Transport Decarbonisation Report

South Hams District Council and West Devon Borough Council

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Contents

Additional support from Energy Saving Trust

To support you on your fleet decarbonisation journey, Energy Saving Trust's DfT-funded Local Government Support Programme can provide workshops to explore BEV procurement advice, and sustainable transport policy/plan reviews for internal discussions to councillor support. The team can also provide support through "Go Electric!". These are events that help to demystify electrification, presented in 1-hour sessions.

Glossary of terms

Abbreviation	Meaning
BE/BEV	Battery-Electric, Battery Electric Vehicle
CAZ	Clean Air Zone (England and Wales, excluding London)
CCC	UK Climate Change Committee
CNG/LNG	Compressed/Liquid Natural Gas - methane
BEIS (DBEIS)	(Department for) Business, Energy and Industrial Strategy
Defra	Department for Environment Food and Rural Affairs
DVLA	Driver and Vehicle Licencing Agency
DVSA	Driver and Vehicle Standards Agency
EV	Electric Vehicle - usually battery-powered (BEV)
GHG	Greenhouse Gas - in transport usually CO_2, CH_4 and N_2O
GVW	Gross Vehicle Weight – Replaced by MAM
GWP	Global Warming Potential
H2FC	Hydrogen (H_2) Fuel Cell
HCV	Heavy Commercial Vehicle – also known as HGV – over 3.5t MAM
HDV	Heavy Duty Vehicle – All large vehicles: HCVs, Buses, Cranes
HGV	Heavy Goods Vehicle – also known as HCV – over 3.5t MAM
HMT	Her Majesty's Treasury
HVO	Hydrotreated Vegetable Oil – also known as biodiesel HVO
ICE	Internal Combustion Engine – Petrol/Diesel/Gas
ILUC	Indirect Land Use Change – important when considering biofuels.
LCV	Light Commercial Vehicle – Van – up to 3.5t MAM
LEZ	Low Emission Zone (Scotland)
MAM	Maximum Authorised Mass – replaces GVW Gross Vehicle Weight.
NAEI	National Atmospheric Emissions Inventory – Transport Factors
NCAP	New Car Assessment Programme- Safety
NDC	Nationally Determined Contributions (2015 Paris Agreement)
NEDC	New European Driving Cycle (now replaced by WLTP)
NPV	Net Present Value
OCA	Open Charge Alliance
OCPP	Open Charge Point Protocol (currently v2.0.1)
OEM	Original Equipment Manufacturer, e.g. Tesla, Ford, Nissan, Toyota etc.
OZEV	Office for Zero Emission Vehicles
OSCP	Open Smart Charging Protocol (currently v1.0)
PHEV	Plug-in Hybrid Electric Vehicle
PM	Particulate Matter – associated with wide range of human illness
RCV	Refuse Collection Vehicle (eRCV - electric RCV)
RDE	Real Driving Emissions (RDE1 and RDE2)
REEV	Range Extended Electric Vehicle
RRV[1]	Resource Recycling Vehicle (eRRV - electric RRV) – Waste usage
RRV[2]	Rapid Response Vehicle – Emergency Service usage
RTFO	Renewable Fuels Transport Obligation
SECR	Streamlined Energy and Carbon Reporting
TTW	Tank to Wheel – Scope 1 and 2 GHG emissions
UCO	Used Cooking Oil – the primary feedstock for HVO
ULEV	Ultra-Low Emission Vehicle – under $50gCO_2/km$, 70 mile ZE range
ULEZ	Ultra-Low Emission Zone (London only)
V2G	Vehicle to Grid – Technical Guidance (UK Power Networks)
V2O	Vehicle to Office: also V2H – Home, V2S – Site.
VCA	Vehicle Certification Agency
VED	Vehicle Excise Duty – also called Vehicle Tax.
VRM	Vehicle Registration Mark (also VRN – Number)
WLC	Whole Life Cost
WLTP	Worldwide harmonised Light vehicle Test Procedure
WTT	Well to Tank – Scope 3 GHG Emissions
WTW	Well to Wheel – Combination of WTT and TTW – Scope 1, 2 & 3
ZEV	Zero Emission Vehicle
ZEZ	Zero Emission Zone (TfL and Mayor of London Guidance)

1. Executive summary

West Devon Borough Council (WDBC) declared a Climate Emergency in May 2019, and South Hams District Council (SHDC) declared a Climate Change and Biodiversity Emergency in July 2019.

With a joint goal of reducing organisational carbon emissions to zero by 2030, a strategic partnership was formed between the organisations which is referred to hereafter as 'SHWD'.

SHWD sought this report to help identify opportunities to decarbonise its fleet of 118[1] vehicles, and to assess the GHG emissions from its grey fleet, Section 4.2 refers. The analysis was undertaken by Energy Saving Trust and funded by the Department for Transport (DfT).

13	4	43	58
Refuse collection vehicles (RCV)	Cars	HCVs[2] and agricultural vehicles	LCVs (GVW up to 3.5t)

The report's key findings for the 12-month period (May 2021 to June 2022) are:

- The 118 vehicles travelled 1,106,602 miles and was responsible for 1,215 tonnes (t) of Scopes 1, 2 and 3 greenhouse gases (GHG) emissions, Section 4 refers
- The grey fleet travelled 103,368 miles and emitted 36t of GHG, Section 4.2 refers
- The majority of emissions (642t a year) were attributable to the 13 RCVs – Section 4
- There are BEV alternatives currently available for 73 of the 118 vehicles that SHWD operates.
- The availability of battery electric (BE) versions of vehicles with gross vehicle weight of over 3.5t (categorised as HCVs in this report) and agricultural vehicles, including mowers and tractors,) is currently poor but improving, Section 10 refers
- Replacing only those (73) vehicles for which we know there is currently a BEV alternative (cars, LCVs and RCVs), would reduce annual operating costs by £97,000 and GHG emissions by 740t, Section 2

If the entire fleet was converted to BE by 2030, annual energy costs (diesel) would reduce by £488,000 (Section 3). This recurring saving can contribute to funding the higher purchase

SHWD's vehicles

Drove 1,106,602 miles

Was responsible for 1,215 **tonnes** of GHG emissions

BEVs could reduce fleet WLC by **£97,000, and GHG emissions by 740t,** annually

[1] Excludes 33 'waste' vehicles operated under contract by FCC Environment (FCC) for WDBC. A lack of operational data meant that these were excluded from this report. FCC also operates 53 vehicles for SHDC. Later this year, SHDC will take over responsibility for these and they are included in the fleet total of 118 vehicles.

[2] For the purpose assessing the opportunity to transition into BEVs, in this report, we define heavy commercial vehicles (HCVs) as vehicles with a gross vehicle weight (GVW) greater than 3.5t., excluding RCVs.

costs of BEVs. Additional savings arise from the reduced cost of maintaining an electric vehicle drivetrain and chassis. Our whole life cost (WLC) analysis (Sections 7 and 10) discusses this approach in more detail.

If the entire fleet transitioned to BEVs, and all 118 vehicles are powered from the UK Grid in 2030, it will still be associated with 62 tonnes of annual GHG emissions[3], representing a 95% reduction form the current position. However, if powered from private wire renewable generation, fleet emissions would be net zero, with no requirement to fund off-sets of residual GHG emissions. In Section 12, we illustrate the increase in demand (kWh/hr) for each of the seven locations, but stress that this is an illustration only. To provide an accurate assessment would require detail of fuel use by vehicle.

Given the commitment of OEMs to introduce BEVs, we see no reason why SHWD will not be able to transition the entire fleet to BEVs by 2030, Section 11 and Appendix F provides further information[4].

A summary of the key findings and recommendations is provided in Section 2.

[3] Resulting from the continued decarbonisation of the UK electricity grid, Appendix B refers.

[4] This assumes that the demand for charging has been assessed and the appropriate charge points have been installed, as discussed in sections 10 and 12, and Appendix D

2. Summary of findings and recommendations

In Table 2-1, we have summarised key recommendations and the resulting impact of annual WLCs and GHG emissions savings if SHWD transitioned to BEVs. SHWD should check our findings, and ideally test BEVs to confirm suitability (e.g., carrying capacity and single charge range) before committing to a particular model or battery size. Most OEMs will provide demonstrator vehicles for this purpose.

Table 2-1: Summary of recommendations, associated costs and GHG emissions

Item	Recommendation	Notes (Including estimated WLC and GHG savings)	Section
1	As they become due for replacement, replace the 58 diesel LCVs with BE LCVs	There are BEV equivalents readily available. Moving to BEVs would reduce annual GHG emissions by 210t, while the annualised WLC would reduce by £25,130	7
2	As they become due for replacement, replace the 13 RCVs with eRCVs	eRCVs comfortably meet the average duty cycle that we have modelled for the 26t RCVs. Based on our findings, and assuming a similar cost/emissions profile for all RCVs, SHDC would reduce annual GHG emissions by 525t, whilst reducing annual fleet costs by £73,164	10
3	When due replacement, replace the two ICE cars with BEVs	There are BEV equivalents readily available. Moving to BEVs would reduce annual GHG emissions by 5t with an increase in operating costs of £980 each year	7
6	Transition HCVs (e.g., sweepers and tippers) to BE HCVs, as these become available.	Evaluate operational aspects of new BE HCVs, as they become available. Use WLC analysis to compare costs with current diesel models and to assess impact on budgets.	10
7	WDBC should explore the potential for transitioning the waste fleet to BEVs	Work with FCC to identify the operational performance of its waste fleet and use this to help identify the cost and environmental benefits of transitioning its fleet to BEVs.	10
8	Introduce a procurement policy that prioritises the purchase/lease of BEVs over ICE vehicles.	The assumption should be that all replacement vehicles will be BEVs, unless there is a business case that justifies the use of an ICE vehicle. For example, the lack of a suitable BEV alternative.	6
10	Record daily fuel use and mileage, particularly for the more energy demanding vehicles, such as RCVs	For many of the vehicles, SHWD could provide average annual mileage but lacked detail of fuel use. When fuel use is known it is possible to estimate the energy use of each BEV (kWh), and therefore the demand for overnight recharging.	10
	Total	The above actions will result in an annual reduction in GHG emissions of approximately 740t. The annual fleet WLC will reduce by £97,314.	

3. Meeting the net zero target by 2030

WDBC declared a Climate Emergency in May 2019, and SHDC declared a Climate Change and Biodiversity Emergency in July 2019. Both organisations have the objective of reducing vehicle fleet emissions to zero by 2030 and agreed a partnership approach to help achieve this.

Both organisations have contracted out their waste collection to FCC Environmental (FCC). However, SHDC is in the process of taking-back the management and operation of its 53 waste vehicles currently operated by FCC. SHDC was able to provide operating data for these, which we have included in this report.

WDBC was unable to provide operational data for the 33 vehicles that FCC operates on its behalf and following discussions with SHWD's Climate Change Specialist it was agreed to omit these from this report, rather than to risk making inaccurate assumptions that distort the findings, for the rest of the fleet. Therefore, this report is based on a fleet of 118 vehicles, including[5]:

- 53 vehicles operated by FCC, on behalf of SHDC (FCC SH)
- 54 vehicles operated directly by SHBC
- 11 vehicles operated by WD

From the fleet data supplied, there are (currently) BEVs that could replace 75[6] of SHWD's internal combustion engine (ICE) cars, LCVs and RCVs – Sections 7 and 10 refer. For the remaining 43 more niche diesel vehicles, including mowers, sweepers, pickups and tippers, we expect BE alternatives to be available over the next few years, Appendix F and Section 10 refer. This means it should be possible for the whole vehicle fleet to be battery electric by 2030, which is in line with the UK Government's updated Nationally Determined Contributions (NDC) made in compliance with the 2015 Paris Agreement (68% GHG reduction from 1990 levels by 2030) and with the legal commitment (Climate Change Act) to a 78% reduction in UK GHG emissions by 2035.

3.1 Cutting energy costs and GHG emissions

BEVs are significantly more energy-efficient than ICE vehicles and the energy use (MWh) of a BEV fleet will typically be 65% to 75% less than the equivalent ICE fleet. A BE fleet, charged from the UK Grid, and using 30% of the energy used by the ICE fleet, could reduce energy costs by up £488,000 every year[7]. However, the recent and anticipated changes in energy and fuel prices make both short and long-term energy cost predictions very difficult.

Table 3-1: 2030 GHG emissions, energy use and cost savings from an all-BEV fleet

Factor	ICE Current	BEV 2030	Change	Reduction
Energy Consumption (MWh)	4,130	1,240	-2,890	-70%
Annual Energy Cost	£774,000	£286,000	-£488,000	-63%
Annual GHG Emissions (t)	1,215	62	1,153	-95%

BEIS data (Appendix B) shows that between 2014 and 2021, the GHG intensity of the UK Grid has fallen by 57%. By 2030, it is predicted by BEIS and CCC to fall by a further 76% to about 50 gCO_2e per kWh.

Table 3-1 shows that in 2030, if powered from the UK Grid, the fleet of 118 vehicles will still be associated with 62 tonnes of GHG emissions, albeit a reduction from current GHG emissions of 95%. Over the next eight years, SHWD should consider implementing its own private wire renewable generation. If the electricity used to power the fleet is 100% renewable, the fleet will be "net zero".

[5] 103,368 miles of grey fleet mileage is assessed separately in Section 4.2

[6] Includes two electric Nissan Leafs that SHWD has already procured

[7] For illustration we have included the cost of diesel at £1.60 a litre and a commercial cost of electricity at £0.23 a kWh. No allowance has been made for inflation.

4. Benchmark emissions 2021

4.1 Fleet greenhouse gases[8]

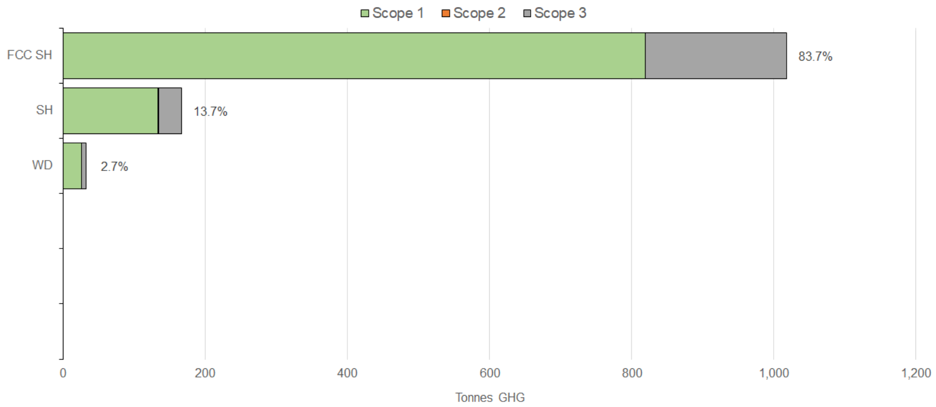
The carbon dioxide (CO_2e) footprint (often shortened to carbon footprint) details the tonnage of carbon dioxide that the 118 vehicles emitted May 2021 to June 2022, the year the data related to. The 'e' in CO_2e stands for 'equivalent' and indicates that the estimate includes the other reportable GHG emitted by the fleet (nitrous oxide and methane) expressed in terms of their carbon dioxide equivalence over 100 years. For example, nitrous oxide (N_2O) has a global warming potential (GWP) 265 times that of carbon dioxide and one tonne of N_2O is therefore equivalent to 265 tonnes of CO_2 (GHG Protocol, GWP Values, AR5). The GWP of methane (CH_4) is 28. In the UK, GHG emissions are usually reported under Scopes 1 - 3 (Figure 4-1).

Figure 4-1: Summary of GHG reporting - Scopes relevant to road transport emissions

Scope 1	Scope 2	Scope 3
		
The Fleet You Directly Operate Owned, Leased, Hired	Electric Vehicle Electricity Generation	Transmission, Distribution, Extraction, Refining. Grey Fleet - Staff Travel
Tank to Wheel (TTW) Direct Emissions Operational Emissions	Well to Tank (WTT) Indirect Emissions Upstream Emissions	
← Well to Wheel (WTW) →		

Summary of GHG emissions (excluding grey fleet)

Figure 4-2: Greenhouse gas emissions (tonnes) by Scope



[8] Following discussions with SHWD, we have separated the assessment of grey fleet GHG emissions, and these are discussed in Section 4-2

Table 4-1: WTW GHG reporting: Scopes, fleet size, mileage, GHG emissions and energy consumption

Organisation	Fleet size	Annual mileage	WTW GHG (tonnes)	Energy (MWh)
FCC SH	53	578,000	1,016	3,446
SH	54	417,775	166	565
WD	11	110,827	32	110
Total	**118**	**1,106,602**	**1,215**	**4,121**

The most accurate method of assessing GHG emissions is to base the calculation on the volume of fuel used, which we understand is the approach used by SHWD. For example, burning one litre of diesel produces approximately 2.5kg of Scope 1 GHG emissions (TTW). These emissions remain constant, irrespective of the type of vehicle burning the fuel - it is simply that some vehicles burn more fuel per mile than others, resulting in greater emissions.

We were provided with a monthly summary of fuel use for SHWD (prior year 2020/2021), plus average fuel use for RCVs (Section 10 refers) and an audit trail of fuel dispensed from Totnes depot. We couldn't attribute fuel use to specific vehicles, and so it was agreed that we would base our WTW GHG calculation (Figure 4-1 and Table 4-1) on the mileage travelled and the manufactures official emission figures for each vehicle. To this, we applied an age-related uplift to reflect emissions from 'real-world' driving. We have calculated this footprint using the year-appropriate GHG Conversion Factors published by BEIS. The methodology used complies with international GHG reporting standards (WRI GHG Protocol) and with UK's SECR Reporting Guidelines which apply to UK public bodies[9]. Not included are the lifecycle GHG emissions associated with the manufacture and disposal of the vehicles, which are out of scope. In Table 4-2, we split the WTW emissions by the different scopes.

