Lowering your emissions through innovation in transport and energy infrastructure

PROJECT

REPORT

Fleet Management Strategy

North West Leicestershire District Council

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Document Revisions

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1	Initial release, for Cenex review	21/06/2021
2	Cenex peer review	22/06/2021
3	NWLDC Feedback	02/07/2021
4	Final Report	08/07/2021

Contents

Abbreviations

BEV	Battery Electric Vehicle
CH_4	Methane
CI	Compression Ignition
CNG	Compressed Natural Gas
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
DF	Dual Fuel
DNO	Distribution Network Operator
FAME	Fatty Acid Methyl Ester
FC REEV	Fuel Cell Range Extended Electric Vehicle
FCEV	Fuel Cell Electric Vehicle
GVW	Gross Vehicle Weight
GWP	Global Warming Potential
HGV	Heavy Goods Vehicle
HRS	Hydrogen Refuelling Station
HVO	Hydrotreated Vegetable Oil
ICE	Internal Combustion Engine
LCV	Light Commercial Vehicle
LEV	Low Emission Vehicle
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
MPV	Multi-Purpose Vehicle
N_2O	Nitrous Oxide
NO	Nitric Oxide
NO_2	Nitrogen Dioxide
NOx	Oxides of Nitrogen
PHEV	Plug-in Hybrid Electric Vehicle
PM	Particulate Matter
PTO	Power Take-Off
RCV	Refuse Collection Vehicle
REEV	Range Extended Electric Vehicle
RRV	Resource Recovery Vehicle
RTFO	Renewable Transport Fuel Obligation
SI	Spark Ignition
TCO	Total Cost of Ownership
TTW	Tank-to-Wheel
ULEV	Ultra-Low Emission Vehicle
WTW	Well-to-Wheel
ZEV	Zero Tailpipe Emission Vehicle

1. Executive Summary

Introduction

North West Leicestershire District Council (NWLDC) commissioned Cenex to undertake the development of a fleet management strategy, roadmap, and action plan with the overall aim of transitioning their existing Council fleet to a zero carbon/low carbon solution by 2030, along with the identification of the infrastructure requirements to support this transformation.

The NWLDC fleet has several components and is made up of around 114 vehicles and is a mix of refuse collection vehicles (RCVs), parks maintenance vehicles, medium sized panel vans and smaller vehicles alongside more specialist equipment, such as sweepers and mowers. The predominant users are Waste Services, which also manages the whole fleet and the in-house workshop, along with the Housing Team which has a home-based fleet of large panel vans.

The NWLDC fleet is diverse, with a wide variety of vehicles in use across multiple operational requirements. With such a wide range of vehicles in operation, NWLDC should accept that there is, at this time, unlikely to be a single technological solution that will enable their fleet operations to achieve zero emissions by 2030. This may result in a mix of technologies being utilised across the fleet depending on vehicle category and operational requirements.

Methodology

This analysis contained within this report is based on fleet operational and performance data supplied by NWLDC, supplemented by independent vehicle ownership cost data, vehicle fuel consumption values, and low emission vehicle energy consumption factors. These energy consumption factors are based on real-world (e.g. chassis dynamometer, test track or in-use) testing of low emission vehicles managed by Cenex or partners (e.g. Emissions Analytics, Zemo partnership) during commercial and research projects. Such vehicle tests are deemed independent as they do not involve vehicle manufacturers as part of the testing team, except as a source of the vehicles. Low emission vehicle data and any associated assumptions have been verified by industry working groups including fleet operators and trade associations. The fleet review was delivered through the following steps which commenced upon receipt of initial fleet data following a project initiation meeting delivered via a web conference.

- Summary of Current Fleet: using the data provided Cenex categorised individual vehicles into relevant operational vehicle segments before baselining the current fleet composition, operations, and emissions profile. Non-operational vehicles were included within the Specialist Fleet Review.
- Low Emission Vehicle Technology Options: an initial screening of low emission vehicle technologies based on current UK vehicle availability and supplier/ market maturity.
- Low Emission Vehicle Technology Selection: input of key fleet parameters such as annual mileage, fuel economy and ownership period into an in-house spreadsheet model to assess the suitability of low emission vehicle technologies against each individual vehicle and selection of the most suitable technologies based on two implementation scenarios – maximum emissions savings (at any cost) and total cost of ownership parity (or better) within each vehicle segment.
- Low Emission Vehicle Infrastructure Review: a high-level assessment to identify the required type, location, and indicative capital and installation costs of any required infrastructure.
- Recommended Replacement Vehicle Technologies: based on the results of the fleet review, Cenex has highlighted those vehicles which could theoretically be replaced by low emission vehicle technologies with minimal changes to the fleet's current operating patterns and planned ownership periods. A final technology selection has been applied based primarily on wider operational suitability, low emission vehicle maturity and viability of infrastructure.
- Implementation Recommendations and Next Steps: a summary of the recommended next steps for NWLDC to take to implement the recommended replacement vehicles.

Summary of Current Fleet

The NWLDC operational fleet numbers around 100 vehicles, dominated by light commercial vehicles (LCVs) less than 3.5t gross vehicle weight (GVW) with medium vans the largest vehicle segment (48% of the fleet). The remainder of the fleet consists mainly of heavy goods vehicles, dominated by 3 axle rigid trucks (16% of the fleet). 14 non-operational vehicles (e.g. tractors and mowers) were removed from this review and are included within a separate Specialist Fleet review.

		Number of Vehicles	Percentage of Total Fleet	% Contribution to Total WTW CO_2e Emissions	% Contribution to Total NO_X Emissions	% Contribution to Total PM Emissions
Car	**Small Car**	4	4%	1%	3%	1%
LCV	**Large Commercial SUV**	2	2%	1%	3%	0%
	Small Van	7	7%	1%	6%	3%
	Medium Van	48	48%	20%	60%	69%
	Large Van (< 3.5t GVW)	11	11%	5%	10%	2%
HGV	**Large Van (> 3.5t GVW)**	1	1%	0%	0%	0%
	Rigid Truck - 2 axles (7.5t GVW)	4	4%	3%	0%	1%
	Rigid Truck - 2 axles (18t GVW)	7	7%	15%	1%	2%
	Rigid Truck - 3 axles (26t GVW)	16	16%	54%	16%	22%
	Total	**100**	**100%**	**1,130 tonnes**	**1,100 kg**	**10 kg**

The medium van segment (accounting for 48% of the total fleet) produces the highest proportion of air quality emissions on the fleet, amounting to 60% and 69% of NO_X and PM emissions respectively. The high NO_X and PM emissions are impacted by the large proportion of Euro 4 diesel vehicles currently in operation within this van segment.

However, the Rigid Truck – 3 axles (26t GVW) segment contributes 54% of CO_2e emissions despite only accounting for 16% of the total fleet. This is a result of the high fuel consumption of these vehicles and associated high energy usage due to the use of bin lifts and compaction units.

Recommended Replacement Vehicles (TCO Parity with HVO)

Across the NWLDC fleet, there are opportunities to introduce battery electric vehicles (BEV) within the small car, small van, and particularly the medium van vehicle segments.

The table below shows a summary of the recommended replacement vehicles, with a focus on the deployment of BEV vehicles were identified as suitable and utilising Hydrotreated Vegetable Oil (HVO), a renewable diesel that is a 'drop-in' replacement for fossil diesel, across the remaining fleet vehicles.

In terms of number of vehicles, capital and revenue costs, and emissions savings. All values are compared to the procurement of a new Euro 6/ VI diesel vehicle excluding VAT. All costs are represented as a difference to an equivalent diesel vehicle where **positive values** are higher than the equivalent vehicle and **negative values** are lower than the equivalent vehicle. This is further highlighted by the use of **red** and **green** text across both tables.

Introducing 54 BEVs (55% of the fleet) would require additional capital of **£420,000** for vehicles and **£82,000** for electric vehicle charging infrastructure (hardware and installation costs only). These vehicles could provide total cost of ownership (TCO) savings of **£37,000** whilst reducing fleet well to wheel (WTW) CO_2e emissions by **16%** and fleet air quality pollutant emissions up to **60%** in NOx and **35%** in PM.

Fuelling the remaining fleet vehicles with HVO would lead to an increase in running costs of **£420,000** over the 7-year vehicle ownership period. Whilst HVO increases running costs and thus TCO, WTW CO_2e savings of **68%** of the fleet emissions can be achieved. As HVO uses the same engine as a diesel vehicle, there are no guaranteed air quality savings; only BEVs contribute to air quality pollutant emissions reductions.

Over all this scenario equates to a potential increase of **£4,700** per vehicle or £670/ vehicle per year for an **84%** reduction in fleet WTW greenhouse gas emissions.

	Small Car	Small Van	Medium Van	Small Van	Large Van	Rigid Truck	Large 4x4	Total
Replacement Technology	BEV (OEM)			HVO				
Number of Vehicles	4	2	48	5	12	26	2	**99**
% of vehicle segment	100%	29%	100%	71%	100%	100%	100%	**100%**
Additional Capital Cost (£)	£32,000	£12,300	£375,400	£0	£0	£0	£0	**£419,700**
Difference in Running Costs (£)	-£19,900	-£11,800	-£380,500	£3,500	£26,600	£385,400	£4,500	**£7,700**
Difference in Residual Values (£)	£12,600	£1,100	£31,100	£0	£0	£0	£0	**£44,800**
Difference in TCO (£)	£500	£600	£36,200	-£3,500	-£26,600	-£385,400	-£4,500	**-£382,600**
Ownership Period (years)	7	7	7	7	7	7	7	**7**
% of Fleet TTW CO_2 Savings	1%	1%	20%	0%	5%	67%	1%	**95%**
% of Fleet WTW CO_2 Savings	1%	1%	15%	0%	4%	62%	1%	**84%**
% of Fleet NOx Savings	3%	2%	55%	0%	0%	0%	0%	**62%**
% of Fleet PM Savings	3%	1%	31%	0%	0%	0%	0%	**36%**
Number of 7 kW Chargepoints	0	0	43	0	0	0	0	**43**
Number of 22 kW Chargepoints	4	2	5	0	0	0	0	**16**
Number of 50 kW Chargepoints	0	0	0	0	0	0	0	**0**
Infrastructure Capital Cost	£14,200	£7,100	£60,800	£0	£0	£0	£0	**£82,100**

The total column in the above table highlights the total saving that can be achieved, or cost increases resulting from adopting the recommended vehicles. In the case of TCO, while there are TCO savings available through the adoption of electric vehicles, these are outweighed by the increased costs associated with operating the remaining fleet on HVO.

The above costs for cars and LCVs (e.g. capital costs, residual values, TCO) have been derived from industry standard information readily available from Fleet News and Commercial Motor. All costs are based on the average of the top three bestselling models from each vehicle segment, where information is available.

The calculated infrastructure costs are based on the installation of 7 kW chargepoints at all relevant home locations and depot based dual socket 22 kW chargepoints, assuming that no grid upgrades are required.

Recommended Replacement Vehicle Schedule (TCO Parity with HVO)

The Recommended Replacement Vehicle Schedule presented below can be considered an outline action plan for the deployment of BEV and HVO across the NWLDC fleet. However, this plan assumes that NWLDC can readily purchase or lease the relevant vehicle models and specifications required for their operational requirements. The impacts of potential vehicle delivery lead times has not been accounted for as this can differ greatly from manufacturer to manufacturer. Similarly, the impact of any potential delays in deploying the relevant charging infrastructure has not been accounted for.

It will be essential that NWLDC discuss their vehicle and infrastructure needs with relevant vehicle and chargepoint suppliers to gain a clear understanding of the likely timeline for delivery/ installation. This will enable a more accurate vehicle and infrastructure deployment plan can be generated.

	Financial Year									
	2021/22	2022/23	2023/24	2024/25	2025/26	2026/27	2027/28	2028/29	2029/30	2030/31
Small Car (BEV)	3	1	0	0	0	0	0	0	0	0
Large Commercial SUV (HVO)	1	1	0	0	0	0	0	0	0	0
Small Van (BEV and HVO)	5	1	0	0	1	0	0	0	0	0
Medium Van (BEV)	26	2	7	0	13	0	0	0	0	0
Large Van (HVO)	9	1	1	0	0	0	0	0	0	0
Large Van (> 3.5t GVW) (HVO)	0	0	0	0	1	0	0	0	0	0
Rigid Truck - 2 axles (7.5t GVW) (HVO)	0	0	1	0	2	0	0	0	0	0
Rigid Truck - 2 axles (18t GVW) (HVO)	0	0	0	5	1	1	0	0	0	0
Rigid Truck - 3 axles (26t GVW) (HVO)	9	1	2	0	4	0	0	0	0	0
Vehicle Replacements	53	7	11	5	22	1	0	0	0	0
Cumulative % of Fleet Replaced by LEV	54%	61%	72%	77%	99%	100%	100%	100%	100%	100%
Additional Vehicle Capital Costs (£)	£227,345	£29,823	£54,740	£0	£107,835	£0	£0	£0	£0	£0
Infrastructure Cost (£)	£41,757	£14,205	£9,551	£0	£16,551	£0	£0	£0	£0	£0
Annual Running Cost Savings (£)	£5,211	£4,271	£5,439	-£2,936	£633	-£1,094	-£1,094	-£1,094	-£1,094	-£1,094
Annual TTW CO_2 Savings (tonnes)	411.8	465.2	565.7	660.0	849.8	869.3	869.3	869.3	869.3	869.3
Annual WTW CO_2 Savings (tonnes)	446.1	508.3	617.2	725.7	929.2	951.5	951.5	951.5	951.5	951.5
Annual NOx Savings (kg)	103.3	112.6	136.6	136.6	194.1	194.1	194.1	194.1	194.1	194.1
Annual PM Savings (kg)	0.5	0.5	0.6	0.6	0.8	0.8	0.8	0.8	0.8	0.8

There is a need for the immediate replacement of some 53 vehicles (54% of the fleet) which are at the end of their current ownership cycle (predominantly medium vans and 3 axle 26t GVW rigid trucks). The replacement of these vehicles will need to be carefully managed as it entails significant capital costs for both vehicle and infrastructure. However, the staged replacement of these vehicles will enable NWLDC to make immediate gains on their decarbonisation plans.

Most of the recommended replacement vehicles are medium vans which are due to be replaced during FY2021/2022 to FY2025/2026. By this date 99% of the entire fleet could be replaced by BEVs and HVO fuelled vehicles.

Other low emission vehicle technologies, such as bio-CNG, dual fuel hydrogen and hydrogen fuel cell electric, are currently economically challenging for the remainder of the fleet. This is mainly due to the high initial vehicle purchase costs and low market maturity combined with low annual mileages which limit the opportunities for running cost savings.

Implementation Recommendations and Next Steps

The recommendations in this section are of most relevance over the next five years with any occurring after these timescales considered closer to an outline strategy to 2030.

1. **Implement battery electric cars and light commercial vehicles (i.e. small cars and small and medium vans) along with the associated electric vehicle charging infrastructure** according to the current vehicle replacement schedule, if not sooner.
    a. Confirm which specific vehicle models meet the required operational specifications in terms of payload, towing capacity and minimum viable battery capacity required to meet day to day mileage variation. For a given vehicle model this is a trade-off between cost, payload, and range (smaller batteries = lower cost, higher payload, and lower operating range). It should be recognised that the analysis in this report has been based on average daily mileage and does not include the impact of additional factors (cabin heating, towing, etc.).
    b. Where possible, consider specifying vehicles with optional on-board AC chargers with increased power ratings, to enable higher rates of vehicle charging to occur (e.g. 11 kW or 22 kW vs. 7 kW).
    c. Undertake a short-term managed vehicle trial of between 4 – 8 weeks in each identified vehicle segment to confirm operational suitability and to verify the potential running cost and emissions savings.
    d. Plan and rollout a home charging pilot scheme, including the installation of appropriate 7 kW chargers, with targeted drivers to confirm applicability, operational suitability and to verify the running cost and emissions savings.
    e. Procure and install 22 kW AC chargepoints at the depot locations identified during the infrastructure review.
    f. Investigate the potential to reduce the ownership period of the remaining non-BEV vans from 7 years to 4 years to ensure that the results of the above electric vehicle trial can be implemented as quickly as possible.
2. **Investigate the feasibility of using renewable diesel (HVO) as an interim solution across all remaining vehicle segments to provide immediate WTW CO_2e emissions reductions.**
    a. Contact fleet operators currently using HVO to discuss operational experiences, implications and to verify potential cost increases.
    b. Contact relevant vehicle manufacturers to discuss verify any potential warranty and maintenance changes.
    c. Contact relevant fuel suppliers to discuss supply requirements such as volumes, delivery, costs, etc.

3. **Prepare for the potential introduction of ULEV HGVs (i.e. RCVs, Food Waste Disposal, etc.) beyond 2025;** vehicle segments without recommended replacement ULEVs account for 45% of the current fleet. This is primarily due to the relative immaturity of ULEV HGVs and the resulting increase in additional capital costs.
    a. Undertake the further analysis of journey profiles and daily routes within the relevant vehicle categories to assess and verify the suitability of BEV as a replacement technology.
    b. Where possible undertake vehicle trials within those operations identified as suitable for BEV deployment.
    c. The majority of rigid trucks are due for replacement from FY2024 onwards, therefore this date is considered critical to achieving NWLDC’s 2030 aspirations. Any vehicles replaced after this point will likely remain on the fleet until at least 2031.
4. **NWLDC should consider the process of assessing, trialling, and implementation of ULEVs across the fleet as a continuous one, depending on the requirements of different vehicle segments.**
5. **Consider operational improvements that could increase the uptake of ULEVs.**

2. Purpose of Fleet Decarbonisation Options Review

North West Leicestershire District Council (NWLDC) commissioned Cenex to undertake the development of a fleet management strategy, roadmap, and action plan with the overall aim of transitioning their existing Council fleet to a zero carbon/ low carbon solution by 2030, with a focus on greenhouse gas emission savings, along with the identification of the infrastructure requirements to support this transformation.

The NWLDC fleet has several components and is made up of around 114 vehicles and is a mix of refuse collection vehicles (RCVs), parks maintenance vehicles, medium sized panel vans and smaller vehicles alongside more specialist equipment, such as sweepers and mowers. The predominant users are Waste Services, which also manages the whole fleet and the in-house workshop, along with the Housing Team which has a home-based fleet of large panel vans.

The recent UK Government Net Zero 2050 target will require zero-emission vehicles to be deployed across all industry sectors. For many sectors, especially those that utilise cars and light commercial vehicles (LCV), this transition should occur seamlessly, as there are a wide variety of electric options within these vehicle categories that are suitable for many business operations.

The harder task for fleet decarbonisation relates to heavier duty vehicles, where electric variants are either not currently available, not cost effective, or not applicable due to operational considerations.

The NWLDC fleet is diverse, with a wide variety of vehicles in use across multiple operational requirements. With such a wide range of vehicles in operation, it may be difficult to identify a specific technology or technologies that are most appropriate for the NWLDC fleet. NWLDC should therefore accept that there is, at this time, unlikely to be a single technological solution that will enable their fleet operations to achieve zero emissions by 2030.

2.1 Scope

To fulfil the requirements of the commission, Cenex undertook the following Work Packages:

- **ULEV Fleet Review**, where the operational fleet was analysed to identify the economic and operational suitability of selected Low Emission Vehicle (LEV), Ultra-low Emission Vehicle (ULEV), and Zero Emission Vehicle (ZEV) technologies taking into consideration the different ownership and usage patterns of individual fleet vehicles. This generated an indicative vehicle replacement schedule based on current replacement schedules, economic considerations, and vehicle availability.
- **Charging/ Refuelling Infrastructure Review**, where those operational vehicles identified as being suitable for replacement with LEVs, ULEVs and ZEVs were assessed to determine the likely infrastructure requirements needed to support their roll out. This analysis included a review into home charging, which is provided as a separate report with a summary contained in this report.
- **ULEV Specialist Fleet Review**, where the specialist fleet (e.g. tractors and mowers) was assessed to identify the possible low emission technology options that could be deployed within the fleet. The results of this analysis have been provided in a separate report.

2.2 Methodology

Figure 1 provides a summary of the overall methodology used during this Fleet Decarbonisation Options Review. This analysis has been undertaken using fleet and specialist fleet data (e.g. mileage, fuel use) supplied by NWLDC supplemented by the results of interviews with selected department managers. The work packages commenced upon receipt of initial fleet data following a project initiation meeting delivered via a web conference.

Low Emission Fleet Review
(Section 4)

- Fleet benchmarking to provide a baseline for the assessment of the suitability of LEVs.
- Performance Review to assess the relative performance of LEVs within the fleet
- Vehicle Down Selection to highlight the opportunity for LEVs to replace vehicles across the fleet
- Additional Daily Fuel/ Energy Requirementsto assess the potential energy requirements of identified LEV technologies.

Low Emission Vehicle Infrastructure Review
(Section 5)

- Review of types, indicative costs and considerations
- Depot focused EV charging infrastructure assessment based on average daily energy consumption, and required charging power
- Home charging review

Recommended Replacement Vehicles
(Section 6)

- Highlighting those vehicles which could theoretically be replaced by ZEV, ULEV and LEV technologies with minimal changes to the fleet’s current operating patterns and planned ownership periods.

Figure 1 - Summary of Methodology

3. Low Emission Vehicle Technology Options

This section introduces the main technologies discussed in this report by providing basic definitions and technology descriptions alongside an initial screening of LEV technologies based on current UK vehicle availability and supplier/ market maturity.

More detail on LEV technologies, including case studies, can be found in Appendix G – Low Emission Technology Factsheets or in the Low Emission Van Guide[1] and Renewable Fuels Guide[2] produced by Zemo Partnership and Cenex.

3.1 Zero Tailpipe Emission Vehicle Technologies

A zero-tailpipe emission vehicle or ZEV is a **vehicle which does not emit greenhouse gas (e.g. carbon dioxide (CO_2)) or air quality pollutant emissions from the vehicle exhaust/ tailpipe**.

ZEVs do not have an internal combustion engine (ICE) and instead are driven by an electric motor which is powered by electricity generated by a battery and/ or a hydrogen fuel cell which converts stored chemical energy into electrical energy. Several types of battery electric vehicle (BEV) are described below, which have different levels of supplier maturity and different economic models, all three technologies have been assessed and reported within this analysis.

Table 1 provides a description of currently available ZEV technologies.

Table 1 - Zero Tailpipe Emission Vehicle Technologies

Technology	Example	Description
Battery Electric Vehicle (OEM)		A battery electric vehicle (BEV) stores energy in a battery and delivers its power to the wheels through an electric motor. Original equipment manufacturer (OEM) vehicles are supplied by mainstream vehicle suppliers.
Battery Electric Vehicle (low volume)		A new vehicle 'glider' chassis is taken from the production line and a battery electric drivetrain is fitted. Low volume (and re-powered) BEVs are available from the likes of Emoss, Magtec and Tevva.
Battery Electric Vehicle (re-power)		A new electric drivetrain is fitted into a reconditioned second-hand vehicle. Re-power units are often used for trucks to help reduce the capital cost of an electric truck and improve payback time.
Fuel Cell Range Extended Electric Vehicle (FC REEV)		A BEV which also has an onboard hydrogen fuel cell to recharge the battery on the go. The wheels are always powered by the electric motor. The battery can also be recharged by plugging the vehicle into a mains power source.
Fuel Cell Electric Vehicle (FCEV)		Hydrogen is taking its first steps to becoming commercially available as a road transport fuel in the UK. Compressed hydrogen can be used to power an electric motor by generating electricity through a fuel cell. A small battery is often used for peak power requirements and for regenerative braking only.

[1] https://www.lowcvp.org.uk/assets/reports/Low_Emission_Van_Guide_2019_Update.pdf
[2] https://www.zemo.org.uk/assets/lowcvpreports/ZEMO_Renewable%20Fuels%20Guide%20_2021.pdf

3.2 Ultra-Low Emission Vehicle Technologies

An ultra-low emission vehicle (ULEV) is currently defined as **any car or van that emits less than 75 g/km of CO_2 from the exhaust/ tailpipe**. Due to advances in technology, it is expected that from 2021 an ULEV will be defined as a car or van that emits less than 50 g/km with a minimum required zero emission range.

To be eligible for the UK Government plug-in grant[3], which offers up to £2,500 off the price of a brand-new car, a vehicle must have CO_2 emissions of less than 50 g/km and can travel 70 miles with zero tailpipe emissions. Conversely, for a brand-new van up to 3.5t gross vehicle weight (GVW) to be eligible for up to £6,000 off the purchase price the vehicle must have CO_2 emissions of less than 50 g/km and can travel 60 miles with zero tailpipe emissions. Further details of the current plug-in vehicle grants is available in Section 16 (Appendix I – Grant Funding Options).

Currently any private or public sector organisation can claim the above grant, which is usually administered through the vehicle supplier (i.e. retail or leasing company).

No equivalent definition currently exists for heavy duty vehicles, although the Zemo Partnership are current developing ultra-low emission truck (ULET) standards[4].

ULEV technologies include all ZEVs in addition to range extended electric vehicles (REEV) which use ICE generators, and plug-in hybrid electric vehicles (PHEV). Several types of ULEV are described below, which have different levels of supplier maturity and different economic models, all technologies have been assessed and reported within this analysis.

Table 2 provides a description of additional, currently available, ULEV technologies.

Table 2 - Ultra-Low Emission Vehicle Technologies

Technology	Example	Description
Range Extended Electric Vehicle (REEV)		A BEV which also has an onboard generator (powered by an ICE) to recharge the battery on the go. The wheels are always powered by the electric motor. The battery can also be recharged by plugging the vehicle into a mains power source.
Plug-in Hybrid Electric Vehicle (PHEV)		A PHEV has an internal combustion engine as well as a battery and electric motor. The wheels can be driven by either the combustion engine or the electric motor. The battery can be recharged by plugging the vehicle into a mains power source.

[3] https://www.gov.uk/plug-in-car-van-grants
[4] https://www.lowcvp.org.uk/projects/commercial-vehicle-working-group/developing-ulet-standards.htm

3.3 Low Emission Vehicle Technologies

Low emission vehicle (LEV) technologies include all ULEVs and ZEVs in addition to **ICE vehicles capable of using renewable fuels**. This includes compressed natural gas (CNG), biodiesel (FAME) and renewable diesel (HVO), as described below, which have different levels of supplier maturity and different economic models. All three technologies have been assessed and reported within this analysis.

Table 3 provides a description of additional, currently available, LEV technologies.

Table 3 - Low Emission Vehicle Technologies

Technology	Example	Description
Compressed Natural Gas* (CNG)		CNG is the compressed form of natural gas. It is stored on vehicles in pressurised cylinders at 200 to 250 bar and consumed via a dedicated gas engine.
Biodiesel (FAME)	BIODIESEL	Biodiesel, also known as Fatty Acid Methyl Esters (FAME) is primarily produced from waste plant products and is a low carbon, sustainable alternative to mineral diesel. Biodiesel is already present in regular diesel at up to 7%. High blend biodiesel contains at least 20% biodiesel (B20), most truck manufacturers warranty vehicles up to B20. It is possible to run on B100, but this requires additional equipment, fuel management and is not covered by all warranties.
Renewable Diesel (HVO)	NESTE MY Renewable Diesel	Renewable diesel, such as Hydrotreated Vegetable Oil (HVO) is chemically identical to fossil diesel but produced from waste feedstock and vegetable oil. It is classed as a 'drop-in' fuel, which means it can be substituted for conventional fossil fuel diesel with no impact on maintenance and warranty conditions.

* Natural gas vehicles can be powered by biomethane (bio-CNG) which is a sustainable and renewable version of natural gas.

4. Low Emission Fleet Review

This section focuses on the NWLDC operational fleet, with the specialist fleet being covered in a separate report.

The modelling presented in this report assumes all vehicles are fitted with a standard body without any additional ancillary equipment. Any differential in purchase cost is assumed to be dominated by the powertrain. The impact on vehicle energy consumption associated with loading, towing, and the use of ancillary equipment (e.g. bin lifts, waste compaction, charging of hand tools, etc.) is assumed to be included in any fleet provided fuel consumption data. As such the operating ranges of ZEVs, ULEVs and LEVs are scaled appropriately to accommodate for these additional energy demands.

It is understood that NWLDC is currently trialling an ISUZU 7.5t refuse vehicle for food waste, with the intent to acquire additional vehicles for operational rollout during 2021 – 2022. This vehicle has been included within the fleet summary and benchmarking analysis, (Section 4.1) but is not included within the accompanying Technology Performance Assessments and Recommended Vehicle Replacement Schedule. Instead, a separate performance review has been carried in Section 7 to identify the operational conditions that would need to be achieved to make deployment cost effective.

Therefore, Sections 4.5, 4.6, 5, and 6 do not include this trial vehicle in their analyses.

It should be recognised that NWLDC is reviewing their current operations due to COVID-19 and new services, which is expected to result in additional vehicles and working patterns being adopted. However, it is anticipated that the result contained within this review will be applicable for future vehicle deployments.

Further details, including data sources and references, can be found in Appendix A – Fleet Review References.

4.1 Summary of Current Fleet

This section reviews the NWLDC fleet list to understand and baseline the current fleet size, vehicle types, emissions profile, and current vehicle replacement schedule. The purpose of this section is to provide context for subsequent analysis and to provide a baseline for the assessment of the suitability of LEVs. This analysis has been undertaken using data relating to 2019 – 2020 as it captured the expected typical working environments experienced by NWLDC.

4.1.1 Fleet Vehicles in Use

Table 4 provides an overview of the types of vehicles operated by NWLDC.

Table 4 - NWLDC Fleet Vehicles

		Description
Car	**Small Car**	Small passenger cars with 5 seats (e.g. Ford Fiesta)
LCV	**Large Commercial SUV**	Pick up trucks, with up to 5 seats and exposed loading area (e.g. Ford Ranger)
	Small Van	Light commercial vehicles with up to 3 seats and a gross vehicle weight not exceeding 2 tonnes. (e.g. Ford Transit Connect)
	Medium Van	Light commercial vehicles with up to 3 seats and a gross vehicle weight not exceeding 3.1 tonnes. (e.g. Ford Transit Connect)
	Large Van (< 3.5t GVW)	Light commercial vehicles with up to 3 seats and a gross vehicle weight not exceeding 3.5 tonnes. (e.g. Ford Transit Tipper)
HGV	**Large Van (> 3.5t GVW)**	Heavy duty vehicles with up to 3 seats and a gross vehicle weight exceeding 3.5 tonnes but not exceeding 7.5 tonnes. (e.g. Iveco Daily)
	Rigid Truck - 2 axles (7.5t GVW)	Heavy duty vehicles with two axles and a gross vehicle weight exceeding 7.5 tonnes but not exceeding 12 tonnes. (e.g. Iveco Eurocargo)
	Rigid Truck - 2 axles (18t GVW)	Heavy duty vehicles with two axles and a gross vehicle weight exceeding 12 tonnes but not exceeding 18 tonnes. (e.g. Mercedes Econic Refuse Collection Vehicle)
	Rigid Truck - 3 axles (26t GVW)	Heavy duty vehicles with three axles and a gross vehicle weight exceeding 18 tonnes but not exceeding 26 tonnes. (e.g. Mercedes Econic Refuse Collection Vehicle)

4.1.2 Combined Fleet Composition

Table 5 shows a breakdown of the NWLDC fleet by vehicle type and sub-type. As can be identified from the table below, the NWLDC operational fleet numbers around 100 vehicles, dominated by medium vans and 3 axle rigid trucks (26t GVW).

Table 5 - Summary of Fleet Composition

		Average Annual Mileage (miles)	Average Fuel Consumption (MPG)	Number of Vehicles	Percentage of Total Fleet
Car	Small Car	8,600	49.6	4	4%
LCV	Large Commercial SUV	8,800	27.8	2	2%
	Small Van	5,200	42.8	7	7%
	Medium Van	8,900	27.0	48	48%
	Large Van (< 3.5t GVW)	5,500	15.6	11	11%
HGV	Large Van (> 3.5t GVW)	2,400	9.9	1	1%
	Rigid Truck - 2 axles (7.5t GVW)	11,200	12.6	4	4%
	Rigid Truck - 2 axles (18t GVW)	5,600	3.4	7	7%
	Rigid Truck - 3 axles (26t GVW)	10,000	3.8	16	16%
	Total	**8,225**	**21.7**	**100**	**100%**

68% of the fleet consists of light commercial vehicles (LCVs) less than 3.5t gross vehicle weight (GVW) with medium vans the dominant vehicle segment (48% of the fleet). The remainder of the fleet consists mainly of heavy goods vehicles, dominated by 3 axle rigid trucks (16% of the fleet).

