesel	122.6 p/litre
LPG	60.4 p/litre

3. The vehicle price used in the fuel and VED cost comparison tables is the On-the-road price (OTR) which is the car's list price and includes the additional costs of first registration fee, delivery fees, number plates and first year's road tax. OTR prices were derived from vehicle manufacturers websites in March/April 2018. GasCab prices were derived from VRS in April 2018. Vehicle prices are subject to changes and readers should contact vehicle manufacturers/dealers for current prices.
4. The vehicle cost calculations are done based on a TPH vehicle that does 30,000 miles per year over a period of four years.
5. The NEDC electric range figure is quoted in the guide unless it is otherwise stated. The NEDC is adjusted by a 21% uplift in fuel consumption for ICE vehicles and electricity for EVs to reflect the estimated real world range. This adjustment aligns with EST's methodology for calculating fleet CO_2 emissions.
6. CO_2 emissions quoted in the guide are NEDC tailpipe emissions (g/km).
7. For PHEVs the battery depleted fuel consumption is sourced from Comcar, using the liquid fuel consumption calculated from the official NEDC figures (subject to rounding) with a 21% uplift to reflect more closely real world driving.
8. In calculating fuel costs for PHEVs and E-REVs it is assumed a PHEV is driven by electric propulsion for 20% of a shift and there is no recharging after starting the shift with a full battery. An LEVC TX(E-REV) is assumed to be driven by electric propulsion for 80% of a shift. starting the shift with full battery.

Appendix 2 – Further information

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[9]HM Government, Deregulation Act 2015

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[13]Motorcycles and mopeds are not routinely included under any category. Local authorities may choose to include them under class D

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