Table 4-2: GHG Reporting by Scopes – Scope 1 and Scope 2 are mandatory, Scope 3 is discretionary

Organisation	Scope 1 GHG Fossil Fuel Burnt (tonnes)	Scope 2 GHG Electricity Consumed (tonnes)	Scope 3 GHG Extraction/Distribution (tonnes)	Out of Scope CO_2 emissions (tonnes)
FCC SH	818	0.0	198	49
SH	133	0.8	33	8
WD	26	0.1	6	2
Total	**977**	**1**	**237***	**59**
* In Section 4.2, grey fleet (Scope 3) emissions are detailed. These increase the total Scope 3 emissions to 273t				

Table 4-2 provides a breakdown of the WTW GHG emissions by reporting Scope. Scope 1 is the most important because it is the fossil-fuel GHG emissions for which each organisation is directly responsible. This is because the vehicles burning the fuel are fully controlled and operated by that organisation and all aspects of their use from specification, driving standard and monitoring, are the organisation's direct responsibility. No other organisation can reduce these emissions. The figures for 'out of scope' emissions relate to the burning of the biofuel element of diesel fuel.

Table 4-3 identifies the emissions by fleet category, and demonstrates the significance that RCVs have on emissions, as discussed in Section 10.

[9] This is the second most accurate method for calculating GHG emissions. It enabled us to assess the GHG emissions, and energy use, for each vehicle, whilst including the FCC waste vehicles. Due to this, our GHG emissions findings are unlikely to reconcile with SHWD's reporting.

Table 4-3, summarised emissions by fleet category

Category	Fleet Category	Total Annual Mileage	Scope 1 GHG Fossil Fuel Burnt (tonnes)	Scope 2 GHG Electricity Consumed (tonnes)	Scope 3 GHG Extraction/ Distribution (tonnes)	Out of Scope CO_2 emissions (tonnes)
RCV	13	158,000	518	0	125	31
Small van	39	389,175	110	0	27	7
HCV	33	333,209	267	0	65	16
Large Van	17	168,986	67	0	16	4
Car	4	30,892	4	1	1	1
Medium Van	2	11,972	5	0	1	0
Pickup	3	14,367	6	0	1	0
Agricultural*	7	0	0	0	0	0
Total	**118**	**1,106,602**	**977**	**1**	**237**	**59**

*Category includes items such as mowers and tractors, for which there was insufficient data to calculate emissions

Table 4-4: energy use (MWh) by fleet type

Category	Fleet Category	Total Annual Mileage	Total Energy MWh
RCV	13	158,000	2,177
Small van	39	389,175	463
HCV	33	333,209	1,129
Large Van	17	168,986	284
Car	4	30,892	21
Medium Van	2	11,972	21
Pickup	3	14,367	25
Agricultural*	7	n/a	0
Total	**118**	**1,106,602**	**4,121**

*Category includes items such as mowers and tractors, for which there was insufficient data to calculate emissions

Electric vehicle (EV) emissions (Scope 2 and Scope 3 GHG Reporting)

BEVs have no Scope 1 GHG tailpipe emissions from directly burning fuel. They do, however, have GHG emissions associated with the generation of electricity (Scope 2 GHG emissions), with its transmission and distribution (Scope 3 GHG emissions) and with the operation of the plant as well as the extraction and transport of fuels (Scope 3 GHG emissions).

Plug-in hybrid and range-extended electric vehicles (PHEVs and REEVs) have a mix of fossil fuel emissions (Scope 1 and 3) and generation, transmission and distribution emissions (Scope 2 and 3). Where data on the actual kWh used to charge the vehicles is not available, we use the vehicle's annual mileage and the BEIS GHG emissions per km factors.

4.2 Grey fleet greenhouse gases

SHWD requested that we include emissions from grey fleet miles[10], so that it could assess their impact on Scope 3 emissions.

To ensure compliance with the General Data Protection Regulation (GDPR), SHWD provided a summary of grey fleet mileage that excluded all staff and vehicle details. Therefore, our calculation uses BEIS quoted average UK car emissions and the distance travelled to determine GHG emissions.

Table 4-5: Well to wheel emissions from grey fleet mileage, measured in tonnes

Organisation	Grey Fleet Miles	Scope 3 GHG(t) TTW
SHDC	68,516	23.9
WDBC	34,852	12.1
Total	**103,368**	**36**

We understand that consideration is being given to the use of a car club to encourage grey fleet drivers to use BEVs for business travel, rather than their own vehicles. A key element of the proposition is allowing staff to access the cars during working hours, and then make them available to the public to hire through the car club outside of working hours. The aim is to fund these BE cars through the reduction in grey fleet reimbursement costs. Whilst we can't comment on the commercial viability of such a scheme, it would certainly help to reduce the 36t of GHG.

4.3 Air quality: Substances of concern

Every litre of fuel burnt, or mile driven by an ICE vehicle, is associated with emissions of many substances of concern (SOC), which have an adverse impact on human health. The emissions reported on include hydrocarbons (HC), non-methane hydrocarbons (NMHC), carbon monoxide (CO), nitrogen oxides (NO_X – nitrogen monoxide NO and nitrogen dioxide NO_2) and particulate matter (PM). NO_X from vehicle emissions is measured because NO in the presence of sunlight and ozone (O_3) forms NO_2, a regulated pollutant.

Emissions of these SOCs are much harder to estimate than CO_2 emissions. This is because they depend on mileage, how the vehicle is driven, speed, load, usage cycle, the standard of maintenance, fuel type, Euro emission category, engine technology and the effectiveness of the exhaust clean-up system.

We have determined the data in Table 4-4 using the average emissions of a 2018 UK car, LCV, or HCV adjusted for the area of operation as published by the National Atmospheric Emissions Inventory. This analysis is based on vehicle mileage and cannot be determined from fuel data alone, so where mileage driven is missing, emissions cannot be calculated.

Table 4-4: Estimated annual emissions of nitrogen oxides (NO_X) and particulate matter (PM_{10} and $PM_{2.5}$)

Fleet Category	NO_X (kg)	PM (kg)
RCV	254	4.1
Small van	637	6.9
HCV	505	7.3
Large Van	277	3.0
Car	15	0.2
Medium Van	20	0.2
Pickup	24	0.3
Agricultural*	0	0.0
Total	**1,731**	**22**
*Category items such as mowers and tractors, for which there was insufficient data to calculate emissions		

[10] Grey fleet refers to vehicles, privately owned by staff, and used for business travel

A more accurate assessment of the air quality impact would require the use of the COPERT V5 model and much more detailed usage data about each vehicle. Some fleets may have much higher emissions due to slow operating speeds, low engine temperatures, and stop/start operation which results in the Euro VI exhaust clean up technology being switched off by the engine management system to avoid emissions of ammonia and other noxious substances; this is not reflected in the above figures.

Each year in the UK, between 28,000 and 36,000 deaths can be attributed to a combination of $PM_{2.5}$ exposure, and NO_2 exposure (Public Health England, March 2019). In England alone, the cost burden to society of these two pollutants over a ten year period (to 2025) is estimated as being in the range £5 billion to £20 billion, depending on how many diseases with links to poor air quality are included in the estimate (Public Health England, May 2018).

NO_2 is strongly linked to childhood asthma and less strongly associated with adult asthma, diabetes, lung cancer, low birth weight, and dementia. Particulates are strongly associated with coronary heart disease, childhood asthma, stroke and lung cancer. There is less strong evidence of an association between particulates and chronic obstructive pulmonary disease, diabetes, and low birth weight. Recent research in London has further linked both $PM_{2.5}$ and NO_2 to increased mental health service use among people recently diagnosed with psychotic and mood disorders.

Research has also linked particulates with dementia and the World Health Organisation (WHO) fact sheet on air pollution states that there is no known safe level of particulate pollution: *"Small particulate pollution has health impacts even at very low concentrations – indeed no threshold has been identified below which no damage to health is observed."*

The WHO Guidelines were recently revised. The WHO has encouraged all countries to work towards the new recommended levels and for decision-makers to use the Guidelines *"as a tool to steer their legislation and policies"* (September 2021).

The previous (2005) WHO Guidelines were already much stricter for fine particulate matter ($PM_{2.5}$) than the UK legal limits for this type of pollution (10µg/m^3 compared to 25µg/m^3), and the new WHO Guidelines are even tighter, at 5µg/m^3 as an annual mean limit. The new WHO Guidelines also include a huge reduction in annual mean NO_2 compared to the UK legal limit; 10µg/m^3 compared to 40µg/m^3 permitted by current UK legislation. The WHO estimates that 80% of global deaths relating to $PM_{2.5}$ could be avoided if current air pollution levels were reduced to the new WHO 2021 Guideline level.

Moving to BEVs will eliminate tailpipe emissions of NO_X and PM but will still leave particulate "emissions" associated with the brakes, tyres and recirculation. If driven well, BEVs can make extensive use of regenerative braking, so particulates from this source should be reduced. However, there is a concern that this may be offset by increased emissions from tyre wear, as BEVs are heavier than equivalent ICE vehicles.

The make of the tyre itself is a critical factor and tyres that meet the EU AA standard for energy efficiency and wet grip, as well as being quiet in use, can have very different wear rates (mg/km). Unfortunately, there is no UK or European tyre-label guidance regarding wear rate to help purchasers select tyres that are energy-efficient, give good grip in the wet, are quiet, and also minimise particulate emissions.

Recent research on car tyre emissions by Emission Analytics has suggested the average wear rate across a range of brands was 64 mg/km but this varied between brands from less than 40 mg/km to nearly 90 mg/km.

5. Fleet data quality and data management

Central to any well-managed and energy-efficient fleet is good data management. Transport and operational managers should have up-to-date, comprehensive, accurate and accessible data about the vehicles in use, their energy consumption (litres or kWh) and the distance driven, or hours worked. This applies regardless of the ownership of the vehicles (purchased, leased, hired, or third-party contractors delivering statutory services). In addition, fleet operators should hold robust information regarding their drivers, and be able to link this to the data about the vehicles they have driven.

Where commercial vehicles and passenger services are involved, it is also important to record information about the work done; for example, the load carried (tonnes or cubic metres), bins emptied, households serviced, repairs or job-sheets completed, passengers transported. With all this data available the performance of an operation can then be linked back to the service it delivered and form part of a suite of Driver, Vehicle and Fleet Performance Indicators.

Systems have been widely available for some time to accurately monitor bulk fuel tank drawings recording both litres and mileage, record off-site fuel purchases using fuel cards, manage fleet workshops, manage the fleet itself, track all vehicle movements and link to the vehicle's internal information network known as the CAN bus.

The quality of these commercial systems is variable. Some have not kept pace with developments in technology, and there is often a failure, or inability, to fully integrate the data from all the different sources. For example, combining accurate mileage from CAN bus-linked tracking data with actual fuel dispensed from bulk tanks to give accurate energy efficiency (mpg, miles/kWh, Wh/km).

To improve the quality of reporting, assess energy use, and measure efficiency, we recommend that SHWD records mileage travelled, and fuel used, as discussed below and in Section 3. We also recommend that WDBC has access to operational fleet data relating to the waste vehicles that FCC manages, so that it can assess energy use and efficiency, particularly for the RCVs, as discussed Section 10.

5.1 Fleet data management

It is important that the departments operating fleet vehicles understand the respective councils' pathway to net zero and how fleet vehicles is an important element of this.. Departmental GHG targets should be established and monitored. It should therefore be a requirement that the fleet systems should provide regular (monthly or weekly) and accurate, energy efficiency, GHG emission and cost data to service managers and their drivers, as well as the fleet team and climate change or sustainability officers.

The best way to achieve this is to fully integrate the data from all possible sources, where possible – fleet management, service records, fuel drawings, and telemetry – and to make every effort to ensure that accurate data is captured whenever fuel is drawn.

Organisations that have addressed this issue directly have, after a period of adaptation, achieved a very high level of compliance. The capture of mileage data can be further enhanced by using multiple sources, including the vehicle's telemetry, workshop service records, and odometer data capture built-in to the recording of the daily walk-around vehicle check - some systems now allow this to be carried out using a smartphone App.

5.2 Using the data to improve ICE fleet energy efficiency

While the main reason to improve the energy efficiency data is to inform the move to zero emission vehicles, organisations that introduce tight monitoring of fuel use and a focus on fuel efficiency (mpg) have achieved reductions of 5% to 15% in fossil fuel use, the range depending on how weak fuel management has been in the past.

With accurate energy efficiency monitoring in place and targets established, driver training that focuses on efficiency can be an effective and immediate way to save money by reducing fuel consumption and GHG emissions. (As an illustration, a 5% reduction in diesel fuel use across all 118 vehicles would result in an annual cost saving of approximately £31,000 and a reduction in WTW GHG emissions of 61 tonnes). As electric vehicles are introduced, driver training can also be used to ensure drivers make full use of the energy recovery capabilities of electric vehicles and that drivers are familiar with the procedures around recharging the vehicles.

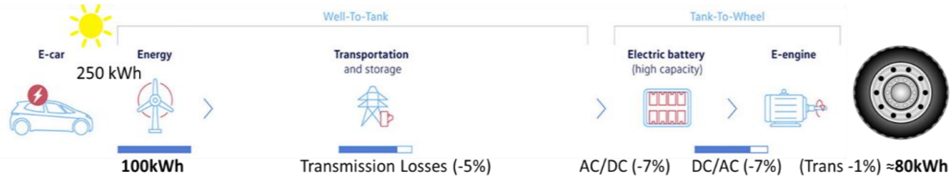
5.3 The importance of accurate fuel and mileage data

As previously discussed, accurate energy usage and energy efficiency is critical when trying to determine the future energy requirements of a zero-emission battery electric fleet.

Figure 5-1: Energy efficiency of an internal combustion engine vehicle

Many ICE vehicles are only 25% to 30% efficient (Figure 5-1) with the losses – mostly heat and friction – occurring in the engine and the transmission. Smaller ICE vehicles like cars and car-derived vans should achieve a higher level of efficiency (up to 30%) especially if they are not used in a start-stop environment. ICE hybrids can achieve efficiencies in the order of 30% to 35% because they make use of energy recovery when braking and energy assist when accelerating to reduce the load on the ICE. Most diesel engine vehicles are at their most efficient when cruising at 50-60 mph.

Figure 5-2: Energy efficiency of a battery electric vehicle



Business vectors created by macrovector - www.freepik.com
Other Images VW: Battery or fuel cell? That is the question

Electric vehicles and the electricity supply network are about 80% efficient at converting electricity supplied to the grid into useful kinetic energy driving the wheels (Figure 5-2). Most of the losses occur in the conversion of AC to DC from the grid to the battery and then back from DC to AC for the electric motor. As a result, BEVs will typically use between one quarter and one third of the ICE vehicle's energy, which gives us an indication of the battery size needed for a replacement BEV and, therefore, whether a suitable vehicle is available.

The tracking data of the ICE vehicle, if combined with accurate energy consumption[11], allows daily variations in energy use (kWh per day) to be determined and when aggregated across the fleet, this can be modelled to provide an indication of the peak overnight charging demand (kWh) and the site maximum import capacity (kVA) required at the offices and depots where those vehicles are based.

With only fuel data, only mileage data or inaccurate data, only part of the picture is available, and the analysis has to be based on "average" daily performance of similar vehicles, which may not reflect the daily operating environment, particularly if there are local challenges such as particularly hilly refuse collection rounds.

5.4 Implementing future-proof BEV compatible telemetry

Any telemetry system used on fleet vehicles should be able to accommodate both legacy ICE vehicles, as well as new and future BEVs. In particular, it is important that the system can report on the electric vehicles' consumption of electricity, the state of charge (SoC) of the battery, the number of times it has been charged, the type of charge point used and the vehicle's energy efficiency in terms of miles/kWh or Wh/km. All this information should be accessible from the CAN bus.

[11] Each litre of diesel provides 10.6 kWh of energy, the full set of government conversion factors refers

Ideally, the system should also have an Application Programming Interface (API) to allow smart charging systems to access this data set to optimise charging and minimise the site's grid connection. This is not yet commercially available, but several suppliers are working to deliver this integration in the near future.

SHWD must be able to determine the key operating parameters, so that a future electric vehicle fleet can be managed, its energy consumption monitored, and its status reported to the charging system, which will allow the optimum charging strategy to be determined.

5.5 Future proofing data management – recommendations

As part of the move to a zero-emission fleet, we would recommend that SHWD carries out a review of any IT systems linked to fuel use, tracking data and charging infrastructure, as well as driver and fleet management, to ensure that all these data sets can be integrated into a single system for the fleet management, energy management, operating departments and the drivers to use.

Real-time energy and battery state of charge (SoC) data linked to smart charging systems will be essential if both organisations are to achieve efficient, low cost, low emission operation of an all-electric fleet, fully integrated with the site energy management systems and the local electricity grid.

6. Achieving a zero-emission fleet 2022-2030

6.1 Establish a transition team

Based on our work with other organisations that are transitioning from an ICE fleet to a zero-emission fleet, SHWD should consider the development of a small team encompassing fleet management; the main vehicle operating departments, estates/facilities, energy management, human resources (for any grey fleet), procurement and finance. The team will need to consider:

- Appraisal of the need and utilisation for each new vehicle
- Changing vehicle procurement to a model based on whole life cost
- Optimum methods of funding the new fleet
- Installing the charging infrastructure to support new BEVs and addressing issues like home-based charging
- A governance and reporting structure with full senior management team engagement

The move to BEVs is a once in a generation transformation and is not just a project for the fleet team. The decarbonisation of the fleet should be occurring in parallel with a move away from the use of fossil fuels such as natural gas or oil for heating buildings, and this will usually involve a move to electric heat pumps. The two projects need to be integrated, and not considered in silos, as site supplies and infrastructure will need to cope with the demands of heat pumps, PV generation (and possibly export), battery storage and vehicle charging. There is also the possibility that the battery capacity in the BEVs could provide site or grid services during peak periods.

6.2 Review vehicle utilisation

It is important to identify and review the requirement for vehicles with a low level of use, for example, under 6,000 miles a year (average 25 miles a day, 240 working days). There may be a good reason for low utilisation, or it may be a consequence of inefficient sharing or allocation of vehicles, resulting in some vehicles spending too much time parked.

Low mileage has an adverse impact on the WLC of BEVs, when compared to ICE vehicles, because the low mileage results in much lower cost savings. Also, most leasing companies do not provide lease rates for vehicles travelling less than 6,000 mpa, therefore the low mileage may not be reflected in reduced lease costs. Even if purchased and retained for the full battery warranty period (typically eight to ten years), energy cost savings may not fully compensate for the higher capital cost of BEVs, which is why we recommend a WLC approach to vehicle selection.