14 non-operational vehicles (e.g. tractors and mowers) were removed from this review and included within the Specialist Fleet review.

While all vehicles operate for approximately five days a week (assumed to be 260 days per year) the overall average annual mileage of 8,200 miles is less than that within other local authority managed fleets assessed by Cenex. As of the 2011 census, NWLDC has a population of ~93,500 with 58% rural population. The local authority district is classified as '**largely rural**'[5]. This will most likely result in several different drive and duty cycles across the fleet. As such **the driving environment has been assumed to be mainly regional (30% urban, 50% rural, and 20% A-road)**.

It should also be noted that the average calculated fuel economy for each vehicle segment is typically similar to the expected ranges for such vehicles.

The annual mileage, number of days per week used and calculated vehicle fuel economy are used as primary inputs to the LEV suitability modelling (see Section 4.5).

4.1.3 Combined Fleet Emissions

The combustion of fossil fuels used for road transport (such as petrol and diesel) produces three main greenhouse gas emissions that contribute directly to climate change. These are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). For reporting purposes, greenhouse emissions are standardised to CO_2 equivalents (CO_2e) based on their global warming potential (GWP). For an equivalent amount of each gas released (e.g. 1 kg) the GWP of CO_2 = 1, CH_4 = 25 and N_2O = 298.

Tank to Wheel (TTW) or Scope 1 emissions represent the amount of CO_2 (derived from fossil fuels) which is released from a vehicle's tailpipe. Under the UK Greenhouse Gas reporting protocol, these Scope 1 emissions are the direct responsibility of the transport operator.

[5] Lookup for 2011 Rural Urban Classification of Local Authorities, Defra

Well to Wheel (WTW) or All Scope emissions are a more complete method of looking at CO_2 emissions and represent the amount of CO_2 emitted during the fuel's life cycle. This includes the upstream emissions associated with fuel extraction, processing, transportation, and dispensing, as well as the emissions from final fuel combustion. Although the upstream emissions from fuel manufacture are not the reporting responsibility of the transport operator (under UK emission reporting guidance), they are considered important by environmentally conscious fleets when making decisions on fuel and transport options.

As such the greenhouse gas emissions in the main body of the report are presented as WTW CO_2e.

In addition to greenhouse gas emissions, high-temperature combustion of fuels used for road transport also produces two main air quality pollutant emissions that at high concentrations or sustained low concentrations contribute directly to several health issues including respiratory and cardiovascular conditions as well as reduced life expectancy. These are **nitrogen dioxide (NO_2)** and **particulate matter (PM)**.

The National Atmospheric Emissions Inventory provide average speed related emissions factors for different vehicle types, euro standards and fuel types. These factors are provided for **oxides of nitrogen (NOx)**, a collective term that includes NO_2 as well as nitric oxide (NO), and PM. Although NO is not considered hazardous to human health it can lead to the formation of NO_2, as such the collective NOx emission factors are still relevant as evidenced by their use in the Emission Factor Toolkit published by Defra.

All data sources and references used within the delivery of this Fleet Review can be found in Appendix A – Fleet Review References.

Table 6 shows the emissions profile of the NWLDC fleet in terms of percentage contribution to annual WTW CO_2e, NOx and PM emissions.

Table 6 – Summary of Annual Fleet Emissions Contribution

		Percentage of Total Fleet	% Contribution to Total WTW CO_2e Emissions	% Contribution to Total NO_X Emissions	% Contribution to Total PM Emissions
Car	Small Car	4%	1%	3%	1%
LCV	Large Commercial SUV	2%	1%	3%	0%
	Small Van	7%	1%	6%	3%
	Medium Van	48%	20%	60%	69%
	Large Van (< 3.5t GVW)	11%	5%	10%	2%
HGV	Large Van (> 3.5t GVW)	1%	0%	0%	0%
	Rigid Truck - 2 axles (7.5t GVW)	4%	5%	1%	1%
	Rigid Truck - 2 axles (18t GVW)	7%	14%	1%	2%
	Rigid Truck - 3 axles (26t GVW)	16%	53%	16%	22%
	Total	100%	1,200 tonnes	1,100 kg	10 kg

The medium van segment (accounting for 48% of the total fleet) produces the highest proportion of air quality emissions on the fleet, amounting to 60% and 69% of NOX and PM emissions, respectively. The high NOX and PM emissions are impacted by the large proportion of Euro 4 diesel vehicles currently in operation within this van segment.

However, the Rigid Truck – 3 axles (26t GVW) segment contributes 53% of CO2e emissions despite only accounting for 16% of the total fleet. This is a result of the high fuel consumption of these vehicles and associated high energy usage due to the use of bin lifts and compaction units.

4.1.4 Combined Fleet Age and Euro Profile

Table 7 shows the calculated fleet age and Euro standard profile. The Euro standard regulations define the maximum acceptable limits for key pollutant emissions (including NOx and PM) for new vehicles sold in the EU.

Euro standards are denoted by Arabic numerals (e.g. Euro 6) for light-duty vehicles which are tested on a chassis dynamometer and Roman numerals (e.g. Euro VI) for heavy-duty vehicles where the engines are certified separately on a test bed.

Table 7 – Vehicle Age and Euro Standard Profile

		Vehicle Age (years)		Engine Euro Standard		
		Average Age (years)	Maximum Age (years)	Euro 4/IV or lower	Euro 5/V	Euro 6/VI
Car	Small Car	6.5	7	0%	75%	25%
LCV	Large Commercial SUV	6.0	7	0%	100%	0%
	Small Van	7.1	11	29%	57%	14%
	Medium Van	6.7	11	33%	25%	42%
	Large Van (< 3.5t GVW)	6.5	10	9%	82%	9%
HGV	Large Van (> 3.5t GVW)	3.0	3	0%	0%	100%
	Rigid Truck - 2 axles (7.5t GVW)	2.8	4	0%	0%	100%
	Rigid Truck - 2 axles (18t GVW)	2.7	3	0%	0%	100%
	Rigid Truck - 3 axles (26t GVW)	6.3	15	6%	13%	81%
	Total	**6.2**	**15**	**20%**	**32%**	**48%**

48% of the fleet meets the latest Euro 6/ VI emissions standard, with most of the HGV segments achieving this standard. A high proportion of the small and medium vans are **Euro 4 or lower**, causing increases in local air pollutants (NO_X and PM).

4.1.5 Current Fleet Replacement Schedule

NWLDC **purchased** 99 of their vehicles, with the capital cost funded and repaid over a seven-year period, although some vehicles may be kept for longer than this. Table 8 shows the vehicle replacement schedule that results from these ownership periods.

While NWLDC previously operated on a fixed 7-year vehicle replacement schedule, it is acknowledged that due to funding considerations and the COVID-19 pandemic this has fallen behind, with some vehicles now overdue replacement.

The below replacement schedule (Table 8) shows that around 60 vehicles are due for replacement in this and the next financial year. These vehicles are predominantly medium vans but does include some 3 axle 26t GVW rigid trucks. A proportion of 18t GWV and 26t GVW rigid trucks due for replacement in 2024 – 2026, which will provide an opportunity for NWLDC to further assess the potential LEV options for these vehicle segments, including trialling suitable vehicles, and preparing to introduce LEVs within this vehicle segment.

Table 8 – Calculated Vehicle Replacement Schedule (financial year)

		2021/2022	2022/2023	2023/2024	2024/2025	2025/2026	2026/2027	2027/2028	2028/2029	2029/2030	2030/2031
Car	Small Car	3	1	0	0	0	0	0	0	0	0
LCV	Large Commercial SUV	1	1	0	0	0	0	0	0	0	0
	Small Van	5	1	0	0	1	0	0	0	0	0
	Medium Van	26	2	7	0	13	0	0	0	0	0
	Large Van (< 3.5t GVW)	9	1	1	0	0	0	0	0	0	0
HGV	Large Van (> 3.5t GVW)	0	0	0	0	1	0	0	0	0	0
	Rigid Truck - 2 axles (7.5t GVW)	0	0	1	0	2	0	0	0	0	0
	Rigid Truck - 2 axles (18t GVW)	0	0	0	5	1	1	0	0	0	0
	Rigid Truck - 3 axles (26t GVW)	9	1	2	0	4	0	0	0	0	0
	Total	**53**	**7**	**11**	**5**	**22**	**1**	**0**	**0**	**0**	**0**

4.2 Operational Constraints

Following a discussion with the NWLDC fleet teams the following potential operational considerations and constraints have also been identified. It is acknowledged that many vehicles within the fleet may be required to meet a minimum specification to complete their daily duties. This may include carrying equipment, towing, use of ancillary power, and off-roading depending on the requirements and location of a given operation.

Table 9 highlights the potential operational restrictions that have been identified, listed out according to vehicle category.

Table 9 - NWLDC Fleet Operational Constraints and Considerations

		Potential Operational Constraint
Car	**Small Car**	No operational restrictions identified.
LCV	**Large Commercial SUV**	Some vehicles may require 4x4/ off road capabilities.
	Small Van	No operational restrictions identified.
	Medium Van	Vehicles currently running at weight limit; all vehicles must be able to undertake maximum potential daily mileages due to need to cover emergency shift patterns.
	Large Van (< 3.5t GVW)	Some vehicles running at weight limit; some vehicles identified as being required to tow. One vehicle identified as having a crane. Charging of electric hand tools required.
HGV	**Large Van (> 3.5t GVW)**	Some vehicles running at weight limit; some vehicles identified as being required to tow.
	Rigid Truck - 2 axles (7.5t GVW)	Some vehicles identified as being required to tow. Some identified as having tail lifts. One identified as being trial food waste vehicle.
	Rigid Truck - 2 axles (18t GVW)	High energy operation due to refuse collection requirements (bin lifts, compaction); up to three loads per day requiring round trip to Loughborough waste site for disposal.
	Rigid Truck - 3 axles (26t GVW)	High energy operation due to refuse collection requirements (bin lifts, compaction); up to three loads per day requiring round trip to Loughborough waste site for disposal.

The following Low Emission Vehicle Technology Selection analysis made no distinction between specific operational requirements as the calculated vehicle fuel economy figures were found to provide a good approximation for the operational weight/ power needs/ etc.

4.2.1 Low Emission Vehicle Technology Screening

To highlight which LEV technologies may have the potential to deliver emissions savings, Cenex has undertaken a high-level assessment of options based on current UK availability and supplier maturity (e.g. availability of service centres, lower technology maturity), as outlined in Figure 2. Further details of these technologies can be found in Appendix G – Low Emission Technology Factsheets. Technologies have been categorised based on the criteria below.

OEM product with a high level of maturity and aftersales support
Re-power or retrofit product with a lower supplier maturity
Technology has been demonstrated but is currently unavailable in the UK
Technology has not been demonstrated or is currently unavailable in the UK

		BEV (OEM)	BEV (low volume)	BEV (re-power)	REEV	PHEV	FCEV	FC REEV	FAME (~B30)	FAME (B100)	HVO	CNG
Car	Small Car	Renault Zoe										
LCV	Large Commercial SUV		Rivian									
	Small Van	Renault Kangoo ZE						Renault Kangoo ZE H2				
	Medium Van	Mercedes eVito			Ford Transit Custom							
	Large Van (< 3.5t GVW)	LDV EV80	Arrival					Renault Master ZE H2				Iveco Daily
HGV	Large Van (> 3.5t GVW)	Iveco Daily Electric	EMOSS	Magtec								Iveco Daily
	Rigid Truck – 2 axles (7.5t GVW)	FUSO eCanter	EMOSS	Magtec	Tevva				DAF LF			
	Rigid Truck – 2 axles (18t GVW)	Volvo FL Electric	EMOSS	Magtec	Tevva				DAF LF	Volvo FL		Iveco Eurocargo
	Rigid Truck – 3 axles (26t GVW)	Volvo FE Electric	EMOSS	Magtec					DAF CF	Volvo FE		Scania

Figure 2 - Low Emission Vehicle Technology Screening

All green and amber technologies have been assessed during the remainder of the report.

As such hydrogen fuel cell vehicles (FCEVs) and dual-fuel hydrogen vehicles (DF H_2) have not been assessed. Hydrogen powered vehicles are not yet market ready and it is not possible to purchase series production hydrogen powered vehicles within any of the NWLDC vehicle segments.

Early trials of such vehicles are underway, but vehicle manufacturers are not expected to release series produced vehicles until at least 2023. As such no costs or verified test data is available and the technology cannot be assessed to the same standard as the others.

4.3 Cenex Fleet Review Methodology

Cenex uses an in-house developed vehicle and fleet analysis spreadsheet model (Fleet Advice Tool) to provide companies with a detailed breakdown of the estimated real-world operating range, total cost of ownership (TCO) and emission reduction performance of low emission technologies relative to a new diesel-powered Euro 6/ VI vehicle.

The Cenex Fleet Advice Tool uses independent vehicle ownership cost data, vehicle fuel consumption values, and low emission vehicle energy consumption factors. These energy consumption factors are based on real-world (e.g. chassis dynamometer, test track or in-use) testing of low emission vehicles managed by Cenex or partners (e.g. Emissions Analytics, Zemo partnership) during commercial and research projects. Such trials are deemed independent as they do not involve vehicle manufacturers as part of the trial team, except as a source of the vehicles.

This wider data set is supplemented by information gathered via stakeholder interviews with vehicle and fuel suppliers. The data contained within the Fleet Advice Tool has been verified by industry working groups including fleet operators and trade associations.

Figure 3 below shows the methodology used during a fleet review and reflects the process undertaken during this commission.

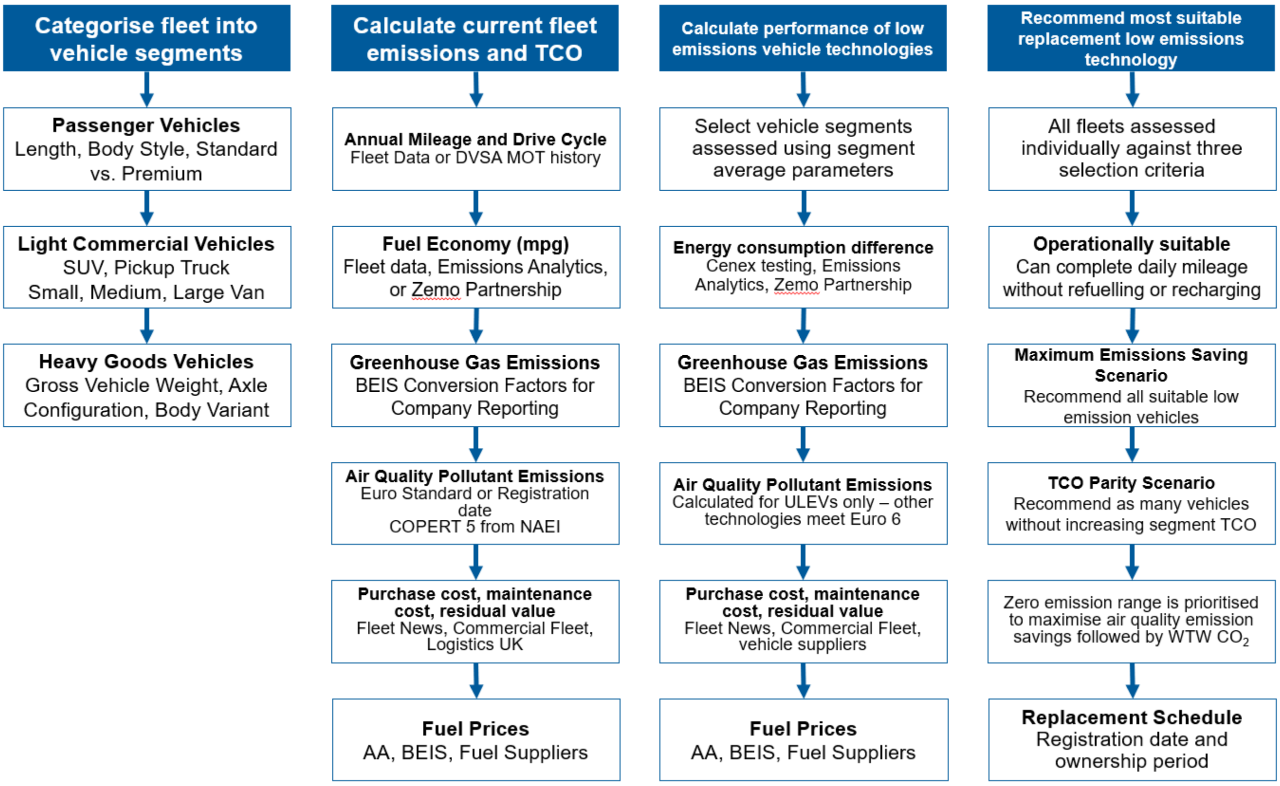


Figure 3 - Fleet review methodology

4.4 Data Input Considerations

The accuracy of this fleet review is dependent on the data provided by NWLDC. The supplied information is used to calculate the current fleet emissions and acts as a baseline for all low emission vehicle suitability calculations (e.g. modelled operating range, total cost of ownership and emissions savings). The list below describes the relationship between the input data and some of the key outputs of the reports. It is acknowledged that the fleet data provided reflects the best available data, as such this information is included to provide context for the subsequent results only.

- **Fuel consumption** is used to calculate the current vehicle CO_2 emissions and fuel costs. Additionally, this fuel consumption is converted into a baseline energy consumption that low emission vehicle technologies are compared against. The biggest risk is that fuel consumption is underreported. This would result in an underestimation of the emissions, fuel costs, and energy consumption requirements of a low emission vehicle. To minimise this risk Cenex check the fuel consumption data against maximum default values to highlight any potential outliers, which are then adjusted.
- **A typical driving environment** (e.g. either mostly congested/ urban/ rural/ motorway or mixed) is used to calculate the energy consumption difference between a low emission vehicle and the current vehicle. This is applied through a database of low emission vehicle 'efficiency factors' determined by independent real-world testing. If the actual drive cycle is significantly different to the assumed drive cycle this could lead to misleading results, particularly relating to the operating range of low emission vehicles. A worked example of the calculation method, for a small battery electric van, is shown below.

	Diesel Fuel Consumption	Electric Vehicle Energy Consumption Reduction	Electric Range	Fuel Cost Savings
Mostly Congested	36 mpg	-74%	104 miles	9.5 ppm
Mostly Motorway	48 mpg	-49%	70 miles	4.2 ppm

- **Annual mileage** is used to calculate the total cost of ownership and emissions savings of low emission vehicles. Typically, due to an increase in ownership costs (e.g. purchase cost and residual values), most low emission vehicle technologies currently have a minimum annual mileage (and ownership period) that is required to be economically viable. The number of days used per week combined with the annual mileage is used to calculate the average daily mileage, this is then compared against the operating range of low emission vehicles to assess operational suitability.

For vehicles on the fleet list **missing information**, average performance data from a similar vehicle in a similar operating group was assigned. Annual mileage, fuel consumption, driving environment, and days of use per week were estimated using this method.

An expanded summary of the key assumptions held within the model's calculation engine is shown in Table 10, with the primary reference for each parameter detailed alongside examples of assumptions for the key technologies (i.e. those which have a significant impact on the results and conclusions). All prices exclude VAT.

Table 10 - Key assumptions within Cenex Fleet Review

<table>
<tr><th>Parameter</th><th>Cars and Vans (up to 3.5t)</th><th>Rigid Trucks and Tractor Units</th></tr>
<tr><td>Energy / fuel consumption</td><td>Diesel: Emissions Analytics real-world testing (https://www.emissionsanalytics.com/)
ULEVs: Cenex real-world testing (https://www.cenex.co.uk/)</td><td>All technologies: LowCVP testing - Emissions Testing of Urban Delivery Commercial Vehicles (https://www.lowcvp.org.uk/resource-library/reports-and-studies.htm)
Gas vehicles: Emissions Analytics and Cenex managed testing - Dedicated to Gas (https://www.cenex.co.uk/app/uploads/2019/11/324-003-004-Dedicated-to-Gas-Assessing-the-Viability-of-Gas-Vehicles.pdf)</td></tr>
<tr><td>Purchase cost</td><td rowspan="3">Fleet News (Car and van running costs) (https://www.fleetnews.co.uk/car-running-costs-calculator)
All costs are an average of the top three bestselling models from each segment, where information is available.</td><td rowspan="3">Diesel: Freight Transport Association operating cost tables
All other technologies: Fleet operators, Manufacturers, and industry interviews
BEVs have the same absolute residual value as diesel equivalent (increased depreciation).
Gas vehicles have 50% of the residual value of diesel equivalent.</td></tr>
<tr><td>Residual value</td></tr>
<tr><td>Maintenance costs</td></tr>
<tr><td>Fuel prices</td><td colspan="2">Diesel: AA fuel price reports
Electricity: BEIS non-domestic electricity prices
Natural Gas: Cenex consultation with gas suppliers</td></tr>
</table>

4.5 Low Emission Vehicle Performance Reviews

This section shows the relative performance of ZEV, ULEV, and LEVs that have been selected for further analysis during the technology screening process.

The **Low Emission Vehicle Performance Reviews** reported below **are based on the combined fleet average vehicle for each segment** as calculated during the fleet baselining and are reported for selected vehicle segments to demonstrate the potential operational impacts of using the identified technologies within the vehicle segment.

Conversely, the **Low Emission Vehicle Technology Selection involves an assessment of each vehicle** to identify the most appropriate technology based on the individual vehicle requirements.

In both cases, the following parameters (exc. VAT) are used as the main inputs to the spreadsheet model:

- Annual mileage and number of used days per week.
- Fuel economy and driving environment of 30% urban, 50% rural, 20% A-road (mostly regional).
- Planned ownership period.
- Diesel = £1.00/ litre, Petrol = £0.96 / litre.
- Electricity = £0.14 / kWh.
- Bio-LPG = £0.53 / kg, CNG = £0.70 / kg (public gas station).
- FAME (B20) = £1.00/ litre.
- HVO = £1.15/ litre.

Table 11 summarises the key assumptions held within the calculation engine of the spreadsheet model. A table of references can be found in Appendix A – Fleet Review References.

Table 11 - Key Modelling Assumptions

Assumption	Description
Estimated real-world operating range	The electric-only vehicle range stated is based on the current vehicle fuel/energy consumption. As such, it includes the average impact of the current duty cycle as well as any ancillary power demands. The actual operating range on any given day will vary by driving style, payload, use of power take off (PTO), use of air conditioning/cabin heating or other external factors (e.g. ambient temperature). The actual electric-only range can vary significantly (by up to 50%) based on these variables.
Vehicle costs - body equipment / variants	The model assumes a standard vehicle configuration without additional equipment. Any differential in vehicle purchase cost is determined primarily by the powertrain. Compatibility between chassis and body variants as well as potential integration issues should be confirmed before procurement of LEVs.
Predicted residual values	Where possible predicted residual values are based on independent data. Despite this, predicted residual values are uncertain and vary significantly based on market factors such as supply vs. demand and policy measures. Additionally, they are forecast over the life of the vehicle. Where predicted residual values are unavailable (e.g. BEV HGVs) it has been assumed the LEVs have the same absolute residual value as an equivalent diesel vehicle. Natural gas vehicles have been assumed to have an absolute residual value of 50% of an equivalent diesel vehicle, this is due to feedback from the gas industry and the lack of a public refuelling network.
Infrastructure costs	Low emission vehicle infrastructure costs are assessed separately in Section 5 (Low Emission Vehicle Infrastructure Review)

Scope of Performance Reviews

Performance reviews have been undertaken for the following vehicle segments:

- Small Car
- Medium Van
- Large Van (<3.5t GVW)
- Rigid Truck – 3 axles (26t GVW)

These vehicle segments account for 80% of the fleet WTW CO_2e emissions, 89% of the fleet NOx emissions, and cover all relevant LEV technologies applicable across all NWLDC vehicle segments.

Table 12 summarises the key vehicle performance criteria used as part of the LEV performance reviews.

Table 12 - Average Vehicle Performance Criteria

	Typical Driving Type	Annual Mileage (miles)	Fuel Consumption (MPG)	Days per Week Used	Ownership Period (years)
Small Car	Mostly regional	8,632	49.6	5	7
Medium Van	Mostly regional	8,915	27.0	5	7
Large Van (< 3.5t GVW)	Mostly regional	5,547	15.6	5	7
Rigid Truck - 3 axles (26t GVW)	Mostly regional	9,995	3.8	4	7

The completed Performance Reviews are presented over two pages with charts for operating range, total cost of ownership (TCO) and CO_2e emissions followed by a summary of the key findings of each technology.

Results are based on a comparison of the identified low emission technology against an equivalent Euro 6 diesel vehicle and presented on a per vehicle basis in order of zero-emission range descending followed by WTW CO_2e emissions savings descending. All prices exclude VAT. **LEV technologies that are of least relevance as potential replacements have been highlighted in amber** with supporting justification provided on the relevant charts.

4.5.1 Low Emission Vehicle Performance Review – Small Car

Figure 4 to Figure 6 show the relative performance of LEV technologies for small cars. The calculations contained in Figure 5 outline the methodology used to calculate the vehicle depreciation.

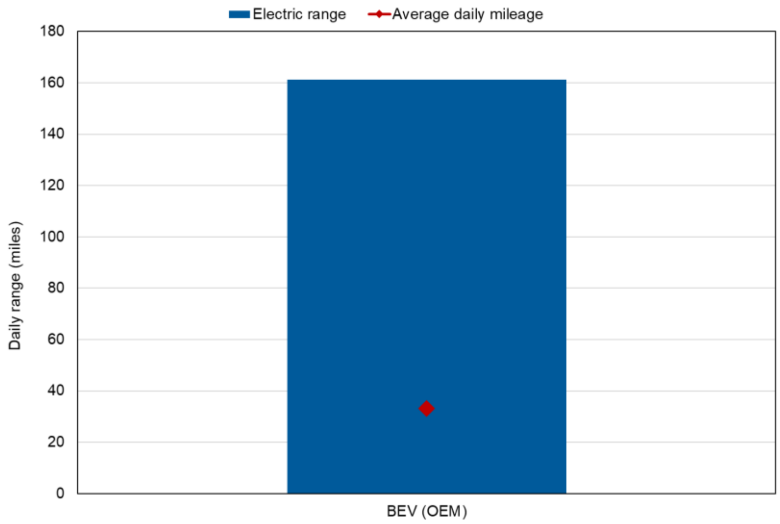


Figure 4 – Operating Range; Small Car

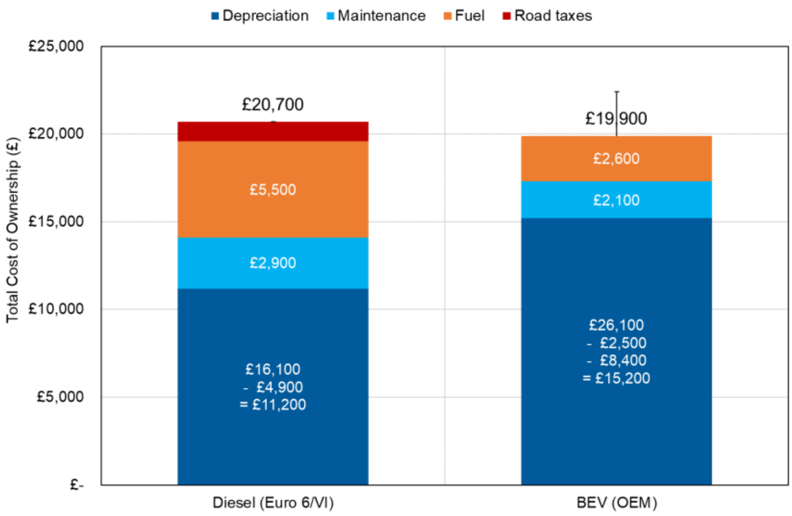


Figure 5 - Total Cost of Ownership; Small Car

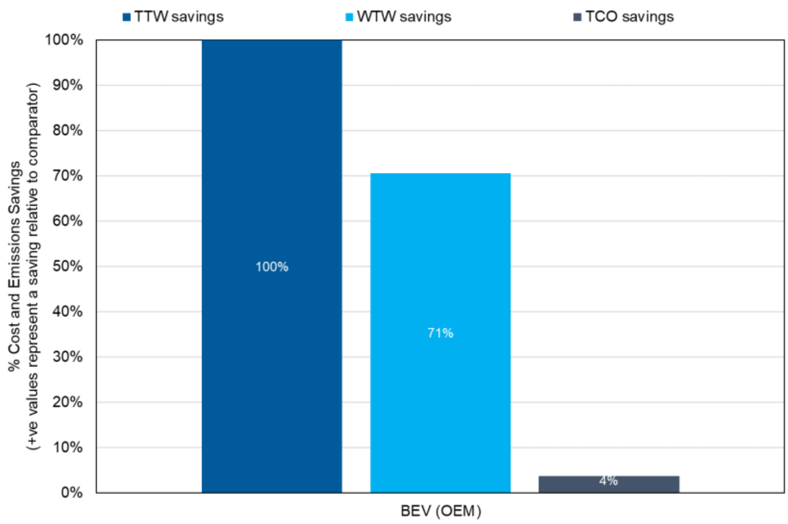


Figure 6 - CO_2e Emissions Savings vs. Cost Difference; Small Car

BEV (OEM)

Criteria	Performance
Operational	• Estimated real-world range of 161 miles (40 kWh battery). • 7kW AC on-board charger as standard = 8h charging time at 7kW chargepoint. • 1 hour to DC charge to 80% capacity using a 50 kW rapid charger.
TCO	• £10,000 increase in purchase cost (including £2,500 Plug-In grant). • No road taxes, lower fuel and maintenance costs result in a TCO saving of £800.
Emissions	• Zero tailpipe emissions. • 71% reduction in WTW CO_2 emissions based on the current UK grid energy mix. This will reduce further as the UK grid decarbonises.

4.5.2 Low Emission Vehicle Performance Review – Medium Van

Figure 7 to Figure 9 show the relative performance of LEV technologies for Medium Vans. The black error bars in Figure 8 highlight the potential impact of any future removal of the Plug in Van Grant, while the calculations outline the methodology used to calculate the vehicle depreciation.

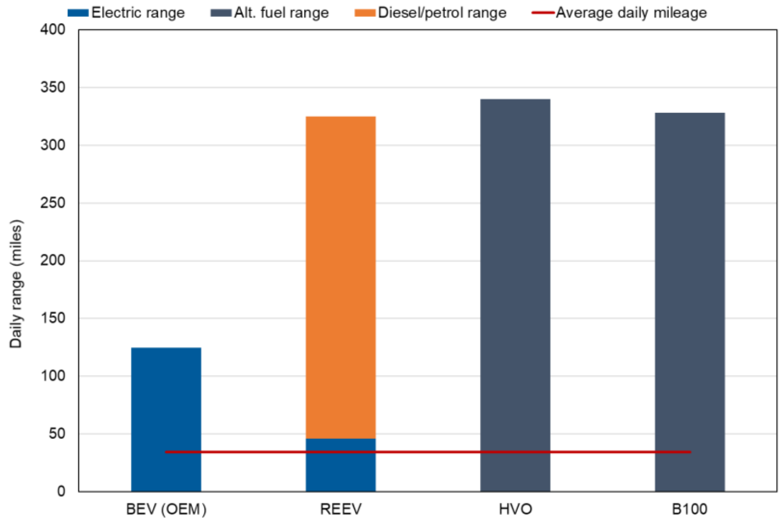


Figure 7 - Operating Range; Medium Van

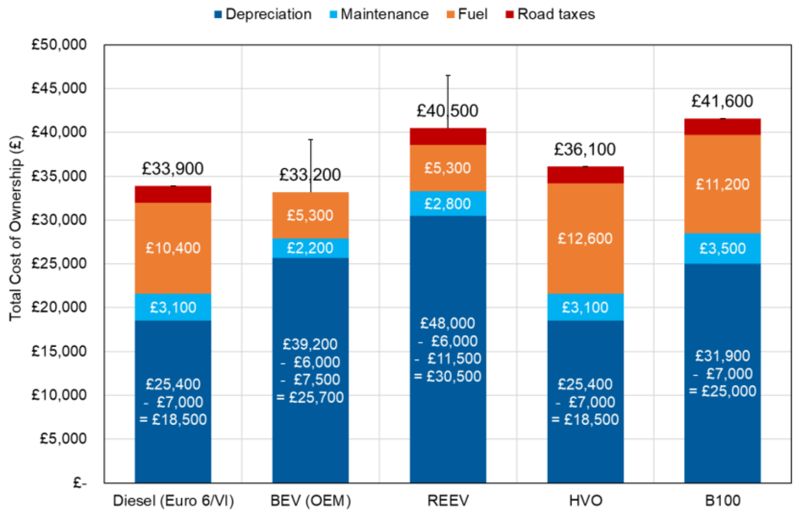
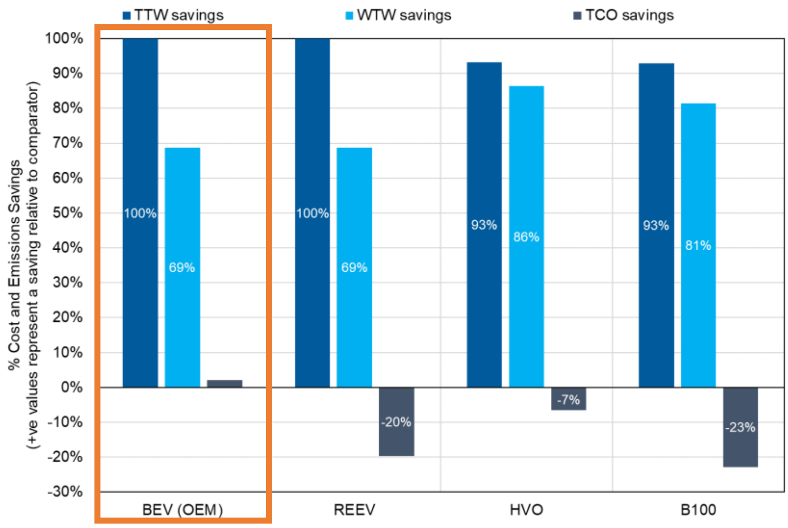


Figure 8 - Total Cost of Ownership; Medium Van



BEV (OEM) operating range is over twice the average daily mileage and provides zero tailpipe emissions, a 69% reduction in WTW CO_2e emissions and is TCO neutral.