6.3 Identify suitable BEV options

The factors to consider when selecting a suitable BEV include:

- Typical daily journey length and load
- Longest daily trip, maximum load
- Single-charge range – avoiding charging during the working day, if possible, as lower costs overnight
- Opportunities to charge during the day – useful for site-to-site services
- Carrying capacity – seats in cars, MPVs and minibuses; weight and volume in LCVs and HCVs
- Towing capacity – with BEVs under 3.5 tonnes, this is currently limited to one tonne
- Whole life cost (WLC) – cost over the operational lifetime
- Grant funding available – any funding to cover whole life cost difference

Based on our analysis of SHDC's mileage profile (Table 6-1), where BE alternatives are available these will be able to meet the average annual mileages, without the need for top-up charging during the daily duty cycle.

Table 6-1: Average annual and daily mileage vehicles in each fleet category

Fleet Category	Fleet size	Average Annual Mileage/Vehicle	Average Daily Mileage (240 Working Days)
RCV	13	12,154	51
Small van	39	9,979	42
HCV	33	10,370	43
Large Van	17	9,940	41
Car	4	7,723	32
Medium Van	2	5,986	25
Pickup	3	4,789	20
Agricultural	**7**	**n/a**	**n/a**

6.4 Downsize the LCV fleet wherever possible

Downsizing a BE LCV fleet will reduce the capital cost and the GHG emissions, as smaller BEVs are more energy efficient (miles/kWh). Downsizing an ICE fleet has similar benefits, in terms of reducing the capital cost and improving fuel efficiency.

Table 6-2: Impact of downsizing on capital costs of a battery electric LCV fleet

Battery electric model	Size Class	GVW/MAM (kg)	Battery	BEV OTR List*	ICE Equivalent
Renault Zoe CDV	CDV	Up to 2,000	50 kWh	£33,300	£18,800
Vauxhall Combo-e Cargo L2	Small LCV	2,001-2,600	50 kWh	£36,600	£24,850
Vauxhall Vivaro-e L1 H1	Medium LCV	2,601-3,100	50 kWh	£44,000	£32,450
Vauxhall Vivaro-e L2 H1	Medium LCV	2,601-3,100	75 kWh	£50,800	£34,250
Fiat e-Ducato L2 H1	Large LCV	3,101-4,250	47 kWh	£69,250	£34,980
Vauxhall Movano-e L3 H2	Large LCV	3,101-4,250	70 kWh	£74,000	£41,300

**The on the road (OTR) price is usually subject to manufacturer discounts.*

Table 6-2 illustrates the increase in the 'on the road' (OTR) cost currently associated with the sample of LCVs. Depending on the fuel efficiency of the ICE vehicle (mpg) being replaced, the recovery of the additional BEV capital cost, from the lower energy (fuel) saving, may require a large BE LCV to travel significant mileages. Even with purchasing framework discounts applied, the cost recovery mileage does not fall significantly because of the higher percentage discounts available from the OEMs for ICE vehicles.

Research carried out by the engineering consultancy Ricardo for DfT showed that the impact on energy efficiency of a fully loaded LCV is a 9% to 10% increase in energy consumption; therefore, it is much more cost effective to have a fully loaded small LCV than a half-empty large one. This means there is an operating cost and capital cost saving from using smaller LCVs wherever possible and avoiding the one-size-fits-all procurement model.

When vehicles are due for replacement, it is important to carry out a robust independent review of current usage and challenge the need for large LCVs – especially if the objective is to replace the ICE vehicle with an BE model. A two tonne BE LCV will have a lower WLC than a three tonne BE LCV which may have a much lower WLC than a 3.5 tonne ICE LCV. Factors to consider include:

- Meeting the occasional need for a large or long-range LCV with a pool or rental vehicle
- Holding rarely used specialist equipment in a central store or depot, not in the back of an LCV
- Using a bespoke fit-out in smaller vehicles to increase carrying or seating capacity
- Closely tailoring the vehicle and the equipment carried to the service level being delivered

Downsizing the 3.5t GVW, and over, vehicles may not be such a viable option because the vehicles should have been carefully selected for their functionality, including load carrying capability. Downsizing these will reduce energy use but will also significantly reduce the maximum load. This can increase the GHG emissions per tonne or per cubic metre transported.

6.5 Adapt the fleet replacement cycles to BEVs

With a diesel ICE fleet, it is important to establish and maintain a rolling fleet renewal programme. Ongoing improvements in emission technology and standards mean that today's Euro 6/VI(d) fossil fuel ICE vehicles will be superseded by cleaner ICE models with Euro 7/VII now under consideration for introduction in 2025/26 or later.

Electric vehicles have no tailpipe emissions, so they cannot be superseded by lower emission models. There are emissions associated with the generation of the electricity used to recharge BEVs and, like all vehicles, BEVs do produce particulates from their brakes and tyres as well as recirculating particulates drawn up from the road surface. Brake dust can be mitigated by training the driver to make full use of regenerative braking, but tyre wear is more difficult to mitigate because the EU Rating Scheme for tyres relates only to the rolling resistance (energy efficiency), wet grip and noise. At present no information is available to the purchaser about the wear rate of a tyre (mg/km), which is the process that generates particulates. However, a range of suppliers are now manufacturing EV specific tyres with compounds tailored to ensure high operational performance and low wear rates for the greater vehicle mass associated with EVs.

Unlike diesel vehicles, keeping BEVs for longer does not have a negative impact on GHG emissions due to deterioration in engine performance. Indeed, as the UK grid decarbonises, BEV GHG emissions will fall year on year. This means the higher procurement cost of a BEV can be written-off over a longer period of ownership, without adverse environmental impact and it also makes best use of the energy and resources used to make the battery. This approach is further supported by the long operational life and simplicity of electric drive train components which have been used across a wide range of transport modes, for example trains and trams, for over 100 years. With the right training, batteries can be serviced, and any faulty cells replaced, to extend their operational life at full capacity.

With electric HCVs, it may be necessary to take a very different approach to the replacement cycle with the chassis, drive train, battery and rig all being treated as separate and independently replaceable components. This approach will be discussed further in the section on HCVs.

To maximise the return on the investment in BEVs, and any conversion costs, we recommend aligning replacement cycles with the vehicle's battery warranty. This might mean planned replacement cycles of eight or, in some cases, ten years where mileage is low. The longer replacement cycle may also require a change in the method of financing the vehicles. For example, many leasing companies that offer contract hire (operating lease) will limit the length of leasing contracts to a maximum of four or five years. In such cases, purchasing, or a fully amortised finance lease may be preferable.

6.6 Introduce a BEV procurement policy

Ideally, the assumption should be that from now on, all ICE vehicles will be replaced with zero emission models as part of the standard fleet replacement programme, and wherever possible BEV should be the preferred zero emission technology.

It is occasionally appropriate to use a plug-in hybrid electric vehicle (PHEV) or an ICE range-extended electric vehicle (REEV) where a BEV is not practical, and the PHEV or REEV offers real GHG reductions because there is a significant opportunity to use it in electric-only mode. However, experience suggests that PHEVs can offer the worst of both worlds, limiting the range of the BE zero-emission mode, due to additional weight of the petrol engine, and increasing the fuel consumption of the petrol engine, due to the additional weight of the batteries and electric motor.

Other technologies like hydrogen fuel cell (H2FC), hydrogen ice (H2ICE), hydrogen-diesel dual-fuel, biomethane (BIOCNG/LNG) and HVO (bio diesel) should only be considered where there is no suitable BEV technology available, or expected to be available, by 2030. See Appendix A and Section 9 for a full discussion of these alternative zero (or low) emission technologies.

It is recommended that procurement follows the process in Table 6-3 which starts with a review of the need for a vehicle and a check to see if it can be downsized.

Table 6-3: BEV procurement process

Step	Question	A	Actions
1	Vehicle under 6,000 miles per annum? Has a business need review been completed?	No	Carry out full business need review. Would hire vehicles be lower cost? Could a shared vehicle fulfil the role?
2	Has a smaller vehicle been considered?	No	Investigate the efficient use of the current vehicle. Has racking been installed? Is the requirement for a big vehicle infrequent? Downsize if possible.
3	Does a suitable BEV with WLC similar to ICE exist? Include grants in cost model.	Yes	Procure BEV
4	Would extending the operation life of the BEV make it affordable?	Yes	Procure BEV
5	Could the life of the ICE be extended until a suitable BEV is available?	Yes	Defer procurement
6	Consider procuring a reconditioned second-hand ICE vehicle or a new vehicle on short term hire linked to anticipated availability of a suitable BEV.		

As discussed previously, if current vehicles are travelling less than 6,000 mpa, the need for replacements should be challenged, particularly because of the high capital cost of BEVs. A well utilized, right-sized BEV can save money. An underutilized, BEV, with unused carrying capacity, costs money.

It is hard to predict when new zero-emission vehicles with longer range or greater carrying capacity will be available, as the market is very dynamic. While a particular type of vehicle may be available, obtaining one with the required load and towing capability may still be a year or two away. In Appendix F we have provided an overview of when different categories are expected to be available from the OEMs based on recent announcements. As might be expected, there is a progression over time from limited availability with limited capability, to full availability and ICE-equivalent capability. We discuss this further in Section 10.

6.7 Use a Whole Life Cost (WLC) selection model

A WLC model calculates all of the predicted costs of owning and operating a vehicle over its operational life, including the funding method (outright purchase or lease), servicing (often included in a lease), vehicle excise duty (also usually included in a lease), National Insurance Contributions (company cars and salary sacrifice schemes) and the fuel or energy cost. Fixed costs such as fleet management overheads, telemetry and fleet insurance may be included, although they do not vary by vehicle type and so don't influence choice. Appendix C discusses the WLC methodology in more detail, including some of the key assumptions made in our modelling.

Why use WLC for vehicle procurement?

For many years, the choice of vehicle power has been limited to petrol or diesel engines, and in the commercial sector the most viable option has been diesel. As a result, many fleet managers and procurement teams focus on comparing the vehicle's purchase price or the lease cost. Servicing costs might be considered during procurement, but the analysis would rarely include fuel costs as, for similar diesel vehicles, they are not expected to be significantly different. Instead, they were regarded as a necessary and unavoidable overhead.

Over a BEV's operational life, the large reduction in energy cost, when compared to an ICE vehicle, may completely offset the higher purchase (or lease) cost resulting in an overall cost saving. The current disruption in the energy markets caused by high gas and oil prices means it is however difficult to predict the long-term prices of electricity, gas, petrol and diesel to 2030.

BEVs are mechanically simpler than ICE vehicles, with significantly fewer components in the drive train and without a complex transmission and exhaust system. As a result, maintenance costs are much lower - up to 40% less. Over an extended operational life of eight to ten years, the saving may be even greater, as ICE vehicles can incur significant costs in later years. The failure of one ICE vehicle component can be very expensive - for example, replacing a gearbox or an exhaust catalyst system. The saving from reduced maintenance costs can further help to offset the higher purchase cost or add to overall cost savings. It also supports the justification of a longer BEV fleet replacement cycle.

Modelling SHWD's WLC

In Sections 7 and 10, we have modelled the WLC of purchasing an illustrative range of vehicles to help identify potential BEV alternatives. Where possible, we have compared WLCs using SHDC's annual average mileage. When summarising the results of our modelling, we have assumed that the SHDC vehicles managed by FCC are all part of SHDC's fleet, so that we can show the total impact on both cost and emissions.

A detailed explanation of how to use and calculate WLCs is available in Appendix C. Some leasing companies and the Crown Commercial Service Fleet Portal also provide an estimate of WLC.

6.8 Putting a cost on GHG emissions – carbon accounting

Implementing GHG emission reductions may have associated costs and deciding what costs are acceptable and where to invest, to optimise GHG reduction, can be achieved by assigning a price, or value, to every tonne of GHG (tCO_2e) emitted or saved. This is referred to as Shadow Carbon Pricing and is a method of investment analysis that adds a hypothetical cost to the cost of projects to 'price in' externalities associated to the carbon emissions generated by the project. This makes it easier identify the financial value of GHG reduction initiatives and helps identify those initiatives that produce the highest return on investment.

Many companies use a notional carbon price (shadow price) for project appraisal, including ASDA, Novartis, BP, and Shell. Some also use an "Internal Price" or "Carbon Fee" which is a charge that is made to departments based on their GHG emissions. The funds raised are then invested to reduce GHG emissions, either by funding GHG reduction schemes within the same company, or by the purchase of independently accredited carbon offsets. Companies in this group include Microsoft, Apple, Disney, and Ben & Jerrys.

A shadow price for carbon can reflect the societal cost of GHG emissions (externalities) or it can assess the mitigation cost linked to specific targets. A review published by BEIS: "Carbon values literature review (2021)" concluded that, for the UK, the use of a "target consistent price path" was most appropriate because the country has stringent GHG reduction targets and there are significant uncertainties over the use of a price linked to societal cost.

Following the announcement by the UK Government of new, more ambitious, Nationally Determined Commitments (NDCs), a review of the target consistent UK shadow carbon price was carried out by BEIS and HM Treasury (October 2021). That review resulted in a significant increase in the UK shadow carbon price from £72/tonne to £248/tonne in 2022, and from £81/tonne to £280/tonne in 2030 (see Appendix B, Table B-1: Central Carbon Value (BEIS 2021)). The increase between 2022 and 2030 reflects the greater impact of emitting a tonne of GHG in 2030 on the UK's ability to reach its new NDCs.

7. Moving to a zero-emission car and LCV fleet

7.1 Electrification of the two ICE cars

There are four cars, which includes two Nissan Leaf BEVs, on the SHWD fleet at present. With the end of sale of ICE cars by 2030 (2035 including PHEVs) OEMs offer a comprehensive range of battery electric cars, including hatchbacks, saloons, estate cars, and SUVs. Many models now support roof rails and towing. Over recent years, battery size and single-charge range has increased, while costs have fallen, and it is not uncommon for a BE car to have a range of 200 - 300 miles. A useful source of information is the Electric Vehicle Database.

Table 7-1: Safety, battery capacity, range, and charge time of a sample of the electric cars now available

Make	Model	NCAP*	Battery kWh	RW Range**	7.4 kW AC	DC
Peugeot	e208 (Hatch)	4 Star	45	145-200	7.25 hrs	27 min 100kW
Vauxhall	Corsa-e (Hatch)	4 Star	45	145-200	7.25 hrs	27 min 100kW
Renault	Zoe 50ZE R110 (Hatch)	0 Star	55	165-225	8.5 hrs	56 min 46kW
Fiat	500e	4 Star	42	120-170	6 hours	25 min 85kW
Nissan	Leaf (Hatch)	5 Star	62	170-230	7.25 hrs	35 min 100kW
VW	ID.3 Pro (Hatch)	5 Star	62	180-250	9.25 hrs	33 min 100kW
MG	5EV (Estate)	Not tested	53 or 61	175-270	8.75 hrs	36 min 80kW
Kia	e-Niro (SUV)	5 Star	39 or 64	145-230	10.5 hrs	44 min 77kW
Hyundai	Kona (SUV)	5 Star	64	205-285	10.25 hrs	44 min 77kW
Skoda	Enyaq iV 80X (SUV)	5 Star	82	205-270	12.25 hrs	36 min 125kW
VW	ID.4 (SUV)	5 Star	77	215-290	12.25 hrs	34 min 126kW
Kia	EV6 (2WD)	Not tested	82	260-328	12.5 hrs	17 min 233kW

**NCAP assessment for ICE version – EV not yet tested. NCAP applies to "all ICE models" https://www.euroncap.com/en.*
***Real World Range – minimum based on "combined" winter use (-10°C) with heating, maximum on mild weather use.*
More information about all these vehicles and others is available from https://ev-database.uk/

The only hydrogen fuel cell (H2FC) cars currently available in the UK are the Toyota Mirai and Hyundai Nexo. Almost all European OEMs including VAG, and Mercedes have abandoned development of H2FC cars and have had to write off many years of development costs. Honda has put H2FC car development on hold (production of the Honda Clarity ended in August 2021) and Hyundai is also understood to be pausing development of both H2FC and ICE.

Based purely on the availability of BEVs, the two diesel ICE cars operated by SHWD could be transitioned to BE cars as soon as SHWD wishes to do so.

In Figure 7-1, we compare the pence per mile cost of a BE and ICE car, based on the models used by SHWD. We assume the vehicles are purchased and retained for seven years and 70,000 miles – 10,000 miles each year. To the left of the Y axis, we represent the WLC of each vehicle as a pence per mile, for ease of comparison. The absence of fuel data meant that we couldn't calculate average efficiency (mpg) and therefore our WLC modelling, assumes 50 mpg for the petrol[12] Ford Fiesta car.

For all of the WLC modelling, we have referenced public sector framework agreements to obtain depreciation, maintenance and procurement costs. These costs exclude VAT. For reference, we have also shown HMT's shadow carbon cost (Section 6 refers) but have not included it in the WLC.

[12] The Ford Fiestas on the fleet are diesel. However, a diesel Fiesta is no longer available and so we have compared the petrol equivalent, for illustration.

Figure 7-1: Comparison the pence per mile cost of a BE and ICE car.

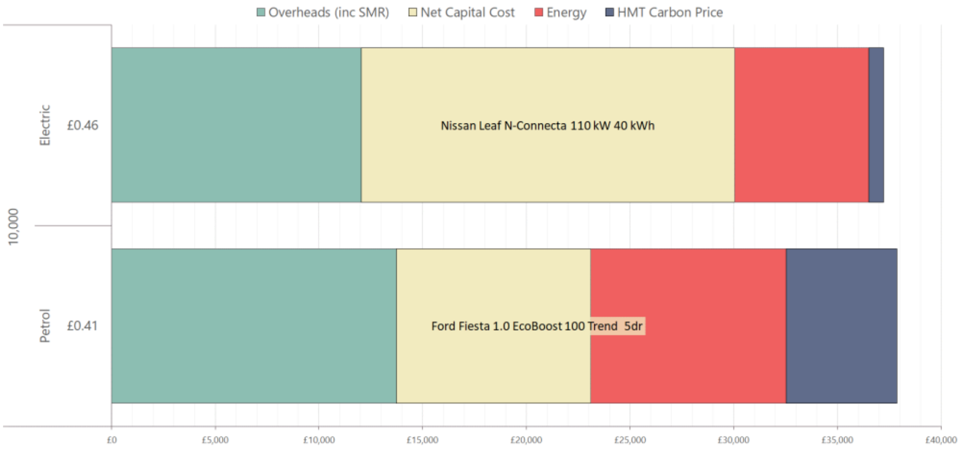


Table 7-2 summarises the WLC data presented in Figure 7-1 and assesses the annual impact.

Table 7-2: Annualised WLC and GHG emission comparison – one car

Make and model	Discounted Purchase Cost	Annualised WLC	Annual GHG (t)	Annual GHG Shadow Carbon Price
Ford Fiesta 1.0 EcoBoost 100 Trend 5dr	£11,150	£4,070	2.9	£760
Nissan Leaf N-Connecta 110 kW 40 kWh	£21,054	£4,560	0.4	£102
Savings from switching to electric	-£9,904	-490	2.5	£656

Based on our analysis, SHWD could replace its two diesel cars for electric Nissan Leafs (or similar) for an additional annual cost of £980. This would reduce annual GHG emissions by an estimated 5 tonnes.

If the shadow carbon price was also considered, the Nissan Leaf would be more cost effective.

7.2 Electrification of the LCV fleet

SHWD's LCV fleet consists of 58 vehicles[13], as shown in table 7-3. There are a range of BEVs that offer a similar carrying capacity and sufficient single charge range, which could replace the diesel LCVs.

Table 7-3: Categories of ICE LCVs on the fleet (2020), their energy efficiency and annual mileage

Fleet Category	Qty	Example Make	Example Model	Uplifted* gCO_2e/km	Av. mpg**	Av. Annual Mileage
Large LCV (2.6t to 3.5t GVW)	19	Peugeot	Boxer	245	25	9,940
Small LCV (1.5t GVW to 2.6t GVW)	39	Citroen	Berlingo	168	40	9,979

*Uplifted: Real World GHG emissions adjusted using BEIS methodology – typically 30% to 40% higher than NEDC OEM factor. **Estimated due to lack of fuel use.

7.3 Small LCVs – up to 2.6 tonnes

The market is reasonably well served for BE alternatives, although Ford don't yet produce a BE vehicle in this category. In Table 7-4, we provide an example of the carrying capacity of a sample of BE alternatives.

New versions of the Stellantis group Peugeot e-Partner, Citroen e-Berlingo and Vauxhall Combo-e Cargo, with larger batteries and improved capabilities, are also available to order. These are all practical BEVs, which achieve real world GHG emission reductions and often lower WLCs than their ICE equivalents.

Table 7-4: Payload (kg) and load space (m^3) of a sample of electric LCVs up to 2.6 tonnes

Make	Model	Battery (kWh)	RW Range[1] (Miles)	Maximum payload (kg)	Capacity Cubic metres
Renault	Zoe CDV	50	150 - 233	380	1.0
Renault	Kangoo E-Tech (2022 model)	44	164	625	3.6
Nissan	Townstar (2022 model)	44	164	625	3.6
Maxus	eDeliver 3	35 or 53	90 – 150	865 – 1020[2]	4.8
Stellantis	e-Partner/ e-Berlingo/ Cargo-e	50	170	800 (tow 750)	3.8/4.4

[1]Real World Range – minimum based on winter use (-10°C) with heating.
[2]Depends on the motor/engine power output chosen and vehicle length.

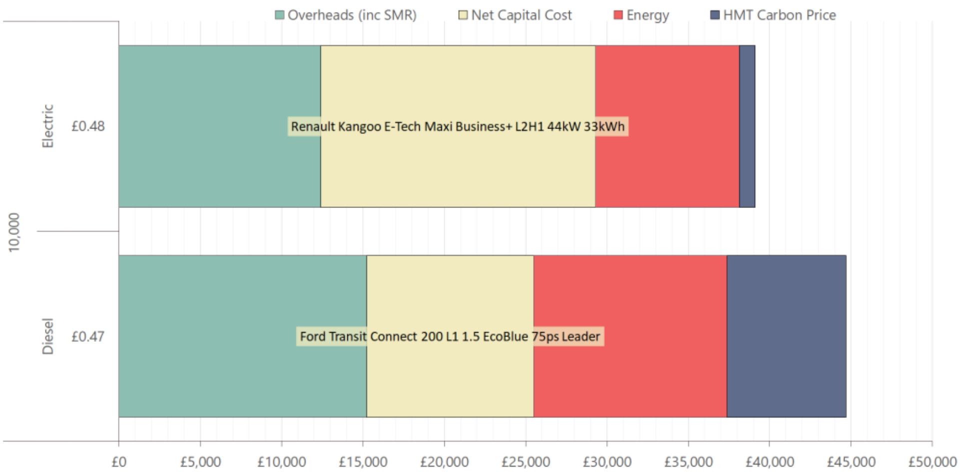
WLC: Small LCVs – up to 2.6 tonnes

In Figure 7-2, we have compared the WLC of two BE LCVs with two similar diesel LCVs, based on purchasing the vehicles and retaining for seven years and a total of 70,000 miles – 10,000 miles each year. The figure shown to the left of the Y axis represents the WLC in an easy to compare pence per mile format. In the absence of fuel data, our modelling assumes the diesel vans are averaging 40 mpg.

We have referenced public sector framework agreements to obtain depreciation and procurement costs. These costs exclude VAT. We have also shown HMT's shadow carbon cost (Section 6 refers) but have not included it in the WLC.

[13] 15 of which are currently managed by FCC on behalf of SHDC

Figure 7-2: Comparison of the whole life cost of ICE and BE small LCVs – purchase, 7-year retention, 10,000 mpa



In Table 7-5, we have summarised the WLC data and assessed the annual impact.

Table 7-5: Annualised WLC and GHG emission comparison, small LCVs

Make and model	Discounted Purchase Cost	Power	Annualised WLC	Annual GHG (t)	Annual GHG Shadow Carbon Price
Ford Transit Connect 200 L1 1.5 EcoBlue 75ps Leader	£12,422	Diesel	£4,982	3.5	£909
Renault Kangoo E-Tech Maxi Business+ L2H1 44kW 33kWh	£22,901	Electric	£4,468	0.5	£128
Saving from switching to electric	-£10,479		£514	3.0	£781

Table 7-5 shows that each BE LCV will reduce annual GHG emissions by 3 tonnes, and annual WLC by £514. If these savings were applied to the fleet of 39 LCVs, annual WLC would reduce by £20,004 and GHG emissions by 117t.

7.4 Large LCVs – 2.6t to 3.5t GVW

SHWD operates 19 large LCVs, which are averaging 9,940 miles each year. The first generation of BEVs in this category, such as the Renault Master E-Tech have limited capabilities because of a small battery size. Newer vehicles such as Fiat E-Ducato and Maxus eDeliver 9 are more capable, with a longer range, much greater carrying capacity and they are both in full production. The Ford E-Transit is now available and with a comprehensive range of size options and is priced very competitively. Stellantis Group have launched the e-Boxer, e-Relay and the Movano-e and these are also available to order now but not all size options are available. Below we have provided an illustration of 3.5t electric LCVs that are available.

Table 7-6: Payload (kg) and load space (m^3) of electric LCVs, 3.5 tonnes.

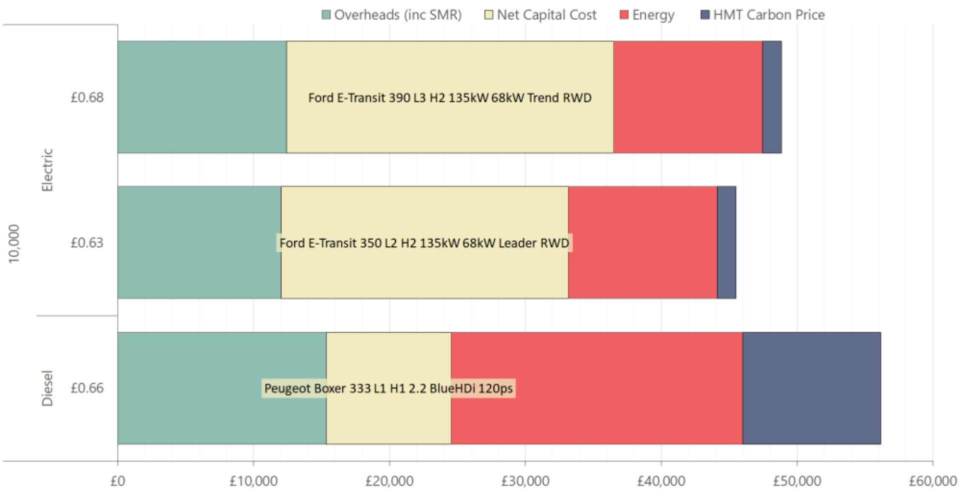
Make	Model	Battery (kWh)	RW Range[1] (miles)	Maximum payload (kg)	Size[2]
Fiat	E-Ducato	47 or 79	91 - 148	1,900	L1-L4/H1-H3
Maxus	eDeliver 9	50, 72, 88	136 - 150	1,400	L2-L3/H2-H3
Mercedes	eSprinter	55	96	774	L2-L3/H2-H3
Renault	Master ZE	33	50 - 75	1,000	L2H2
MAN	eTGE	36	65 - 70	1,700	L2H2
Stellantis	e-Boxer/e-Relay/Movano-e	37 or 70	139	1,260 - 1,890	L2-L4/H2
Ford	E-Transit, 350, 390, 425	70	108 - 126	1,470 - 1,970	L2-L4/H2-H3

[1]Real World Range – WLTP or NEDC adjusted. [2]OEM categories – not the same.

WLC: Large LCVs – 2.6t to 3.5t GVW

Given that Ford currently produce a competitive and comprehensive range of BE vans in this category, we have compared the WLC of two of these with the diesel Peugeot Boxer, which is the main large van used by SHWD (Ford and Peugeot also produce a BE chassis cabs and crew cabs which may be interest). The analysis is based on purchasing the vehicles and retaining on the fleet for seven years and a total of 70,000 miles. The WLC is represented to the left of the Y axis, as a pence per mile.

Figure 7-3: WLC comparison of ICE and BE large LCV



In Table 7-7, we have annualised the WLC (Figure 7-4) and the GHG emissions. The WLC excludes the annual shadow carbon price which is included for reference.

Table 7-7: Annualised whole life cost and GHG emissions

Make and model	Discounted Purchase Cost	Power	Annualised WLC	Annual GHG (t)	Annual GHG Shadow Carbon Price
Peugeot Boxer 333 L1 H1 2.2 BlueHDi 120ps	£16,362	Diesel	£6,570	5.7	£1,454
Ford E-Transit 390 L3 H2 135kW 68kW Trend RWD	£40,600	Diesel	£6,778	0.8	£199
Ford E-Transit 350 L2 H2 135kW 68kW Leader RWD	£36,504	Electric	£6,300	0.8	£199

From the perspective of carrying capacity, the Ford E-Transit 350L2 is the most directly comparable to the diesel Peugeot Boxer (it actually offers an extra 250kg of payload and 1.5 cubic meters of space). From the WLC comparison in Table 7-7, it can be seen that replacing a diesel Peugeot Boxer with the Ford E-Transit would save 4.9t of GHG emissions annually and reduce annualised WLC by £270.

If all 19 diesel vans were replaced with Ford E-Transits, and similar savings achieved, SHWD would reduce annual GHG emissions by 93t and annualised WLC by £5,130.

7.5 Summary of cars and LCVs that could transition to BEV

Given the age of current vehicles and the availability of BEVs, SHWD could start to immediately replace its 60 ICE LCVs and car with BEVs, allowing it to dovetail BEVs into the phased replacement cycle. In Table 7-10, we have summarised the costs and savings, where it can be seen that replacing the 60 vehicles with BEVs would reduce annual operating costs by £24,154 and GHG emissions by 215 tonnes.

Table 7-10: Proposed Implementation programme for BEV LCV fleet

Category	Number	Total annual WLC increase/reduction	Annual GHG saving (t)
Cars	2	-£980	5
Medium LCV (up to 2.6t GVW)	39	£20,004	117
Large LCV (2.6t GVW to 3.5t GVW)	19	£5,130	93
Total Saving if by moving to BEVs	**60***	**£24,154**	**215**

* Excludes the two cars already transitioned to BEVs and the three pickups, discussed in Section 11.

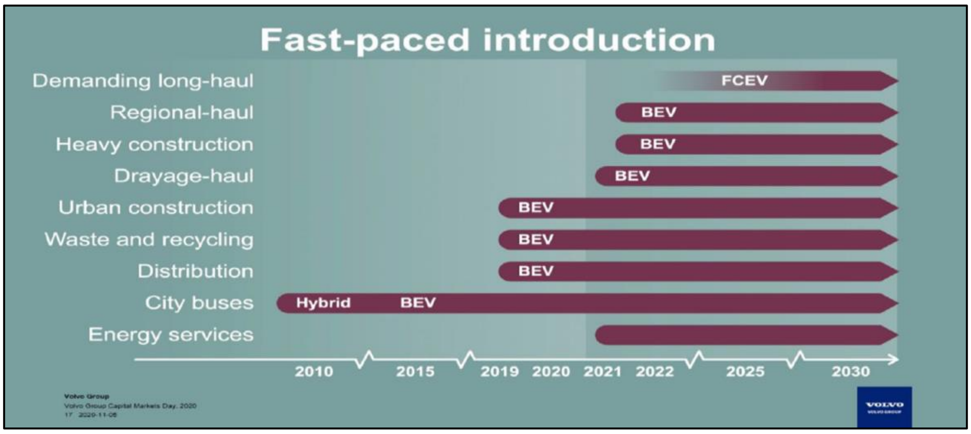
8. The use of hydrogen and HVO

8.1 Battery electric or hydrogen fuel cell?

In the heavy commercial vehicle (HCV, including RCV) segment there is considerable interest in the role of hydrogen fuel cell (H2FC) vehicles. It is certainly the case that in 2022, there are long-range and heavy-duty operations that cannot be transitioned to BEVs because the currently available battery technology cannot store sufficient energy and charging systems cannot recharge them quickly enough.

However, the view from all the major European OEMs is that all regional heavy-duty roles will be met by battery electric technology by 2030, if not before, because of improvements in existing battery technology and the introduction of new battery architecture and chemistry. There are also plans to introduce 1MW and 2MW charging stations for HCVs at service stations and truck stops. The view of the OEMs is best illustrated by Figure 9-1 which shows Volvo Truck's vision for EV development from 2010 until 2030 and beyond.

Figure 9-1: Volvo's vision of the role of electric vehicles in the heavy-duty sector (November 2020)



"Demanding Long Haul" should be seen in an international context – Volvo manufactures "Semi" trucks in the USA. Note that BEV is the preferred technology for most roles. Full presentation: Volvo Group Capital Markets Day 2020

Another company that has also made its views clear on the future for zero emission HCVs is Scania (part of the VW owned Traton Group) which has announced a full range of BE models, while scaling back its development of H2FC vehicles. The full statement from Scania can be read here: "Scania's commitment to battery electric vehicles". It includes the comment that *"In a few years' time, Scania plans to introduce long-distance electric trucks that will be able to carry a total weight of 40 tonnes for 4.5 hours, and fast charge during the drivers' compulsory 45-minute rest."* Scania's sister company MAN has made a similar announcement.

Daimler Trucks (Mercedes/Fuso) has announced plans to offer BE vehicles in all its main sales regions and market segments by the end of 2022: the FUSO eCanter in the light-duty segment, and the Mercedes-Benz eActros in the heavy-duty segment. A low-entry-cab Mercedes-Benz eEconic – the chassis used by many RCVs – is set to go into series production this year. Daimler Trucks sees H2FC as an option for 44 tonne or larger vehicles requiring a 1,000 km range but believes it may require liquid hydrogen stored at -253°C in cryogenic tanks to achieve the energy density needed to differentiate the product from long range 44 tonne battery electric vehicles. It has merged its development of H2FC vehicles with competitor Volvo to reduce costs and aims to bring its first H2FC vehicle to the market in 2025.

At COP26 Christian Levin, CEO of the Traton Group (Scania/MAN) stated, *"I used to be an advocate of hydrogen, but have since changed my mind and am more sceptical and realistic… We agree [with Daimler and Volvo] on most things in the transition to clean energy, but on hydrogen we think they are really over optimistic. And we don't think it is fair to tell governments around the world to invest in a hydrogen infrastructure alongside the battery electric infrastructure. We might be wrong, and they might be right, but that's the standpoint of MAN and Scania."*

H2FC vehicles have a much higher capital cost than a BEV, are energy inefficient, are much more complex and expensive to maintain and require a reliable, affordable source of zero-carbon (green) hydrogen at 350 or 700 atmosphere pressure (H35 and H70); high-carbon sources of hydrogen (black, brown, grey, blue, pink and yellow) are not an acceptable alternative. Manufacturing one kg of green hydrogen by hydrolysis requires 10 to 14 litres of pure water which has a significant environmental impact in its own right – especially in areas of water shortage like the South of England. Even "green" hydrogen is currently only acceptable if manufactured from curtailed renewable generation, if it diverts renewable generation away from the UK National Grid, then GHG accounting standards require the kWh consumed to be associated with the UK Treasury Green Book long run marginal generation factor, which in 2022 is 0.212 $kgCO_2e/kWh$.

Because of its much higher capital cost, the H2FC vehicle also needs to achieve much greater energy cost savings than those achieved by the equivalent BEV, if its WLC is to be similar to, or less than, an ICE vehicle. The current market pump price of "green" hydrogen (£10/kg to £15/kg) makes H2FC vehicles much more expensive to fuel than the diesel vehicles they replace, so there is no energy cost saving to offset the very much higher capital cost of the base vehicle.

According to work covering North East Scotland carried out by Cenex, the price of "green" hydrogen needs to fall below £6/kg for the operating cost (fuel only) to break-even with diesel. It may achieve that price by the middle of the decade but recent increases in the market price of electricity have made this less likely and even grey hydrogen made from natural gas has risen significantly in price from about £1/kg to nearly £5/kg.