All other technologies increase TCO.

Figure 9 - CO_2e Emissions Savings vs. Cost Difference; Medium Van

BEV (OEM)

Criteria	Performance
Operational	• Estimated real-world range of 124 miles (75 kWh battery) • 7kW AC on-board charger as standard = 8-10h charging time at 7kW chargepoint. • 1 hour to DC charge to 80% capacity using a 50 kW rapid charger. • Payloads of 640 kg to 1,000 kg available dependent on the model.
TCO	• £7,200 increase in purchase cost, per vehicle (including £6,000 Plug-In Grant). • Significant running cost savings lead to TCO neutrality.
Emissions	• Zero tailpipe emissions. • 69% reduction in WTW CO_2 emissions based on the current UK grid energy mix. This will reduce further as the UK grid decarbonises.

REEV

Criteria	Performance
Operational	• The estimated combined range is far greater than the average daily mileage. • Electric-only range approximately 40-50 miles • Up to 22kW AC on-board charger as standard = 3-5h charge time • 30 minutes to DC charge to 80% capacity using a 50 kW rapid charger • Payload of 830kg available dependent on model.
TCO	• £6,000 increase in purchase cost, per vehicle (including £6,000 Plug-In Grant). • Although running costs are reduced, TCO increases by £6,600.
Emissions	• Zero tailpipe emissions, when operating in electric mode • 69% reduction in WTW CO_2 emissions based on the current UK grid energy mix. This will reduce further depending on how often the vehicle operates in electric mode.

HVO

Criteria	Performance
Operational	• The estimated range is far greater than the average daily mileage. • Refuelling can be done in a similar time to diesel.
TCO	• No increase in capital cost as the vehicle is the same as a diesel. • The increased cost of HVO results in a TCO increase of £2,200.
Emissions	• 86% reduction in WTW CO_2 emissions. • Air quality pollutant emissions equivalent to Euro 6.

FAME (B100)

Criteria	Performance
Operational	• The estimated range is far greater than the average daily mileage. • Refuelling can be done in a similar time to diesel. • Additional fuel storage and handling requirements.
TCO	• £6,500 increase in purchase cost • Increased maintenance requirements. • Additional running costs results in TCO increase of £7,700
Emissions	• 81% reduction in WTW CO_2 emissions due to high biodiesel blend. • Air quality pollutant emissions equivalent to Euro 6.

4.5.3 Low Emission Vehicle Performance Review – Large Van (<3.5t GVW)

Figure 10 to Figure 12 show the relative performance of LEV technologies for Large Vans (<3.5t GVW). The black error bars in Figure 11 highlight the potential impact of any future removal of the Plug in Van Grant, while the calculations outline the methodology used to calculate the vehicle depreciation.

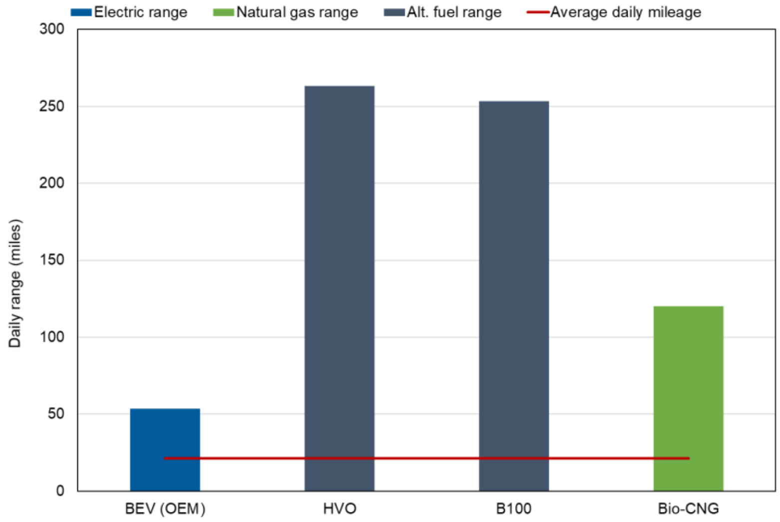


Figure 10 - Operating Range; Large Van (3.5t GVW)

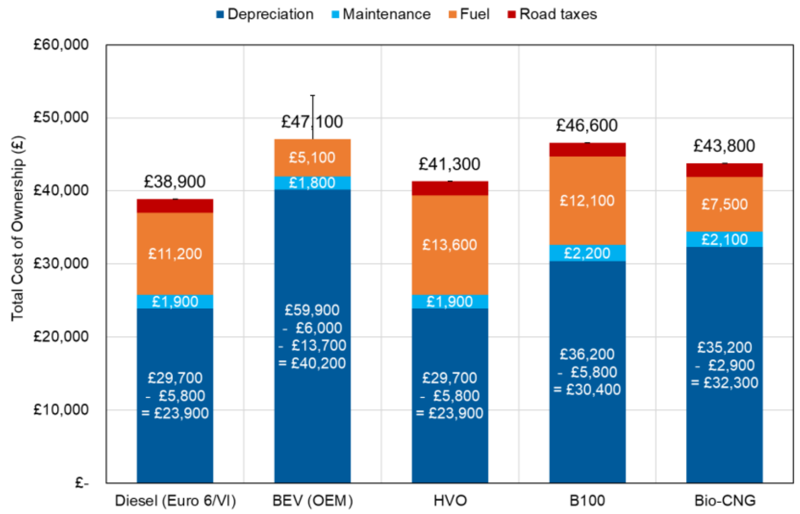
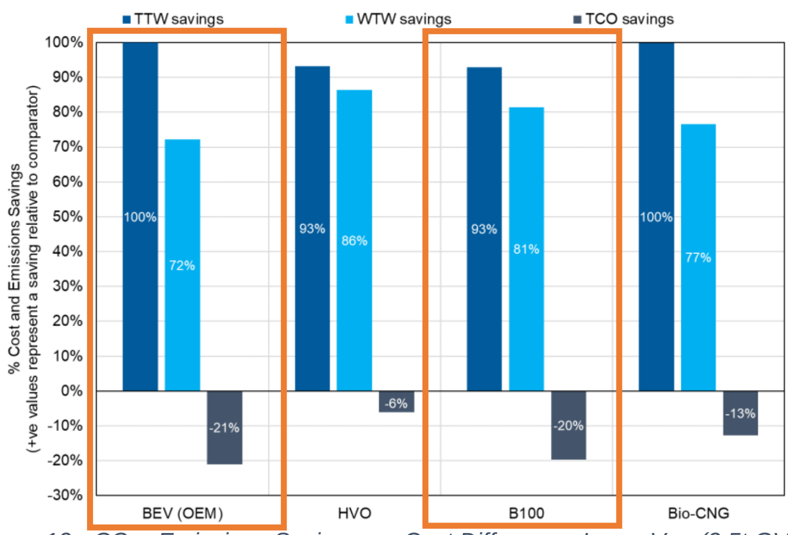


Figure 11 - Total Cost of Ownership; Large Van (3.5t GVW)



The increased purchase cost of BEV (OEM) is the main influencing factor in TCO.

B100 operating range is substantially more than the average daily mileage and provides an 81% reduction in WTW CO_2e emissions. However, TCO increases by 20%.

Figure 12 - CO_2e Emissions Savings vs. Cost Difference; Large Van (3.5t GVW)

BEV (OEM)

Criteria	Performance
Operational	• Estimated real-world range of 53 miles (45 kWh). • 7kW AC on-board charger as standard = 8h charging time at 7kW chargepoint. • 1 hour to DC charge to 80% capacity using a 50 kW rapid charger. • Dependent on the vehicle model and battery capacity, payloads ranging from 700 kg to 1,200 kg are available. • The payload can also be increased by 750 kg by using vehicles that make use of the government **derogation that allows a low emission vehicle to be rated at 4.25t GVW whilst still being used on a category B driving licence**. See Appendix B – for more details. • Except for the new Mercedes-Benz eSprinter, which has a towing capacity of 1,200 to 1,700 kg, **most BEV large vans (<3.5t GVW) are not able to tow**. The additional weight, rolling resistance and aerodynamic drag will also reduce the electric-only range which may further compromise operational suitability.
TCO	• £16,300 increase in purchase cost (including £6,000 Plug-In Grant). • Despite significant running cost savings, there is an overall TCO increase of £8,200.
Emissions	• Zero tailpipe emissions. • 72% reduction in WTW CO_2 emissions based on the current UK grid energy mix. This will reduce further as the UK grid decarbonises.

HVO

Criteria	Performance
Operational	• The estimated range is far greater than the average daily mileage. • Refuelling can be done in a similar time to diesel.
TCO	• No increase in capital cost as the vehicle is the same as a diesel. • Increased running costs lead to a TCO increase of £2,400.
Emissions	• 86% reduction in WTW CO_2 emissions. • Air quality pollutant emissions equivalent to Euro 6.

FAME (B100)

Criteria	Performance
Operational	• The estimated range is far greater than the average daily mileage. • Refuelling can be done in a similar time to diesel. • Additional fuel storage and handling requirements.
TCO	• £6,500 increase in purchase cost • Increased maintenance requirements. • Increased running costs lead to a TCO increase of £7,700.
Emissions	• 81% reduction in WTW CO_2 emissions. • Air quality pollutant emissions equivalent to Euro 6.

Bio-CNG

Criteria	Performance
Operational	• The estimated range is far greater than the average daily mileage. • Refuelling can be done in a similar time to diesel. • Payloads up to 1,200 kg are currently available.
TCO	• £8,400 increase in vehicle capital cost. • Despite access to low-cost public gas prices (£0.70 per kg), increased running costs lead to a TCO increase of £4,900.
Emissions	• 77% reduction WTW CO_2 emissions. • Air quality pollutant emissions equivalent to Euro 6.

4.5.4 Low Emission Vehicle Performance Review – Rigid Truck (26t GVW)

Figure 13 to Figure 15 show the relative performance of LEV technologies for Rigid Trucks (26t GVW). The calculations contained in Figure 14 outline the methodology used to calculate the vehicle depreciation.

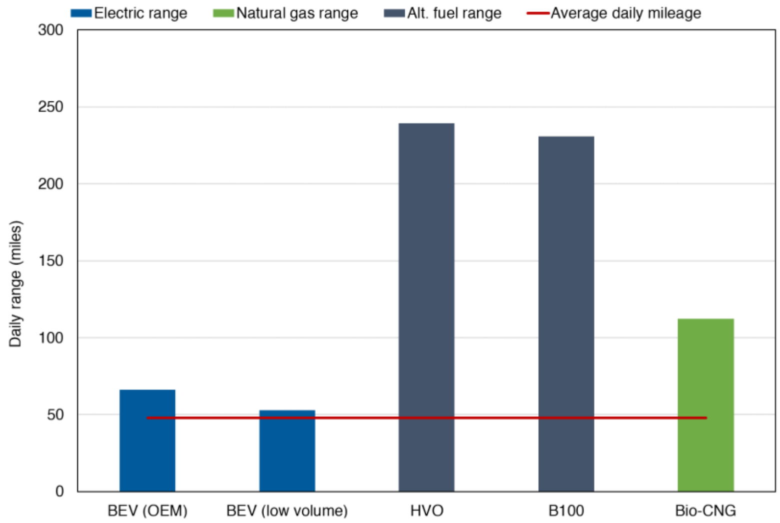


Figure 13 - Operating Range; Rigid Truck (26t GVW)

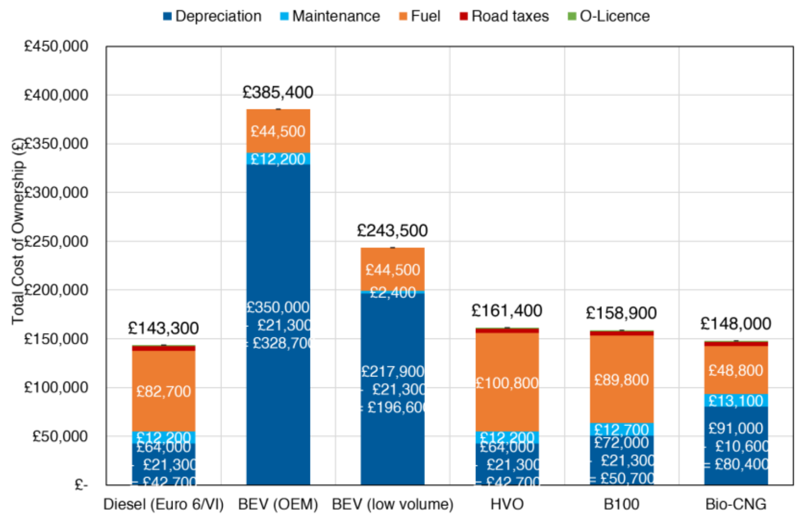
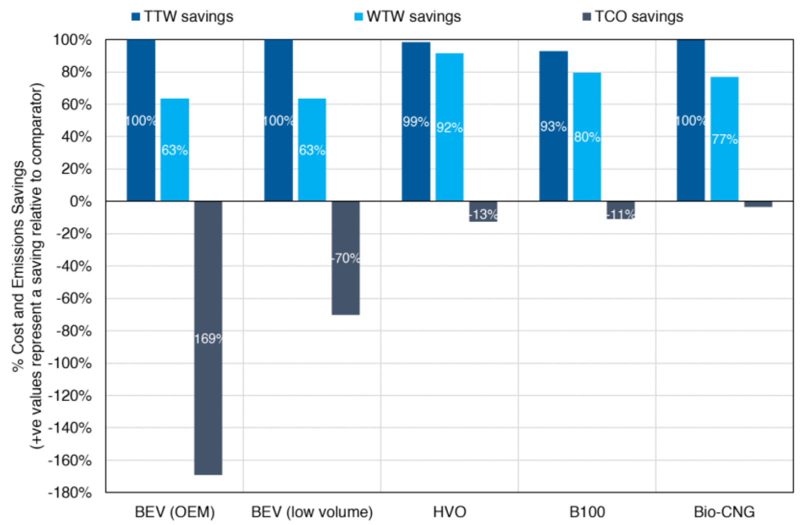


Figure 14 - Total Cost of Ownership; Rigid Truck (26t GVW)



The increased purchase cost of BEV (low volume) and BEV (re-power) is the main influencing factor in TCO.

The bio-CNG operating range is substantially more than the average daily mileage and provides a 77% reduction in WTW CO_2e emissions. However, air quality emissions remain at Euro VI levels.

Figure 15 – CO_2e Emissions Savings vs. TCO Difference; Rigid Truck (26t GVW)

BEV (OEM / low volume)

Criteria	Performance
Operational	• Estimated real-world range of between 44 – 66 miles (180 – 270 kWh). • The daily mileage uses at least half of the battery capacity. The BEV would have to be charged between shifts if it were to be double shifted. • Many of this vehicle category are specialist refuse collection vehicles, which may limit their suitability for battery-electric options due to the lack of available vehicles. • The payload will be reduced due to the additional weight of the batteries. See Appendix B – for more details.
TCO	• An increase in purchase costs of £154,000 – £286,000 leads to large depreciation cost increases. • Despite significant running cost savings, there is an overall TCO increase of at least £100,200 due to the low mileages undertaken by these vehicles. This rises to £242,100 for the BEV (OEM).
Emissions	• Zero tailpipe emissions. • 63% reduction in WTW CO_2 emissions based on the current UK grid energy mix. This will reduce further as the UK grid decarbonises.

HVO

Criteria	Performance
Operational	• The estimated range is far greater than the average daily mileage. • Refuelling can be done in a similar time to diesel.
TCO	• No increase in capital cost as the vehicle is the same as a diesel. • Increased running costs lead to a TCO increase of £18,100.
Emissions	• 92% reduction in WTW CO_2 emissions. • Air quality pollutant emissions equivalent to Euro VI.

FAME (B100)

Criteria	Performance
Operational	• The estimated range is far greater than the average daily mileage. • Refuelling can be done in a similar time to diesel. • Additional fuel storage and handling requirements.
TCO	• £8,000 increase in capital cost. • Increased maintenance requirements. • Increased running costs lead to a TCO increase of £15,600.
Emissions	• 80% reduction in WTW CO_2 emissions. • Air quality pollutant emissions equivalent to Euro VI.

Bio-CNG

Criteria	Performance
Operational	• The estimated range is far greater than the average daily mileage. • Refuelling can be done in a similar time to diesel.
TCO	• £37,700 increase in vehicle capital cost. • Despite access to low-cost public gas prices (£0.70 per kg), increased running costs lead to a TCO increase of £4,700.
Emissions	• 77% reduction in WTW CO_2 emissions. • Air quality pollutant emissions equivalent to Euro VI.

4.5.5 Low Emission Vehicle Technology Options Appraisal

Following the completion of the above Performance Reviews an additional appraisal was undertaken to assess the wider implications of the analysed technologies within the Medium Van and Rigid Truck (RCV) vehicle segments. This high-level options appraisal took into account emission reduction potential, vehicle and fuel availability, operational considerations, ownership costs and refuelling/ recharging infrastructure requirements.

This analysis has been undertaken as a qualitative assessment using a **red**, **amber**, **green** status with an additional grey category for neutral or conditional metrics (e.g. vehicle cost for 'drop-in' fuels). Table 13 shows the colour coding used for this additional low emission vehicle technologies options appraisal.

Table 13 - Technology Options Review Criteria

Key	Cost and Emissions	Maturity and Availability	All Others
	Better than diesel	OEM product	Advantage
	Same as diesel	Conditional	Neutral
	Slightly worse than diesel	Low volume	Minor disadvantage
	Worse than diesel	Demonstration phase	Disadvantage

Table 14 and Table 15 show a summary of the performance of each identified low emission vehicle technology within the Medium Van and Rigid Trucks (RCV) category respectively, against the key metrics studied. Vehicle technologies are presented left to right in order of vehicle cost ascending.

Table 14 - Summary of Low Emission Technology Options – Medium Vans

Performance Metric	Renewable Diesel (HVO)	Biodiesel (B100)	Battery Electric
Greenhouse Gas Emissions		Blend limited	
Air Pollutant Emissions	Euro VI	Euro VI	ZEV
Noise Pollution			
Maturity		Partial OEM	Partial OEM
Availability (2021)			
Availability (2030)			
Typical Operations		Fuel Use / Storage	
Intensive Operations		Fuel Use / Storage	Energy Storage
Vehicle Weight			Batteries
Vehicle Costs			
Fuel Costs			
Maintenance Costs			Currently the same
Existing Infrastructure			Depot Power
Infrastructure Cost			Varies by site
Infrastructure Viability			

Table 15 - Summary of Low Emission Technology Options – Rigid Trucks (RCVs)

Performance Metric	Renewable Diesel (HVO)	Biodiesel (B100)	Bio-CNG	Hydrogen Dual Fuel	Battery Electric	Fuel Cell Electric
Greenhouse Gas Emissions		Blend limited		SR[1] limited		H_2 Production
Air Pollutant Emissions	Euro VI	Euro VI	Euro VI	Euro VI	ZEV	ZEV
Noise Pollution			SI[1] Only			
Maturity		Partial OEM			Partial OEM	
Availability (2021)						
Availability (2030)			Could be phased out			Availability uncertain
Typical Operations		Fuel Use / Storage				
Intensive Operations		Fuel Use / Storage			Energy Storage	
Vehicle Weight[2]			Gas tanks	Gas tanks	Batteries	Batteries
Vehicle Costs						
Fuel Costs						
Maintenance Costs					Currently the same	
Existing Infrastructure					Depot Power	
Infrastructure Cost			Varies by site	Varies by site	Varies by site	Varies by site
Infrastructure Viability						

[1] SR = substitution ratio (by energy), SI = spark ignition engine (similar to a petrol engine)
[2] UK legislation[6] allows a 1,000 kg increase in maximum authorised weight for alternatively fuelled vehicles.

[6] 2017 No. 881 Road Vehicles, UK Government (2017)

4.6 Low Emission Vehicle Technology Selection

In this section, **the suitability of LEV technologies has been assessed for each vehicle in the NWLDC fleet**. The purpose of this assessment is to highlight the overall opportunity for each technology to replace diesel/petrol vehicles within each vehicle segment and across the wider fleet.

This analysis uses the same approach described during the Low Emission Vehicle Performance Reviews, but individual vehicle input parameters are used instead of the vehicle segment averages. The vehicle's locations are considered when analysing the emission performance of battery electric options. NWLDC uses renewable electricity on a Green Tariff at their depot, whereas home charging is accredited to the UK consumer mix. **ULEV pick-up trucks are not currently available in the UK and have been excluded from this analysis**.

The following suitability criteria have been applied to individual vehicles for all assessed LEV technologies.

- **Operating range suitability criteria –** LEVs must be able to complete the average daily mileage on less than one full charge or tank with at least 20 miles range remaining (including any secondary fuels).
- **Greenhouse gas emissions suitability criteria –** LEVs must provide WTW CO_2e emissions savings.

Individual vehicles that do not meet these suitability criteria have been excluded from both the 'Low Emission Vehicle Infrastructure Review' and from any recommendations regarding replacement vehicle technologies.

Technology selection results are reported for the two following potential implementation scenarios:

1. **Maximum emissions savings (at any cost) –** all LEVs that meet the above suitability criteria are included and no additional criteria are applied. This scenario represents the maximum emissions savings that can be achieved for each technology, regardless of the cost implications (e.g. vehicle segment TCO could increase).
2. **TCO parity (or better) within each vehicle segment –** in addition to the above suitability criteria, the number of LEVs is reduced (starting from the vehicle with the largest increase in TCO) until TCO parity is achieved across the vehicle segment. Individual vehicles can provide either an increase or decrease in TCO but the **cumulative TCO** of LEVs within each vehicle segment must **provide parity (or better)** compared to equivalent diesel/petrol vehicles. This scenario represents the emissions savings that can be achieved without increasing fleet TCO (although additional capital funding may still be required).

All previously discussed all relevant LEV technologies have been assessed as part of the Low Emission Vehicle Technology Selection. However, for reporting purposes, **the following LEV technologies have been removed from the technology selection tables and infrastructure reviews – FC REEV, REEV, PHEV, Bio-LPG and DF Bio-LPG**. Individually these technologies have the potential to reduce fleet WTW CO_2e emissions by a maximum of 7%. Additionally, for the reasons discussed previously, these technologies are those which have been identified as of least relevance as potential replacements due to economic or commercial availability reasons.

The Low Emission Vehicle Technology Selection results are presented across a series of tables showing the number and percentage of vehicles that meet the suitability criteria as well the associated emissions savings, additional capital costs and difference in TCO. For some vehicle categories, several technologies have been identified as suitable. This provides NWLDC with technology options, depending on the operational requirements of the vehicles. To provide robust recommendations for replacement vehicle technologies the charging/refuelling infrastructure must either be readily available or be viable to install and operate. LEV infrastructure requirements are assessed separately in Section 5 - Low Emission Vehicle Infrastructure Review.

4.6.1 Low Emission Vehicle Technology Selection – **Maximum Emissions Savings**

Table 16 shows the number and percentage of vehicles that meet the operating range and greenhouse gas emissions suitability criteria for each LEV technology and vehicle segment.

Table 16 - Number of Suitable Vehicles (% of vehicle segment); Maximum Emissions Savings Scenario

	ZEV		ULEV	LEV		
	BEV (OEM)	BEV (low volume)	REEV	Bio-CNG	B100	HVO
Small Car	4 (100%)					
Large Commercial SUV					2 (100%)	2 (100%)
Small Van	7 (100%)				7 (100%)	7 (100%)
Medium Van	48 (100%)		47 (98%)		48 (100%)	48 (100%)
Large Van (< 3.5t GVW)	10 (91%)			11 (100%)	11 (100%)	11 (100%)
Large Van (> 3.5t GVW)	1 (100%)			1 (100%)	1 (100%)	1 (100%)
Rigid Truck - 2 axles (7.5t GVW)	1 (33%)		3 (100%)		3 (100%)	3 (100%)
Rigid Truck - 2 axles (18t GVW)	6 (86%)	1 (14%)		6 (86%)	7 (100%)	7 (100%)
Rigid Truck - 3 axles (26t GVW)	5 (31%)	1 (6%)		16 (100%)	16 (100%)	16 (100%)
Total	**82 (83%)**	**2 (2%)**	**50 (51%)**	**34 (34%)**	**95 (96%)**	**95 (96%)**

It should be noted that more work is required to better understand the RCV daily rounds to determine the suitability of BEV within this vehicle segment. The calculation of vehicle energy consumption is complicated due to a variety of factors including driving, lifting, compacting, increasing payload, etc. In some instances, Cenex have seen ranges of 50 to 130 miles depending on duty cycle, which are achievable if the collection round is repeatable e.g. a vehicle might do 25 miles every day and use 50% of the capacity for a 50 mile 'range'.

Table 17 lists the annual WTW CO_2e emissions savings and annual NOx emissions savings achievable under this scenario.

Table 17 - Annual WTW CO_2e Emissions Savings (% of total fleet); Maximum Emissions Savings Scenario

	ZEV		ULEV	LEV		
	BEV (OEM)	BEV (low volume)	REEV	Bio-CNG	B100	HVO
Small Car	1%					
Large Commercial SUV					1%	1%
Small Van	1%				1%	1%
Medium Van	15%		8%		17%	18%
Large Van (< 3.5t GVW)	4%			4%	4%	4%
Large Van (> 3.5t GVW)	0%			0%	0%	0%
Rigid Truck - 2 axles (7.5t GVW)	1%		2%		3%	3%
Rigid Truck - 2 axles (18t GVW)	12%	1%		3%	12%	13%
Rigid Truck - 3 axles (26t GVW)	10%	0%		43%	44%	47%
Total	**44%**	**1%**	**11%**	**56%**	**81%**	**86%**

Theoretically, 83% of the total fleet (predominately small cars and medium vans) could be replaced with battery electric variants, saving approximately 44% of annual fleet WTW CO_2e emissions and 78% of annual fleet NOx emissions. 34% of the fleet (LCVs and rigid trucks) could be replaced by bio-CNG variants, saving 56% of annual fleet WTW CO_2e emissions with similar Euro 6/ VI air quality pollutant emissions.

The CO_2 savings for HVO and biodiesel are shown as better than BEV due to the emission factors used, which considers the fuel production process, which is currently less polluting for these liquid fuels. However, electricity generation will continue to decarbonise in the future, while the emissions from the production of HVO and biodiesel are unlikely to change.

Table 18 - Annual NOx Emissions Savings (% of total fleet); Maximum Emissions Savings Scenario

	ZEV		ULEV	LEV		
	BEV (OEM)	BEV (low volume)	REEV	Bio-CNG	B100	HVO
Small Car	3%					
Large Commercial SUV					0%	0%
Small Van	5%				0%	0%
Medium Van	55%		52%		0%	0%
Large Van (< 3.5t GVW)	6%			0%	0%	0%
Large Van (> 3.5t GVW)	0%			0%	0%	0%
Rigid Truck - 2 axles (7.5t GVW)	0%		2%		0%	0%
Rigid Truck - 2 axles (18t GVW)	5%	1%		0%	0%	0%
Rigid Truck - 3 axles (26t GVW)	4%	0%		0%	0%	0%
Total	**78%**	**1%**	**53%**	**0%**	**0%**	**0%**

B100 is available for 96% of the fleet, resulting in WTW CO_2e emissions savings of 81% with similar NOx emissions. HVO could cover the same fleet share with marginally higher WTW CO_2e reductions. B100 and HVO could be options for the rigid truck segments, especially those where bio-CNG and battery electric are either not currently available or not viable.

Table 19 and Table 20 highlight the cost differences for the alternative technologies compared to a new Euro 6/ VI vehicle for all vehicles meeting the suitability criteria. The tables show the total cost of ownership and additional capital costs. **Green numbers** indicate lower costs, with **red numbers** indicating higher costs compared to an equivalent Euro 6/ VI diesel option.

Table 19 – Difference in Total Cost of Ownership; Maximum Emissions Savings Scenario

	ZEV		ULEV	LEV		
	BEV (OEM)	BEV (low volume)	REEV	Bio-CNG	B100	HVO
Small Car	£493					
Large Commercial SUV					-£14,754	-£4,499
Small Van	-£10,823				-£51,038	-£6,368
Medium Van	£36,246		-£420,293		-£372,056	-£107,827
Large Van (< 3.5t GVW)	-£95,955			-£55,453	-£83,733	-£24,866
Large Van (> 3.5t GVW)	-£52,760			-£4,706	-£6,636	-£1,724
Rigid Truck - 2 axles (7.5t GVW)	-£38,439		-£137,624		-£32,445	-£16,411
Rigid Truck - 2 axles (18t GVW)	-£1,227,419	-£85,299		-£64,559	-£88,190	-£77,918
Rigid Truck - 3 axles (26t GVW)	-£1,284,206	-£131,067		-£57,172	-£251,058	-£291,091
Total	**-£2,672,863**	**-£216,366**	**-£557,916**	**-£181,891**	**-£530,703**	**-£530,703**

BEV (OEM) small cars and medium vans yield a combined TCO saving of **~£36,500** over the life of the vehicles, procurement of these 52 vehicles would incur additional capital costs of **~£407,000** (excluding infrastructure).

Table 20 - Additional Vehicle Capital Cost; Maximum Emissions Savings Scenario

	ZEV		ULEV	LEV		
	BEV (OEM)	BEV (low volume)	REEV	Bio-CNG	B100	HVO
Small Car	£32,033					
Large Commercial SUV					£13,000	£0
Small Van	£43,223				£45,500	£0
Medium Van	£375,360		£780,435		£312,000	£0
Large Van (< 3.5t GVW)	£242,097			£60,500	£71,500	£0
Large Van (> 3.5t GVW)	£60,000			£5,500	£6,500	£0
Rigid Truck - 2 axles (7.5t GVW)	£54,000		£180,000		£24,000	£0
Rigid Truck - 2 axles (18t GVW)	£1,404,000	£109,550		£120,000	£56,000	£0
Rigid Truck - 3 axles (26t GVW)	£1,430,000	£142,775		£432,000	£128,000	£0
Total	**£3,640,713**	**£252,325**	**£960,435**	**£618,000**	**£656,500**	**£0**

The above tables demonstrate that the economics for the replacement of entire vehicle segments with ZEVs, ULEVs, and LEVs are challenging across the NWLDC fleet. This is primarily due to higher capital costs and the low annual mileages undertaken by most vehicles. High annual mileages allow running cost savings to offset the disadvantage of increased capital costs, especially for BEV rigid trucks with their low relative maturity and increased costs.