The recent Zemo Hydrogen Well-To-Wheel (2021) study concluded: *"FCEV [fuel cell electric vehicle] trucks are in the order of four to six times less energy efficient than BEV on a WTW basis. Irrespective of the low carbon hydrogen supply pathway, the hydrogen production process is energy intensive thereby influencing WTW energy efficiency… Vehicles using hydrogen produced from steam methane reformation and electrolysis using current grid electricity do not perform better than diesel ICEV; grey hydrogen is to be avoided."*

Research by the Fraunhofer Institute for Systems and Innovation Research (ISI) concluded, *"Hydrogen is unlikely to play major role in road transport, even for heavy trucks… If truck manufacturers do not start the mass production of fuel cell trucks soon to reduce costs, such vehicles will never succeed in low-carbon road transport. Policymakers and industry need to decide quickly whether the fuel-cell electric truck niche is large enough to sustain further hydrogen technology development, or whether it is time to cut their losses and to focus efforts elsewhere."* Of course, many suppliers of fuel cells and hydrogen will disagree with this analysis and there are already 30,000 BE HCVs on the road. In total, 150 models are (or will shortly) be available from all the main OEMs and fuel cell trucks are still either pre-production (Europe) or on short production runs (Korea and Japan).

Another issue with the use of hydrogen is its manufacture and distribution. There are essentially three options: make on site by electrolysis using renewable electricity; make off site by the same process then tanker it in using tube (gas) or cryogenic (liquid) trailers; make off-site and distributing to site through the gas grid (this will need on-site purification and compression). Making on-site using electrolysis will require roughly three times the energy required by battery electric vehicles due to the poor energy efficiency of hydrogen production and use. Off-site will require frequent deliveries of hydrogen (up to 20 times as many as required with fossil fuel) unless delivered as a liquid at -253°C (20K).Delivering via the gas grid will require the whole local grid including all domestic users to be converted to hydrogen.

Daimler, DAF, Scania and Volvo have all announced an extensive range of battery electric rigid and articulated HCV chassis options covering all gross vehicle weights from 7.5 tonnes to 44 tonnes and these should be available to order in 2022 with full production of the full range by the end of 2023. Restricting the availability of all types of battery electric HCVs is the availability of the batteries (competing demand from the electronics, car and LCV sectors), the availability of microprocessor chips (a worldwide shortage) and the time it takes for the specialist body manufacturers to transition to an all-electric power source.

Over the next two years, as supply chain issues are resolved, many more battery electric HCV options will be available from the OEMs and by 2025 at the very latest, a full range of battery electric HCVs, and specialist vehicles based on OEM chassis, will be on the market to meet all the road transport needs of most HCV users in the UK. However, there may be a special-use niche that requires a different technology.

9.1 Hydrotreated vegetable oil (HVO)

There has been growing interest in and use of this 'drop-in' diesel replacement liquid fuel, which requires little in the way of retrofit for existing fleets and much of the demand is based around its very low BEIS TTW CO_2e conversion factor - 0.03558 kgCO_2e/litre[14], versus 2.51233 kgCO_2e/litre for (average biofuel blend) diesel. While we recognise the theoretical benefits of HVO, we have strong concerns about the source of its principal feedstock, Used Cooking Oil (UCO) and the use of this fuel under the current supply regime. We expect and hope that one significant positive outcome of the DfT's low carbon fuels strategy will be to improve certainty and transparency around the sourcing and use of this fuel and its feedstock.

In the UK and Europe, where UCO is classified as a waste product and has few approved secondary uses, it is much easier to trace its origin back to its producer, than it is for non-European UCO. Fundamentally, we must be certain that the UCO, used as a feedstock for HVO is in fact a waste product. In south-east Asia and the Americas, where almost all[15] of the UCO imported into Europe originates, UCO has traditionally been used as animal feed (mixed with grain) and so it is not considered a true waste product, as it has a permitted use.

The high price that UCO suppliers are achieving because of its 'waste' classification in Europe, is resulting in a distortion of the world market: UCO is diverted from the less financially rewarding animal feedstock market and is replaced with other farmed crops, which may include palm oil. In instances where palm oil cannot be harvested, soy is grown instead but this crop has a lower energy yield than palm oil and so more land has to be used for crop planting. The greater demand for palm oil and other types of crop-derived oil contributes to further global deforestation, and other indirect land use change (ILUC) leading to reduction in biodiversity, a loss of ecosystem services and further increases in GHG emissions.

Table 9-1: Carbon intensity of HVO, diesel and electricity (BEIS Conversion Factors, 2021)

Fuel or energy	Unit	TTW (Scope 1 kg CO_2e)	Scope 2 kg CO_2e	WTT (Scope 3 kg CO_2e)	T&D Scope 3 kg CO_2e	Out-of-scope kg CO_2	Total WTW
Biofuel HVO (UCO)	kg/litre	0.03558	-	0.21320	-	2.43000	2.67878
Diesel (average biofuel blend)	kg/litre	2.51233	-	0.60986	-	0.15117	3.27336
Electricity	kWh	-	0.21233	0.06018	0.01879	-	0.29130

NOTE: BEIS "Conversion Factors Methodology" states that the DfT factors published on the Renewable Fuel Statistics website take precedence over these BEIS values.

As quoted on the BEIS conversion factors, "All fuels with biogenic content, such as (average biofuel blend) diesel and petrol and all electricity consumption should have the biogenic CO_2 emissions reported, to ensure a complete picture of an organisation's emissions is created". Instead of the 80-95% carbon reduction sometimes quoted from adopting HVO, the combined TTW, WTT and out-of-scope[16] emissions figure, shows a much more modest reduction in carbon intensity (around 18%) when/from switching to HVO, Table 9-1 refers.

According to the DfT's most recent (2020) complete RTFO data[17], 100% of UCO feedstock for UK HVO came from outside Europe and none of the HVO sold in the UK was produced using UCO from the UK[18].

The BEIS Conversion Factors Methodology points users to the DfT RTFO data when determining GHG emission reductions from HVO. It should be noted that in the last full year for which we have figures (2020) the reduction was stated as 85%. The 2021 Second Provisional report puts it at 91% and the 2021 Third

[14] https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2021

[15] 2021: Approximately 70% of the UCO used in UK HVO originates from Venezuela, Indonesia and China

[16] The Scope 1 impact of these fuels has been determined to be a net '0', because the fuel source itself absorbs an equivalent amount of CO_2 during the growth phase as the amount of CO_2 released through combustion.

[17] https://www.gov.uk/government/collections/renewable-fuel-statistics

[18] 104 million litres of UCO were produced in the UK in 2020 but none of this was used to make HVO for domestic use. In 2021, the provisional figures show only 9% of UCO was European in origin (Spain, Italy and Czech Republic). This contrasts with 100% of biomethane feedstock coming from Europe in both years.

Provisional report shows a further adjustment to 88%. Users must be clear about the source of the claimed reductions in GHG emissions and make sure they use the right factor for the year in question.

Finally, after recent events in Ukraine, the world's largest producer of sunflower oil, there is the issue of security of supply. Many of the countries from which the UCO is now being sourced have been subject to sanctions by either the UK, EU, or USA. This further undermines our confidence with regard to the sustainability of HVO made from UCO sourced from outside Europe.

In summary, there is an argument for the use of locally produced HVO in diesel vehicles if there is no suitable BE alternative available. However, HVO should not be used to justify extending the replacement of diesel vehicles, where a suitable BEV is available.

10. Moving to a zero emission RCV fleet

10.1 Overview – battery electric refuse and recycling vehicles

In 2018/19, Electra introduced a prototype all-electric eRCV based on a 26 tonne, three-axle Mercedes Econic chassis with a 200kWh battery. During 2019, the chassis and rig was widely trialled around the UK in several cities. In Manchester, it was operated by Biffa on the City Council domestic contract for a six-month trial and has continued in use as part of the current Biffa fleet. During the trial, the Electra eRCV was successfully used for the collection of all domestic waste streams including garden & food waste, recyclables (plastic, glass, paper, cardboard) and residuals (anything that cannot be recycled).

The 200kWh battery of the prototype completed all the Manchester rounds but had less than 10% charge left when used on the garden waste collection because of a 20-mile run to the composting centre. The vehicle is now available with a range of battery packs up to 300 kWh and can be supplied on 18 tonne and 26 tonne chassis. The range of the 300kWh vehicle is up to 100 miles (160 km).

The City of London (Veolia) and Manchester City Council (Biffa) now have substantial fleets of the 18 tonne (2-axle) and 26 tonne (3-axle) Electra (Figure 10-1) in operation. The Electra vehicle has also entered service with several other councils, and it is currently the only vehicle in this size class to receive the full £25,000 grant funding from OZEV.

Also available to order is the Dennis Eagle eCollect, which is a 300kWh battery electric version of the company's popular 26 tonne "Narrow" model. It has been extensively tested with local authorities around the UK, is in full production and already in service with many councils including Nottingham, Newport, Cardiff, Oxford, Powys, Dundee, York, Cambridge, Sunderland, and Islington.

Volvo/Renault has sold its first UK 26 tonne eRCV (D Wide ZE) to SUEZ Recycling who are using it for commercial waste collections in Bristol city centre. Volvo/Renault have also announced the availability of a low entry cab for the electric HCV range. The first DAF 6x2 eRCV has been supplied to the Dutch waste company ROVA (it has a 170 kWh battery and a 30 minute rapid recharge time).

Figure 10-1: One of the City of Manchester's 27 Electra/Mercedes 26 tonne 300 kWh electric refuse vehicles

An alternative to buying a new electric RCV is offered by the UK company Refuse Vehicle Solutions (RVS) who have entered into an agreement with EMOSS to use its technology to convert donor RCVs from diesel to electric. The old vehicle chassis, cab and waste collection rig are refurbished, new electric bin lifts are fitted, and the diesel drive train is replaced by an EMOSS electric drive with the option of a 200 kWh or 280 kWh battery. The Geesinknorba group have also developed an electric RCV in collaboration with GINAF, using a DAF LF chassis. The vehicle has a 200kWh battery and a 44Kw on-board charge point.

It is understood that a BE resource recovery vehicle (eRRV), called the RQ-E, will shortly be available from Romaquip based on a DAF glider chassis and that Terberg (owners of Dennis Eagle) are working with Electra to produce a RRV based on an IVECO glider chassis for their kerbsider/loader range.

10.2 Operational considerations

As part of our brief, SHWD requested that we model the operational performance of a 26t diesel RCV and compare this to an electric RCV (eRCV), thereby illustrating the WLC differences and the potential for reducing CO_2e.

SHWD's RCVs are managed by FCC Environment and annual mileage data was provided for the 13 Dennis Eagle RVCs that they operate on behalf of SHDC[19].

The operational performance that underpins our analysis is based on the average performance of the 13 RCVs, which includes four 22t models[20], and is summarised in Table 10-1.

Table 10-1: Average RCV performance

Fleet Category	Fleet size	Average mpg*	Average Annual Mileage	Average Daily Mileage	Assumed days used each year
RCV	13	3.5	12,154	51	235
*In the absence of fuel data, we have based this on our previous experience of modelling 26t RCVs					

Energy Use

Each 26t RCV averaging 51 miles a day at 3.5 mpg, will use approximately 66 litres of diesel, equivalent to 703 kWh of energy[21]. Manufacturer comparisons have identified that an eRCV will use an average of 25-30 percent of the energy[22] of a diesel RCV. Using 30 percent, we determined that the daily energy requirement for an eRCV travelling 51 miles will be approximately 211kWh, which is 70 percent of a 300kWh eRCV battery capacity. Therefore, by the end of the average duty cycle, remaining battery capacity will be 89kWh.

The benefit of estimating energy use (kWh) from actual diesel consumption, rather than the typical average we have used, is that it will reflect operational variables such as terrain[23], driving style, load weight and use of ancillary equipment[24]. As the time for replacing the diesel RCVs gets closer, it is recommended that SHWD undertakes more detailed analysis of daily fuel use. This will help identify any vehicles that cannot transition to eRCV due to higher-than-average energy use.

10.3 Modelling the WLC of RCVs

Electric motors, batteries, vehicle chassis and refuse/recycling rigs all have different operational lives. Most heavy-duty electric motors can operate with minimal servicing for 20 years or more (based on experience in trains and trams) and can be easily refurbished – two new bearings and a rewind of the coils.

Batteries can be serviced by replacing faulty cells and, when they are no longer economic to refurbish, they can still be used in a battery storage array as the reduced storage capacity – and therefore range – is not an issue. The chassis and cab can be fully refurbished, and the refuse rig replaced. This means that replacing an eRCV at eight years – common practice for diesel RCVs – is unlikely to be the optimal ownership strategy.

Table 10-2 shows the operational factors that we have included within our modelling. To account for the longer economic-working life of the eRCV, we have modelled this over 10 years and the diesel RCV over eight years. We compensate for this inequality in timing by adding a further two years of depreciation to the eight-year diesel modelling, thereby ensuring the same timeframe for the comparison. What is not included in

[19] FCC's total fuel use allocated to SHDC (226,783 litres) was provided but this could not be apportioned by vehicle or fleet category and therefore we could not determine RCV efficiency (mpg).

[20] These were all older (10 years plus) RCVs, with later models being 26t.

[21] As previously discussed, each litre of diesel provides approximately 10.6kWh of energy. (Source: Full set of government Conversion factors 2021).

[22] This level of efficiency varies a little but is typical of all electric vehicles when compared to ICE equivalents.

[23] We understand that SHWD has a particular concern about the impact that the terrain its fleet operates in will have on BEV range. This approach will help address this but we also recommend borrowing a demonstration vehicle to test the impact of different duty-rounds

[24] Operating in extremes of temperature are not considered.

this model is the cost of rig or battery refurbishment during the operational life of either RCV, or the additional cost of future diesel RCVs associated with meeting the new Euro VII emission standard in 2026/27.

Table 10-2: Electric 26 tonne RCV – factors used in the whole life cost energy model

RCV Factor	Electric	Diesel	Notes/Units
Project Life	10		Years
Vehicle Lifespan	10	8	OEM Advice & Fleet policy
Number	1	1	One vehicle modelled
Annual Mileage/Vehicle	12,154	12,154	Fleet data
Cost of energy/fuel	£0.23	£1.60	Cost is for a kWh and litre (2022 cost excluding VAT)
Annual Inflation to 2030	3.24%	1.79%	Based on BEIS 2009-19

Typical energy/fuel costs for 2022 are used as the base year but an annual inflationary increase has been applied. It is assumed that vehicles will be recharged overnight, using the lowest-cost tariff. Future carbon taxes have not been considered but may be significant.

In Table 10-3, we have modelled the capital cost of both RCVs, and it can be seen that the eRCV requires a greater investment of capital. The residual value of the batteries may be higher than our estimate (they have a second life in energy storage and can be refurbished) and it is possible that in 2030 an electric chassis will be worth more than a diesel chassis.

Table 10-3: Ten-year net capital cost of an electric and diesel RCV

Cost Summary	Electric	Diesel	EV Cost (-Saving)	Notes
Vehicle Capital Cost	£430,000	£220,000	£210,000	OEM data
Residual Value (Chassis)	-£19,600	-£15,400	-£4,200	BEV 5%, ICE 5%
OZEV Grant Funding[25]	£0		£0	Excluded
Residual Value (Battery)	-£22,500		-£22,500	Estimated as 20%
Capital invested at seven years	£387,900	£204,600	£183,300	When diesel RCV is replaced
Investment in new RCV (8th year)	n/a	£51,150	£132,150	2 years of additional funding
Net Capital Cost (depreciation)	**£387,900**	**£255,750**	**£132,150**	**Over 10 years**

In Table 10-4, we have calculated the total WLC by including both operational costs and the net capital cost, as calculated in Table 10-3.

Table 10-4: Ten-year Whole Life Cost – includes fuel, AdBlue, VED and road user levy

Cost Summary (10 years)	Electric	Diesel	EV Cost (-Saving)	Notes
1 x RCV Net Cost	£387,900	£255,750	£132,150	From previous table
Total Energy Cost	£133,906	£273,874	-£139,968	Includes inflation
AdBlue Cost		£6,630	-£6,630	No inflation
SMR (ex-tyres) Costs	£84,000	£120,000	-£36,000	OEM Estimate
VED + Road User Levy	£0	£5,835	-£5,835	DVLA V149/1 - 2020 Policy
Whole Life Cost	**£605,806**	**£662,089**	**-£56,283**	**Annualised cost saving from using one eRCV is £5,628**

[25] The OZEV grant for 26t HCVs is £25,000, capped at five vehicles per organisation (£125,000), £16,000 for the next ten vehicles and then £5,000 per vehicle. We have excluded this because (currently) it only applies to Electra and Renault RCVs, and it may not be available when the RCVs are ready for replacement.

The SMR cost savings from eRCV chassis maintenance are significant but the cost of maintaining the rig is expected to be similar for both vehicle types.

It can be concluded that each RCV replaced with an eRCV will reduce annual fleet costs by £5,628, based on the average profile that we have modelled. eRCVs would also eliminate the need for "AdBlue" exhaust additive and would be zero-rated for Vehicle Excise Duty and Road User Levy.

Based on the modelling, if all 13 (22t and 26t) RCVs were transitioned to eRCVs, SHDC should expect to reduce fleet operating costs by £73,164 each year.

10.4 RCV emissions

Over the ten-year lifetime, replacing an RCV with an eRCV, will reduce GHG emissions by 404 tonnes (Table 10-5). This takes into account the increasing use of renewable energy to generate grid electricity, and consequently the declining GHG emissions associated with recharging the eRCVs, as shown in Appendix B.

The eRCVs have no Scope 1 emissions. All the GHG emissions are Scope 2, from the generation of electricity and Scope 3 from transmission and distribution (T&D) losses as well as "WTT" emissions at the generator – all of these are predicted to fall over the lifetime of the project, as the UK Grid decarbonises.

*Table 10-5: Ten-year energy use (kWh) and GHG Emissions (*kg CO_2e*) of an electric and diesel RCV*

Energy Use and GHG	eRCV	RCV	eRCV Cost (-Benefit)	Notes
Energy consumption (kWh)	502,337	1,674,457	-1,172,120	
Scope 1 kg CO_2e		396,612	-396,612	BEIS TTW Factors
Scope 1 AdBlue kg CO_2e		1,203	-1,203	Used by SCR
Scope 2 kg CO_2e	65,855	0	65,855	UK Grid - Predicted
Scope 3 T&D kg CO_2e	5,828	0	5,828	UK Grid - Predicted
Scope 3 WTT kg CO_2e	18,665	96,276	-77,611	BEIS WTT Factors
WTW GHG (kg CO_2e)	**90,348**	**494,091**	**-403,743**	**-404 tonnes over 10 years**

SHWD may wish to consider local generation of electricity using a wind turbine, or PV array. This would reduce the electrical energy costs by at least 60-70% (typically to around £0.04/kWh), mitigating uncertainty regarding the future cost of energy and generating further savings.