Under this scenario the adoption of 12 battery electric rigid trucks would increase TCO by **~£2,545,000**.

However, even bio-CNG priced at £0.70/ kg, such as from a large public gas station, would increase fleet TCO by **~£182,000**. As reported in Section 5, this represents a realistic best-case scenario as small-scale depot based natural gas stations typically yield an increased gas price.

4.6.2 Low Emission Vehicle Technology Selection – ***Total Cost of Ownership Parity***

Table 21 shows the percentage of vehicles that meet the additional TCO parity selection criteria. This represents the percentage of vehicles that provide enough operating range, WTW CO_2e emissions savings **and** could be introduced **without** increasing fleet TCO.

Table 21 - Number of Suitable Vehicles (% of vehicle segment); TCO Parity Scenario

	ZEV	LEV
	BEV (OEM)	Bio-CNG
Small Car	4 (100%)	
Large Commercial SUV		
Small Van	2 (29%)	
Medium Van	48 (100%)	
Large Van (< 3.5t GVW)		
Large Van (> 3.5t GVW)		
Rigid Truck - 2 axles (7.5t GVW)		
Rigid Truck - 2 axles (18t GVW)		
Rigid Truck - 3 axles (26t GVW)		13 (81%)
Total	**54 (55%)**	**13 (13%)**

The introduction of battery electric and bio-CNG can provide some level of TCO parity within their respective vehicle segments although the suitability of bio-CNG is dependent on the provision of bio-CNG at £0.70/ kg. In addition, while both biodiesel and HVO provide emission savings and are operationally suitability, these fuels have been excluded from this analysis as their introduction increases TCO, due to increased fuel prices, and in the case of biodiesel, increased maintenance and vehicle capital costs.

Table 22 and Table 23 show the annual WTW CO_2e emissions savings and annual NOx emissions savings for the TCO parity scenario.

Table 22 - Annual WTW CO_2e Emissions Savings (% of total fleet); TCO Parity Scenario

	ZEV	LEV
	BEV (OEM)	**Bio-CNG**
Small Car	1%	
Large Commercial SUV		
Small Van	1%	
Medium Van	15%	
Large Van (< 3.5t GVW)		
Large Van (> 3.5t GVW)		
Rigid Truck - 2 axles (7.5t GVW)		
Rigid Truck - 2 axles (18t GVW)		
Rigid Truck - 3 axles (26t GVW)		39%
Total	**16%**	**39%**

Table 23 - Annual NOx Emissions Savings (% of total fleet); TCO Parity Scenario

	ZEV	LEV
	BEV (OEM)	**Bio-CNG**
Small Car	3%	
Large Commercial SUV		
Small Van	2%	
Medium Van	55%	
Large Van (< 3.5t GVW)		
Large Van (> 3.5t GVW)		
Rigid Truck - 2 axles (7.5t GVW)		
Rigid Truck - 2 axles (18t GVW)		
Rigid Truck - 3 axles (26t GVW)		0%
Total	**60%**	**0%**

In this scenario, 55% of the fleet, including all small cars, all medium vans and two small vans could be replaced by battery electric variants, saving 16% of annual fleet WTW CO_2e emissions and 60% of NOx emissions.

For larger vehicle segments, 81% of the rigid truck - 3 axles (26t GVW), could be replaced with bio-CNG variants, saving 39% of annual WTW CO_2e emissions while achieving Euro 6/ VI air quality pollutant standards.

Table 24 and Table 25 show the difference in total cost of ownership and additional capital cost **compared to a new Euro 6/ VI diesel vehicle** for all segments which contain ZEV and LEV technologies that can achieve TCO parity.

The procurement of 54 BEV (OEM) vehicles (55% of the fleet) would result in additional capital costs of **~£420,000** and would return TCO savings of **~£36,000**.

The procurement of 13 bio-CNG rigid trucks (13% of the fleet) would result in additional capital costs of **~£351,000** and would achieve TCO savings of **~£10,500**.

Table 24 - Difference in Total Cost of Ownership; TCO Parity Scenario

	ZEV	LEV
	BEV (OEM)	Bio-CNG
Small Car	£493	
Large Commercial SUV		
Small Van	£644	
Medium Van	£36,246	
Large Van (< 3.5t GVW)		
Large Van (> 3.5t GVW)		
Rigid Truck - 2 axles (7.5t GVW)		
Rigid Truck - 2 axles (18t GVW)		
Rigid Truck - 3 axles (26t GVW)		£10,528
Total	**£36,246**	**£10,528**

Table 25 - Additional Vehicle Capital Cost; TCO Parity Scenario

	ZEV	LEV
	BEV (OEM)	Bio-CNG
Small Car	£32,033	
Large Commercial SUV		
Small Van	£12,349	
Medium Van	£375,360	
Large Van (< 3.5t GVW)		
Large Van (> 3.5t GVW)		
Rigid Truck - 2 axles (7.5t GVW)		
Rigid Truck - 2 axles (18t GVW)		
Rigid Truck - 3 axles (26t GVW)		£351,000
Total	**£419,743**	**£351,000**

As a result of the above Low Emission Vehicle Technology Selection process, a decision was made to focus on the introduction of **BEV and bio-CNG** technologies as these provide a reduced risk solution to achieving a lower emission fleet. These technologies have been taken forward for an assessment of the average daily fuel/ energy requirements associated with their use, followed by the Low Emission Vehicle Infrastructure Review.

4.6.3 Additional remarks on range suitability for battery electric vehicles

The above technology selection process uses range suitability criterion based on average daily mileage. In reality, vehicle operations will vary from day to day. This daily variation can cause concern where on average vehicles have been identified as suitable, but not for every single day. Such exceeding days, if frequent, will compromise the suitability of BEVs.

Given the data provided by NWLDC, Cenex undertook an additional analysis of the suitability of battery electric options, based on the actual mileage data provided. The focus of this analysis was on medium vans, as these vehicles were identified as being the most operationally constrained due to mileage requirements.

Using the provided data it was calculated that a medium van with a battery capacity of 68 kWh has an average daily range of 125 miles. Figure 16, below, compares that value with the logged daily distances for the financial years 2019/2020 and 2020/2021. It should be noted that data logging started on the 12th of August 2019, resulting in fewer counts of daily distances for the period of 2019/20.

However, the calculated distributions between the two periods are similar, although financial year 2020/2021 skews towards shorter distances, which is believed to be a result of the COVID-19 pandemic.

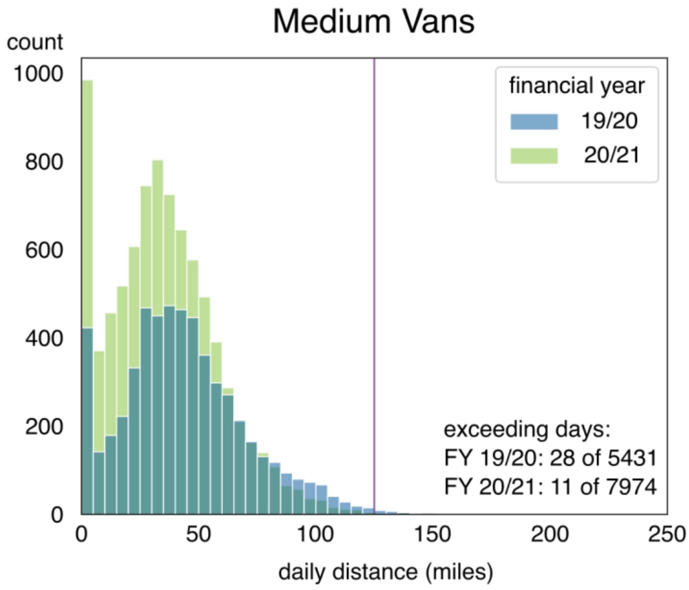


Figure 16 – Daily distance distribution for medium vans in the financial years 19/20 and 20/21

The share of trips exceeding the required 125 miles range is 0.5% for 2019/2020 and 0.14% for 2020/2021. While there are a proportion of journeys that are close to the available range, overall the bulk of daily journeys are shorter than the average BEV range of 125 miles and not all vehicles exceeded this. Table 26 lists the medium vans with logged daily distances above the battery range (Table 42 in the Appendix is an extended version of Table 26 containing all relevant vehicles). Most of them only show two or fewer days of exceedance a year.

Those numbers suggest that battery electric technology can be considered a suitable option, which is not likely to interfere with the current vehicle operation as **very few vehicles** have been found to exceed the calculated battery range. It would be expected that the low number of range exceedances can be overcome by opportunity charging during the day. However, further investigation in to the vehicle start locations and daily duties would need to be undertake the verify their suitability for BEV technology.

Table 26 – Medium vans with daily trips that exceeding battery range

Fleet Number	Vehicle Type	Department	Usable Battery Capacity (kWh)	Average BEV Range (Miles)	FY 2019/2020		FY 2020/2021	
					Number of Daily Trips Exceeding BEV Range	Number of Daily Trips	Number of Daily Trips Exceeding BEV Range	Number of Daily Trips
701	Medium Van	Housing Maintenance	68	125	1	164	2	232
710	Medium Van	Housing Maintenance	68	125	2	114	0	221
720	Medium Van	Refuse Department	68	125	3	223	2	200
735	Medium Van	Housing Maintenance	68	125	0	151	2	184
737	Medium Van	Housing Maintenance	68	125	11	134	2	189
739	Medium Van	Housing Maintenance	68	125	3	120	0	185
742	Medium Van	Housing Maintenance	68	125	2	64	1	149
743	Medium Van	Housing Maintenance	68	125	5	140	0	189
746	Medium Van	Housing Maintenance	68	125	0	111	1	68
748	Medium Van	Housing Maintenance	68	125	0	135	1	145
782	Medium Van	Housing Maintenance	68	125	1	131	0	231

4.6.4 Additional remarks on double shifting of RCVs

It is anticipated that it will be challenging to double shift battery electric RCVs. Initial calculations indicate that, using current usage patterns, the NWLDC BEV RCVs are projected to use on average 70% of their battery capacity each day so most vehicles would have to be charged between the two shifts if double shifted.

This would require multiple high power rapid chargepoints to charge the waste fleet during the limited charging window during shift changeover (as opposed to overnight charging when single shifted). It should be noted that currently available BEV RCVs cannot charge at high powers and typically take 4-8 hours to charge; however, the 2022 Mercedes eEconic will be able to charge at 150kW.

While it would be possible to double shift the BEV RCVs in the future, when suitable vehicles are available, it would require significant investments in to infrastructure and increased site grid capacity.

It should be noted that all current UK BEV RCV deployments have been single shifted days of around 8 hours.

4.7 Additional Daily Fuel/ Energy Requirements

Table 27 shows the average daily fuel or energy requirements by location for the ZEV, ULEV, and LEV technologies that have been selected for further analysis based on the Low Emission Vehicle Technology Selection. The main purpose of this analysis is to highlight which location(s) to study during the Low Emission Vehicle Infrastructure Review whilst also providing key economic modelling inputs such as the average daily fuel consumption for gaseous and liquid fuels.

The table includes all vehicles that meet the operating range and greenhouse gas emissions suitability criteria regardless of TCO. This provides a complete overview of the **maximum** potential energy requirements of ZEV, ULEV, and LEV technology per location.

Table 27 - Average Daily Fuel or Energy Consumption of Selected ZEV and LEV Technologies

Location	Baseline	ZEV	ULEV	LEV		
	Diesel (litres)	BEV (OEM) (kWh)	REEV (kWh)	Bio-CNG (kg)	B100 (litres)	HVO (litres)
Linden Way Depot	1,300	1,761	181	1,023	1,409	1,355
Home	256	950	535		277	266
London Road Depot	40	115		29	43	42
Council Offices	26	83	17		15	14
Total	**1,622**	**2,909**	**733**	**1,052**	**1,743**	**1,677**
Number of Vehicles	**99**	**82**	**51**	**34**	**95**	**95**

The current NWLDC vehicle fleet is spread across three Council locations, with a proportion taken home overnight. The introduction of BEVs has the potential to increase depot energy consumption depending on the number of vehicles based at each location. The largest increase in energy consumption is likely to be experienced by the Linden Way Depot due to the high number of rigid trucks and other HGVs stored there.

On an average day, the potential fleet of natural gas vehicles could consume about 1,000 kg of bio-CNG (assuming a shared natural gas station). This is a very small use demand with a typical small natural gas station having a daily capacity of ~10,000 kg.

High volumes of B100 biodiesel are required for economic delivery, with typical minimum on-site delivery of 10,000 litres required. Biodiesel is organic and has a shelf life meaning it requires using within three to four months. This means only sites with the capacity of at least 30,000 – 40,000 litres per annum are appropriate. With a daily demand in excess of 1,400 litres, the Linden Way Depot would have enough demand to consume the B100 before it exceeds its shelf life.

HVO does not suffer from a short shelf life like B100, although minimum deliveries are required to ensure reduce prices.

5. Low Emission Vehicle Infrastructure Review

This section assesses the infrastructure required to facilitate the uptake of those vehicles identified as being suitable for replacement with ZEV, ULEV, and LEV alternatives. This includes a high-level assessment of the required type, location, and indicative capital costs of any required infrastructure. Supporting guidance regarding the key factors to consider when installing and operating ZEV, ULEV, and LEV infrastructure are available in Appendix H – Infrastructure Considerations.

Although there are installation and operational considerations associated with the use of bunkered renewable fuel supplies, these are considered less significant than those associated with **electric vehicle charging infrastructure,** and **natural gas refuelling stations**.

5.1 Charging and Refuelling Infrastructure Baselining

To enable NWLDC to better understand whether staff can utilise existing publicly available infrastructure during their daily duties Cenex undertook an infrastructure mapping exercise, where NWLDC depot locations were mapped against the existing publicly available electric vehicle and natural gas infrastructure. The results of the exercise can be found in Figure 17, below.

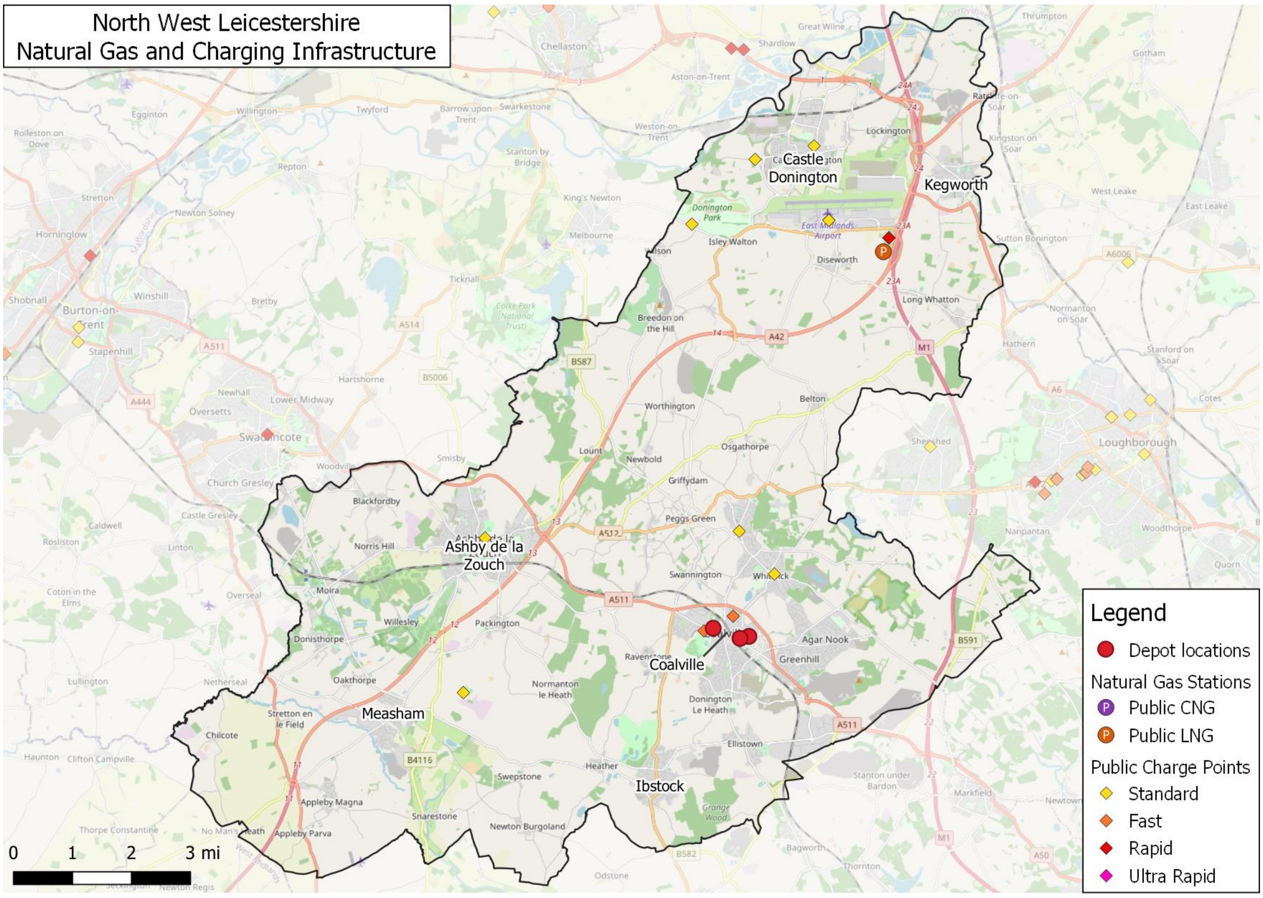


Figure 17 – Locations of Offices and Depots with EV and Natural Gas Infrastructure

The results of the benchmarking exercise indicate that there is some publicly available standard power infrastructure in the main population centres of the district. Additionally, there are 12 three-phase fast chargepoints in Coalville that can charge supported vehicles at up to 22 kW. Finally, there is one rapid charger in the district located at Castle Donington motorway services which can deliver 50 kW. Just outside the district, there are more fast and rapid chargers in the towns of Loughborough and Swandicote. Relying purely on publicly available electric vehicle infrastructure would not be appropriate given its limited availability. However, there are currently enough public chargepoints that a vehicle would not have to travel far if it required a top-up charge during the day. If NWLDC were to install additional public chargepoints across the region it would benefit both the operational fleet and residents wishing to transition to electric cars.

In terms of natural gas refuelling, there is one major liquified natural gas refuelling station in North West Leicestershire although this fuel is more relevant to long haul transit. The nearest public compressed natural gas stations are in Erdington (near Birmingham) and Newark.

5.1.1 Electric Vehicle Charging Infrastructure – Assessment

A high-level assessment of electric vehicle charging infrastructure requirements has been undertaken to identify the required number, type, and location of chargepoints based on the number and types of BEVs identified as being suitable under the **Maximum Emission Savings** and **TCO Parity** scenarios.

In addition, and for each scenario, the implications of operating all vehicles from a single depot has also been assessed.

The assessment has been undertaken based on the following assumptions:

- **Total time available for charging between shifts = 14 hours.**
  - Most vehicles in operation between 8:00 am and 6.00 pm.
  - Some housing vans are required to be on call until 9.00 pm, so would experience a reduced window for charging.
- **Calculated charging time = average daily energy consumption** (kWh) **/ minimum charging power** (kW, on-board vehicle or chargepoint output) **x additional charging time safety factor** (1.25)
- The most suitable chargepoint has been selected out of three charging options assessed:
  - **7 kW AC** (230V, 32A single phase) – Home-based infrastructure only.
  - **22 kW AC** (400V, 32A three phases) **–** for reference the installed cost of a 22 kW AC chargepoint is typically only ~£225 more than a 7 kW AC chargepoint, based on a level depot installation, this provides a level of future-proofing and is considered best practice for fleet operators installing new chargepoints at operational sites. The costs for installing a 7kW charger at a depot are higher than those for a home charger due to the additional ground works and wiring usually involved.
  - **50 kW DC** (400V, 32A three phases)
  - Charging power is increased until the calculated charging time is less than the total time available. Vehicles can be excluded from the recommended replacement vehicles if charging under these conditions is not viable.
- Indicative hardware and installation costs are based on Cenex experience from electric vehicle charging infrastructure projects assuming 5m cabling and 2.5m^2 ducting; these costs include any relevant chargepoint grants:
  - 7 kW AC (Home – single output e.g. one vehicle) = £1,000
  - 22 kW AC (dual output e.g. two vehicles) = £7,103
  - 50 kW DC (single output e.g. two vehicles) = £24,087
  - **Prices exclude a warranty, annual operating costs** (e.g. back office system, 4G connection, maintenance etc.) **and any required grid upgrade costs**
  - **Infrastructure costs are reported on a per vehicle basis** (e.g. a vehicle requiring a 50 kW DC chargepoint will be assigned a hardware and installation cost of £12,043 or £24,087 divided by 2).

Table 28 shows a summary of the number, type, location, installed hardware costs, and peak charging power for the **maximum emissions savings scenario (i.e.** Low Emission Vehicle Technology Selection – **Maximum Emissions Savings**.)

Table 28 - Electric Vehicle Charging Infrastructure Requirements; Maximum Emissions Saving Scenario

	Number of 7 kW chargepoints (Home Charging)	Number of 22 kW chargepoints	Number of 50 kW chargepoints	Typical Hardware and Installation Cost (£)	Additional Power Needs (kW)
Home	43	0	0	£43,000	N/A
Linden Way Depot	0	21	0	£75,000	327
London Road Depot	0	10	0	£36,000	66
Council Offices	0	8	0	£28,000	56
Total	**43**	**39**	**0**	**£182,000**	**449**

All vehicles which were taken home were assumed to be able to charge at home using a 7 kW chargepoint, thus highlighting the maximum possible costs of chargepoint deployment. However, further investigation will need to be undertaken to assess the actual number of chargepoints that can be deployed for home-based vehicles. Further details of these considerations are summarised in Section 5.2 Home Charging and in the accompanying Home Charging Review report.

Additionally, for those vehicles stored at a depot, the 22 kW chargepoint was identified as having the ability to charge vehicles in a sufficient time, given the identified downtime. The procurement and installation of the above mix of 7 and 22 kW chargepoints to support the maximum uptake of BEVs would cost in the region of **£182,000**.

Without mitigating measures, such as smart charging (i.e. the ability for chargepoints to manage the timing and power of charging in response to user or site requirements), this could result in peak charging power demands that exceed the existing site electricity capacity. For example, at the Linden Way Depot, there would be an additional power demand of 327 kW if all the BEVs were plugged in to charge at the same time.

NWLDC voiced the possibility of redeploying all vehicles to operate from a single depot, including those that are currently home-based, therefore Table 29 includes such a scenario (in the last row).

With costs in the region of **£291,000**, the single depot option is **60%** more expensive due to the installation of additional 22 kW chargepoints instead of 7 kW, which would be sufficient to charge the currently home-based fleet. This cost can therefore be interpreted as an upper limit as Table 29 also shows additional scenarios for a single depot operation, with different numbers of vehicles from the housing fleet stationed at the depot.

The scenarios range from purely home-based operation (0% at the depot) to a purely depot-based operation (100%).

Table 29 - Electric Vehicle Charging Infrastructure Requirements for a single depot scenario and different percentages of the housing fleet stationed at the depot; Maximum Emissions Saving Scenario

	Number of 7 kW chargepoints (Home Charging)	Number of 22 kW chargepoints	Number of 50 kW chargepoints	Typical Hardware and Installation Cost (£)	Additional Power Needs (kW)
0% of the housing fleet at the depot					
Home	43	0	0	£43,000	N/A
Single Depot	0	39	0	£139,000	449
Total	**43**	**39**	**0**	**£182,000**	**449**
25% of the housing fleet at the depot					
Home	32	0	0	£32,000	N/A
Single Depot	0	50	0	£178,000	526
Total	**32**	**50**	**0**	**£210,000**	**526**
50% of the housing fleet at the depot					
Home	21	0	0	£21,000	N/A
Single Depot	0	61	0	£217,000	603
Total	**21**	**61**	**0**	**£238,000**	**603**
75% of the housing fleet at the depot					
Home	10	0	0	£10,000	N/A
Single Depot	0	72	0	£256,000	680
Total	**10**	**72**	**0**	**£266,000**	**680**
100% of the housing fleet at the depot					
Total Single Depot	**0**	**82**	**0**	**£291,000**	**750**

Table 30 and Table 31 show the respective results for the **TCO parity scenario (**Low Emission Vehicle Technology Selection – **Total Cost of Ownership Parity)**. Table 30 shows a summary of the number, type, location, installed hardware costs, and peak charging power.

Table 30 - Electric Vehicle Charging Infrastructure Requirements; TCO Parity Scenario

	Number of 7 kW chargepoints (Home Charging)	Number of 22 kW chargepoints	Number of 50 kW chargepoints	Typical Hardware and Installation Cost (£)	Additional Power Needs (kW)
Home	43	0	0	£43,000	N/A
Linden Way Depot	0	5	0	£18,000	35
Council Offices	0	6	0	£21,000	42
Total	**43**	**11**	**0**	**£82,000**	**77**

A single depot operation with different levels of stationing the housing fleet at the depot is summarised in Table 31.

Table 31 - Electric Vehicle Charging Infrastructure Requirements for a single depot scenario and different percentages of the housing fleet stationed at the depot; TCO Parity Scenario

	Number of 7 kW chargepoints (Home Charging)	Number of 22 kW chargepoints	Number of 50 kW chargepoints	Typical Hardware and Installation Cost (£)	Additional Power Needs (kW)
0% of the housing fleet at the depot					
Home	43	0	0	£43,000	N/A
Single Depot	0	11	0	£39,000	77
Total	**43**	**11**	**0**	**£82,000**	**77**
25% of the housing fleet at the depot					
Home	32	0	0	£32,000	N/A
Single Depot	0	22	0	£78,000	154
Total	**32**	**22**	**0**	**£110,000**	**154**
50% of the housing fleet at the depot					
Home	21	0	0	£21,000	N/A
Single Depot	0	33	0	£117,000	231
Total	**21**	**33**	**0**	**£138,000**	**231**
75% of the housing fleet at the depot					
Home	10	0	0	£10,000	N/A
Single Depot	0	44	0	£156,000	308
Total	**10**	**44**	**0**	**£166,000**	**308**
100% of the housing fleet at the depot					
Total Single Depot	**0**	**54**	**0**	**£192,000**	**378**

In the short term, introducing those BEVs which achieve TCO parity would require **£82,000** of capital for the installation of the required mix of chargepoints across the identified sites (or up to **£192,000** for a single site depot).

As fewer vehicles have been identified as being suitable for replacement in the TCO Parity scenario, there is lower peak power. While this is the case it is assumed that smart charging enabled chargepoints would be installed to future-proof the depot.

5.2 Home Charging

Since a majority of the fleet vehicles are currently taken home, identifying options to allow drivers to charge their vehicles overnight at their homes would reduce the need for the installation of additional depot-based or on-street/ public charging infrastructure. Given the overall analysis of the fleet the objective of this work package was to determine:

- What best practice would look like for a home charging scheme
- Provide recommendations for how such a scheme could work within NWLDC, and
- Outline a trial roll-out of the scheme.

Cenex carried out research across fleets that have already investigated home charging to give a range of perspectives on the rollout of home charging schemes for operational vehicles. In addition, Cenex explored a range of chargepoint providers including reviewing the types of chargepoint infrastructure and back office systems available for an employee home charging scheme.

The information outlined below has been taken from a separate, more in-depth, report which should be consulted before deciding on the best approach to implementing a home charging scheme.

5.2.1 Charging powers

Most EV drivers with off-street parking have a choice of two options for charging at home either by installing a dedicated EV chargepoint or by using a standard 3 pin household plug.

Home chargepoints typically have a power rating of 3.7 kW or 7 kW, with the UK Government proposing a minimum 7kW chargepoint for residential buildings. Some early home installations are 3.6 kW chargepoints but today the majority of the installations are 7 kW. Expected increases in battery sizes and technology developments could make chargepoints less powerful than 7 kW obsolete for future car models, so these should be avoided.

5.2.2 Chargepoint providers

There are many models of domestic chargepoint available from several reputable manufacturers. Cenex interviewed a selection of hardware providers and network operators to get an industry-wide perspective on the potential for offering an employee home charging scheme. All interviewees acknowledged that issues associated with charging multiple EVs at the same place and time are becoming more common as vehicles reach mass adoption. They are increasingly developing solutions to mitigate this challenge, including smart charging, and giving customers better remote visibility and control of charging events.

Results of this qualitative data collection exercise suggest that there are hardware and software solutions available in the market to support a home charging scheme, with remote visibility of energy consumption and the ability to reimburse drivers accurately for the electricity used.

5.2.3 Type of parking

Ideally, employees would have off-street parking where a standard 7 kW chargepoint can be connected directly to their home electricity supply.

For those without off-street parking, various solutions such as lamppost chargers are in trial and early development stages but are not considered suitable for widespread deployment by an employer.

Alternatively, these employees could make use of public charging infrastructure, providing there is availability in proximity to where they live. However, this solution relies on these public chargepoints being available when required and relevant chargepoint access cards being provided. It is also likely to be a much more expensive mode of charging.

5.2.4 Reimbursement mechanism

When charging at home there needs to be a method for reimbursing employees for the cost of the electricity that they have used. This requires a back-office system connected to the chargepoints with an associated web-based portal through which the relevant manager (e.g. fleet, energy, etc.) would be able to remotely monitor the energy consumption from charging events of all drivers. Some systems offer automatic reimbursement of employees based on tracked charging session data.

- For reimbursement, drivers usually have to submit proof of their electricity tariff. There is a risk here that employees might claim for personal use, so procuring a robust system is important.
- Smart cables such as that developed by Ohme or Ubitricity can connect to an existing chargepoint and identify the vehicle being charged to record the energy use and allow accurate reimbursement. Every vehicle is equipped with a Smart Cable featuring a mobile electricity meter and mobile power contract. Smart cables enable fleet managers to monitor and report the cost of charging at fleet and individual vehicle level, calculate home charging expenses and view CO_2 emissions and savings.
- There are hardware and software solutions (Mina, Chargepoint) available in the market to support a home charging scheme, with remote visibility of energy consumption and the ability to reimburse drivers accurately for the electricity used. The idea behind these solutions is that employees' chargepoints are integrated into a platform and the software operator is linked directly to their energy suppliers. All the drivers need to do is plug in and the employer gets a single invoice for all energy used.

5.2.5 Grant support

The installation of home chargepoints is incentivised by government funding under the Electric Vehicle Homecharge Scheme (EVHS) administered by The Office for Zero-Emission Vehicles (OZEV). The EVHS scheme provides funding for 75% of the total cost of the purchase and installation (up to a maximum threshold) of a chargepoint providing AC power between 3.5 – 22 kW. From 1st April 2020, the maximum eligible grant amount was reduced from £500 to £350 to enable a greater number of installations to be funded under the scheme.

Currently any private or public sector organisation can claim the above grant, which is usually administered through the chargepoint supplier.

5.2.6 Tax implications

According to the Income Tax Earnings and Pensions Act 2003 s149(4), electricity is not treated as a transport fuel. As a result, no benefit in kind tax arises if an employer:

- Pays to charge a pure-electric company vehicle;
- Pays for a chargepoint to be installed at the employee's home to charge the company vehicle; or
- Pays for a charge card to allow individuals access to commercial or local authority charging points

5.2.7 Ensuring installation readiness

We recommend that NWLDC engage with an installer and insist that surveys of properties are completed to find out any upgrades that may be required and the likely costs in advance of rollout.

The installation must be undertaken by an OZEV approved chargepoint installer. Installers will advertise if they are an approved installer, and OZEV also maintains a list [7]. Note that installers must also be approved by the chargepoint manufacturer to install their product. This helps to provide additional confidence that the installer has the necessary product knowledge to be able to deliver good quality and compliant installation.

5.2.8 Liability for home chargepoints

Cenex recommends that NWLDC only pay for damages to home chargepoints due to general wear and tear and not due to misuse.

NWLDC should encourage employees and train them in the proper use of chargepoint equipment to avoid any damages due to misuse (e.g. not dropping the cable, not leaving the cable uncoiled etc). The chargepoint provider may issue such guidelines themselves.

If the installed home chargepoint remains the property of NWLDC, this means they can be removed if an employee terminates employment, moves to a new property or stops participating in the scheme for any reason. In this instance, NWLDC would be responsible for the cost of removing the hardware and making good the site.

5.2.9 Planning a home charging trial

Cenex recommends that NWLDC plan, deliver and evaluate a trial of home EV charging for their operational fleet. A methodology for such a trial is provided below, which also explains how to transition from a trial into a wider deployment phase, assuming the trial is successful.

- **Consider an industry partner**: chargepoint providers may be enthusiastic to support a home chargepoint scheme trial since they recognise the need to demonstrate that their products and services can support fleets with the mass adoption of EVs. Working with an industry partner could potentially leverage funding to reduce the cost of running a trial. We recommend contacting more than one potential supplier to compare proposals.

[7] https://www.gov.uk/government/publications/electric-vehicle-homecharge-scheme-authorised-installers

- **Scale and duration**: decide how many vehicles and drivers should be involved. A trial with 10-50 employees should be enough to generate plenty of data and driver feedback and identify any potential challenges. The trial should be run for several months to allow any initial problems to be addressed and for drivers to get fully accustomed to the technology. The intention should be for the scheme to continue through the vehicle lifecycle, with an evaluation after six months.
- **Select hardware and back office system**: 7 kW wall-mounted chargepoints are best suited to this type of charging. All home chargepoints funded by the OZEV grant must use innovative 'smart' technology meaning that chargepoints must be able to be remotely accessed, and capable of receiving, interpreting, and reacting to a signal. This is a helpful piece of legislation for home charging as it means all of the offerings on the market have the capability to report their consumption for billing and monitoring purposes.

  Specify a back-office system that supports remote monitoring of energy consumption and shows when charging events take place. It is vital to have a remote web portal to track electricity consumption to ensure compliance, ensuring drivers are not overclaiming or not being fully reimbursed. Some systems offer automatic reimbursement of employees based on tracked charging session data.
- **Reimbursement mechanism**: The trial should consider how to automate the process of reimbursement to reduce driver and fleet administration. Reimbursements can either be provided as a flat fee per charging event or an accurate reimbursement using energy consumption data. The former is easier to administrate and provides a small incentive to drivers to take part. However, we strongly recommend seeking verification from your tax office to ensure compliance with the relevant legislations. While the flat fee approach is straightforward and could be used to get a trial set up, we recommend using accurate reimbursement when deploying at scale.

  It is worth mentioning that many electricity suppliers are starting to offer tariffs specifically targeted at EV drivers which charge higher electricity price tariffs at peak times and lower tariffs at off-peak times.
- **Monitoring and evaluation:** define the criteria that will be used to evaluate the trial and the methods for data collection. This should include quantitative data such as energy consumption and cost, as well as qualitative feedback from drivers and department managers. Feedback could be gathered via email, internal meetings, or workshops.
- **Select participants**: Survey drivers to determine who is eligible and gather expressions of interest. At a minimum, drivers will need to have off-street parking and have a vehicle that is allocated solely for their use. NWLDC may wish to set other criteria for participation but be mindful that additional criteria will reduce the pool for potentially eligible drivers.
- **Launch the trial and evaluate**: once underway, the trial should run for several months before carrying out a formal evaluation. Interim evaluation of driver and manager experiences and monitoring of energy consumption data is recommended to ensure any potential problems can be rectified during the trial. After six months, evaluate the trial using the criteria identified. Check that vehicles have been able to meet operational needs and that any concerns from departmental managers, drivers and/or union representatives are collated and addressed.
- **The business case** for EVs should be updated with a 'home charging scheme business case' to include the cost of electricity from employees' homes, cost of hardware and associated support. This can be compared to the current diesel vehicle business case to evidence the cost saving available.
- **Communicate findings** throughout the organisation and, assuming the pilot was successful, secure funding for wider deployment.
- **Wider deployment:** wider roll-out of the scheme should be undertaken until all relevant drivers have an EV and a home chargepoint. At the same time, any new employees that have off-street parking should be provided with an EV as a default, with a home chargepoint

installed. Their interest and eligibility for participating in the scheme can be assessed during the recruitment process.

Drivers who were unwilling to participate in the original trial may change their views once a successful pilot has been undertaken. Survey these individuals again to assess their appetite for involvement in the scheme.

5.3 Natural Gas Refuelling Infrastructure

While bio-CNG has been identified as a potential replacement technology within the Large Van and Rigid Truck vehicle segments, its use depends greatly on the availability of low-cost fuel.

A high-level assessment of natural gas refuelling infrastructure viability has been undertaken by mapping nearby gas stations then calculating the estimated gas price that NWLDC could achieve from a small gas station with an average daily gas demand of 1,082 kg.

Figure 18 shows the typical economics for a small bio-CNG station funded by a station supplier with a 10-year payback period.

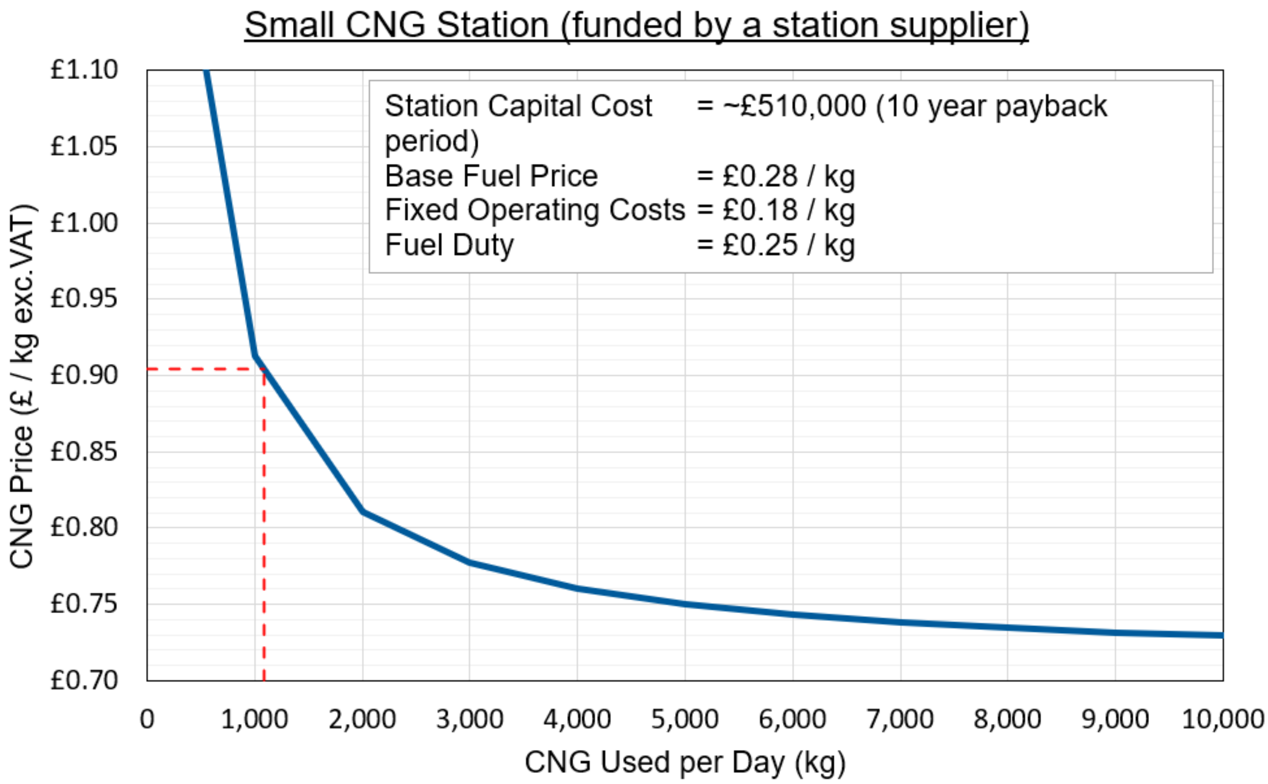


Figure 18 - Typical Economics for a Small Capacity Bio-CNG Station

This shows that **with an average daily gas demand of 1,082 kg** (as identified in the Additional Daily Fuel/ Energy Requirements) **NWLDC could expect a gas price of £0.90/ kg**, compared to the **£0.70/ kg** that could be achieved from a larger public station. Natural gas supplied at this price would result in an increase in fuel costs of **~£325,000** across the fleet.

For a bio-CNG fleet to break even on TCO, NWLDC would require bio-CNG to be supplied at a price of **~£0.57/ kg**; well below that of a depot-based station. This calculated fuel price is close to the base fuel cost (inc. fuel duty) and does not include capital and operational expenditure so is not financially viable for a fuel station provider.

Given the current public station availability and viability of a depot-based station, bio-CNG is deemed unsuitable across the entire NWLDC fleet and has not been considered within the following replacement analysis.

6. Recommended Replacement Vehicle Technologies

Based on the results of the Low Emission Vehicle Technology Selection process and Low Emission Vehicle Infrastructure Review, **Cenex has highlighted those vehicles which could theoretically be replaced by ZEV, ULEV and LEV technologies with minimal changes to the fleet's current operating patterns and planned ownership periods (i.e. TCO Parity)**. The recommended replacement vehicles focus on two technologies: BEV and HVO.

Acknowledging that several practical considerations could limit the introduction of certain technologies, a final technology selection has been applied based primarily on wider operational suitability, ownership costs, technology maturity and viability of fuelling/ charging infrastructure.

Table 32 and Table 33 show a summary of the recommended replacement vehicles in terms of the number of vehicles, capital costs, and emissions savings. All values are compared to the procurement of a new Euro 6/ VI diesel vehicle (excluding VAT). All costs are represented as a difference to an equivalent diesel vehicle where **positive values** are higher than the equivalent vehicle and **negative values** are lower than the equivalent vehicle. This is further highlighted by the use of **Red** and **Green** text across both tables.

A further analysis, taking account of the impact of the Maximum Emissions Savings scenario is presented in Appendix B – NWLDC Maximum Emission Savings Results.

Table 32 summarises the impacts of deploying the identified BEVs within the **TCO Parity scenario**.

Table 32 - Summary of Recommended BEV Replacement Vehicles

	Small Car	Small Van	Medium Van	Total
Replacement Technology	BEV (OEM)			
Number of Vehicles	4	2	48	**54**
% of Vehicle Segment	100%	29%	100%	**55%**
Additional Capital Cost (£)	£32,000	£12,300	£375,400	**£420,000**
Difference in Running Costs (£)	-£19,900	-£11,800	-£380,500	**-£412,000**
Difference in Residual Values* (£)	£12,600	£1,100	£31,100	**£45,000**
Difference in TCO (£)	£500	£600	£36,200	**£37,000**
Ownership Period (years)	7	7	7	**7**
% of Fleet TTW CO_2 Savings	1%	1%	20%	**22%**
% of Fleet WTW CO_2 Savings	1%	1%	15%	**16%**
% of Fleet NOx Savings	3%	2%	55%	**60%**
% of Fleet PM Savings	3%	1%	31%	**35%**
Number of 7 kW Chargepoints	0	0	43	**43**
Number of 22 kW Chargepoints	4	2	5	**11**
Number of 50 kW Chargepoints	0	0	0	**0**
Infrastructure Capital Cost	£14,200	£7,100	£60,800	**£82,000**

* Estimated residual values are an incoming payment rather than a cost, as such positive / higher values are better. Due to the selected sign convention, the difference in TCO = difference in vehicle capital cost – difference in residual value + difference in total running costs. For example, for small cars the difference in TCO is calculated as follows: £32k – £12.6k – £19.9k = – £500.

Across the NWLDC fleet, there are opportunities to introduce battery electric vehicles within the small car, small van, and particularly the medium van vehicle segments.

Introducing 54 BEVs (55% of the fleet) would require additional capital of **£420,000** for vehicles and **£82,000** for electric vehicle charging infrastructure (hardware and installation costs only). These vehicles could provide TCO savings of **£37,000** over their 7 year ownership period, whilst reducing fleet WTW CO_2e emissions by **16%** and fleet air quality pollutant emissions up to **60%** in NOx and **35%** in PM.

It is acknowledged that the identified Medium Vans may need to meet a minimum specification to complete their daily duties especially if the main role of the vehicle is carrying equipment and towing required depending on the location of a given job. However, the Vauxhall Vivaro-e has a payload capacity of between 970 – 1,000 kg with a towing capability of 1,000 kg. While this may be short of what is typically required by the NWLDC operations, it should be sufficient to account for a high proportion of the vehicles. It is recommended that further investigation is made into the carrying and towing needs of these vehicles.

In addition to the BEVs identified in the TCO Parity scenario, NWLDC has expressed an interest in fuelling the remaining fleet vehicles with HVO. Table 33 summarises the impacts of this fuel within these remaining vehicles.

Fuelling the remaining fleet vehicles with HVO would lead to an increase in running costs of **£420,000** over their 7 year ownership period. Whilst HVO increases running costs and thus TCO, significant WTW CO_2e savings of **68%** of the fleet emissions can be achieved. As HVO uses the same engine as a diesel vehicle, there are no guaranteed air quality savings; only BEVs contribute to air quality pollutant emissions reductions. These remaining vehicles would require an estimated 1,400 litres of HVO per day.

Table 33 - Summary of Recommended HVO Vehicles

	Small Van	Large Vans	Rigid Truck	Large 4x4	Total
Replacement Technology	HVO				
Number of Vehicles	5	12	26	2	**45**
% of vehicle segment	71%	100%	100%	100%	**45%**
Additional Capital Cost (£)	£0	£0	£0	£0	**£0**
Difference in Running Costs (£)	£3,500	£26,600	£385,400	£4,500	**£420,000**
Difference in Residual Values (£)	£0	£0	£0	£0	**£0**
Difference in TCO (£)	-£3,500	-£26,600	-£385,400	-£4,500	**-£420,000**
Ownership Period (years)	7	7	7	7	**7**
% of fleet TTW CO_2 savings	0%	5%	67%	1%	**73%**
% of fleet WTW CO_2 savings	0%	4%	62%	1%	**68%**
% of fleet NOx savings	0%	0%	0%	0%	**0%**
% of fleet PM savings	0%	0%	0%	0%	**0%**

Table 34 combines the two separate replacement recommendations into an overall summary.

Table 34 - Summary of Recommended Replacement Vehicles

	Small Car	Small Van	Medium Van	Small Van	Large Van	Rigid Truck	Large 4x4	Total
Replacement Technology	BEV (OEM)			HVO				
Number of Vehicles	4	2	48	5	12	26	2	**99**
% of vehicle segment	100%	29%	100%	71%	100%	100%	100%	**100%**
Additional Capital Cost (£)	£32,000	£12,300	£375,400	£0	£0	£0	£0	**£419,700**
Difference in Running Costs (£)	-£19,900	-£11,800	-£380,500	£3,500	£26,600	£385,400	£4,500	**£7,700**
Difference in Residual Values (£)	£12,600	£1,100	£31,100	£0	£0	£0	£0	**£44,800**
Difference in TCO (£)	£500	£600	£36,200	-£3,500	-£26,600	-£385,400	-£4,500	**-£382,600**
Ownership Period (years)	7	7	7	7	7	7	7	**7**
% of Fleet TTW CO_2 Savings	1%	1%	20%	0%	5%	67%	1%	**95%**
% of Fleet WTW CO_2 Savings	1%	1%	15%	0%	4%	62%	1%	**84%**
% of Fleet NOx Savings	3%	2%	55%	0%	0%	0%	0%	**62%**
% of Fleet PM Savings	3%	1%	31%	0%	0%	0%	0%	**36%**
Number of 7 kW Chargepoints	0	0	43	0	0	0	0	**43**
Number of 22 kW Chargepoints	4	2	5	0	0	0	0	**16**
Number of 50 kW Chargepoints	0	0	0	0	0	0	0	**0**
Infrastructure Capital Cost	£14,200	£7,100	£60,800	£0	£0	£0	£0	**£99,900**

Over all this scenario equates to a potential TCO increase of **£4,700** per vehicle or **£670**/ vehicle per year for an **84%** reduction in fleet WTW greenhouse gas emissions.

In the above scenario, any vehicle that cannot be replaced with an equivalent battery electric variant is assumed to be using HVO. In the case of Small Vans, only 2 have been identified as being appropriate for battery electric, hence the remaining 5 are deemed to be using HVO.

6.1 Recommended Replacement Vehicle Schedule

The current vehicle age and planned ownership periods have been used to calculate the replacement schedule for the recommended replacement vehicles. It shows the required number of replaced vehicles each year as well as the associated vehicle and infrastructure costs and emissions savings.

Table 35 shows the calculated recommended replacement vehicle schedule highlighted by the fleet review. This is reported by financial years to 2030. HVO vehicles have been shown entering the fleet when the current diesel vehicles are replaced, however, as HVO is a drop-in fuel the introduction can be moved forward without replacing the vehicles. The identified schedule and costs only include the first replacement and not recurring substitutions. With technological advancement and an increase in low-emission options, especially for HGVs, it is not meaningful to recommended subsequent replacements. Instead, Cenex advises repeating the present analysis in 2023 to identify whether there are any viable options to replace HVO with BEV or hydrogen power (dual fuel or fuel cell).

All costs are represented as a difference to an equivalent diesel vehicle where **positive values** are higher than the equivalent vehicle and **negative values** are lower than the equivalent vehicle. This is further highlighted by the use of **Red** and **Green** text across both tables.

Table 35 - Recommended Replacement Vehicle Schedule

	Financial Year									
	2021/22	2022/23	2023/24	2024/25	2025/26	2026/27	2027/28	2028/29	2029/30	2030/31
Small Car (BEV)	3	1	0	0	0	0	0	0	0	0
Large Commercial SUV (HVO)	1	1	0	0	0	0	0	0	0	0
Small Van (BEV and HVO)	5	1	0	0	1	0	0	0	0	0
Medium Van (BEV)	26	2	7	0	13	0	0	0	0	0
Large Van (HVO)	9	1	1	0	0	0	0	0	0	0
Large Van (> 3.5t GVW) (HVO)	0	0	0	0	1	0	0	0	0	0
Rigid Truck - 2 axles (7.5t GVW) (HVO)	0	0	1	0	2	0	0	0	0	0
Rigid Truck - 2 axles (18t GVW) (HVO)	0	0	0	5	1	1	0	0	0	0
Rigid Truck - 3 axles (26t GVW) (HVO)	9	1	2	0	4	0	0	0	0	0
Vehicle Replacements	53	7	11	5	22	1	0	0	0	0
Cumulative % of Fleet Replaced by LEV	54%	61%	72%	77%	99%	100%	100%	100%	100%	100%
Additional Vehicle Capital Costs (£)	£227,345	£29,823	£54,740	£0	£107,835	£0	£0	£0	£0	£0
Infrastructure Cost (£)	£41,757	£14,205	£9,551	£0	£16,551	£0	£0	£0	£0	£0
Annual Running Cost Savings (£)	£5,211	£4,271	£5,439	-£2,936	£633	-£1,094	-£1,094	-£1,094	-£1,094	-£1,094
Annual TTW CO_2 Savings (tonnes)	411.8	465.2	565.7	660.0	849.8	869.3	869.3	869.3	869.3	869.3
Annual WTW CO_2 Savings (tonnes)	446.1	508.3	617.2	725.7	929.2	951.5	951.5	951.5	951.5	951.5
Annual NOx Savings (kg)	103.3	112.6	136.6	136.6	194.1	194.1	194.1	194.1	194.1	194.1
Annual PM Savings (kg)	0.5	0.5	0.6	0.6	0.8	0.8	0.8	0.8	0.8	0.8

There is a need for the immediate replacement of some 53 vehicles (54% of the fleet) which are at the end of their current ownership cycle; these are predominantly medium vans and 3 axle 28t GVW rigid trucks. The replacement of these vehicles will need to be carefully managed as it entails significant capital costs for both vehicle and infrastructure. However, a staged replacement of these vehicles will enable NWLDC to make immediate gains on their decarbonisation plans.

Most of the recommended replacement vehicles are medium vans which are due to be replaced during FY2021/2022 to FY2025/2026. By this date 99% of the entire fleet could be replaced by BEVs and HVO fuelled vehicles.

The largest additional capital costs are incurred during FY20201/2022 of **£227,000** for vehicles and **£42,000** for infrastructure.

Where possible, it is suggested that NWLDC should investigate the feasibility of redeploying vehicles to bring forward the introduction date of LEVs. This would entail replacing an end of service life vehicle with another vehicle already in the fleet to allow the replacement BEV to be used on the most suitable or cost-effective duty cycle.

6.2 Emission Impacts

Figure 19 and Figure 20 show the effects of the suggested replacement schedule contained in Table 35 on Greenhouse Gas (expressed as CO_2e) and air quality emissions. The figures illustrate the potential reduction trajectory in comparison to a Euro 6/VI diesel fleet and the maximum achievable emission savings, i.e. the strongest promotion of battery-electric vehicles.

Greenhouse gas emissions from internal combustion engines are directly linked to the amount of petrol or diesel burnt. In this fleet review, the amount of diesel burnt has been calculated using the annual mileage and the fuel consumption of each vehicle. It should be noted that the average CO_2 emissions of new vehicles have decreased over the last decades.[8] Newer vehicles therefore tend to have marginally improved fuel consumption compared to older models, but moreover, show reduced pollutant emissions such as particle matter and NOx.

Other factors such as driving duty, payload, and driving style have a larger impact on fuel consumption than recent Euro standards. This means the possible CO_2 savings that can be achieved when moving from a Euro 4 engine to a Euro 6 engine are marginal. Regarding any replacement schedule, Euro 6/VI is the latest emission standard and represents standard practice.

Any efforts to actively reduce carbon emissions should therefore be benchmarked against a Euro 6/VI vehicle.

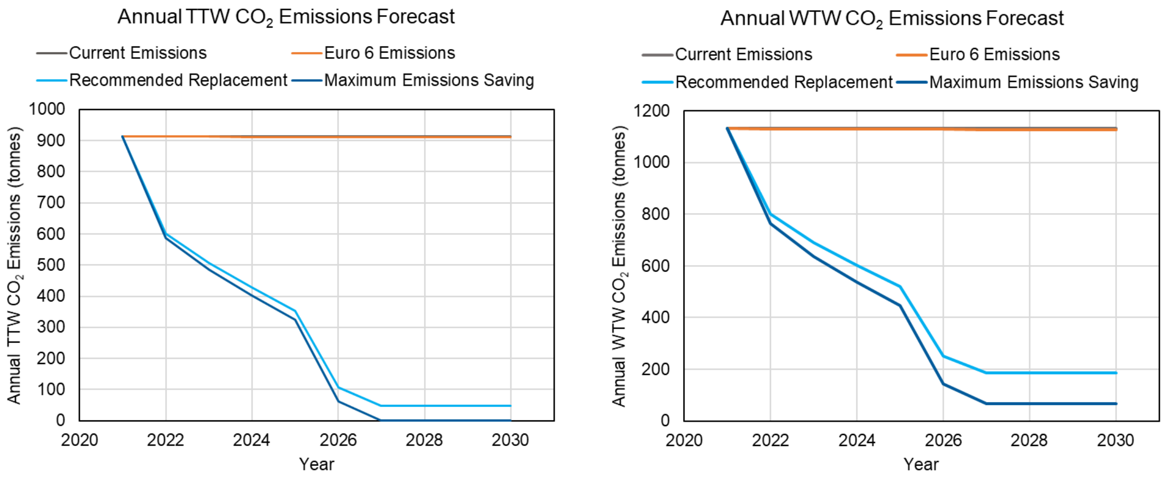


Figure 19 - Annual TTW and WTW CO_2 emissions for different replacement scenarios

[8] https://www.smmt.co.uk/reports/co2-report/

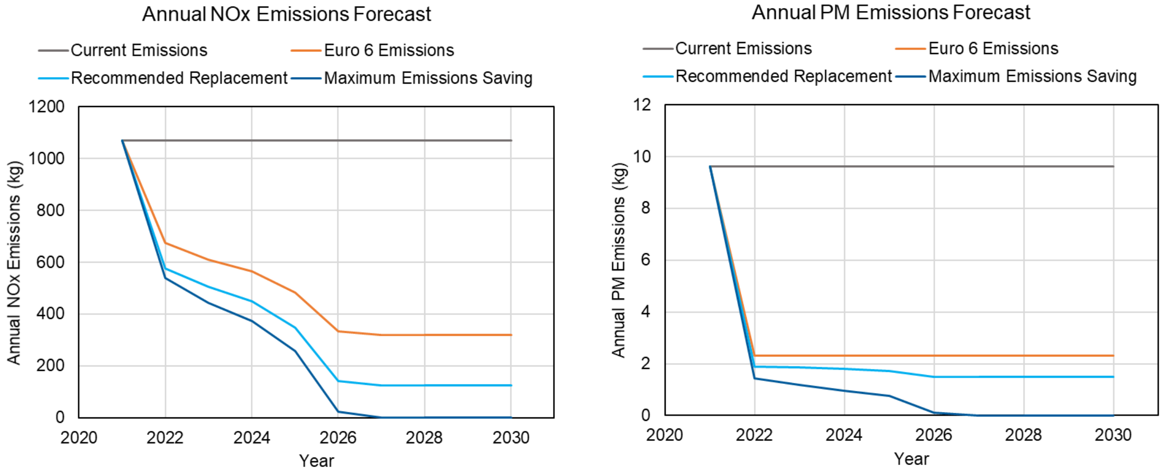


Figure 20 - Annual NOx and PM emissions for different replacement scenarios

The replacement of 53 vehicles in 2021/2022, as identified previously, has the potential to reduce greenhouse gas emissions significantly. It should be noted that the differences between the projected TTW and WTW emissions arise from the fuel supply, which entails the production and distribution of electricity and HVO.

The effect on air quality pollutants is even more pronounced. With many small and medium vans on the fleet currently conforming to Euro 4 standards, their replacement in 2021 significantly reduces NOx and PM emissions from the fleet. This means that in all scenarios there is a considerable drop in PM emissions.

Using HVO as a transition fuel can significantly reduce carbon emissions compared to the Euro 6/VI diesel alternative. While the carbon savings are close to the maximum achievable values, the level of air quality pollutant emissions is unchanged for HVO and any savings relative to the Euro 6/VI lines are due to introduced BEVs.

When the last vehicle gets replaced in 2026/27, the annual WTW CO_2e emissions would be 950 tonnes (see Table 35) lower than the present value of 1,130 tonnes (see Table 6). This is a reduction of 84% in annual emissions.

Table 36, below, provides an outline of the potential annual emission impacts of the switch to the identified vehicle technologies, based on the difference between Euro 6/ VI diesel and BEV or HOV.

Table 36 - Potential Annual Emission Savings Compared to Euro 6/ VI

	Vehicle Category	Annual TTW CO_2e Savings (Tonnes)	Annual WTW CO_2e Savings (Tonnes)	Annual NOx Savings (Kg)	Annual PM Savings (Kg)
BEV	Small Car	2.0	1.8	2.3	0.02
	Small Van	2.4	2.0	3.8	0.02
	Medium Van	3.9	3.3	3.7	0.01
HVO	Large Commercial SUV	3.6	4.2	0	0
	Small Van	0.9	1.1	0	0
	Large Van	3.6	4.2	0	0
	Large Van (> 3.5t GVW)	2.6	3.0	0	0
	Rigid Truck - 2 axles (7.5t GVW)	8.8	10.1	0	0
	Rigid Truck - 2 axles (18t GVW)	17.9	20.6	0	0
	Rigid Truck - 3 axles (26t GVW)	29.0	33.3	0	0

Table 37, below, provides an outline of the potential annual emission impacts of the switch to the identified vehicle technologies, based on the difference between Euro 4/ IV diesel and BEV or HOV.

Table 37 - Potential Annual Emission Savings Compared to Euro 4/ IV

	Vehicle Category	Annual TTW CO_2e Savings (Tonnes)	Annual WTW CO_2e Savings (Tonnes)	Annual NOx Savings (kg)	Annual PM Savings (kg)
BEV	Medium Van	3.9	3.3	10.0	0.39
HVO	Small Van	0.6	0.7	1.8	0.10
	Large Van	0.8	0.9	1.2	0.07
	Rigid Truck - 3 axles (26t GVW)	4.8	5.5	18.8	0.14

6.3 Deployment Planning

The Recommended Replacement Vehicle analysis outputs presented in this Section, specifically the information outlined in Table 35 can be considered an outline action plan for the deployment of BEV and HVO across the NWLDC fleet. In addition to this outline plan, more detailed vehicle by vehicle information is provided in an accompanying MS Excel spreadsheet which provides further evidence of the potential emission and ownership cost savings that could be achieved through the deployment of the identified low emission technologies.

The plan outlined in Table 35 assumes that NWLDC can readily purchase or lease the relevant vehicle models and specifications required for their operational requirements; the impacts of potential vehicle delivery lead times has not been accounted for as this can differ greatly from manufacturer to manufacturer. Similarly, the impact of any potential delays in deploying the relevant charging infrastructure has not been accounted for.

It will be essential that NWLDC discuss their vehicle and infrastructure needs with relevant vehicle and chargepoint suppliers to gain a clear understanding of the likely timeline for delivery/ installation. This will enable a more accurate vehicle and infrastructure deployment plan can be generated.

7. Food Waste Refuse Disposal Vehicle

This section takes a separate look at the hired Isuzu 7.5t GVW rigid truck which is currently being trialled as part of the NWLDC food waste disposal scheme. Like Section 4.5, this section of the fleet review carries out a low emission vehicle performance review to identify the most likely ZEV, ULEV or LEV replacement technology. The methodology is identical to the previous analyses and described in Section 4.5.

It should be recognised that this analysis has been undertaken using fuel and mileage data from a single vehicle. In addition, Cenex have been informed that the daily duties of this vehicle have changed significantly during its trial period. It is likely that these issues will impact on the accuracy of the results generated through this analysis but will identify potential operational parameters that should be met to ensure the successful transition to low emission technologies.

Table 38, below, lists the performance criteria used for the analysis, which are based on the monitored trial vehicle. Section 7.2 shows a more detailed analysis regarding variations in daily operation (compared to average values).

Table 38 - Average Vehicle Performance Criteria for Rigid Truck (7.5t GVW)

	Typical Driving Type	Annual Mileage (miles)	Fuel Consumption (MPG)	Days per Week Used	Ownership Period (years)
Rigid Truck (7.5t GVW)	Mostly regional	10,994	8.9	4	7

7.1 Low Emission Vehicle Performance Review – Rigid Truck (7.5t GVW)

Figure 13 to Figure 15 show the relative performance of LEV technologies for Rigid Trucks (7.5t GVW). The black error bars in Figure 22 highlight the potential impact of any future removal of the Plug in Truck Grant, while the calculations outline the methodology used to calculate the vehicle depreciation.