Based on each RCV emitting (annually) 40.4t more GHG than the eRCV, if all 13 (22t and 26t) RCVs were transitioned to eRCVs, SHDC should expect to save a total of 525t of GHG, annually.

Air quality improvements

The diesel RCV engine has significant emissions of both NO_X and PM, which must be controlled using a selective catalytic reduction system (SCR) for the NO_X, and a particulate trap for the PM. Both of these technologies struggle to work well at the low exhaust temperatures associated with low speeds and with intensive stop/start operations. The SCR may switch off as it can release ammonia at low temperatures and the particulate trap may need to be regenerated by driving the vehicle at sustained speed.

Table 10-6 below, has been determined using the COPERT5 model for a Euro VI diesel operating at an average speed of 10 km per hour reflecting semi-urban operation. It is based on one RCV over a 10-year period.

Table 10-6: Air quality emissions: one RCV over the 10-year life

Air Quality (Project Life)	eRCV	RCV	eRCV emission reduction	Notes
Nitrogen Oxides (NO_X) kg	0	373	-373	NAEI COPERT5 (10 km/hr)
Particulate matter (PM) kg	0	2.9	-2.9	NAEI COPERT5 (10 km/hr)

Based on the modelling of the 26t RCV, if all 13 (22t and 26t) RCVs were transitioned to eRCVs, SHDC should expect to save a total of 485kg of NOx, and 3.8kg of PM each year.

Benefit to Society – HM Treasury Net Present Value

The HM Treasury Green Book (2021) provides a methodology to assess the net present value (NPV) of the transition to eRCVs in terms of the reduced UK shadow carbon cost of the vehicles' GHG emissions, and societal benefits of improved air quality. The NPV model also includes a measure of the cost saving to HM Treasury from the change in fuel use, and factors such as improved health. The results from the HMT Green Book NPV methodology are shown in Table 10-7.

Table10-7: HMT Green Book (2021) valuation of energy use, GHG emissions and air quality impact

eRCV Project – NPV	Electric	Diesel	Variance
Energy use change (HMT impact)	£41,573	£62,861	-£21,288
UK GHG (CO_2e) emission reduction	£16,707	£90,452	-£73,745
Local air quality - reduced health impacts	£939	£10,853	-£9,914
Net Present Value (NPV)	**£59,219**	**£164,167**	**-£104,948**

The tax paid on road fuel is not included in the HMT cost saving model as both the road fuel duty and VAT is recovered by the Treasury. As a result, the cost saving in the NPV model is significantly less than the actual energy cost saving we estimate could be achieved by SHDC, by switching to eRCVs.

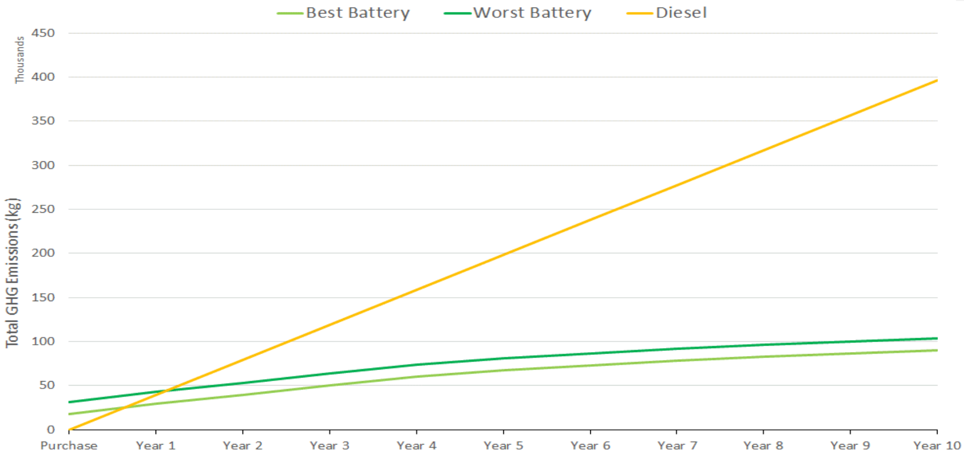
The high shadow carbon price for UK GHG emissions is associated, in part, with the significantly higher cost of meeting the UK's more ambitious Nationally Determined Contributions (NDCs) announced in April 2021 prior to COP26, and in compliance with the Paris Agreement (2015).

Offsetting the GHG embedded in the battery

One concern often expressed when evaluating electric vehicles is the embedded GHG in the battery, associated with the manufacture of the battery cells. Research by the Swedish Environmental Research Institute in cooperation with the Swedish Energy Agency has identified the variation in GHG emissions associated with each kWh of capacity (Lithium-Ion Vehicle Battery Production, 2019) depending on the GHG intensity of the manufacturing process.

In 2019, the range was from 61 $kgCO_2e/kWh$ to 106 $kgCO_2e/kWh$. Figure 10-2 demonstrates that even with the most GHG intense battery (worst battery) the eRCV offsets the GHG embedded in its manufacture within 14 months - when the yellow line of cumulative diesel emissions crosses the green lines of cumulative EV emissions. In the case of the "best battery" this occurs after about nine months use.

Figure 10-2: Cumulative GHG Emissions, 300 kWh battery, 10-year life, UK Grid, RCV operation.



During 2019-2022, many battery manufacturers around the world have moved to using renewable energy for the production process which would place their batteries in the "best" category. There are still GHG emissions associated with the extraction, processing and transport of the raw materials required for manufacture of the battery, but these are soon offset through the operational CO_2 savings achieved by replacing an ICE vehicle with a BEV.

10.5 RCVs – summary of key findings

Based on experience working with other clients with 26t RCVs, the majority if not all of, an eRCV fleet should be capable of completing daily duty cycles without top-up charging. However, to confirm this SHDC will need detail of daily fuel use and mileage[26]. We recommend that this is obtained prior to a more detailed evaluation of eRCVs (it is expected that the methodology set out in this report will guide SHDC on the data required for this assessment, and Energy Saving Trust may also support this analysis).

It is also recommended that SHDC discusses the development of the <26t eRCVs with OEMs and organises a demonstration of both this model and the 22t eRCV to help test a 'proof of concept', prior to committing to the purchase of these[27]. Based on our illustrative modelling, if all 13 (22t and 26t) RCVs were transitioned to eRCVs, SHDC would reduce annual:

- Fleet costs by £73,164
- Reduce annual GHG emissions by 525t
- Emissions of NOx by 485kg
- Emissions of PM by 3.8kg

Whilst these findings focus on SHDCs fleet of RCV's, it is reasonable to expect FCC (WDBC) to achieve similar reductions in cost and emissions for each of its RCVs, assuming a similar operating profile.

[26] If this data is not available from telemetry fitted to the RCVs, a process should be established that will capture the data so that it is ready to support the analysis of procurement choice.

[27] Detail of daily fuel use by each RCV will also be required to determine the charge point infrastructure, as discussed in this section and in Appendix D.

11. Limited BEV alternatives

OEM focus has been on the development of BEVs for the more mainstream commercial vehicle market, largely LCVs up to 3.5tGVW – Sections 7 refers. Consequently, there are limited, BEV options for the larger commercial vehicles, the notable exception being RCVs.

Over the next few years, we expect this to change (Appendix F), and already, we are starting to see the signs of this, as discussed below. Even when new BEV vehicles are introduced, it is often difficult for us to obtain 'real-world' performance data, and operating costs to support WLC comparisons.

In common with other local authorities SHWD's fleet includes a range of (43) vehicles that fall into this 'difficult to electrify' category, including: pickups, agricultural machinery, tankers and sweepers.

Sweepers, gritters, tankers, tippers and pickups

Scarab has confirmed that it is developing a BE sweeper and plans to launch it by June 2023. In advance of this, (end of 2022) Scarab plans to launch a truck-based BE sweeper called the Emerlin62, which will be based on the diesel Merlin62. The expectation is that the Emerlin62 will retail at about £400,000.

Recently launched from the Fayat group, which owns Scarab, is the ERavo, which is an 11.5t sweeper with a payload of approximately 5t and retail cost of approximately £390,000. Whilst we don't have access to sufficient BE sweeper specifications, cost or operating data required for a comparison between BEV and ICE sweepers, it is prudent to plan for the electric sweepers to have a capital cost that is approximately 2.5 times the cost of the diesel sweeper.

Nottingham City Council is operating a fleet of eight small electric sweepers (Boschung). Companies like Whale (tankers and gully cleaners – Figure 11-1) and Johnston/Bucher sweepers have used electric drive kits from the Dutch company EMOSS to convert donor vehicles.

Figure 11-1: Whale battery electric MVC tanker and Bucher V65e electric street sweeper

Edinburgh recently took delivery of an electric street sweeper manufactured by Bucher Municipal which is estimated to reduce diesel fuel costs by £18,000 per annum.

Figure 11-2: Electra Gritter developed for Transport Scotland for use on the Forth Bridges

Pickups

Currently, there are no electric pickups available, although there is the Maxus T90EV pickup due in early 2023. Key specifications for this vehicle are:

- Base price of £50k ex vat
- 88.5 kWh battery
- 220-mile WLTP range
- Payload of 1,000kg
- CVW 2,300 kg, GVW 3,300 kg, GTW 4,050 kg –
- Towing capacity TBC

Ford has committed to making available “plug-in versions” of its entire commercial vehicle range, including 4x4 pickups, by the end of 2024.[28]

We are aware that some organisations are using an EV chassis cab with a flat-bed conversion, until they can procure electric pickups. We don’t have the cost of these, but an example of the Maxus eDeliver 3 is pictured below. However, this is only available in 2-wheel drive configuration.

Figure 11-3: Maxus eDeliver 3

[28] For an example of some planned introductions, visit https://www.parkers.co.uk/vans-pickups/best/electric-pickups/

12. BEV charging requirement

It is extremely difficult to roll out an electric vehicle fleet if the fleet cannot be charged at their normal overnight location, whether in the depot, or at the employee's home. We recommend that, at sites where fleet vehicles are based, there is initially one charge point for each vehicle. This ensures that all the vehicles can be fully recharged overnight for the next working day and allows pre-conditioning in summer and winter.

In most cases, low cost 7.4 kW AC charge points will be able to recharge the cars and LCVs overnight, and these can also be used for home-based charging where the employee has off-road parking[29]. Changing demand on fleet vehicles may mean that occasionally, 11 kW or 22 kW AC charge points could be needed for the bigger LCVs and minibuses with a large battery (typically over 75 kWh) and a high daily energy use, that makes full use of the battery capacity. This would ensure that these vehicles could be fully charged overnight or a during a shorter period. These larger charge points cannot typically be home-based, as they need a three-phase power supply, which is unusual in domestic properties.

12.1 Assessing energy use by location

SHWD requested that we estimate the energy required to charge an all-electric fleet, based on the different locations that vehicles will be charged at. To calculate this accurately, we need to know the fuel use of each vehicle, and ideally by day[30]. From this we can estimate daily energy use of a BEV[31], and the electricity required to recharge each BEV. SHWD was not able to provide detail of each vehicle's fuel use and so we agreed to provide a considerably less accurate illustration, based on the annual mileage provided by SHWD. This is summarised in Table 12-1.

Table 12-1: An illustration of how energy demand may increase at the top seven locations

Top seven locations	Number of vehicles assigned to location	Annual EV kWh	Energy use each working day (kWh)	Energy demand (kW/hr*) for recharging
Torr Quarry	28	582,914	2,429	202
Ivybridge	20	419,659	1,749	146
Totnes	28	90,370	377	31
No data provided	7	23,015	96	8
Plymouth	6	17,829	74	6
Plympton	3	16,221	76	6
Total	**92**	**1,150,008**	**4,801**	**399**
*Assumes a 12-hour window to recharge				

Table 12-1 shows the top six locations and the potential increase in demand (kWh) as a result of transitioning to an all-electric fleet. We have assumed that the vehicles will be deployed an average of 240 days each year and that there will be a (daily) 12-hour window for recharging. Again, we must stress that, due to the lack of fuel data, this is provided only as an illustration. SHWD must not rely on this for any other purposes.

[29] For those that don't there are a number of potential solutions gradually coming to the market. For example, Charge My Street is a social enterprise that installs and operates public electric vehicle (EV) charge points funded by community investment. It aims to solve a major barrier to entry for EV users that do not have off-street parking by installing public charge points throughout residential areas and is working to ensure that EV drivers are no more than a five-minute walk from the nearest charge point.

[30] Daily use is particularly important for the vehicles that use the greatest energy, such as RCVs.

[31] Each litre of diesel produces the energy equivalent of 10.6kWh

12.2 Full EVCI review

When SHWD has developed a more detailed understanding of each vehicle's mileage and fuel use (in particular vehicles with high energy use, such as RCVs), a more accurate analysis of the location's EVCI requirement can be provided by Energy Saving Trust as a separate report.

The "EVCI Review" will require data on the maximum import capacity (MIC) at the depot, the power factor (PF) and the half hour (HH) energy consumption data (kWh) for a whole year.

All this information should be available from your energy management team, or from your energy supply company. Information about installed or planned private wire renewable generation can also inform an EVCI review, as it may impact on the maximum import capacity required.

SHWD should engage with its DNO to determine if any depots are constrained by local grid capacity. Consideration should be given to implementation of both PV generation on site and battery storage.

12.3 Further information

Appendix D provides a brief introduction to electric vehicle charging infrastructures.

The Energy Saving Trust Guide to Chargepoint Infrastructure (2017) has more information on EV charging as does the older Beama Guide To Electric Vehicle Infrastructure (2015). Also useful are the Beama Best Practice for Future Proofing Electric Vehicle Infrastructure (2020), Making the right connections, UK EVSE, (2019), BVRLA Fleet Charging Guide (2022) and SPEN Connecting your EV Fleet.

Appendix A: Current ZEV and ULEV technology

There are several ZEV and ULEV technologies that could help SHWD reduce GHG emissions in its fleet. Current ZEV and ULEV technologies are considered and given in order of preference below:

A.1 Battery Electric Vehicles BEVs

- Large number of OEM cars, LCVs and Buses available now including many third generation BEVs
- Full range of BE HCVs from all European OEMs by end 2024 including 44 tonne tractor units
- Widespread national charging infrastructure, although some gaps still persist
- Can charge at staff homes but usually limited to 7.4kW AC charging, off-street parking required
- Immediate GHG reduction currently about 70% less than ICE equivalent, will be 95% by 2030
- GHG intensity falls with grid intensity and faster if using on-site renewable generation
- Secure supply almost all electricity generated in the UK (some imported by interconnects at peak)
- Daily range limited by current battery technology unless opportunistic rapid charging is an option
- Higher capital cost but lower running cost, typically a 75% reduction in energy costs v ICE

A.2 H2FC (including range-extended fuel cell – REFCs)

- Very limited OEM vehicles currently available, Vauxhall Vivaro-e Hydrogen available in UK 2022.
- Production H2FC from European OEMs not expected until end of the decade (2027/28)
- Very limited national infrastructure, currently refuelling infrastructure is sparse and London centric
- Cannot be refuelled at home, vehicles will always require refuelling stations
- No guarantee of GHG reduction, may increase, depends on how the hydrogen has been produced
- GHG intensity falls with grid intensity if hydrogen generated from UK Grid
- Variable security of supply, depends on how the hydrogen is made – grey/blue = imported methane
- Daily range will be higher than the current generation of BEVs but limited by tank capacity/space
- Higher capital cost and higher running cost than both ICE and BEV

A.3 Biomethane – bioCNG and bioLNG (Natural Gas)

- Limited OEM vehicles available, the IVECO Daily is the only CNG LCV available
- Mercedes, Scania and Volvo produce a range of CNG and LNG HCVs
- Limited national infrastructure, currently aimed at HCV market so mostly on or near trunk roads
- Cannot be refuelled at home, vehicles will always require refuelling stations
- Robust GHG reduction, feedstock not imported, most fuel manufactured in UK, good audit trail
- Secure supply manufactured in the UK from UK waste feedstock; limited bioLNG imported from EU
- CNG has reduced range (tank capacity), LNG has comparable range to ICE
- Higher capital cost offset by gas fuel duty discount, so small savings are possible

A.4 Biodiesel – HVO and FAME

- HVO is a ‘drop-in’ fuel – use in any diesel ICE.
- FAME (fatty acid methyl ester) is another biodiesel product but has limited use due to waxing – not ISO diesel
- Depot based bulk tank fuel. We are not aware of any publicly accessible 24/7 refuelling sites at present
- Cannot be refuelled at home, vehicles will always require refuelling stations
- Good GHG reduction, presuming all feedstocks are genuine waste and no GHG displacement
- Poor security of supply - over 80% of the feedstock for UK HVO comes from outside Europe
- No change in capital cost, higher energy cost but any ICE diesel vehicle or plant can be used
- Still produce particulates and nitrogen oxides - no known safe level of particulates.

When a BEV can do the job, it will be the most energy efficient, have the lowest emissions and may cost less to operate than any of the other technologies, when assessed using WLC. For HCVs, the catenary or electric road system (ERS) could be a very cost effective and energy efficient option but will only be relevant to long-distance heavy haulage. A BEV with a hydrogen fuel cell range extender is the next best technology, and after that fuel cell, but Hydrogen made from renewable energy is not widely available and is currently expensive. Biomethane is a good alternative but still has tailpipe emissions. Biodiesel and in particular HVO, is only ethical if the feedstock is genuine waste, with no displaced emissions; the HVO-powered diesel engine will still have tailpipe emissions of particulates and nitrogen oxides (NO_X) and will need both a particulate trap and a SCR (AdBlue) system. Robust, published, peer-reviewed, research detailing reductions in PM and NO_X emissions from using HVO as a drop in fuel, in a range of vehicles, is in short supply at present

Appendix B: UK Grid 2014 to 2030

There are several organisations attempting to predict future carbon intensity of the grid, and these are often updated during the year to reflect changes in policy or grid performance.

Table B-1 shows:

- The BEIS GHG Scope 2 Factor for the year, which is about two years behind real-time emissions because of the verification process. This is used for GHG reporting.
- The real time performance of the grid, in year (or year to date) as calculated from the Elexon data set.
- The Committee on Climate Change (CCC) and BEIS projections (Updated October 2021).
- The average of the CCC and BEIS data sets.
- The HM Treasury Green Book – Central Non-Traded Cost of Carbon Emissions (BEIS 2021).