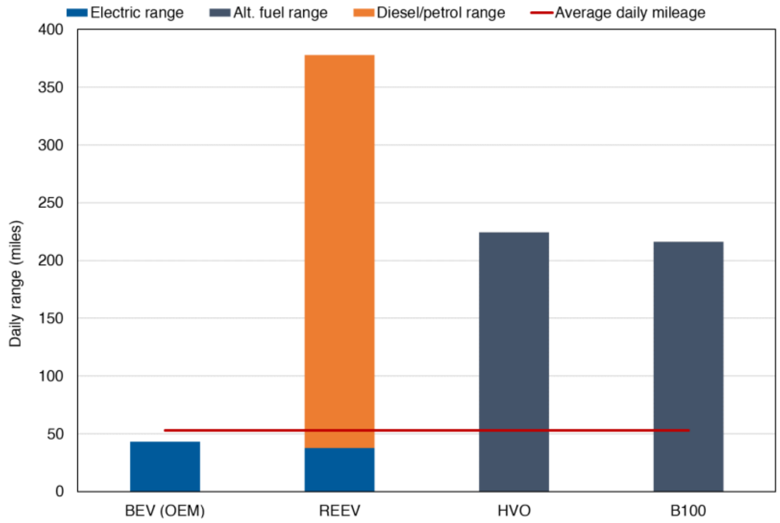


Figure 21 - Operating Range; Rigid Truck (7.5t GVW)

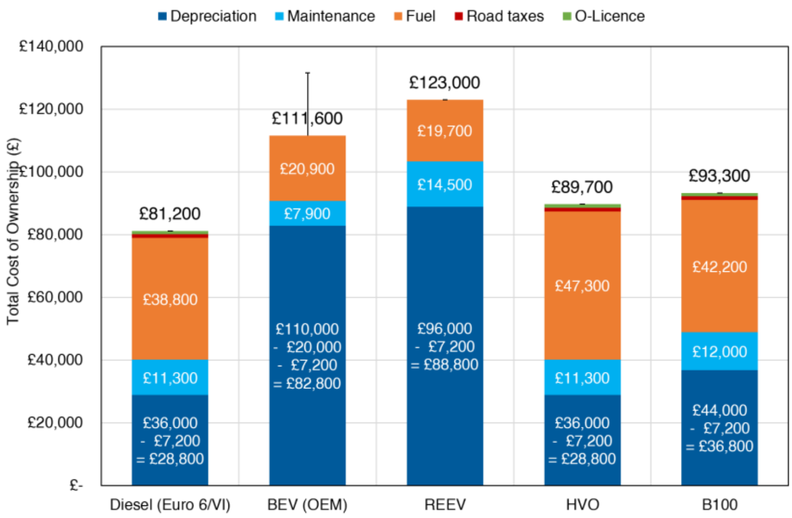
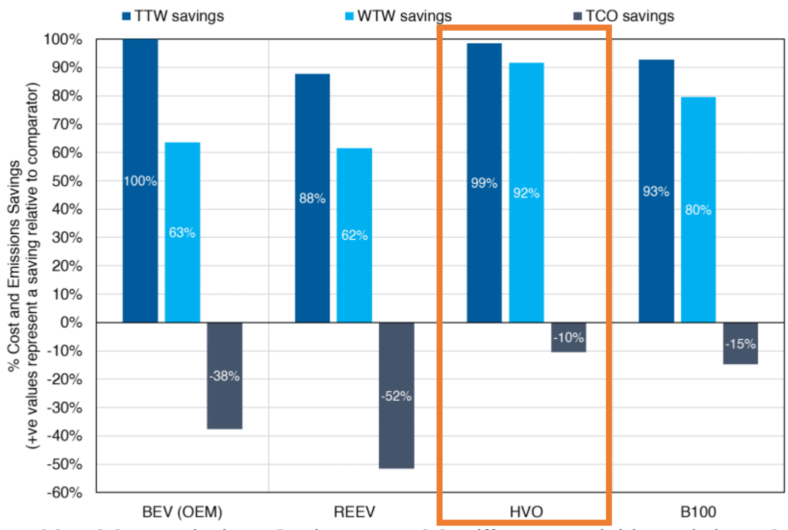


Figure 22 - Total Cost of Ownership; Rigid Truck (7.5t GVW)



The increased purchase cost of BEV and REEV is the main influencing factor in TCO.

The HVO operating range is substantially more than the average daily mileage and provides a 92% reduction in WTW CO_2e emissions. However, air quality emissions remain at Euro VI levels.

Figure 23 – CO_2e Emissions Savings vs. TCO Difference; Rigid Truck (7.5t GVW)

BEV (OEM)

Criteria	Performance
Operational	• Estimated real-world range around 43 miles with an 83 kWh battery. • The daily mileage seems to exceed the battery range • Many of this vehicle category are specialist refuse collection vehicles, which may limit their suitability for battery-electric options due to the lack of available vehicles. Only one OEM produced BEV exists in this vehicle segment. • The payload will be reduced due to the additional weight of the batteries. Approximate payload of 4,200 kg.
TCO	• An increase in purchase costs of £54,000 leads to large depreciation cost increases. • Despite significant running cost savings, there is an overall TCO increase of £30,400
Emissions	• Zero tailpipe emissions. • 63% reduction in WTW CO_2 emissions based on the current UK grid energy mix. This will reduce further as the UK grid decarbonises.

REEV

Criteria	Performance
Operational	• The estimated combined range is far greater than the average daily mileage. • Electric-only range approximately 35-45 miles with a 74 kWh battery. • 22kW AC on-board charger as standard = 3-5h charge time. • Many of this vehicle category are specialist refuse collection vehicles, which may limit their suitability for range extended options due to the lack of available vehicles. Only one REEV exists in this vehicle segment, and it is produced by a low-volume manufacturer. • The payload will be reduced due to the additional weight of the batteries.
TCO	• £60,000 increase in purchase cost. • Although running costs are reduced, TCO increases by £41,800.
Emissions	• Zero tailpipe emissions, when operating in electric mode • 62% reduction in WTW CO_2 emissions based on the current UK grid energy mix. This will reduce further depending on how often the vehicle operates in electric mode.

HVO

Criteria	Performance
Operational	• The estimated range is far greater than the average daily mileage. • Refuelling can be done in a similar time to diesel.
TCO	• No increase in capital cost as the vehicle is the same as a diesel. • Increased running costs lead to a TCO increase of £8,500.
Emissions	• 92% reduction in WTW CO_2 emissions. • Air quality pollutant emissions equivalent to Euro VI.

FAME (B100)

Criteria	Performance
Operational	• The estimated range is far greater than the average daily mileage. • Refuelling can be done in a similar time to diesel. • Additional fuel storage and handling requirements.
TCO	• £8,000 increase in capital cost. • Increased maintenance requirements. • Increased running costs lead to a TCO increase of £12,100.
Emissions	• 80% reduction in WTW CO_2 emissions. • Air quality pollutant emissions equivalent to Euro VI.

7.2 Analysis of daily operation

NWLDC provided monitored data covering daily vehicle operations for the food waste trial vehicle, which allow for a more detailed investigation to be undertaken. Figure 24 – Monitored daily distances for the food waste trial Figure 24 illustrates the daily driven distances of this vehicle.

The left-hand side chart represents the data as a timeseries; the effects of the Covid-19 pandemic are evident as there are fewer trips from April 2020 through to September. However, from November 2020, it seems regular service has been reinstated.

On average, a battery electric 2-axle rigid truck with 7.5t GVW has an electric range of about 61 miles. However, this range depends on the vehicle operation. The duty cycle of the food waste disposal truck could lower the range to 43 miles (dashed line in Figure 24, consistent with Figure 21). Even when assuming the average value, the truck runs into range limitations. Up to 35% of the daily trips within a year could not be performed without some form of additional charging; Table 39 lists the detailed results from this analysis.

The right-hand side chart in Figure 24 indicates that a BEV range around 100 miles would be required to achieve greater than 95% of all recorded mileages. However, his is about twice the average BEV range of such vehicles.

Figure 24 reveals severe range limitations for a batter-electric option. REEV or HVO provide enough range and could also significantly reduce carbon emissions. Therefore, switching to HVO would provide a transitory option until BEVs with larger ranges are available.

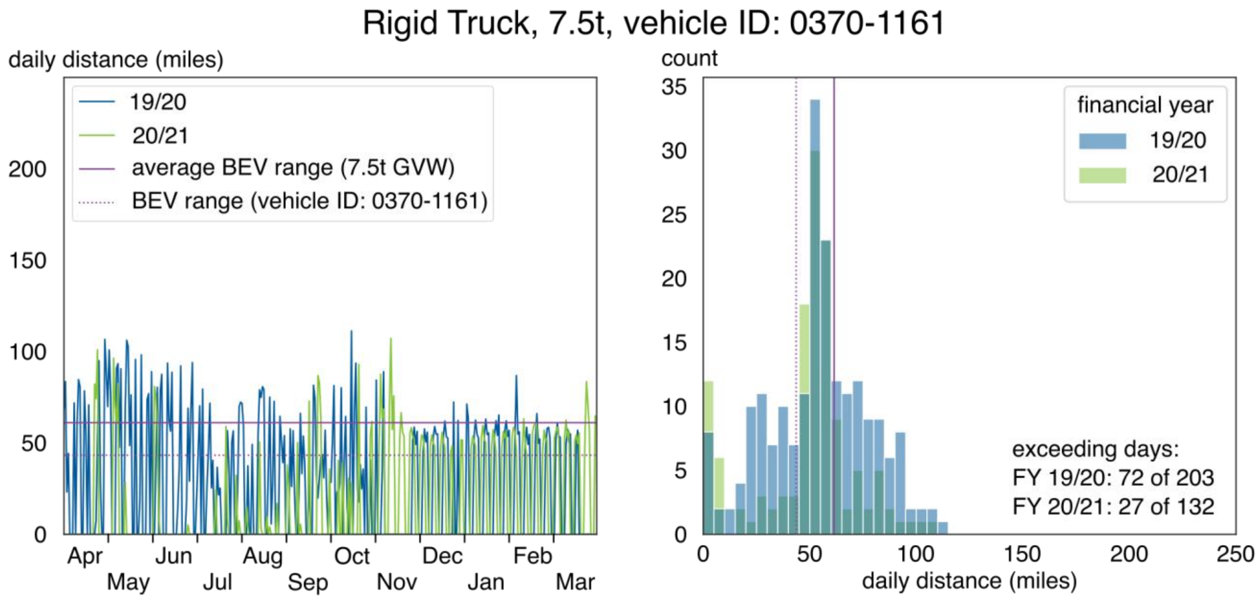


Figure 24 – Monitored daily distances for the food waste trial vehicle.

Table 39 –Exceeding daily trips for food waste disposal vehicle.

Fleet Number	Vehicle Type	Department	Usable Battery Capacity (kWh)	Average BEV Range (Miles)	FY 2019/2020		FY 2020/2021	
					Number of Daily Trips Exceeding BEV Range	Number of Daily Trips	Number of Daily Trips Exceeding BEV Range	Number of Daily Trips
0370-1161	Rigid Truck	food waste trial vehicle	75	61	72	203	27	132

8. Recommended Next Steps and Implementation Guidance

The Recommended Replacement Vehicle analysis outputs presented in Section 6, specifically the information outlined in Table 35 can be considered an outline action plan for the deployment of BEV and HVO across the NWLDC fleet. In addition to this outline plan, more detailed vehicle by vehicle information is provided in an accompanying MS Excel spreadsheet which provides further evidence of the potential emission and ownership cost savings that could be achieved through the deployment of the identified low emission technologies.

The plan outlined in Table 35 assumes that NWLDC can readily purchase or lease the relevant vehicle models and specifications required for their operational requirements; the impacts of potential vehicle delivery lead times has not been accounted for as this can differ greatly from manufacturer to manufacturer. Similarly, the impact of any potential delays in deploying the relevant charging infrastructure has not been accounted for.

It will be essential that NWLDC discuss their vehicle and infrastructure needs with relevant vehicle and chargepoint suppliers to gain a clear understanding of the likely timeline for delivery/ installation. This will a more accurate vehicle and infrastructure deployment plan to be generated.

This section provides a summary of the recommended next steps for NWLDC required to implement those LEVs highlighted as candidate replacement vehicles. The actions outlined below are based on Cenex's recommended approach to deploying LEVs within a fleet of:

Trial → Review → Assess → Deploy

This approach is recommended as the analysis and results contained within this report are based on historical fleet and vehicle performance and operational data and therefore may not fully reflect the current operations experienced within NWLDC. Undertaking trials of relevant LEVs within the selected fleet operations will enable a more accurate assessment of possible day to day impacts to be undertaken. These can then be reviewed and adapted to ensure additional LEVs can be deployed with minimum impact on service provision.

It is recognised that NWLDC may wish to accelerate the deployment of LEVs within their fleet; while this ambition is to be applauded Cenex would still recommend a period of vehicle trials to ensure that their implementation does not adversely impact on service delivery.

The below recommendations and actions are presented in order of priority (although many will occur in parallel) with an initial focus on those vehicles that can be replaced by BEV and HVO most easily before targeting the harder to transition vehicles. This results in a phased transition, which as outlined above is in line with Cenex's recommended approach. Appendix C, along with the accompanying MS Excel spreadsheet should be used by NWLDC to identify those operational vehicles that can be transitioned to BEV and HVO in the first instance.

Supporting justifications are provided below each recommendation. Where appropriate, additional implementation recommendations are provided. These typically relate to operational considerations or measures to increase the uptake of LEVs (with a focus on ZEVs and ULEVs).

The recommendations in this section are of most relevance over the next five years with any occurring after these timescales considered closer to an outline strategy to 2030.

6. **Implement battery electric cars and light commercial vehicles (i.e. small cars and small and medium vans) along with the associated electric vehicle charging infrastructure** according to the current vehicle replacement schedule, if not sooner.
    a. Confirm which specific vehicle models meet the required operational specifications in terms of payload, towing capacity and minimum viable battery capacity required to meet day to day mileage variation. For a given vehicle model this is a trade-off between cost, payload, and range (smaller batteries = lower cost, higher payload, and lower operating range). It should be recognised that the analysis in this report has been based on average daily mileage and does not include the impact of additional factors (cabin heating, towing, etc.).
        i. BEVs have been highlighted as potentially suitable replacements for:

1. 100% of small cars (45 kWh battery)
2. 29% of small vans (40 kWh battery)
3. 100% of medium vans (75 kWh battery)

b. Where possible, consider specifying vehicles with optional on-board AC chargers with increased power ratings, to enable higher rates of vehicle charging to occur (e.g. 11 kW or 22 kW vs. 7 kW).

c. Undertake a short-term managed vehicle trial of between 4 – 8 weeks in each identified vehicle segment to confirm operational suitability and to verify the potential running cost and emissions savings.

   i. Vehicles should initially be trialled within lower mileage applications with the implementation advised by real world performance and day to day mileage variation considered before a more detailed implementation phase is undertaken, this will ensure that all relevant preparations are made for their introduction.

d. Plan and rollout a home charging pilot scheme, including the installation of appropriate 7 kW chargers, with targeted drivers to confirm applicability, operational suitability and to verify the running cost and emissions savings.

   i. Details of how to manage such a trial, including operational and deployment considerations, is provided in the accompanying Home Charging Review report.

e. Procure and install 22 kW AC chargepoints at the depot locations identified during the infrastructure review.

   i. Engage with a certified installer to undertake detailed site assessments and discuss power supply capacity with the DNO.

   ii. Any deployment of charging infrastructure should take into consideration any potential future changes to depot locations.

f. Investigate the potential to reduce the ownership period of the remaining non-BEV vans from 7 years to 4 years to ensure that the results of the above electric vehicle trial can be implemented as quickly as possible.

   i. This may result in new Euro 6 diesel vehicles being deployed across the fleet for a short period of time. However, this approach will ensure that the NWLDC have sufficient time to assess the possible impacts of deploying BEV across this vehicle segment, considering the operational requirements of these vehicles.

7. Investigate the feasibility of using renewable diesel (HVO) as an interim solution across all remaining vehicle segments to provide immediate WTW CO_2e emissions reductions.

a. Contact fleet operators currently using HVO to discuss operational experiences, implications and to verify potential cost increases.

   i. Cenex can provide details or make introduction to such organisations if required.

b. Contact relevant vehicle manufacturers to discuss verify any potential warranty and maintenance changes.

c. Contact relevant fuel suppliers to discuss supply requirements such as volumes, delivery, costs, etc.

   i. Cenex can provide details or make introduction to such organisations if required.

   d. A recent study by the Zemo Partnership explored the opportunity for high blend renewable fuels to decarbonise heavy duty vehicles over the next decade and beyond. The renewable fuels covered were biodiesel, hydrotreated vegetable oil (HVO) and biomethane – considering blends of more 20% renewable fuel content[9]

8. **Prepare for the potential introduction of ULEV HGVs (i.e. RCVs, Food Waste Disposal, etc.) beyond 2025;** vehicle segments without recommended replacement ULEVs account for 45% of the current fleet. This is primarily due to the relative immaturity of ULEV HGVs and the resulting increase in additional capital costs.

   It is reasonable to expect that the availability, purchase cost, and capabilities of ULEV rigid trucks and large vans will improve significantly by NWLDC's next major replacement date. Despite this it is suggested that NWLDC should be proactive in preparing for the potential introduction of additional ULEVs from this date.

   a. Undertake the further analysis of journey profiles and daily routes within the relevant vehicle categories to assess and verify the suitability of BEV as a replacement technology.

      i. Such an assessment should take into considerations any proposed changes to collection routes and the potential for double shifting of vehicles. Such operational changes will have additional implications on the deployment of charging infrastructure and associated depot power demands.

   b. Where possible undertake vehicle trials within those operations identified as suitable for BEV deployment.

      i. BEVs are currently the only technology that could be deployed at scale across the HGV segments within the next 3 – 5 years and have potential to provide the lowest running costs of all LEVs studied within the large van and rigid truck vehicle segments. The main challenges associated with these vehicles are the limited availability of appropriate variants, the increased purchase costs, the availability of appropriate charging infrastructure and the potential impact on the depot power supply.

   c. The majority of rigid trucks are due for replacement from FY2024 onwards, therefore this date is considered critical to achieving NWLDC's 2030 aspirations. Any vehicles replaced after this point will likely remain on the fleet until at least 2031.

      i. NWLDC should formally review ULEV options again in 2023; this review would likely include a much wider selection of ZEVs including BEV, FC REEV and FCEV.

9. **NWLDC should consider the process of assessing, trialling, and implementation of ULEVs across the fleet as a continuous one, depending on the requirements of different vehicle segments.**

10. **Consider operational improvements that could increase the uptake of ULEVs.**

   a. Confirm specific towing requirements and investigate the feasibility of introducing operational changes to reduce this requirement for potential ULEV replacement vehicles (e.g. designation of dedicated towing vehicles, moving any towing requirement to ULEV technologies or vehicle segments with increased capabilities such as pickup trucks).

   b. Review and, if necessary, optimise the number of vehicles on the fleet to increase utilisation.

[9] https://www.zemo.org.uk/assets/lowcvpreports/Market_opportunities_decarbonise_HDV_using_HBRF_2021.pdf

9. Appendix A – Fleet Review References

Table 40 shows a table of references used during the fleet review. It should be noted that wherever possible data provided by the fleet takes priority over supplementary data sources (such as baseline fuel economy) and likewise, independent data takes priority over information provided by suppliers.

Table 40 - Table of References

Parameter	Reference
Vehicle Details	**Driver and Vehicle Licensing Agency (DVLA)** https://ukvehicledata.co.uk/dvla-data-api
Annual Mileage	**Driver and Vehicle Standards Agency (DVSA)** https://www.gov.uk/check-mot-history
Baseline Fuel Economy	**Emissions Analytics** – Passenger Vehicles and LCVs https://www.emissionsanalytics.com/
	Low Carbon Vehicle Partnership (LowCVP) – HGVs https://www.lowcvp.org.uk/
Greenhouse Gas Emissions Factors and Energy Content	**UK Government** https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2020
Air Quality Pollutant Emissions Factors	**National Atmospheric Emissions Inventory (NAEI)** https://naei.beis.gov.uk/data/ef-transport
Low Emission Vehicle Energy Consumption (Examples from the public domain)	**Cenex** – ULEV passenger vehicles and LCVs https://www.cenex.co.uk/ **Cenex, Emissions Analytics and LowCVP** – LCVs and HGVs Unpublished testing of plug-in commercial vehicles completed on behalf of LoCITY in 2019 Dedicated to Gas - Assessing the Viability of Gas Vehicles Emissions Testing of Urban Delivery Commercial Vehicles Emissions Testing of Gas-Powere Commercial Vehicles
Vehicle Costs Purchase Cost Maintenance Costs Predicted Residual Values	**Fleet News and Commercial Fleet** – Passenger vehicles and LCVs https://www.fleetnews.co.uk/car-running-costs-calculator https://www.commercialfleet.org/tools/van/running-costs/ **Logistics UK (formerly the FTA)** – HGVs (diesel only) https://logistics.org.uk/distribution-costs **Vehicle Suppliers and Fleet Operators** – Any remaining technologies
Fuel Prices	**AA** – Diesel, petrol and LPG https://www.theaa.com/driving-advice/driving-costs/fuel-prices **Department for Business, Energy and Industrial Strategy (BEIS)** – electricity https://www.gov.uk/government/statistical-data-sets/gas-and-electricity-prices-in-the-non-domestic-sector **Low Emission Fuel Suppliers** – natural gas, hydrogen and biofuels

10. Appendix B – NWLDC Maximum Emission Savings Results

Table 41 shows the Maximum Emissions Saving Scenario with a focus on ZEVs as these make the largest combined greenhouse gas and air quality emission savings.

Table 41 - Maximum Emissions Saving Replacement Summary Table

	Small Car	Small Van	Medium Van	Large Van	Large Van - (> 3.5t GVW)	Rigid Truck - 2 axles (18t GVW)	Rigid Truck - 2 axles (7.5t GVW)	Rigid Truck - 3 axles (26t GVW)	Large Commercial SUV	Total
Replacement Technology	BEV (OEM)								HVO	
Number of Vehicles	4	7	48	11	1	7	3	16	2	**99**
% of Vehicle Segment	100%	100%	100%	100%	100%	100%	75%	100%	100%	**100%**
Additional Capital Cost (£)	£32,000	£43,200	£375,400	£266,300	£60,000	£1,638,000	£162,000	£4,576,000	£0	**£7,152,900**
Difference in Running Costs (£)	-£19,900	-£28,700	-£380,500	-£84,800	-£7,200	-£208,400	-£52,500	-£712,500	£4,500	**£1,490,000**
Difference in Residual Values (£)	£12,600	£3,700	£31,100	£83,400	£0	£0	£0	£0	£0	**£130,800**
Difference in TCO (£)	£500	-£10,800	£36,200	-£98,100	-£52,800	-£1,429,600	-£109,500	-£3,863,500	-£4,500	**-£5,532,100**
Ownership Period (yearts)	7	7	7	7	7	7	7	7	7	**7**
% of Fleet TTW CO_2 Savings	1%	1%	20%	5%	0%	15%	3%	54%	1%	**100%**
% of Fleet WTW CO_2 Savings	1%	1%	15%	5%	0%	15%	3%	54%	1%	**94%**
% of Fleet NOx Savings	3%	5%	55%	8%	0%	5%	2%	22%	0%	**99%**
% of Fleet PM Savings	3%	3%	31%	4%	0%	9%	3%	45%	0%	**98%**
Number of 7 kW Chargepoints	0	0	43	0	0	0	0	0	0	**43**
Number of 22 kW Chargepoints	4	7	5	11	1	7	3	16	4	**58**
Number of 50 kW Chargepoints	0	0	0	0	0	0	0	0	0	**0**
Infrastructure Capital Cost	£14,200	£24,900	£60,800	£39,100	£3,600	£24,900	£10,700	£82,300	£0	**£260,500**

10.1 Replacement Vehicle Schedule

	Financial Year									
	2021/22	2022/23	2023/24	2024/25	2025/26	2026/27	2027/28	2028/29	2029/30	2030/31
Small Car (BEV)	3	1	0	0	0	0	0	0	0	0
Large Commercial SUV (HVO)	0	0	0	0	0	0	0	0	0	0
Small Van (BEV)	5	1	0	0	1	0	0	0	0	0
Medium Van (BEV)	26	2	7	0	13	0	0	0	0	0
Large Van (BEV)	9	1	1	0	0	0	0	0	0	0
Large Van (> 3.5t GVW) (BEV)	0	0	0	0	1	0	0	0	0	0
Rigid Truck - 2 axles (7.5t GVW) (BEV)	0	0	1	0	2	0	0	0	0	0
Rigid Truck - 2 axles (18t GVW) (BEV)	0	0	0	5	1	1	0	0	0	0
Rigid Truck - 3 axles (26t GVW) (BEV)	9	1	2	0	4					
Vehicle Replacements	53	7	11	5	22	1	0	0	0	0
Cumulative % of Fleet Replaced by LEV	54%	61%	72%	77%	99%	100%	100%	100%	100%	100%
Additional Vehicle Capital Costs (£)	£3,050,105	£340,033	£704,950	£1,170,000	£1,653,835	£234,000	£0	£0	£0	£0
Infrastructure Cost (£)	£140,425	£29,800	£23,757	£17,757	£44,963	£3,551	£0	£0	£0	£0
Annual Running Cost Savings (£)	£100,614	£112,868	£137,815	£160,006	£208,328	£212,879	£212,879	£212,879	£212,879	£212,879
Annual TTW CO_2 Savings (tonnes)	433.3	489.9	595.7	696.9	896.7	917.5	917.5	917.5	917.5	917.5
Annual WTW CO_2 Savings (tonnes)	499.4	569.4	691.6	817.1	1045.4	1071.3	1071.3	1071.3	1071.3	1071.3
Annual NOx Savings (kg)	166.3	184.5	225.7	239.3	318.9	319.9	319.9	319.9	319.9	319.9
Annual PM Savings (kg)	1.1	1.3	1.6	1.7	2.3	2.3	2.3	2.3	2.3	2.3

11. Appendix C – NWLDC logger data evaluation

Table 42 compares the average BEV ranges by vehicle type with the recorded distances for each vehicle within the financial years 2019/2020 and 2020/2021. It is accepted that the provided data for this analysis did not cover a full year, however this analysis should provide an initial insight into the applicability of vehicles for the first phase of electric vehicle deployment.

The below table has been colour coded, to enable NWLDC to identify relevant vehicles: **Red** (exceeding range); **Amber** (no range exceedance but less than 20 miles remaining range); **Green** (no range exceedance with more than 20 miles remaining range). It is recommended that those vehicles highlighted in **Green** are investigated as a priority.

Table 42 – List of daily trips that exceeding battery range by vehicle

Fleet Name	Vehicle Type	Department	Usable Battery Capacity (kWh)	Avg. BEV Range (miles)	FY 2019/2020			FY 2020/2021		
					Number of Daily Trips Exceeding BEV Range	Number of Daily Trips	Worst Case Remaining Range (miles)	Number of Daily Trips Exceeding BEV Range	Number of Daily Trips	Worst Case Remaining Range (miles)
626	Small Car	Enforcement Team	45	161						
627	Small Car	Enforcement Team	45	161						
628	Small Car	Enforcement Team	45	161						
629	Small Car	Office Pool Vehicle	45	161						
679	Small Van	Office Pool Vehicle	36	93						
680	Small Van	Garage	36	93						
681	Small Van	Garage Pool Vehicle	36	93						
682	Small Van	Parks Department	36	93						
684	Small Van	Parks Department	36	93						
686	Small Van	Commercial Team	36	93						
687	Small Van	Pest Control	36	93						
700	Medium Van	Housing Maintenance	68	125	0	133	12.2	0	127	28.9
701	Medium Van	Housing Maintenance	68	125	1	164	-7.0	2	232	-12.6
702	Medium Van	Housing Maintenance	68	125	0	130	13.4	0	235	7.9
703	Medium Van	Housing Maintenance	68	125	0	138	31.6	0	174	45.0
704	Medium Van	Housing Maintenance	68	125				0	89	61.8
705	Medium Van	Housing Maintenance	68	125				0	8	54.0
706	Medium Van	Housing Maintenance	68	125	0	139	3.6	0	169	17.9
707	Medium Van	Housing Maintenance	68	125	0	123	39.9	0	156	42.9
708	Medium Van	Housing Maintenance	68	125	0	130	15.2	0	190	38.2
709	Medium Van	Housing Maintenance	68	125	0	145	23.1	0	213	33.2
710	Medium Van	Housing Maintenance	68	125	2	114	-4.5	0	221	11.5
711	Medium Van	Housing Maintenance	68	125	0	102	13.9	0	76	48.0
712	Medium Van	Housing Maintenance	68	125	0	88	21.4	0	205	4.4
720	Medium Van	Refuse Department	68	125	3	223	-6.1	2	200	-7.1
730	Medium Van	Housing Maintenance	68	125	0	151	36.2	0	206	20.6

Fleet Name	Vehicle Type	Department	Usable Battery Capacity (kWh)	Avg. BEV Range (miles)	FY 2019/2020			FY 2020/2021		
					Number of Daily Trips Exceeding BEV Range	Number of Daily Trips	Worst Case Remaining Range (miles)	Number of Daily Trips Exceeding BEV Range	Number of Daily Trips	Worst Case Remaining Range (miles)
731	Medium Van	Housing Maintenance	68	125	0	141	38.1	0	208	30.7
732	Medium Van	Housing Maintenance	68	125	0	53	38.5	0	188	30.4
733	Medium Van	Housing Maintenance	68	125	0	131	53.5	0	143	47.7
734	Medium Van	Housing Maintenance	68	125	0	102	48.0	0	192	27.8
735	Medium Van	Housing Maintenance	68	125	0	151	4.4	2	184	-49.1
736	Medium Van	Housing Maintenance	68	125	0	140	91.3	0	207	67.7
737	Medium Van	Housing Maintenance	68	125	11	134	-23.3	2	189	-12.8
738	Medium Van	Housing Maintenance	68	125	0	153	27.6	0	251	16.9
739	Medium Van	Housing Maintenance	68	125	3	120	-15.7	0	185	17.0
740	Medium Van	Housing Maintenance	68	125	0	69	37.1	0	159	54.1
741	Medium Van	Housing Maintenance	68	125	0	119	35.5	0	41	49.7
742	Medium Van	Housing Maintenance	68	125	2	64	-32.7	1	149	-3.8
743	Medium Van	Housing Maintenance	68	125	5	140	-141.1	0	189	35.5
744	Medium Van	Housing Maintenance	68	125	0	131	40.6	0	166	37.8
745	Medium Van	Housing Maintenance	68	125	0	119	63.1	0	164	63.1
746	Medium Van	Housing Maintenance	68	125	0	111	27.2	1	68	-4.0
748	Medium Van	Housing Maintenance	68	125	0	135	19.7	1	145	-31.2
749	Medium Van	Housing Maintenance	68	125	0	163	18.6	0	247	6.8
750	Medium Van	Housing Maintenance	68	125	0	129	46.4	0	199	23.3
751	Medium Van	Housing Maintenance	68	125	0	166	61.8	0	235	73.6
752	Medium Van	Housing Maintenance	68	125	0	134	32.2	0	212	48.2
777	Medium Van	Garage Pool Vehicle	68	125				0	0	0.0
779	Medium Van	Housing Maintenance	68	125				0	74	23.8
780	Medium Van	Housing Maintenance	68	125	0	131	25.9	0	151	4.0
782	Medium Van	Housing Maintenance	68	125	1	131	-0.5	0	231	27.5
783	Medium Van	Enforcement Team	68	125	0	0	0.0	0	0	0.0
784	Medium Van	Housing Maintenance	68	125	0	110	55.1	0	172	20.2
785	Medium Van	Street Cleansing	68	125	0	221	6.8	0	259	13.6
786	Medium Van	Housing Maintenance	68	125	0	136	19.5	0	224	26.3
787	Medium Van	Housing Maintenance	68	125	0	0	0.0	0	62	43.3
788	Medium Van	Housing Maintenance	68	125	0	127	8.9	0	194	13.5
789	Medium Van	Housing Maintenance	68	125	0	37	40.2	0	174	65.3
790	Medium Van	Housing Maintenance	68	125	0	153	53.2	0	211	68.6
721	Large Van	Refuse Department	45	52	143	211	-104.7	127	229	-84.0

Fleet Name	Vehicle Type	Department	Usable Battery Capacity (kWh)	Avg. BEV Range (miles)	FY 2019/2020			FY 2020/2021		
					Number of Daily Trips Exceeding BEV Range	Number of Daily Trips	Worst Case Remaining Range (miles)	Number of Daily Trips Exceeding BEV Range	Number of Daily Trips	Worst Case Remaining Range (miles)
797	Large Van	Garage Pool Vehicle	45	52						
798	Large Van	Parks Department	45	52						
799	Large Van	Parks Department	45	52						
800	Large Van	Parks Department	45	52						
801	Large Van	Parks Department	45	52						
802	Large Van	Parks Department	45	52						
803	Large Van	Street Cleansing	45	52	2	279	-56.4	42	263	-26.6
804	Large Van	Parks Department	45	52						
805	Large Van	Parks Department	45	52						
806	Large Van	Street Cleansing	45	52	194	335	-29.6	99	353	-61.6
807	Large Van	Parks Department	50.4	52						
810	Rigid Truck	Commercial Team/ Housing	75	61	38	51	-73.7	63	141	-51.9
811	Rigid Truck	Refuse Department	75	61	97	135	-80.2	93	140	-105.2
812	Rigid Truck	Street Cleansing	75	61	89	171	-57.0	72	132	-57.8
827	Rigid Truck	Street Cleansing/ Parks	270	66	9	93	-39.5	10	60	-38.2
867	Rigid Truck	Refuse Department	250	55	10	150	-16.2	35	200	-27.3
868	Rigid Truck	Refuse Department	250	55	33	210	-22.9	21	199	-28.0
870	Rigid Truck	Refuse Department	250	55	2	198	-13.8	12	212	-19.6
871	Rigid Truck	Refuse Department	250	55	16	204	-15.3	36	211	-20.4
878	Rigid Truck	Refuse Department	250	55	3	209	-11.3	29	205	-23.7
879	Rigid Truck	Refuse Department	250	55	1	207	-3.1	40	208	-35.1
880	Rigid Truck	Refuse Department	270	66	120	207	-43.9	105	212	-54.3
881	Rigid Truck	Refuse Department	270	66	114	206	-42.5	105	212	-46.8
882	Rigid Truck	Refuse Department	270	66	148	247	-63.1	143	231	-51.0
883	Rigid Truck	Refuse Department	270	66	47	205	-39.6	76	226	-52.1
884	Rigid Truck	Refuse Department	270	66	93	206	-35.2	104	209	-37.0
885	Rigid Truck	Refuse Department	270	66	130	203	-45.8	116	201	-46.9
886	Rigid Truck	Refuse Department	270	66	128	205	-30.7	113	210	-59.4
888	Rigid Truck	Refuse Department	270	66	20	63	-44.4	29	182	-30.3
889	Rigid Truck	Refuse Department	270	66	10	133	-17.2	19	184	-21.4
894	Rigid Truck	Refuse Department	270	66	70	183	-47.0	48	130	-71.9
895	Rigid Truck	Refuse Department	270	66	10	183	-39.8	36	182	-43.1
896	Rigid Truck	Refuse Department	270	66	15	186	-38.4	10	174	-34.5
897	Rigid Truck	Refuse Department	270	66	16	204	-33.2	4	136	-4.9

Fleet Name	Vehicle Type	Department	Usable Battery Capacity (kWh)	Avg. BEV Range (miles)	FY 2019/2020			FY 2020/2021		
					Number of Daily Trips Exceeding BEV Range	Number of Daily Trips	Worst Case Remaining Range (miles)	Number of Daily Trips Exceeding BEV Range	Number of Daily Trips	Worst Case Remaining Range (miles)
898	Rigid Truck	Refuse Department	270	66	180	215	-52.6	144	197	-50.4
899	Rigid Truck	Street Cleansing	250	55	6	127	-42.1	1	88	-6.6
856	Rigid Truck	Street Cleansing/ Parks	270	66	9	93	-39.5	10	60	-38.2
0370-1161	Rigid Truck	Food Waste Trial Vehicle	75	61	72	203	-50.2	27	132	-46.1

12. Appendix E – Alternatively Fuelled Vehicle Derogations

A 2018 UK Government licensing derogation allows Category B license holders to drive an alternatively fuelled vehicle that weighs up to 4.25t (as opposed to 3.5t GVW)[10]. The existing derogation will remain in place until at least 2023. The conditions for this derogation are:

- The licence holder must undertake a minimum of five hours training by a registered instructor on the driving of an alternatively fuelled vehicle.
  - "registered instructor" means a person who is on the National Register of LGV instructors or the National Vocational Driving Instructors Register.
- The vehicle must be driven for the purpose of transporting goods.
- The vehicle must not have a trailer attached.
- The vehicle must not be driven outside of the territory of Great Britain.

For HGVs, a 2017 amendment increased the maximum allowable weight of an alternatively fuelled HGV by 1,000kg[11]. The conditions are:

- A type or individual approval has been granted to the vehicle under the Framework Directive which provides evidence that the weight of the alternative fuel powertrain exceeds the weight of a conventional powertrain by a specified amount.
- The weight of the alternative fuel power train is included in the maximum permitted gross or train weight specified on any plates required by regulation 66(a) or regulation 70(b) of the 1986 Regulations.

10 https://www.legislation.gov.uk/uksi/2018/784/pdfs/uksi_20180784_en.pdf
11 https://www.legislation.gov.uk/uksi/2017/881/pdfs/uksi_20170881_en.pdf

13. Appendix F – Funding and Managing Vehicle Trials

Where it is not currently possible or economically viable to deploy a significant number of LEVs at a depot or fleet level there can still be numerous benefits to running a trial of an individual or small number of vehicles as follows:

- Validate any assumptions made during initial fleet analysis.
- Gain real-world experience with both the vehicle and required infrastructure (recharging and ease of use), validate the real-world technical capabilities of the vehicle (range, payload) and gain driver feedback.
- Quantify the real-world operating and maintenance costs.
- Provide a competitive advantage and a positive company image by being proactive in supporting the low emission transport agenda.

Vehicle trials can either be self-funded or can make use of public funding. Funding calls are often announced by Innovate UK, The Office for Low Zero Vehicles and through EU funding streams such as EU Horizon 2020.

To maximise learnings and ensure good value for money (particularly when public funds are used) vehicle trials should adhere to the following process:

1. **Plan and allocate resources**: allocation of sufficient financial and staffing resources for the successful delivery of the trial.
2. **Define output criteria**: definition of key metrics and how to monitor them such as fuel consumption, range, driver perceptions, costs and practicality. Consideration of baseline for comparison purposes.
3. **Minimise sources of variation**: to ensure repeatability of the trials sources of variation should be considered including driver, route(s) and season. It may be desirable to control some of these parameters, such as operating in urban vs. rural environments, to measure the vehicle performance across the entire fleet.
4. **Drive cycle development or Duty cycle selection**: For large fleets it may be desirable to define a fleet wide drive cycle to represent vehicle usage patterns which can be used to assess numerous technologies on a chassis dynamometer in controlled conditions. Alternatively, smaller fleets may choose to select a vehicle which is running on their preferred duty cycle and route for detailed analysis.
5. **Data collection**: consider manual (such as fuel and mileage records) or automatic (such as telemetry and fuel monitoring devices) collection of data.
6. **Secure vehicle and fuel supply**: finalise and secure supply of vehicle and infrastructure before commencing trial.
7. **Data analysis and project meetings**: data should be reviewed on an ongoing basis during the trial to highlight and resolve any issues.
8. **Partnership approach**: it may be possible to enter into partnership with vehicle manufacturers, fuel suppliers and fleet operators to reduce the individual cost burden of running the trial.
9. **Reporting**: a comprehensive written report should accompany the results of the trial; additional dissemination events or workshops are also worth considering to gain third party input.

14. Appendix G – Low Emission Technology Factsheets

Battery Electric Vehicles

<table>
<tr><td rowspan="1">Technology Introduction</td><td colspan="2">A battery electric vehicle (BEV or EV) stores energy in a battery (usually lithium-ion) and delivers its power to the vehicle's wheels through an electric motor. Braking energy can be captured by the electric motor, through regenerative braking, and stored as electrical energy in the battery.

Most battery electric vehicles are available through major OEMs and smaller low volume manufacturers; however, there are a growing number of vehicle conversion companies who can covert a standard commercial vehicle to run on electric power.</td><td colspan="2">
An OEM manufactured battery electric large van.

Source: Ford UK</td></tr>
<tr><td>Availability</td><td colspan="4">Cars: Available from OEMS in most vehicle form factors.
Small Vans: Available from most OEMs.
Large Vans: Available from a growing number of OEMs.
Rigid Trucks: Available from early adopter OEMs as well as low-volume manufacturers such as EMOSS and Magtec.
Tractor Units: Not available in the UK.</td></tr>
<tr><td rowspan="4">Cost
(vs. Diesel)</td><td colspan="2" rowspan="4">Battery electric vehicles are currently more expensive to purchase. This is largely due to the cost of batteries and as such the cost premium tends to grow considerably for heavier vehicles with larger batteries.
Residual values are currently uncertain.
Due to a reduced number of moving parts, maintenance costs are reduced.
Fuel costs are significantly reduced as BEVs are more efficient than diesel vehicles so require less energy and electricity is cheaper than diesel.</td><td>Capital</td><td>+</td></tr>
<tr><td>Maintenance</td><td>-</td></tr>
<tr><td>Fuel</td><td>-</td></tr>
<tr><td>Residual Value</td><td>~</td></tr>
<tr><td>Operational Performance</td><td colspan="4">Most electric vehicles have a real-world range of 80 – 200 miles on a single charge depending on battery size. This will reduce if the vehicle is driven aggressively or with high heater use in winter. However, vehicle range can be increased by using specialist routing software to optimise daily journeys.
The time taken to fully charge an electric vehicle depends on the size of the battery and the power rating of the charging infrastructure. A full charge typically takes between 30 mins (rapid charge) and 8 - 10 hours (standard charge).
The payload on electric vehicle is lower than on a diesel vehicle due to the additional weight of the batteries. A payload reduction of around 5% – 30% can be expected, depending on the vehicle type and battery size. However, load volume is not generally changed.</td></tr>
<tr><td>Environmental Performance</td><td colspan="4">Electric vehicles produce zero tailpipe emissions. This makes them ideal for improving air quality in our cities and reducing CO_2 emissions. They can offer CO_2 savings of up to 70% even when the carbon intensity of electricity production is considered.</td></tr>
<tr><td>Case Studies</td><td colspan="4">Electric vehicles have been deployed by many British councils, British Gas, DPD, Mitie, Severn Trent Water, Warburtons and many more.</td></tr>
<tr><td>Further Information</td><td colspan="4">https://www.zap-map.com/live/ for a map public charging locations.</td></tr>
</table>

Hydrogen (H_2)

<table>
<tr><td rowspan="1">Technology Introduction</td><td colspan="3">
• Hydrogen is taking its first steps to becoming commercially available as a road transport fuel in the UK.
• Hydrogen can be used to power a vehicle by burning it in an engine or to generate electricity through a fuel cell (FCEV).
• There is currently a limited but growing public hydrogen refuelling station network.
• Hydrogen is stored on a vehicle in compressed gas cylinders.

An FCEV rigid truck on a Swiss trial. Source: Hyundai
</td></tr>
<tr><td>Availability</td><td colspan="3">
Cars: A limited number of hydrogen fuel cell vehicles are available, such as the Toyota Mirai and Hyundai Nexo.
Small Vans: Fuel cell range extenders can be fitted to battery electric vans which generate electricity from on-board hydrogen to charge their batteries. These are available in the UK through Arcola Energy.
Large Vans: Diesel vans converted to operate on hydrogen and diesel (dual-fuel) are available from ULEMCO.
Rigid Trucks: Diesel trucks converted to operate on hydrogen and diesel (dual-fuel) are available from ULEMCO. FCEVs are currently in the early stages of European trials.
Tractor Units: Not available in the UK.
</td></tr>
<tr><td rowspan="4">Cost (vs. Diesel)</td><td rowspan="4">
Hydrogen vehicles are currently more expensive to purchase and operate than their fossil fuel counter parts. Most hydrogen vehicle deployments are subsidised through UK and EU funding programmes to allow technology demonstration and development.

Savings accrued through daily use of a zero emission H_2 powered vehicle in the London Congestion Zone can reduce the total cost of ownership to a similar level to a conventional vehicle.
</td><td>Capital</td><td>+</td></tr>
<tr><td>Maintenance</td><td>+</td></tr>
<tr><td>Fuel</td><td>+</td></tr>
<tr><td>Residual Value</td><td>-</td></tr>
<tr><td>Operational Performance</td><td colspan="3">
• Hydrogen cars and dual-fuel vehicles have a similar range to their fossil fuel equivalents of 300 - 800 km depending on vehicle size and tank options.
• Hydrogen range extenders typically double the range of an electric vehicle.
• Payload and load space of range extended hydrogen vans are often reduced (by around 10%) as the fuel cell and tank components are normally located within the load space.
• Dual-fuel hydrogen vehicles offer the same load space, but payload is reduced by around 150kg for vans and 300kg for trucks.
</td></tr>
<tr><td>Environmental Performance</td><td colspan="3">
• Hydrogen releases no tailpipe CO_2 when used to power a vehicle, and when used in a fuel cell only water vapour is emitted.
• When hydrogen is combusted alongside other fuels, such as diesel, the hydrogen proportion reduces the vehicle's tailpipe emissions.
• The fuel life cycle CO_2 emissions of hydrogen vans depend on how the hydrogen is manufactured and the technology used on the van: they can be worse than diesel when the hydrogen is manufactured from fossil fuels (brown hydrogen); or have a very low carbon intensity when made from renewable green hydrogen.
</td></tr>
<tr><td>Case Studies</td><td colspan="3">Hydrogen fuel cell cars are operated by fleets such as Green Tomato Cars (as taxis) and the Metropolitan Police. Range extended and dual fuel vehicles are operated by fleets such as Aberdeen City Council and the Commercial Group.</td></tr>
<tr><td>Further Information</td><td colspan="3">https://www.zap-map.com/live/ for a map of hydrogen refuelling station locations.</td></tr>
</table>

Natural Gas (CNG, LNG, Biomethane)

<table>
<tr><td rowspan="1">Technology Introduction</td><td colspan="3">

Natural gas-powered vehicles run on either Compressed Natural Gas (CNG) or Liquefied Natural Gas (LNG).
A dedicated gas vehicle uses CNG or LNG in a spark ignited internal combustion engine similar to a petrol engine.
Volvo’s Dual Fuel LNG technology uses a typical compression ignition engine and a blend of natural gas and diesel.
Whilst CNG and LNG are fossil fuels, Biomethane is the renewable and sustainable form. Biomethane is produced from organic waste and can be directly used in gas powered vehicles. Biomethane is available in compressed and liquefied forms.

LNG tractor unit refuelling
Source: NGV Network
</td></tr>
<tr><td>Availability</td><td colspan="3">Cars: Not available in the UK.
Small Vans: Not available in the UK.
Large Vans: Available in most body configurations from Iveco.
Rigid Trucks: Available from Iveco, Volvo, and Mercedes in varying configurations.
Tractor Units: Available from Iveco, Scania, and Volvo</td></tr>
<tr><td rowspan="4">Cost
(vs. Diesel)</td><td rowspan="4">

Gas vehicles cost a premium price from around £5k (vans) to around £30k (depending on vehicle class and gas tank size).
Maintenance costs increase and the residual value of the vehicles is lower due to limited infrastructure and demand for second-hand vehicles.
Fuel consumption increases due to a reduction in engine efficiency between a diesel compression ignition engine and petrol spark ignition engine vehicles.
Fuel price can be significantly cheaper leading to an overall cost saving if an attractive fuel supply deal is available.

</td><td>Capital</td><td>+</td></tr>
<tr><td>Maintenance</td><td>+</td></tr>
<tr><td>Fuel</td><td>-</td></tr>
<tr><td>Residual Value</td><td>-</td></tr>
<tr><td>Operational Performance</td><td colspan="3">

CNG range of between 300 – 800 km depending on vehicle and tank size.
LNG range can be over 1,000 km dependent on fuel tank sizes.
Load space is the same as diesel equivalent.
Payload is marginally reduced (by around 200kg for vans to 750kg for trucks).

</td></tr>
<tr><td>Environmental Performance</td><td colspan="3">

Fossil natural gas vehicles have similar or better CO_2 emissions but when operated on 100% biomethane they offer around 85% WTW CO_2 emission savings compared to diesel.
Dedicated gas vehicles generally produce lower noise than Euro VI diesel.
Air quality performance between Euro VI gas and diesel vehicles is similar.

</td></tr>
<tr><td>Case Studies</td><td colspan="3">Natural gas vehicles operated by the John Lewis Partnership, Tesco, Ocado, Asda, Kuehne + Nagel, Great Bear, Muller Wiseman and more.</td></tr>
<tr><td>Further Information</td><td colspan="3">www.gasvehiclehub.co.uk provides a maps of gas refuelling stations and further information on the vehicle availability and making the switch to gas vehicles.

http://www.ngvnetwork.co.uk/ The natural gas vehicle network website provides information promoting natural gas vehicles as a transport solution</td></tr>
</table>

Liquefied Petroleum Gas (LPG)

Technology Introduction	• Liquified petroleum gas (LPG) is a fossil fuel extracted alongside natural gas and is also a by-product of the oil refining process. LPG is stored on vehicles under pressure as a liquid. • A **dedicated LPG vehicle** uses LPG in spark ignited (petrol) engine to power the vehicle. • A **dual fuel LPG vehicle** simultaneously combusts diesel and LPG in a compression ignition (diesel) engine.		
Availability	Although LPG conversions are available from mainstream manufacturers in Europe, here in the UK you have to have a dedicated LPG system retrofitted to a petrol van, or a dual fuel LPG system retro-fitted to a diesel truck.		
Cost (vs. Diesel)	**Dedicated LPG:** • Retro-fit conversion costs start from around £1k. • There is a marginal increase in maintenance costs. • LPG fuel cost is low; however fuel consumption increases due to the engine efficiency loss between diesel (CI) engine and petrol (SI) engine vehicles. **Dual fuel LPG:** • Conversion costs range from £4.5 - £7.5k depending on GVW. • Maintenance costs increase by around £360 per annum. • LPG fuel is much lower cost than diesel.	**Capital** **Maintenance** **Fuel** **Residual Value**	+ + - ~
Operational Performance	• LPG vehicles offer similar duties and performance to regular vehicles due to the long range available between refuelling events. • Refuelling is easy, there are nearly 1,500 refuelling stations offering LPG across the UK suitable for vans. Trucks that cannot fit under a forecourt canopy would normally be refuelled from a bunkered supply of fuel at a depot. • The vehicles retain their original refuelling system and can switch back to petrol or diesel operation if LPG is not available. Payload is similar to a regular vehicle.		
Environmental Performance	• **Dedicated LPG** vehicles offer similar CO_2 emissions compared to diesel vehicles, with lower noise operation. LPG powered vans offer improved CO_2 emissions compared to petrol vans. • **Dual-fuel LPG** vehicles offer similar or better CO_2 emissions compared to diesel vehicles, with lower noise operation. • **Bio-LPG** is a renewable and sustainable version of LPG that can significantly reduce CO_2 emissions.		
Case Studies	LPG vehicles are used by Humberside Police Force, Grass Hopper Couriers, Clear Channel UK, Nobel foods and more.		
Further Information	For advice and information about converting to LPG including a list of approved installers and UK refuelling stations see DriveLPG: www.drivelpg.co.uk More information on the use of LPG as an automotive fuel can be found via UK LPG, the trade association for the LPG industry in the UK: https://www.uklpg.org/ Locations of current LPG refuelling stations within the UK can be found via MyLPG: https://www.mylpg.eu/stations/united-kingdom/		

Biodiesel (FAME)

Technology Introduction	Biodiesel, also known as FAME (Fatty Acid Methyl Esters), is a renewable fuel produced from vegetable crops or used cooking oil. It has similar properties to fossil fuel diesel and is already present in regular diesel purchased at public forecourts up to 7% blend. High blend biodiesel usually contains at least 20% biodiesel. Common blend strengths are B20 (20% biodiesel), B30 (30% biodiesel) and B100 (100% biodiesel).	 *An HGV using biodiesel.* *Source: McDonald's*
Availability	• All diesel vehicles sold within the EU must be warranted to run on BS EN 590 diesel fuel, which can contain up to 7% biodiesel. • Many manufacturers design their vehicles to operate on higher biodiesel blends, normally up to a 30% blend (B30). For example, Citroen and Peugeot warrant their range of high-pressure diesel injection engines to run on B30 biodiesel blends. • Truck manufactures such as Mercedes, DAF, Scania, Dennis Eagle, and Volvo also warrant various blends up to B100 depending on vehicle model.	
Cost (vs. Diesel)	• Operating on biodiesel incurs slightly greater costs (~3%) dependent on the biodiesel blend. • Some manufacturers require a biodiesel upgrade package to be purchased with the vehicle which involves a negligible cost increase. • Maintenance frequency also increases with biodiesel use. • Fuel consumption may decrease due to the lower energy content of biodiesel.	**Capital** ~ **Maintenance** ~ **Fuel** ~ **Residual Value** ~
Operational Performance	• **Similar range and performance** to a regular diesel vehicle, maintains the ability to run on diesel which can be used in the same tank. • **Payload and load space are unaffected**. • Biodiesel blends are normally provided as bunkered supplies to a fleet depot. Fuel is organic and has a shelf life of around 3-4 months. Fuel quality requires monitoring and lower blends (~B20) or heated fuel tanks are normally used during the winter months to improve cold temperature flow characteristics.	
Environmental Performance	• **Biofuel use can offer significant reductions in carbon emissions**. Blends of 25% to 100% biodiesel offer emission improvements of 16% to 68% WTW, with greater savings if the biodiesel is manufactured from used cooking oil. • You should ensure that biodiesel used is from sustainable sources. Biodiesel manufactured from used cooking oil has a very low environmental impact as it is a waste material and does not require food crops to be grown to produce it. • Biodiesel vehicles normally emit less particulate matter with similar, or marginally decreased, NOx emissions.	
Case Studies	Biodiesel vehicles are operated by fleets such as McDonalds, Environment Agency, Gateshead Council and many more.	
Further Information	See the LowCVP Renewable Fuels Guide for more information: https://www.lowcvp.org.uk/assets/reports/RenewableFuelsGuide_March2020.pdf	

Renewable Diesel (HVO)

<table>
<tr><td>Technology Introduction</td><td colspan="3">Hydrotreated vegetable oil (HVO) is a paraffinic fuel that is chemically similar to conventional fossil fuel diesel. It is classed as a ‘drop-in’ fuel, which means it can be substituted for conventional fossil fuel diesel with no impact on operational requirements. HVO can be produced from virgin vegetable oil, typically crude palm oil, and waste feedstock such as UCO and waste vegetable oils.

UK suppliers of HVO include Green Biofuels and Prema Energy. These companies import HVO produced in continental Europe by Neste.

An RCV in Hackney operating on HVO.</td></tr>
<tr><td>Availability</td><td colspan="3">As HVO is a drop-in fuel its use has no impact on maintenance or warranty. All major truck OEMs approve 100% HVO for use in their vehicles as long as the fuel meets European Standard EN15940.</td></tr>
<tr><td rowspan="4">Cost (vs. Diesel)</td><td rowspan="4">• As HVO is a drop-in fuel it can be used in diesel vehicles. Therefore, the costs of purchasing and maintaining the vehicles is the same as diesel. The residual value of the vehicles will also be identical to that of a diesel vehicle.
• No specialist equipment is needed to store HVO.
• The cost per litre of HVO is typically higher than diesel.</td><td>Capital</td><td>=</td></tr>
<tr><td>Maintenance</td><td>=</td></tr>
<tr><td>Fuel</td><td>+</td></tr>
<tr><td>Residual Value</td><td>=</td></tr>
<tr><td>Operational Performance</td><td colspan="3">• Similar range and performance to a regular diesel vehicle, maintains the ability to run on diesel which can be used in the same tank.
• Payload and load space are unaffected.
• HVO is not currently available at retail fuel forecourts, although HVO suppliers can provide and install refuelling infrastructure at depots. HVO can be stored in the same way and has the same storage life as regular diesel. There is no need for any specialist equipment.</td></tr>
<tr><td>Environmental Performance</td><td colspan="3">• HVO use can offer significant reductions in carbon emissions. WTW CO_2 savings of around 91% are expected from the use of HVO instead of diesel.
• The GHG emission savings of HVO varies depending on the type of feedstock. Efforts are being made to increase the volume of HVO produced from waste based raw materials.</td></tr>
<tr><td>Case Studies</td><td colspan="3">Currently the UK market for HVO is very small, its use is more prevalent in Europe. HVO is used by the London Borough of Hackney, Luckett’s Travel and Red Funnel.</td></tr>
<tr><td>Further Information</td><td colspan="3">See the LowCVP Renewable Fuels Guide for more information:
https://www.lowcvp.org.uk/assets/reports/RenewableFuelsGuide_March2020.pdf</td></tr>
</table>

UK ULEV Waste & Recycling Vehicle Deployment Status

Technology	Deployment Status
Battery Electric Vehicle 	**Largest Single Deployment (to date)** • Biffa[12] / Manchester City Council – 27 vehicles. • Vehicles produced by Electra Commercial Vehicles. • £10m investment (£370,000 per vehicle[13]). **Other Known Deployments** • At least 12 local authorities with 1 or 2 vehicles each including City of London, Nottingham and Newport.
Fuel Cell Electric Vehicle Demonstration vehicles coming soon	**Largest Single Deployment (to date)** • Fuel cell electric trucks have not been used in the UK. **Other Known Deployments** • Glasgow City Council[14] – £10.5m agreed for 19 vehicles. • Arcola Energy awarded ~£685k for the first vehicle[15]. • Aberdeen City Council – 1 vehicle to be delivered by Q2 2021 under the HECTOR project[16].
Natural Gas Vehicle 	**Largest Single Deployment (to date)** • Liverpool City Council[17] – 20 vehicles. • Mercedes-Benz Econic NGT 2630L (CNG). • £3.4m investment (~£170,000 per vehicle). **Other Known Deployments** • Bradford[18] (formerly Leeds) – £5.5m plan to install a grid connected CNG station in 2021/22 for 77 HGVs, including ~54 RCVs over the next seven years.
Hydrogen Dual Fuel 	**Largest Single Deployment (to date)** • Glasgow City Council[19] – 20 gritters (by winter 2021). • ULEMCo to convert half of existing fleet, remainder to be new vehicles. • Supported by Transport Scotland funding. **Other Known Deployments** • Cheshire East, Grundon, Aberdeen and Fife.
Renewable Diesel (HVO) and High Blend Biodiesel (B100) 	**Largest Single Deployment (to date)** • London Borough of Hackney[20] – 100 vehicles (HVO). • Considered a cost-effective option for reducing greenhouse gas emissions despite higher fuel costs. • Used biodiesel up to B100 for several years. **Other Known Deployments** • Babergh[21] District Council (proposed to 2023).

12 https://www.biffa.co.uk/media-centre/news/uks-largest-fleet-of-electric-waste-vehicles-launches-in-manchester
13 EST Fleet Review - Electric Refuse Collection Vehicles, EST (2019)
14 https://fuelcellsworks.com/news/worlds-largest-fleet-of-hydrogen-powered-bin-lorries-to-arrive-in-glasgow/
15 The Conversion of a Council RCV to Hydrogen Fuel Cell, Glasgow City Council (2020)
16 HECTOR Project, Life N Grab Hy Conference (2021)
17 https://airqualitynews.com/2020/03/12/liverpools-waste-vehicles-to-be-powered-by-biomethane/
18 Advanced Fuel Centre, City of Bradford Metropolitan District Council (2020)
19 https://ulemco.com/delivering-hydrogen-fuelled-gritters-to-glasgow-cc/
20 The Renewable Fuels Guide, Zemo Partnership and Cenex (2021)
21 Transfer of the Council's Vehicle Fleet to HVO, Babergh District Council (2021)

15. Appendix H – Infrastructure Considerations

15.1 Electric Vehicle Charging Infrastructure

Electric vehicle chargepoints can output AC and / or DC electricity ranging from 3.7 kW to 22 kW AC (using a 230V / 16A domestic supply and 400V / 32A three phase supply respectively) or 50+ kW DC. Figure 25 shows three common connector standards that are typically used for charging of plug-in vehicles.

Figure 25 - Common Electric Vehicle Connector Types

Electric vehicle charging speeds are dependent on several factors including but not limited to:

- Chargepoint power output (kW)
- On-board vehicle charger power rating (kW, for AC charging only)
    - Charging power is limited to the minimum of the chargepoint power output or the on-board vehicle charger power rating
- Battery capacity (kWh) and starting state of charge (%)

Charging rates vary from slow chargers which can take more than 12 hours to completely replenish a battery to rapid chargers which can provide 80% charge in 30 minutes.

Table 43 summarises electric vehicle chargepoint types, typical locations and provides indicative hardware costs. More detail on electric vehicle chargepoints can be found in the UK EVSE Procurement Guide[22].

Table 43 - Electric Vehicle Chargepoint Types

<table>
<tr><th></th><th>Charging Time (50 kWh battery)</th><th>Vehicle Connector Type</th><th>Typical Locations</th><th>Indicative Hardware Costs*</th></tr>
<tr><td rowspan="2">AC Standard - 7kW to 11kW</td><td rowspan="2">5 – 7 hours</td><td>Type 1</td><td rowspan="2">Domestic, Workplace, On-street, Public Car Park</td><td rowspan="2">£750 - £5,000</td></tr>
<tr><td>Type 2</td></tr>
<tr><td>AC Fast - 11kW or 22kW</td><td>2 – 5 hours</td><td>Type 2</td><td>Domestic, Workplace, On-street, Public Car Park</td><td>£1,800 - £5,000</td></tr>
<tr><td>AC Rapid - 43kW</td><td>~1 hour</td><td>Type 2</td><td rowspan="2">Workplace, On-Street, Public Car Park, Motorway Services</td><td rowspan="2">£15,000 - £30,000</td></tr>
<tr><td>DC Rapid - 50kW</td><td>~1 hour</td><td>CCS, CHAdeMO</td></tr>
<tr><td>DC Ultra-rapid - 150kW</td><td>20 minutes</td><td>CCS, CHAdeMO</td><td>Charging Hub, Public Car Park, Motorway Services</td><td>> £30,000</td></tr>
</table>

* excluding VAT

[22] https://www.r-e-a.net/wp-content/uploads/2020/03/Updated-UK-EVSE-Procurement-Guide.pdf

Chargepoint Installation Process

Once it is decided which chargepoints are needed, then the process of planning, installation and procurement begins. Contracting the services of a reputable certified installer will help with this process and includes:

- Testing and surveying the power supply of your site to determine the available capacity i.e. the number and type of chargepoints it could support.
- Liaising with the distribution network operator (DNO) on any upgrades needed to support the charging capacity that has been identified.

Getting good information on these parameters early in the planning process will support informed decision making. Cenex's Energy Systems and Infrastructure team has experience in managing or supporting both activities, if appropriate.

The number of vehicles being charged is closely linked to downtime because fleets where many EVs charge for longer periods of time require a greater number of lower-powered chargepoints. On the other hand, fleets where many vehicles charge at different times and for shorter periods of time may need fast or rapid chargepoints to ensure vehicles receive an adequate charge before the next vehicle arrives or the next shift begins.

A site survey should be conducted to determine the supply and any spare capacity available (the difference between actual load used and the maximum available) before vehicles or infrastructure are acquired. If electrical capacity limitations are identified on a site where many EVs are planned to operate from, it is important to consider that these limitations could quickly become an issue, regardless of the type of chargepoint used.

For example, a very similar amount of available capacity would be required to run a fleet of 15 EVs in the following configurations:

- One 50 kW rapid charger, with EVs scheduled to charge one-by-one;
- Two 22 kW fast and one 7 kW slow charger, all being used at the same time; or
- Seven 7 kW slow chargers, all being used at the same time.

This means that electrical capacity should be considered, ideally even before EVs are procured.

When it comes to locating chargepoints, there are a number of key factors to take into account, which Cenex or an experienced installer can advise on. Air flow to charging equipment is critical for preventing overheating and ensuring safe and effective working of the power electronics. Trailing cables can also create trip hazards and unnecessary obstructions. This can be minimised for slow and fast charging by installing non-tethered units where users provide their own charging cables. This also reduces the requirement to provide both type 1 and 2 connectors to the chargepoint. Where tethered (non-detachable) charging cables are employed, provision should be made for safe storage when not in use. Furthermore, the placement of the chargepoint should not present any unnecessary obstructions.

Figure 26 shows the two main mounting methods for electric vehicle chargepoints.

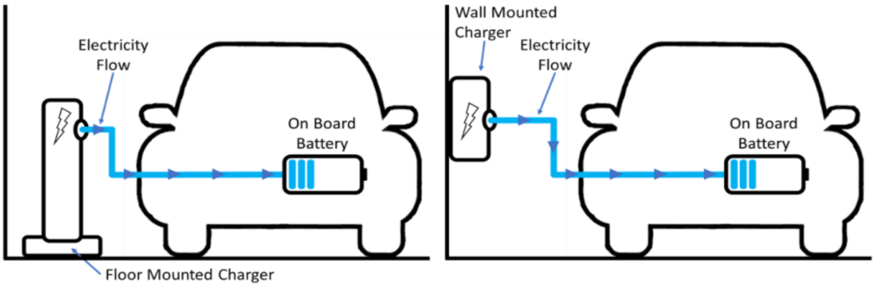


Figure 26 - Typical Mounting Methods for EV Chargepoints

Indoor EV charging tends to favour wall mounted units, which take up less space and can be fed using cabling on the surface of walls and ceilings. For central areas within a floor, floor mounted chargepoints may need to be used as wall space is not available. Where floor-mounted chargepoints are used, impact barriers or kerbing may be worth installing to protect the chargepoint for accidental damage by moving vehicles.

The success of chargepoint installations hinge on the successful cooperation between multiple stakeholders. Table 44 outlines the high priority stakeholders and the recommended steps required to ensure delivery can be achieved on time and within budget.