Table B-1: UK Grid future carbon intensity – BEIS Factors, Actual (Elexon), CCC and BEIS Predictions

Year	BEIS GHG Scope 2 Factor	Year on Year Change	Actual in year from Elexon Portal	CCC Balanced Pathway 6th Budget	BEIS 2021 (Table 1)"	CCC - BEIS Average	Central Carbon Value (BEIS 2021)
2014	494.26		415.7				
2015	462.19	-6%	364.2				
2016	412.04	-11%	277.1	269.0	287.6	278	
2017	351.56	-15%	247.1	240.0	257.0	248	
2018	283.07	-19%	227.8	219.0	238.8	229	
2019	255.60	-10%	204.3	193.0	212.9	203	
2020	233.14	-9%	184.4	153.0	159.4	156	£241
2021	**212.33**	**-9%**	**184.9**	**151.0**	**148.7**	**150**	**£245**
2022	193.52			148.4	138.9	144	£248
2023	176.32			134.5	133.3	134	£252
2024	160.67			135.4	145.4	140	£256
2025	146.40			125.2	123.0	124	£260
2026	133.40			93.3	90.7	92	£264
2027	121.56			74.8	75.0	75	£268
2028	110.76			64.6	69.4	67	£272
2029	100.93			58.1	65.0	62	£276
2030	91.96			46.1	51.6	49	£280
2031	83.80			37.1	40.8	39	£285
2032	76.36			26.5	35.3	31	£289
This data is available from CCC and BEIS until 2050							

When calculating the future emissions of a BEV fleet, it is important to use these predictions, to ensure the potential GHG reduction from the switch to electric power, is fully assessed.

These figures do not take account of the most recent British Energy Security Strategy (April 2022) which envisages a significantly faster growth in off-shore wind, raising the target for 2030 from 40GW to 50GW, which may result in even lower average grid emissions by 2030.

Appendix C: Whole Life Cost (WLC) in practice

Calculating the WLC is straight forward, but it becomes complicated when you try to include the treatment of interest on capital and taxes. These vary and are outside the scope of this report; you should consult with your finance team about how to handle the capital deployed and whether there is a preference for purchase or lease. Similarly, VAT is handled differently in the private and public sectors and even between similar public sector bodies – our costings always exclude VAT.

The following factors need to be considered in a WLC model. The (L) indicates when a factor is usually included in a lease agreement and does not have to be considered separately.

Purchase price/capital cost (L): Most large organisations will be able to obtain a discount, especially if committing to the purchase of several vehicles, or purchasing from one manufacturer for a period. Our modelling includes a discount that is generally available to public sector organisations, and any grant that may be available – see below.

OZEV grant (L): OZEV offers grants to encourage the take-up of some ZEVs. This is accessed by the manufacturer or dealer and will have been deducted from the purchase price at the point of sale. They have been included in both lease and purchase costs.

Residual value (L): This represents the value of the vehicle at the end of its operational life. The difference between the initial purchase cost and the residual value is known as depreciation. It will vary significantly depending on vehicle type, age, and final condition. Some methods of finance fully-amortise the cost of depreciation over the vehicle's operational life. Any residual value is then treated as a disposal surplus.

Fuel: Unless otherwise stated in the modelling, we have estimated the cost of diesel at £1.60/litre and the cost of electricity at £0.23/kWh, based on overnight charging at a commercial rate. These costs exclude VAT

Net Capital Cost (L): This is the amount that the vehicle is expected to depreciate (the loss of capital) over the stated time and mileage. It is calculated as the difference between the purchase price and residual value.

Servicing, Maintenance, Repair (SMR) and Tyre Costs (L): Several organisations can provide a forecast of SMR and tyre costs. However, these are usually limited to four or five-year budgets. If you are planning to keep a vehicle for longer than this, you will need to base this cost on your experience, or past fleet records. Where we have modelled a longer replacement cycle, the SMR cost has been extrapolated from industry forecasts of four and five year cost data.

Vehicle Excise Duty (VED) (L): This is the annual road use charge; for new cars it is linked to OEM published carbon emissions in the first year but is then a flat rate. VED for zero emission vehicles is currently fixed at zero.

Fleet Management Charge: For budgetary purposes, some fleet operations include an internal management fee to cover day-to-day management of the vehicle including organising servicing, breakdown cover, fuel cards, driver training and other support services. We have applied an annual cost of £550 for each vehicle.

Insurance: Corporate insurance rarely takes account of the risk of individual vehicles or drivers, instead it applies a fixed charge for the whole fleet, normally reflecting previous claims history. We have applied an annual cost of £650 for each vehicle.

National Insurance Contributions (NICs): If the vehicle is made available for private use, the employee will incur a benefit-in-kind (BIK) scale charge and the employer will pay Class 1A NIC on the scale charge. We have excluded this cost.

CAZ/LEZ/ULEZ charges: While ICE diesel vehicles that meet the Euro 6/VI standard currently get charge-free access to clean air zones, this may not be true over their entire operational life. Several towns and cities are considering zero emission zones (ZEZ) and the London ultra-low emission zone (ULEZ) only guarantees Euro 6/VI diesels charge-free access to the zone until 2025.

WLC/Savings

Our estimated savings are for illustration. Any actual cost/saving (both financial and CO_2e) will be determined by factors such as the type of BEV selected, mileage travelled, and the costs/emissions of the vehicle it is replacing.

Table C-1: Whole life cost model – the factors you need to consider.

Factor	Units	Calculation	Example	Notes/Observations
Make			Electric	
Model			LCV	
Operational Period	years	Y	5	
Annual Mileage	miles	AM	10,000	This needs to be realistic.
Discounted On-The-Road Price	£	A	£25,000	All these costs are included in the lease cost giving a fixed lifetime cost. This is based on the expected condition of the vehicle at the end of the lease and the annual mileage.
ZEV grant if not in OTR Price	£	B	Included	
Residual value battery	£	C	£2,000	
Residual value vehicle	£	D	£3,000	
Capital Cost or Lease Cost	£	CC=A-B-C-D	£20,000	
SMR and Tyres	£/annum	E	£150	Usually included in lease cost
Vehicle Excise Duty	£/annum	F	£0	Usually included in lease cost
Fleet Management Charge	£/annum	H	£550	Same for ICE and BEV
Insurance Cost	£/annum	I	£500	Usually same for ICE and BEV
Class 1A National Insurance	£/annum	J	£0	Only if private use
CAZ/LEZ/ULEZ charges	£/annum	K	£0	Any zones in operational area?
Energy/Fuel Cost	£/annum	L	£300	Try to source real-world figures
Overhead Cost	£/annum	OC = SUM (E to L)	£1,750	Total annual overhead costs
Whole Life Cost	£	WLC=CC+(OC×Y)	£28,500	Capital plus Overheads (WLC)
Total Mileage over period	Miles	TM=Y*AM	50,000	
Cost per mile	£/mile	WLC/TM	£0.57	Use this for evaluation

The GHG emissions of the ICE fleet are straight forward to determine, as they are based on the carbon emitted by burning a litre of fuel and that will stay fairly constant over the lifetime of the vehicle. BEVs are more complicated, as the electricity supply will decarbonise over the next 10 years and that means the GHG emissions of the vehicles will decrease year-on-year (see Table B-1).

Wherever possible, use real world figures in the WLC model from your own fleet, or from your own diesel, petrol and electricity supply contracts. ICE vehicles used in urban operations often have significantly higher fuel consumption that the OEM mpg data would suggest and equally, BEV vehicles will be significantly more efficient in urban operation, as their energy efficiency is not impacted by slow stop-go operation but is affected by high-speed operation – for example sustained motorway driving.

Table C-2: Costs and emission factors included in the WLC models presented in this report

Item Description	Value	Value	Units
Diesel cost (ex VAT) in first year and annual inflation rate	£1.60	+2%	£/litre
Petrol cost (ex VAT) in first year and annual inflation rate	£1.52	+2%	£/litre
Electricity cost (ex VAT) in first year (off peak) and annual inflation rate	£0.23	+3%	£/kWh
Average GHG emissions of diesel (BEIS 2021)	2.512		kgCO_2/litre
Average emissions of electricity (CCC/BEIS predictions)	See Appendix B		gCO_2/kWh
Average GHG emissions of petrol (BEIS 2021)	2.194		kgCO_2/litre

Item Description	Value	Value	Units
Average GHG Shadow Price: HM Treasury Central Carbon Value	See B		£/tonne
Fleet Insurance and Fleet Management costs	£650	£550	£/annum

Over the last year there has been considerable disruption to energy prices, and it is difficult to predict for how long the higher prices for diesel, petrol, natural gas and electricity will be sustained. As the BEV fleet grows, it is expected that diesel and petrol prices will increase, as garages try to recover their fixed costs from reduced fuel sales. Many garages rely on income from their associated shops but with fewer visits, that source of income will also reduce putting even greater pressure on fuel prices.

Appendix D: Introduction to EVCI

D.1 Charging an electric vehicle fleet

With the exception of some emergency service vehicles and 24/7 delivery vehicles, or passenger services, most BEV fleets can be fully recharged overnight, or during other periods of inactivity. If the BEV has been matched to the service being delivered, it should, if fully charged, be able to complete its normal working day without top-up charging. There are high mileage services that do offer frequent top-up charging opportunities – for example, an inter-site delivery or minibus service – but these are a special case. It is also possible to consider a split shift service where a rapid charge point top-up to 80% battery capacity during the day would enable a second shift to operate. These are special cases and the business case for each needs to be considered separately.

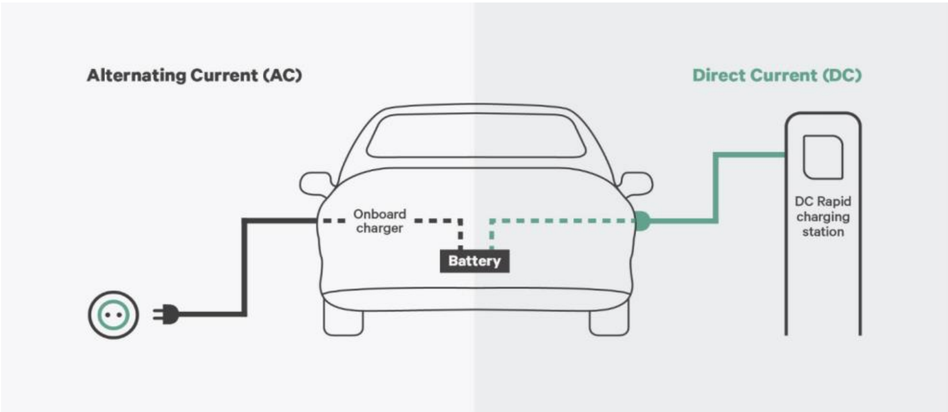
D.2 AC or DC charging and Smart Management

There are two basic types of charging infrastructure: alternating current (AC) and direct current (DC). Electricity that comes from the grid, or a private wire electrical supply, is always AC. However, batteries within BEVs only store power as DC. AC charge points are usually referred to as fast and DC charge points as rapid.

AC (fast) charging

If a vehicle is using an AC charge point, it must convert the electricity to DC. On board the vehicle is a conversion system known as the 'onboard charger', which converts the power and feeds it into the vehicle's battery. The output of AC charging systems ranges from 3.4kW up to 43kW but are usually 7.4kW or 22kW. Charging speed is dictated by the vehicle. Different vehicles have different maximum charging rates when charging on AC. Most new BE cars available today can charge at 7.4kW, or up to 11kW, and a few can charge at 22kW. These types of charge points are usually found in domestic properties, commercial sites for overnight charging and destination charging locations (tourist attractions, sites where people stay for several hours). In BE LCVs and HCVs, higher AC and DC charge rates are more common.

Figure D-1: AC and DC charging



(Source: https://wallbox.com/en_uk/faqs-difference-ac-dc)

DC (rapid) charging

If a vehicle is using a DC charge point, the conversion system is within the charge point itself. This means the power bypasses the vehicle's on-board conversion system and flows directly into the vehicle's battery. The output of DC charge points ranges from 20kW up to 600kW. Usually, DC charge points are classified as rapid (50kW – 100kW), or ultra-rapid (100kW and above). Like AC charging, the speed of charge is dictated by the battery technology vehicle. The speed of charge is concurrent with the battery size and voltage. As vehicles with larger batteries are introduced to the market, the charging speed of these vehicles is increasing. These types of charge points are usually found at motorway service stations, on-street in cities, and at depots housing larger vehicles such as eRCVs.

Table D-1: Indicative BEV charging times (assumed from 20% state of charge[32])

Battery size (right) Power output of charger (below)	25kWh	50kWh	75kWh	100kWh	200kWh
7.4 kW	3h 45m	7h 45m	10h	13h 30m	59h 15m
11 kW	2h	5h 15m	6h 45m	9h	16h 9m
22 kW	1h	3h	4h 30m	6h	8h 4m
50 kW	36m	53m	1h 20m	1h 48m	3h 33m
120 kW	11m	22m	33m	44m	1h 28m
150 kW	10m	18m	27m	36m	1h 11m
240 kW	6m	12m	17m	22m	44m
350 kW	3m	7m	11m	15m	30m

D.3 Hardware

EVCI is designed in a number of ways. Fast charge points can have a single or dual socket (Type 2[33]) and can come with charging cables tethered (cables affixed, largely for domestic charging) or untethered (just the sockets). Rapid charge points can have either one charging port (CCS or CHAdeMO), two charging ports (both the same connector or one of each) or three charging ports (CCS, CHAdeMO and AC Type 2). Charge points can be post mounted, wall mounted, mobile, part of an overhead gantry system, stand alone, satellite posts and more. It is important to consider specific site requirements when procuring hardware.

D.4 Smart charging and load management

Our guide to BEV smart charging provides comprehensive information on smart charging systems, and should be read in conjuction with this report.

Smart charging

Smart charging is a system whereby a BEV and a charge point share a data connection, and the charge point shares a data connection with an operating system. Older charge points would simply allow for a BEV to plug into a charge point and receive a charge. Smart charge points are connected to a cloud network, either through Wi-Fi, ethernet or 3G/4G/5G. This allows the charge point to monitor, manage, and restrict the use of the device remotely to optimise energy consumption. Connected vehicles, in a smart charging system, will react with the changes in the grid system in order not to overload or unbalance the grid. Smart charging allows you to set your charging preferences, which may include:

- Desired charge level
- Charge-by time
- Minimum charge level

Smart charging is essential as BEV uptake continues to exponentially increase. There are many benefits to fleet operators looking to implement smart charging systems within their workplace.

Table D-2: Benefits of smart charging

Feature	Benefit
Cost saving	By using an energy tariff that has been designed specifically for BEV drivers, you can make the most out of smart charging, as lower tariff rates are applied during off-peak times (e.g., overnight). Smart charging can reduce organisational costs overall, when compared to traditional charging using a standard BEV tariff.
Convenience	Smart charging requires little effort – when the vehicle is returned to a site, or an employee's home, you just plug your BEV into its smart charge point. The smart functionality ensures the vehicle is charged by the time set by the user.

[32] Battery charging times are universally calculated from 20%. With rapid charging, the charging speed can slow down above an 80% state of charge.

[33] AC and DC charge points have different connectors. Information on these can be found here.

Feature	Benefit
Environmental benefits	BEVs produce no emissions when being driven, and the electricity used to charge them is increasingly being generated from renewable sources. In the future, smart charging will also increasingly be used to charge BEVs when renewable energy is more abundant on the grid, such as after windy or sunny periods. This would help reduce carbon emissions further.
Balancing grid demand	Most BEV users charge their vehicles after a shift, or at the end of the working day, corresponding with peak demand on the grid. Using smart charging, you can still plug in your vehicle when it is returned to the depot, or the employee's home, but the charge point then manages and adjusts the vehicle's charging to a time when electricity demand is lower.

D.5 Load Management

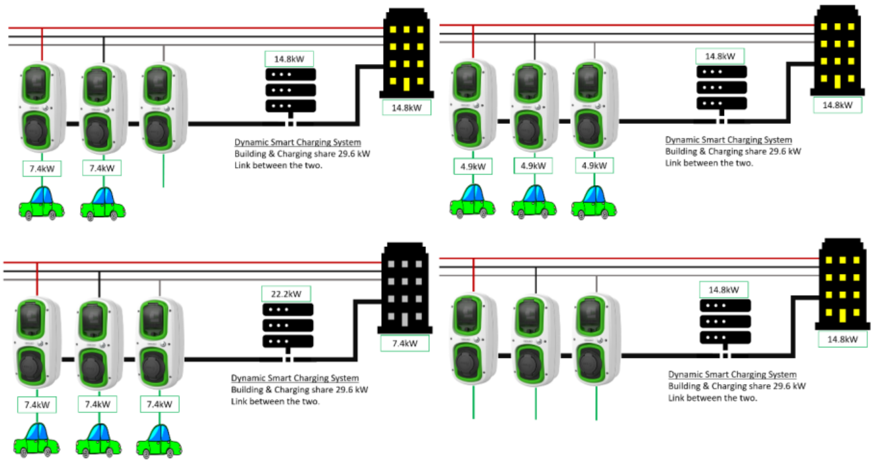
Through smart charging, charge point operators have the ability to distribute power to different charge points on a network (reactively) with demand from the vehicles, to ensure that the total incoming supply capacity can not be exceeded. Charge points will analyse the available capacity of the supply and distribute the power based on the maximum capacity of the connection. This is known as static load management, or static load balancing.

Dynamic load balancing is more complex but can benefit sites which have other electrical requirements on the same circuit as the charge points. The load balancing system will take into accunt other electrical circuits when vehicles are charging. For example, if vehicles are plugged in during the day time and the building supply is powering the lighting at the same time, the vehicles will receive a reduced rate of charge. Once the lighting system is turned off, more power will be available for the electric vehicles to use, and the charge rate will increase. This is the same for heating generators in the winter months turning off, once employees have left site.

For private and public sector organisations, load balancing means they can avoid cost increases in connection capacity and prevent peak loads that result in extra charges. The operation of a fleet would not be restricted as a result of load balancing through slower charging, as the vehicles can retire to charging points when shifts have ended and charge overnight during downtime hours.