Table 44 – Stakeholder Engagement Recommendations

	Recommendations
DNO	Ensure the DNO is engaged as early as possible.
	Reinforcement costs to the network required for the installation will be passed onto the user.
	Any grid upgrades required will impact the delivery timescale.
	Engagement can be carried out through the installer assuming this is agreed before works begin.
Energy Supplier	Some chargepoint installations may require the installation of a new electrical supply point which is completed by the energy supplier. Disruption can be reduced by early engagement.
Landlord	The landlord should be notified of the project, permission is required to start the work on site.
	There may be a requirement for legal agreements, which will carry a financial impact in addition to increasing delivery timescales.
Internal Stakeholders	Health and safety representatives at the organisation should be notified well in advance of works starting to allow for additional procedure to be developed if required. Facilities, energy and fleet managers will need to cooperate to ensure a smooth and effective installation

Installation Costs

Before engaging a charge point installer, it is advisable to first develop a clear strategy for the location and power of chargers required for the site. This will prevent issues with re-quoting or receiving tenders for inadequate or differing scopes of work.

The cost of an installation can be greatly impacted by several factors, including:

- **Distance from electrical supply** - A greater distance requires more excavation and electrical cabling. These are two of the highest cost aspects of installation so should be minimised where possible. Electrical cabling diameter will also increase with distance, adding further cost.
- **Ground type** - If cabling to the chargepoint is to be run underground this will require excavating and replacing the ground. Different ground types could have a significant impact on the cost, with excavating road typically costing more than double that of excavating turf or soil.
- **Demarcation of parking bays** - the addition of bay painting, protective barriers and signage can often be missed off an installers original price, resulting in delays and additional costs to rectify post project. Therefore, it is important to consider any requirements for demarcation prior to engaging with an installer.

Table 45 shows typical installation cost items and indicative costs for each.

Table 45 - Typical Chargepoint Installation Costs

	Typical Costs
Excavations	Turf: ~£120 per meter; Pavement: ~£200 per meter; Road: ~£250 per meter
Earthing	£300 - 500 per pit
Electrical Cabling	£40 - 50 per meter
Signage	£75 - 100 per sign
Road Markings	£75 - 150 per bay
Protective Barriers	£200 - 300 per bay

Grid Upgrade Costs

DNOs are responsible for ensuring that the local electricity network has the capacity and reliability to meet demand. Increases in demand by a customer can require the DNO to carry out network upgrades.

Costs vary significantly depending on the characteristics of the network, the additional demand required and whether the site is owned or leased. Large upgrades can take six months or more, and can be very costly, so early engagement with the DNO to agree timescales and secure funding is essential.

Although the latest decarbonisation plan from Ofgem proposes to give DNOs greater leeway to decide on upgrades to enable the future electrification of heat and transport, the funding model that DNOs operate under means the customer making the request shoulders the cost burden. Many customers are unable to pay these costs so seek alternative technical measures to manage within existing constraints until the connection is upgraded by someone else.

Table 46 shows indicative costs and timescales for various upgrades ranging from small (70 kVA) to large (1,000+ kVA).

Table 46 – Indicative Grid Upgrade Costs and Timescales

	Small	Medium	Large
Power	Up to 70 kVA	200 to 1,000 kVA	Above 1,000 kVA
Number of charge points	• 1-3 fast, or • 1 rapid	• 10-50 fast, • 4-20 rapid, or • 1-6 ultra-rapid	• 50+ fast, • 20+ rapid, or • 6+ ultra-rapid
Approximate connection time	8-12 weeks	8-12 weeks	6 months +
Approximate connection cost	£1,000 - £3,000	£4,500 - £75,000	£75,000 - £2 million

Alternative Power Supply Options

It is possible to avoid paying for grid upgrade using alternative power supply options such as:

- **Load management**
  - Using controllable hardware or switches and a series of business rules to ensure that the load from chargers never exceeds a pre determined level.
  - Implemented as standard in many available chargepoint solutions (‘smart charging’).
- **On site generation and storage**
  - On site generation (e.g. solar PV) and battery storage can reduce the overall demand of the installation by trickle charging batteries which then accommodate peaks in demand.

Load Management

The most common way to manage a constrained connection is through load management. This involves using controllable hardware or switches and a series of business rules to ensure that the load from chargers never exceeds a pre determined level. This is implemented as standard in many chargepoint solutions available on the market (usually referred to as ‘smart charging’) and involves measuring demand of other loads on site in order to calculate the available capacity for chargers. Charger powers are modulated accordingly to ensure that any capacity threshold is not breached. Attention should be paid to the load management strategy for instance are some chargers turned on/off, is the power varied across chargers or are certain chargers given priority in order to ensure it meets NWLDC needs.

Timed connections These give a different approach which acknowledges that constraint is more than simply the total current carrying capacity of the wire to the site. Network constraints change in time and space, so there may be set times when demand must be constrained in one location but other periods when a higher draw can be permitted. This minimises the DNO upgrade work required to meet the fluctuating demand but must be coupled with load management technologies. This service is not currently available from all DNOs and terminology can vary between regions.

Multiple connections A large site may be supplied by more than one substation, so the DNO may be able to provide the necessary additional capacity at a cheaper cost elsewhere on the estate. This option would normally be highlighted by a survey.

Alternatively, other organisations sharing the same connection or substation may also need additional capacity. If applicable, an arrangement with such organisations may be possible to spread costs.

On-site Generation and Storage

In areas where network constraints are significant, systems involving on-site generation such as solar PV and battery storage may be beneficial. This can be used to reduce the overall demand of the installation by trickle-charging batteries which then accommodate any peaks in demand. Additional revenue may be gained from generation assets or cost-savings as demand is managed in accordance with variable tariffs.

Additionally, the electrical topology should be carefully examined in order to reduce losses associated with on-site storage. Some chargepoints come equipped with in-built battery storage which can be charged on low power and then supplement the existing grid connection to deliver high kW rapid charging. Whilst more compact, these do limit the regularity with which single chargepoints can be used, potentially leading to multiple vehicle swaps to free up parking spaces with charged chargepoints. An alternative approach is to install a single large battery on a site which feeds a series of chargers. The most common systems charge and discharge on AC to allow interconnection with existing equipment and wiring on-site. The size of the battery, charging power and discharging power can vary significantly according to the specific make and model of the battery. It should be noted that this may also make any grid connection requests more complex because the DNO has to consider that on-site storage may export back to the grid. The downside of this approach is that electricity stored has to undergo AC/DC conversion three times when rapid charging is required. Firstly AC>DC for the storage, then DC>AC when releasing power and finally AC>DC at the chargepoint for rapid charging.

Therefore, a less common but electrically optimised solution would be to install a battery storage system which feeds DC directly to rapid chargers. This would bring the advantage of the battery-backed rapid chargers together with the benefit of a single large battery, without the efficiency losses of multiple conversions between AC and DC.

Solar PV

Efficiency: The higher a solar panel's efficiency, the more energy it will generate, relative to its size. Modern commercial solar panel efficiency is typically 16 –20%. However, you should also consider the size of your roof: if you do not have much roof space, then you will need to buy a small number of the most energy efficient panels you can afford. If you have a large roof you can install more panels of a lower efficiency, reducing your upfront costs. Other factors which affect how much energy a solar panel can generate are:

- Seasonal variations – more electricity will be generated in the summer rather than winter.
- Weather variations – more electricity will be generated on a sunny day as opposed to a cloudy one.
- Daily variations – electricity generation will peak at noon and obviously not occur at night
- Panel orientation – electricity generation will be optimised with a south-facing panel at a tilt angle appropriate for the latitude of the location (typically around 30°from horizontal in the UK)
- Shading – the panels should be situated to avoid any shading from surrounding buildings or trees as well as self-shading (being in the shadow of an adjacent panel) as this will reduce the electricity generated.

Cost: Due to advancements in the technology the cost of solar panels has reduced significantly in recent years. An average business could have a system of around a 5-9kW output but a commercial operation with large land or roof space could install a system with an output of 25kW to even as much as 200kW.

Table 47 - Indicative costs for solar PV systems

Commercial PV System Size	Typical Cost
<9 kW	£8,000 – £14,500
10 kW	£15,000 – £17,000
25 kW	£40,000 – £43,500
50 kW	£70,000 – £74,000

Installation: It usually takes between 2 and 5 days to install solar panels, depending on the size of the panels required and the complexity of the system. Scaffolding will need to be erected around the premises prior to the solar panel installation so that workers can access the roof. Most installers will arrange this, but they may require that this is organised by the site owners.

Exporting to the Grid: Solar panel owners can benefit from the Smart Export Guarantee (SEG) scheme. This requires electricity suppliers to pay their customers for any electricity generated from renewable sources which they export into the grid. Table 48 shows some indicative prices from 2020.

Table 48 - SEG prices for UK energy suppliers, 2020.

Energy Supplier	SEG price (p/kWh)
E.ON / Npower	3-5.5
Octopus	5.5
EDF	3.5
SSE	3.5
OVO	4
British Gas	1.5
Bulb	5.38

Battery Storage

At times of high generation and low demand for renewable energy sources, integrated energy storage can allow a site to be energy self-sufficient by capturing the electricity when it is readily available and saving it for a time when it is useful.

While the use of an energy storage system can reduce your fuel bills and carbon emissions, the savings are dependent on the system installed and how it is used. Most energy storage systems offer smart operations, allowing you to keep track of your energy use online and to decide when to charge your storage unit and when to draw power from it.

Energy storage systems manufactured using lithium-ion batteries are the best on the market, offering fast charging and high capacity. The cost of such a system generally ranges from £200,000 to £600,000, depending on variables such as the capacity of the battery, material, lifespan, and installation process.

Capacity: the market standard battery size ranges from 1-13MWh. A battery's 'useable capacity' is the percentage of a battery's energy that can be used before having to recharge, otherwise it can be damaged. It is thus less than the 'total capacity'.

Power: the higher a battery's power rating, the more devices it can power. A high-capacity battery with a low power rating will store a lot of energy but will not be able to discharge it at a high rate. A standard battery's power rating typically ranges from 2-5kW.

Depth of Discharge: if a battery's full capacity is continually used before recharging, its total capacity will be reduced over time. A battery's depth of discharge dictates how much of the battery's capacity should be used before recharging. Most modern lithium-ion batteries come with a depth of discharge of 90-95%.

Warranty: every battery comes with a guaranteed number of 'cycles', with one 'cycle' being one complete discharge and one complete recharge. Most operations use about 50% of the battery capacity before charging it back up to 100%; this would count as half a cycle. Every battery also comes with a product warranty, which is usually 10 years.

15.2 Natural Gas Refuelling Infrastructure

Natural gas refuelling can take place either on-site at depots (with an installed refuelling station), or at a commercial natural gas station. Natural gas refuelling typically occurs at either a gas grid connected CNG station or by using a station that is supplied by CNG / LNG delivered by road tanker.

All major station suppliers now offer biomethane certified under the Renewable Transport Fuel Obligation (RTFO) scheme. This ensures that the fuel is produced from renewable sources and allows reporting of the CO_2 savings by the transport operator (the fuel dispensed into the vehicle is balanced with biomethane injected into the grid elsewhere). Any additional cost due to this certification is included in the gas price used during the fleet review (historically 3 p/kg).

Additional details about natural gas stations, including current UK availability, can be found on the Gas Vehicle Hub[23], managed by Cenex.

Gas Grid Connected Stations (CNG Only)

Natural gas is extracted from the gas grid and conditioned before being compressed into storage tanks. Grid connected stations are cost effective for delivering large volumes of CNG, but the suitability of the connection depends on the pressure and distance from the network.

- Higher pressure = lower compression costs but potentially greater distance (e.g. higher connection costs)

CNG is dispensed at 200 bar or 250 bar using an NGV1 (cars and some LCVs) or NGV2 (HGV) connector. Refuelling is convenient, safe and takes a similar amount of time to a diesel vehicle at a fast fill station (in comparison to a plug-in electric vehicle). Slow fill stations, which compress gas directly into the vehicle tanks, can be suitable for some applications.

Figure 27 shows the typical configuration of a CNG station.

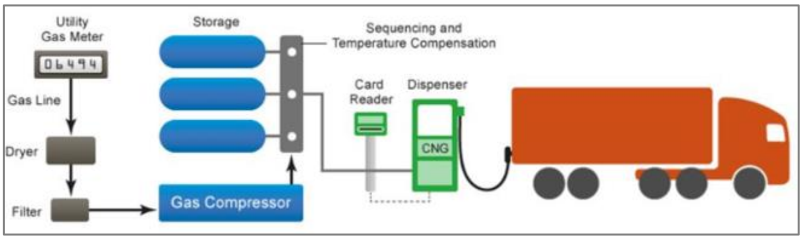


Figure 27 - Typical CNG Station Configuration (Source: US Environmental Protection Agency, Image: CNG Fuels Station, Warrington)

Mother and Daughter Arrangement

A 'mother and daughter' station arrangement can be used when a gas grid connection is not feasible, or additional flexibility is required, or for fleets with low natural gas usage. In this arrangement the daughter

[23] https://gasvehiclehub.org/

station is supplied by CNG using a tanker or consists of a CNG tube trailer, coupled to a dispenser. The mother station, often grid connected, supplies CNG as and when required.

LNG Stations

LNG is not available via a grid connection, instead LNG is delivered to stations by tanker from LNG terminals such as the Isle of Grain. LNG stations consist of low-pressure cryogenic storage tanks and a fuel dispenser. LNG can be dispensed with the aid of a cryogenic pump or by the pressure difference between the station and vehicle storage tanks.

LNG stations may suffer from very slow fuel loss as heat ‘boils off’ the stored LNG and increases pressure in the storage tank. As such, modern stations have vent capture systems to prevent leakage. Stations are designed to ensure an optimal storage capacity that allows for regular LNG deliveries to maintain a low temperature in the storage tank.

LNG is dispensed at 3 bar to 8 bar using an JC Carter or Mactrotech connectors.

Figure 28 shows the typical configuration of an LNG station.

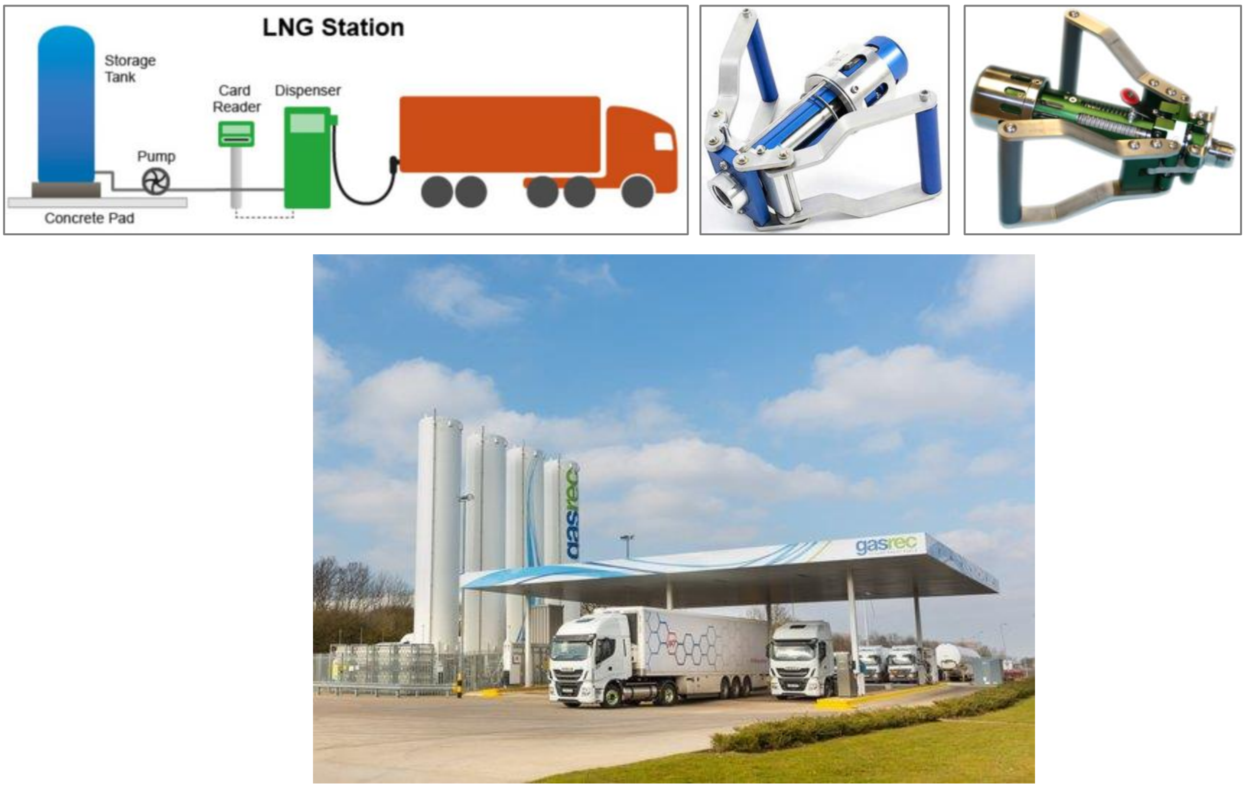


Figure 28 – Typical LNG Station Configuration (Source: US Environmental Protection Agency, Image: Gasrec Station, Daventry International Rail Freight Terminal)

Access Arrangements

There are currently ~11 public access natural gas stations in the UK (CNG and LNG), these stations are typically openly accessible, available 24/7 and require either an account with the station operator or provide payment via a key fob.

All other stations have some form of access restrictions. Stations located on customer depot sites typically require third parties to make prior arrangements to access these facilities.

Options for Funding Depot Based Natural Gas Stations

There are two options for funding depot based natural gas stations:

1. **A gas station supplier installs and operates the refuelling station**. This reduces capital outlay and risk, but a marginally higher price is paid per kilo dispensed. Contracts include agreed prices for fuel and maintenance, helping fleets forecast ongoing expenditure.

a) Station suppliers rely on demand for an acceptable business case: an indicative cost for grid connected public CNG station = >£1.95m with a minimum viable natural gas demand of ~900 kg per day

b) Gas price = fuel duty + wholesale gas price (variable) + station CAPEX + station OPEX + profit

2. **The fleet pays for and operates the station**. This provides the cheapest cost per kilo gas dispensed but requires substantial upfront capital and the fleet takes on the risk of making the station viable.

As previously discussed, vehicle total cost of ownership relies heavily on the provision of low-cost gas. Advantageous fuel duty of 24.7 p/kg until 2032, compared to 57.95 p/litre for diesel, provides some stability in fuel price.

Natural Gas Station Installation Process

To install depot based natural gas stations, fleets need to first assess the following:

- The distance from the refuelling station to the national gas grid – this will have a significant impact on installation costs. CNG station providers can carry out the necessary site survey.
- The number of vehicles to be refuelled and the time of day they will use the station. This will determine the number of dispensers required and the required refuelling speed.
- Availability of space for storage tanks, compression systems and dispensers.
- The distance from the refuelling station to a suitable electricity connection, as this will also influence the cost of the installation.

Table 49 shows the key processes and timescales involved in station delivery as reported by Element Energy.

Table 49 - Natural Gas Station Installation Process

	Process	Tasks	Timeline
Site Concept	Establish demand	Engage with local fleets to assess appetite for a shared station	↓
↓	Identify suppliers	Tender for suppliers, define contract for equipment and gas supply	6 months
	Identify site	Identify potential locations and arrange site surveys	↓
	Site design	Security arrangements, layout drawings, design work (for civils and station), safety assessment	
	Planning and consent	Submit planning application	10 months
	Site preparation and civil works	Carry out civil works (electrics, pipework, firewalls)	↓
	Installation and commissioning	Installation, testing and commissioning	
Site Operation	Operation and maintenance	Day to day station operation, servicing and maintenance	18 months

15.3 Biodiesel Fuel Use and Storage Considerations

Vehicle Operational Considerations

Biodiesel has a lower energy content than diesel (~8%) resulting in slightly higher fuel consumption at higher blends.

Biodiesel requires more fuel management than regular diesel. It absorbs more water than diesel and can be susceptible to microbial growth, additives are added to fuel tanks to prevent fuel filter blockages. Manufacturers also recommend increased fuel filter and oil inspections.

Biodiesel can gel or wax at cold temperatures. Depending on the feedstock, B100 can start to be affected at temperatures as high as 10°C. Low temperature waxing can be controlled and eliminated through interventions such as fuel additives, feedstock control and varying seasonal blends.

Biodiesel Infrastructure Considerations

Although the basic components used for refuelling high blend biodiesel are the same as diesel there are several operational changes that must be considered in infrastructure design and maintenance before use. The specific properties of the fuel that result in increased infrastructure and fuel management considerations are as follows:

- Long term storage stability / oxidation – fuel quality can degrade over a period of months resulting in increased acidity, increased viscosity and the formation of deposits in filters.
- Microbial contamination – bacteria can grow if water accumulates, draining of tanks and use of biocides may be required to avoid formation of 'sludge'.
- Cleaning / solvent effect – methyl esters in biodiesel have a cleaning effect which can flush any existing deposits in the fuel system after transitioning from diesel to biodiesel.
- Materials compatibility – biodiesel can degrade certain materials used for hoses and gaskets.
- Low temperature operability – biodiesel may freeze or gel at typical winter temperatures, this can lead to poor flow properties and even difficulties pumping from the fuel tank. Low temperature flow additives, lower blends or heated fuel systems may be required in some climates.

Additional fuel management to address these challenges is often required, Shell provides the following 'housekeeping' guidance to its customers using B100 and blends above 10%:

- Is the construction material of your tanks, fuel lines, hoses and seals suitable?
- Is your system able to store biodiesel at the required temperature?
  - Follow the temperature requirements for storage.
- Is your system clean and dry and have you removed excess deposits?
  - Drain water from tanks regularly (dependant on turnover at your site). Recording of water content, quantity of water drained, and any abnormal observations will help to monitor the effectiveness of the housekeeping.
  - Check your filters periodically.
  - Consider stability checks if biodiesel is stored for longer periods.
  - Consider testing for microbial contamination at certain occasions.

Biodiesel Fuel Costs

High volumes of biodiesel are required to guarantee economic delivery. Fuel suppliers typically require a minimum on-site delivery of 10,000 litres and as biodiesel has a shelf of 3-4 months this equates to 30,000 to 40,000 litres a year. Additional delivery charges may also be applicable at lower volumes.

15.4 Hydrogen Refuelling Stations

The installation of a hydrogen refuelling station (HRS) typically involves a number steps, some of which are dependent on preceding activities, whereas others may be undertaken in parallel.

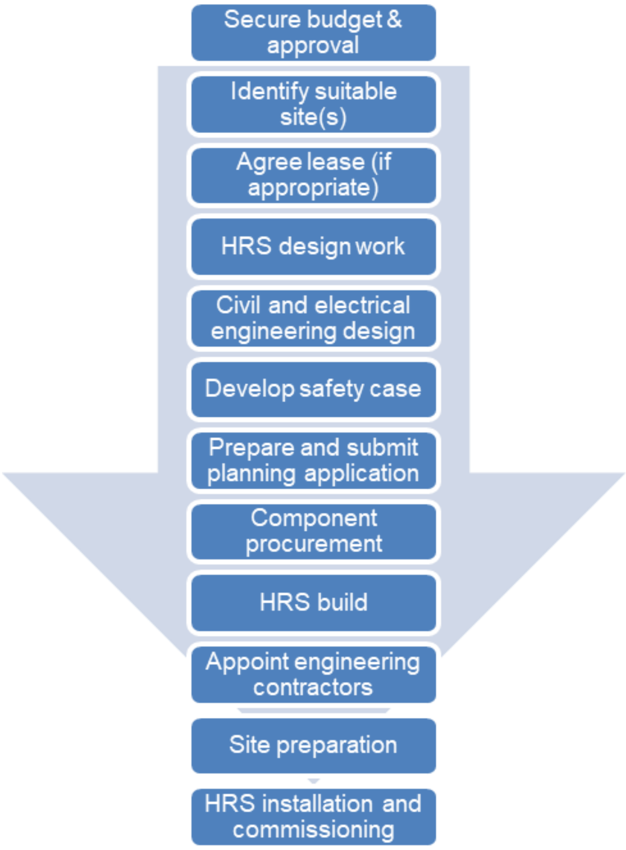
Given the low number of HRS in the UK today, it is difficult to characterise the installation process in terms of a typical installation time. However, experience from several pre-commercial demonstration projects suggests that a period of eighteen months or more from project start to station commissioning is not unusual.

Most HRS installed to date in the UK have been through projects with an element of public funding. Given the poor business case for HRS during the early years of FCEV commercialisation, it is likely that some form of support will continue to be required for a number of years.

Budgeting therefore involves establishing a breakdown of the total costs (capex and opex), securing grant funding as necessary, and agreeing a budget allocation between partners.

Challenges in this process include determining costs (until a site is selected and detailed design work completed it can be difficult to assess the total installation costs), and uncertainty over future demands for hydrogen (which affects revenues and the overall business case for investment).

The figure below shows a typical HRS design, development and installation process.



The technical design of hydrogen refuelling stations is becoming increasingly standardised. Most HRS are based on a modular arrangement, with three principal elements:

- The main skid, housing any on-site production equipment, the hydrogen compressor, control equipment, and a small amount of high-pressure storage.
- Bulk hydrogen storage – bottles / tubes / vertical tanks. Bottles of compressed hydrogen offer insufficient storage capacity for most HRS. Vertical tanks around 20m high are being installed in a number of HRS in Germany. These are preferred over tubes when space is at a premium as they offer a lower footprint solution.
- Hydrogen dispenser (which may include pre-cooling equipment depending on distance from the main skid). This is generally the only part of the station that is publicly accessible.

Costs for HRS installations are difficult to calculate as they depend on many factors, as outlined previously.

Most HRS installations are part funded through government grants, due to the high cost and risks associated with the deployment. As an example, Logan Energy has been chosen as the partner to supply two publicly accessible hydrogen refuelling stations in Teesside, as part of a £2.25m project. The initial four-year contract is part of a government project, funded by the Office for Low Emission Vehicles' (OLEV) Hydrogen for Transport Fund, which aims to deliver five new hydrogen refuelling stations across the UK.

15.5 Example Infrastructure Costs

To put the vehicle total cost of ownership and energy demand results in context, this subsection provides a summary of typical costs for permanent depot based refuelling infrastructure and electric vehicle charging infrastructure.

This is based on publicly available reports supplemented by previous Cenex studies.

Table 50, Table 51 and Table 52 show example infrastructure costs for compressed natural gas, hydrogen and electric vehicle charging, respectively.

Table 50 - Example Infrastructure Costs; Compressed Natural Gas Stations

Source	Description
City of Bradford Metropolitan District Council (2020)	• Council owned Household Waste Recycling Facility. • 77 HGVs including RCVs (+ 3rd party access to improve business case, also considering mother and daughter station arrangements). • Estimated CNG station cost = £1.6m to £1.8m. • Gas grid connection = £0.5m. • 500 kVA power supply = £0.25m (contingency). • Total additional capital (including vehicles, site prep etc.) = £5.5m • Funding = £0.77m loan, fuel cost savings = £2.3m by 2027, royalties at 5p / kg = £1.4m by 2027, other = £0.025m
Cenex (2020)	• Private depot based CNG station (10,000 kg capacity) • Estimated CNG station cost = £0.51m (approx. costs for compressors, dispensers, civils and other installation costs). • Estimated CNG price = £0.91 / kg at 1,000 kg a day and £0.79 / kg at 2,500 a day (including base fuel cost, capital payback over ten years, operating costs, fuel duty, excludes operator profit).
Element Energy (2015) Transport & Travel Research (2011)	• CNG station (5,000 kg capacity). • Estimated CNG station cost = £0.47m. • Estimated CNG price = £0.69 / kg at 5,000 kg a day.

Table 51 - Example Infrastructure Costs; Hydrogen Refuelling Stations

Source	Description
Department of Energy (2020)	• Capital equipment cost estimates for 111 grant funding proposals submitted to the California Energy Commission. • 700-bar fuelling capability for passenger and light commercial vehicles, stations supplied by tube trailers or liquid hydrogen tanks. • Median capacity = 1,500 kg / day. • Median capital cost = \$1.9m (£1.34m).
Logan Energy (2020)	• £2.25m contract to supply two publicly accessible hydrogen refuelling stations for cars and vans in Teesside. • £1.3m funding from the Hydrogen for Transport Programme.
Element Energy (2015)	• Hydrogen refuelling station cost (1,000 kg / day) = £1.3m (2025)

Table 52 - Example Infrastructure Costs; Electric Vehicle Charging

Source	Description
Cenex (2021) UK EVSE	• 22 kW AC chargepoints = £0.33m (ground mounted, dual output including typical installation costs). • 50 kW DC chargepoints = >£1.8m (ground mounted, single output including typical installation costs). Not recommended. • Grid power supply upgrade = £0.05m to £0.5m but can be higher. • Excludes annual operating costs such as back office / control systems and maintenance.

16. Appendix I – Grant Funding Options

Low Emission Vehicle Plug-in Grant

A discount on the purchase cost of a brand new low-emission vehicle is available through the government's plug-in grant scheme. The grant is applied by the dealer and is included in the purchase cost of the vehicle. The grant amount depends on the category of the recipient vehicle. Only vehicles that have been approved by the government are eligible, even if the vehicle otherwise meets the emissions criteria.

Category	CO_2 emissions limit (g/km)	Zero emission distance (miles)	Percentage of purchase paid by grant	Maximum grant value
Cars	50	70	35%	£2,500
Vans (<2.5t GVW)	50	60	35%	£3,000
Vans (2.5 – 3.5t GVW)	50	60	35%	£6,000
Small Trucks (>3.5 – 12t GVW)		60	20%	£16,000
Large Trucks (>12t GVW)		60	20%	£25,000

Notes (Truck Grants):

- Grants for Small Trucks are available for the first 250 orders placed per financial year and are limited to 10 per customer.
- Grants for Large Trucks are available for the first 100 orders placed per financial year and are limited to 5 per customer.

Electric Vehicle Charging Infrastructure Grants

There are three UK Government schemes that provide financial support to assist with the installation of electric vehicle charge points. Depending on the exact use case of each vehicle, different schemes may be most appropriate.

Grant Scheme	Details
Workplace Charging Scheme (WCS)	• Voucher-based scheme that provides support towards up-front costs of the purchase and installation of chargepoints at workplaces. • Covers 75% of costs up to a maximum of £350 for each socket for up to 40 sockets across all sites. • Authorised installer claims voucher from the Office for Low Emission Vehicles (OLEV) following installation.
Electric Vehicle Homecharge Scheme (EVHS)	• Aimed at private plug-in vehicle owners (registered keeper, lessee or have primary use of the vehicle) to their home. • 75% grant funding contribution towards the cost of one chargepoint and its installation up to a maximum of £350. • Includes "Individuals who are named by their employer as the primary user of an eligible vehicle for at least six months".
On-Street Residential Chargepoint Scheme (ORCS)	• Grant funding for local authorities towards the cost of installing on-street residential chargepoints. • Grant set at £6,500 funding per chargepoint. • "The location(s) will meet current or anticipated future demand".

Workplace Charging Scheme (WCS)
Any business, charity or public authority is eligible to claim this grant towards the cost of installing EV chargepoints provided they have dedicated off-street parking for staff or fleet use only.

Electric Vehicle Homecharge Scheme (EVHS)
The scheme allows for third party contributions so the cost of charger and installation at an employee's home can be covered by the employer in this way.

The installation address must have designated private off-street parking which is suitable for chargepoint installation. If an individual moves to a new address, they must contact the DVLA to notify them. They can request permission to take their chargepoint with them but OLEV will not contribute to the costs of moving the chargepoint to a new address.

Benefit in Kind Tax Considerations

For BEVs newly registered after April 2020, company cars for personal use will pay no Benefit in Kind (BIK) tax. The tax rate will rise to 1% in April 2021, then to 2% in April 2022, until in 2023 the BIK tax rates are realigned. This means that for the next three years significant tax savings are available from the use of a pure-electric company vehicle.

Additionally, according to the Income Tax Earnings and Pensions Act 2003 s149(4), electricity is not treated as a transport fuel. As a result, no benefit in kind tax arises if an employer:

- Pays to charge a pure-electric company vehicle.
- Pays for a chargepoint to be installed at the employee's home to charge the company vehicle.
- Pays for a charge card to allow individuals access to commercial or local authority charging points.

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