Figure D-2 shows a basic example of dynamic load balancing with three BEVs using the same electrical supply as a building, at different stages of charge, where the distribution of power changes according to demand. The images follow on from one another from top left, to top right, then bottom left and finally bottom right. Image three shows an increased charge rate to each vehicle once the building's lighting system has switched off.

Figure D-2: Dynamic load balancing example (29.6kW supply – building plus 3 x 7.4kW EVCPs)



(Source: Gfleet Services)

D.6 V2X Technology (vehicle to grid, building, and home)

V2X is a collective term made up of Vehicle to Grid (V2G), Vehicle to Home (V2H) and Vehicle to Building (V2B) technologies. These technologies enable energy to be pushed back into either the power grid, home or building, from the battery of a BEV through the charge point it is connected to. Vehicle batteries can be charged and discharged depending on energy production, nearby consumption, or through periods of high energy demand. This technology goes one step further than smart charging and the ability to increase and decrease charging power when required, by balancing variation in energy production and consumption. A good example of how this technology works, is Octopus Energy's Powerloop project, in which Energy Saving Trust is a partner.

V2X technology can benefit organisations, through commercial buildings and the local grid. The electrical connection can be the largest cost of any EVCI installation project, as upgrades are expensive. Combined with smart energy management and dynamic load management, V2X can assist with providing this additional power. Grid consumption can be overloaded when demand increases in the local area. As the grid decarbonises over the years, V2X technology could play a crucial role in stabilising the grid electricity, as renewable energy sources such as wind and solar are volatile within the grid. In situations such as this, grid congestion can occur, preventing electricity from reaching its destination.

V2X is currently available through CHAdeMO compatible vehicles, however there is currently a roadmap in place for CCS to reach full V2X capacity by around 2025, therefore making V2X technology in Europe a technology of the future. BEVs produced by Nissan are the only vehicles that can utilise this technology at present. For organisations which carry out seasonal work, for example gritters on highways, batteries are problematic, as these vehicles are only required for a certain number of months annually, V2X technology would allow these vehicles to act as a power bank for depots when not in use. This could resolve the issue of battery degradation which is possible from long periods of inactivity.

D.7 Charge Point Management and Back Office

Smart charge points are managed through a 'back office' system. Data is transferred by connecting the charge points to a cloud-based platform through SIM cards within the units, through a Wi-Fi connection or through ethernet cables. This system enables the operator to manage their charge points remotely. Through the back office, the organisation can schedule charging, set tariffs (if open to visitors to the site or the public), see (and fix) live faults within charge points, observe live charging sessions, obtain management information data including billing, energy consumed, charging session times and a variety of other features.

A comprehensive back-office system, including a fleet platform, should be considered when installing EVCI. Similar to the hardware, there are a variety of platforms and fleet portals to choose from. A number of hardware OEMs have their own system. Alternatively, most charge points are manufactured in line with the latest Open Charge Point Protocol (OCPP – currently OCPP 2.0.1). With this protocol, charge points can be managed by a different back-office system to the hardware manufacturer. This enables an organisation to tailor their fleet management platform to their requirements, while fulfilling the hardware needs of the BEVs they operate. Some innovative solutions to BEV fleet management are listed below.

Table D-3: Charge point fleet platform back-office features

Feature	Breakdown
Integration	• Integration with telematics systems already in use by an organisation • Integration with employee's energy provider and home charge points to calculate true charging cost • Business platform integration • Energy trading to buy electricity at flexible tariffs • Operable with multiple hardware OEMs
Reimbursement	• Automatic reimbursement from home charging through charge point tracking • Reimburse employees directly through back-office platform • Home and public charge costs directly reimbursed through energy provider invoicing. Employee pays nothing

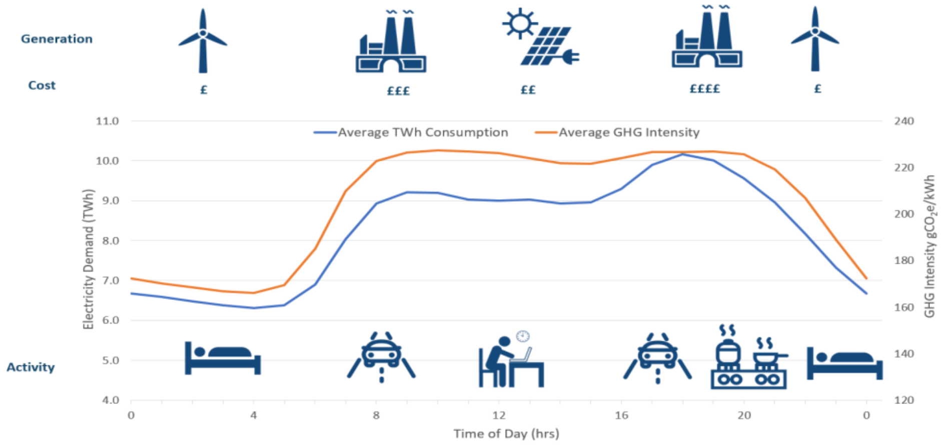
Feature	Breakdown
Reporting	• View CO2e savings to help monitor net zero targets • View all costs of charging in one place, including split bills from home, work, and public charging • View charging sessions (kWh, session times) • Download management information reports (useful for OZEV workplace charging scheme reporting) • Track business and personal mileage
Scheduling and Accessibility	• Set charging times for vehicles to make use of off-peak electricity tariffs and manage site electrical supply. • Multi-user access. Ability to make EVCI available to different fleets (grey fleet, company cars, main fleet).

D.8 Selecting the right time to charge

Ideally, vehicles should be charged overnight, to avoid the demand from large scale EV charging having a negative impact on the UK grid. During the working week demand on the UK Grid is at its maximum in the early morning and late afternoon, during these periods the GHG intensity ($kgCO_2e/kWh$) of the grid may be high due to the use of fossil-fuel based generation – typically gas – to meet the high demand (Figure D-3).

However, avoiding these peaks entirely leaves a narrow window of six or seven hours in which to charge vehicles and that may require the use of 11kW or 22kW AC charge points rather than the slightly lower-cost 7.2kW AC points. The reduction in GHG emissions from avoiding the high intensity periods is typically 10%-15% over the entire charging period and in terms of tonnes of GHG this will diminish in importance as the grid decarbonises and significantly less use is made of fossil fuel generation. What may have a bigger impact on the decision to delay charging is the higher cost of electricity during peak periods and this may prove to be a greater incentive to time-shift charging vehicles to off-peak, low cost and low GHG periods.

Figure D-3: UK Grid: Relationship between Consumption, Cost, Generation and GHG (Data: Mon-Fri, 2021)



(Based on graphic by Char.gy)

During the summer months, on-site or private wire PV generation can be used during the late afternoon and early evening to charge vehicles that have returned early at a time when the site load is falling as people go home. Using the PV to displace grid import at this time will have a significant cost saving and will maximise the charging window.

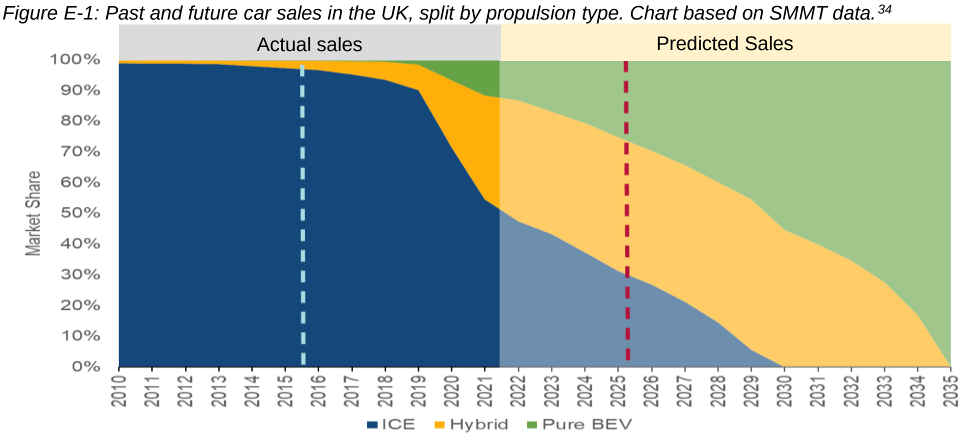
Please contact Energy Saving Trust for more detail on a separate, standalone EVCI report for your organisation.

Appendix E: ICE car availability 2025 to 2030

Consumer demand and the EU's introduction of Euro 7 emission standards, currently expected in 2025/26, may have a much earlier impact on the availability of ICE cars than the UK Government's ban on their sale in 2030.

The significant cost associated with developing engines to meet the Euro 7 standard may not be recoverable, as the sale of ICE vehicles is restricted and market share in all sectors is lost to BEVs. Where manufacturers do make a Euro 7 engine, it is expected to significantly increase the vehicles' capital cost, in turn pushing more consumers towards ever cheaper and more capable BEVs, so further reducing potential sales.

Figure E-1: Past and future car sales in the UK, split by propulsion type. Chart based on SMMT data.[34]



The Euro 6 emissions standard for cars was introduced in September 2015 (Figure E-1 - pale blue dashed line), and engines that comply to these standards can be sold until the introduction of Euro 7, expected in 2025/26 (Figure E-1 - red dashed line). By the time Euro 7 is mandatory, engine manufacturers will have had a decade of Euro 6 car sales, and several years with ICE vehicles holding near 100% market share, to recover development costs.

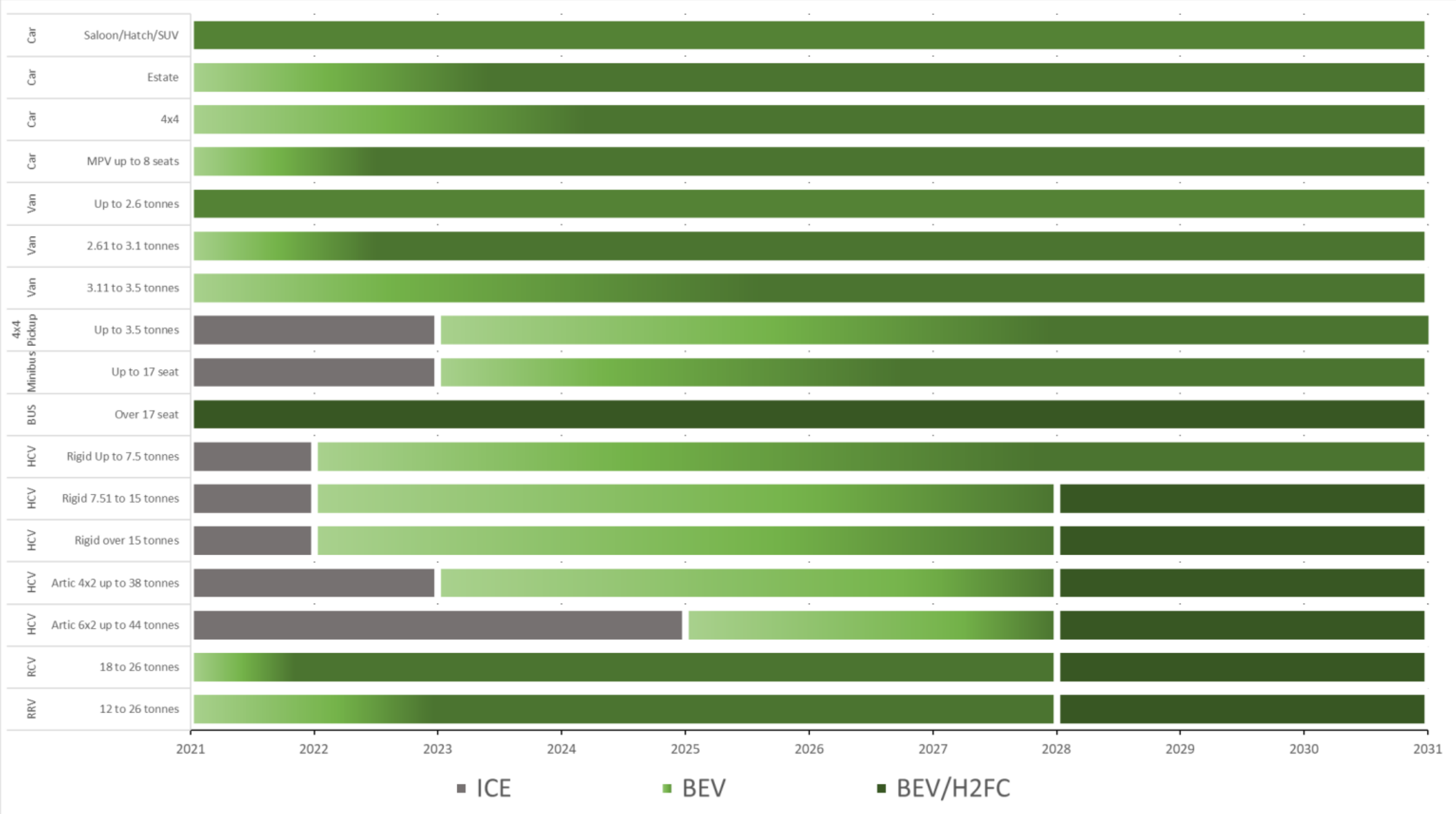
Between the introduction of Euro 7 and the ban on ICE car sales in 2030, manufactures have half as long, and a minority market share, to recover the development costs. By 2025, we predict there will have been approximately 15 million Euro 6 compliant cars sold in the UK. Total UK Euro 7 sales are predicted to be under 1.7 million units, less than the number of Euro 6 engines sold in the first year. Given the reduction in predicted sales, manufacturers can be expected to limit the number of ICE models available and focus on BEV and hybrid drive train development but even the hybrid engines will have a limited lifespan and diminishing market share.

Audi have announced they have halted pure-ICE development; BMW have announced they will not develop a diesel Euro 7 engine for cars, Nissan has suspended development of new combustion engines in all markets except the USA, and Mercedes intend to halve the number of engines variants available. Stellantis have announced phase out dates for all its European brands between 2024 and 2028. In all cases the reason given is to free up resources and capital for the development of BEV drives. Depending on the final standard agreed, and uptake of BEVs over the next five years, we could see the 2030 phase out date for large numbers of ICE car models effectively brought forward to 2026 by market factors.

For this reason, all organisations with large car fleets – and this includes the emergency services who tend to have the largest car fleets – need to be prepared to transition all new car procurement to ZEVs or ULEVs by 2026. From a planning perspective, this will require a charging infrastructure to be in place for the car fleet by 2026 at the latest.

[34] Data from SMMT's new car market outlook to 2035, adjusted to match Q4 2021 car sales data.

Appendix F: Availability of OEM Zero Emission vehicles



Commented [RH1]: Text too small to read

The graduated bars indicate a period of introduction and solid colours represent availability of a full range of vehicles.

As can be seen, most vehicle categories are already available as BEVs, but the full range of specialist body types is not yet available. Not all vehicles can carry the same load or tow as well as their ICE equivalent – but this position should improve. By 2027/28, it is expected most vehicle categories will be available as a BEV, with equivalent load carrying capability and that in the last few years of the decade, fuel cell models may come to market, although that may not happen if new energy-dense battery technology like solid state or semi-solid-state lithium is available by then. This chart is indicative and may be pessimistic in some categories but optimistic in others.

Appendix G: Sources of Information

Further information on a range of topics relating the UK's current GHG emissions, decarbonisation of the UK road fleet and the use of a range of alternative fuels are available from:

IPCC comprehensive Assessment Reports – AR6 (2021 and 2022)
World Resources Institute: GHG Reporting Protocol
Defra/BEIS UK Environmental Reporting Guidelines including SECRBEIS UK GHG Emissions – Updated Annually
BEIS UK GHG Emission Reporting Factors – Updated Annually
DfT Renewable Fuel Statistics – Updated Quarterly
DfT UK Vehicle Statistics – Updated Quarterly and Annually
BEIS Predicted UK Grid GHG Intensity – Updated Annually
HM Treasury Green Book: Valuation of energy use and GHG emissions
Global EV Outlook 2021 – International Energy Agency (2021)
Determining the Environmental Impact of conventional and alternatively fuelled vehicles through LCA, Ricardo, For ECDG Climate Action (2020)
A comparative life-cycle analysis of low GHG HGV powertrain technologies and fuels. Ricardo (2020)
Zero Emission HGV Infrastructure Requirements, Ricardo. For UK CCC (2020)
Making zero emission trucking a reality, PWC, (2020)
Decarbonising the UK's Long-Haul Road Freight – UK Centre for Sustainable Road Freight (2020)Hydrogen in a low-carbon economy – UK Committee on Climate Change (CCC -2020)
Zemo: Hydrogen Vehicle Well-to-Wheel GHG and Energy Study
The carbon credentials of hydrogen gas networks and supply chains, Imperial College (2018)
JIVE (Joint Initiative for Hydrogen Vehicles across Europe) (2017)
Hydrogen technology is unlikely to play a major role in sustainable road transport, Nature, (2022)Separating Hype from Hydrogen – Part One: The Supply Side (BNEF - 2020)
Separating Hype from Hydrogen – Part Two: The Demand Side (BNEF - 2020)
Hydrogen Is Big Oil's Last Grand Scam, CleanTechnica, (2021)
COP26: Widespread use of green hydrogen in heating and cars is practically impossible, Recharge, (2021)
End of the road for pioneering TfL hydrogen buses, Bus and Train User, (2020)
French city cancels purchase of 51 hydrogen buses, Recharge, (2022)
Hydrogen Mobility Europe (H2ME) – Emerging Conclusions (2021)
Battery or fuel cell? That is the question, VW Group, (2020).
Volvo Group Capital Markets Day, Volvo, (2020)
Scania's commitment to battery electric vehicles, Scania, (2021)
Toyota Mirai: As Easy as a Conventional Car, Toyota, (2015-20)Environmental sustainability of biofuels: a review, Proceedings Royal Society, 2020
ICCT: estimating displacement emissions from waste, residue, and by-product biofuel feedstocks (2020-22)
Used Cooking Oil (UCO) as biofuel feedstock in the EU
Used Cooking Oil (UCO) demand likely to double, and EU can't fully ensure sustainability (2021)
Implications of imported Used Cooking Oil (UCO) as a biodiesel feedstock (2019)
Targeting net zero – Next steps for the Renewable Transport Fuels Obligation, T&E, (2021)
Europe's imports of dubious 'used' cooking oil set to rise, fuelling deforestation, (2021)The Uninhabitable Earth: A Story of the Future. David Wallace-Wells, Penguin, 2019

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