Department for Transport

Fleet Report

Colchester Borough Council

Lead Author – Steve Williams
Peer Reviewed by – Peter Eggeman
24th July 2020

energysavingtrust.org.uk

Contents

Glossary of Terms

Abbreviation	Meaning
BEV	Battery-electric Vehicle
CAZ	Clean Air Zone (England and Wales, excluding London)
CCC	UK Committee on Climate Change
CNG	Compressed Natural Gas - methane (CH_4)
DBEIS/BEIS	(Department for) Business, Energy and Industrial Strategy
DVLA	Driver and Vehicle Licencing Agency
EV	Electric Vehicle - usually battery-powered (BEV)
EVCI	Electric Vehicle Charging Infrastructure
GHG	Greenhouse Gas, CO_2e, in transport usually CO_2, CH_4 and N_2O
GVW	Gross Vehicle Weight – Replace by MAM
GWP	Global Warming Potential
HCV	Heavy Commercial Vehicle – also known as HGV – over 3.5t MAM
HGV	Heavy Goods Vehicle – also known as HCV – over 3.5t MAM
ICE	Internal Combustion Engine – Petrol/Diesel/Gas
LCV	Light Commercial Vehicle – Van – up to 3.5t MAM
MAM	Maximum Authorised Mass – replaces GVW Gross Vehicle Weight.
NAEI	National Atmospheric Emissions Inventory – Transport Factors
NPV	Net Present Value
OEM	Original Equipment Manufacturer, e.g. Ford, Nissan, Toyota etc.
OLEV	Office of Low Emission Vehicles
PHEV	Plug-in Hybrid Electric Vehicle
PM	Particulate Matter – associated with wide range of human illness
RCV	Refuse Collection Vehicle (eRCV - electric RCV)
REEV	Range Extended Electric Vehicle
SoC	State of Charge – how much charge is left in the battery.
TTW	Tank to Wheel
ULEV	Ultra-Low Emission Vehicle
VED	Vehicle Excise Duty – also called Vehicle Tax.
VRM	Vehicle Registration Mark – also VRN - Number
WLC	Whole Life Cost
WTT	Well to Tank
WTW	Well to Wheel

1. Executive summary

Colchester Borough Council (CBC) has sought this report to assess the efficiency of its vehicle fleets in terms of greenhouse gas (GHG) emissions, energy consumption and operating cost. The analysis was undertaken by the Energy Saving Trust (EST) using CBC data.

The report identifies any of CBC's heavy commercial vehicles (HCVs) that could be replaced by zero or ultra-low emission models. A separate report covering vehicles of 3.5t MAM or less has already been provided to CBC in June 2020. In July 2019, CBC declared a climate emergency and set the target of Colchester being carbon-neutral by 2030. In its Climate Emergency Action Plan, it identifies its own vehicle fleet as accounting for 1,383 tonnes of Scope 1 emissions in 2018/19 which was 22% of its total emissions for that year.

During the 12 months ending 31st March 2020 CBC operated 51 HCVs and items of plant, including 31 refuse collection vehicles (RCVs). Based on the data sets that CBC have supplied, we estimated these HCVs/items of plant:

- drove at least 289k miles,
- produced an estimated 920 tonnes of greenhouse gases - carbon dioxide equivalent (CO_2e)
- consumed an estimated 3,746-megawatt hours of energy,
- emitted up to 843 kgs of nitrogen oxides (NO_X),
- emitted up to 8.8 kg of particulate matter (PM),
- was 65% clean air zone compliant.

Added to the sub 3.5t fleet - profiled in an earlier report the overall summary for the CBC fleet is that it

- drove at least 859k miles,
- produced an estimated 1,167 tonnes of greenhouse gases - carbon dioxide equivalent (CO_2e)
- consumed an estimated 4,758-megawatt hours of energy,
- emitted up to 1,555 kgs of nitrogen oxides (NO_X),
- emitted up to 17.74 kg of particulate matter (PM),
- was 37% clean air zone compliant.

This report focuses on the opportunities to introduce Ultra Low Emission Vehicles (ULEVs) in the HCV fleets. In the period reviewed, the HCV fleet consisted of 32 RCVs, 11 large trucks mostly operated by the Waste and Recycling department and nine items of plant (mostly sweepers).

Of the 32 RCVs, five were listed as "back-up" vehicles and one of these returned no mileage or fuel use data. 27 of the 32 CBC RCVs have been replaced within the last 18 months, meaning that the RCV fleet is a very modern fleet and only the five "back-up" vehicles do not comply with the latest Euro VI (trucks) emission standards. This is reflected in the high level of clean air zone (CAZ) compliance, with 87% of the fleet passing the CAZ standard, which is a very high percentage for a council fleet not operating in an active Clean Air Zone. As a result, most of the RCV fleet is not due for replacement until 2026/27, at which time the whole fleet could be switched to battery electric power, which should reduce GHG emissions of the RCV fleet by at least 80% (570 tonnes per year) depending on the UK grid carbon intensity at that time.

The 11 large trucks (with a MAM of 7.5t) are older and consequently likely to be replaced in the next 12 months or so. Whilst we are not currently aware of any OEM 7.5t trucks, we believe the Mitsubishi Canter will be available from 2021 and there are third party REEV conversions of OEM chassis available from companies such as Tevva and Paneltex. Based on the data provided, it is feasible that vehicles could be switched to battery electric power, which should reduce GHG emissions of the LCV fleet by at least 68% (95 tonnes/year) upon adoption, with savings increasing as the grid decarbonises, to at least 109 tonnes by 2030. However, detailed daily mileages (from tracking data) were not available and CBC should compile this data and analyse this data to ensure a conversion to electric is possible in all cases, or if a mix of pure electric, and REEVs or diesels will be necessary.

CBC also operate nine items designated as Plant and these include 7 Sweepers (four compacts and three mediums) and two waste loaders. Electric sweepers are now available from several manufacturers, for example, Johnson, Boschung and Schmidt have offerings which between them cover sub compact, compact, medium and large sweepers sectors. Adopting electric sweepers will cut emissions from that section of the fleet by approximately 80% but those organisations who have already adopted them have received grant funding to offset the higher initial purchase costs.

When assessing the operation of ULEVs we use a whole life cost (WLC) model which includes the cost of funding and operating the vehicle. ULEVs are more expensive to buy but cheaper to fuel and maintain and so a WLC model is the most accurate way to compare them with their diesel equivalents.

As our previous report on the sub 3.5t fleet has demonstrated, as at June 2020, small and medium electric vans are usually no more expensive to buy and operate than diesel vans, when assessed from a WLC perspective, and the same typically applies to electric RCVs (eRCV) when the operational life is optimised. It is more difficult to replace, larger commercial vehicles (excluding RCVs) with a MAM of between 3.5 tonnes and 26 tonnes with ULEV in the present market however that will change over the next five years.

There are now viable eRCVs in a range of size options from both Electra/Mercedes and Dennis Eagle. The manufacturers of these vehicles promote the mechanical simplicity and long operating life of the electric version. With a small fraction of the moving parts in the electric drive train, both Electra and Dennis Eagle suggest their eRCVs can have an operational life of ten years whereas most diesel RCVs, often supplied by the same companies (Electra has a partner leasing company) are written off after seven years.

The eRCVs on order for the City of London (Electra) Manchester City Council (Electra) and Nottingham City Council (Dennis Eagle) have all been costed on a ten year model and the cost includes a residual value for the battery which can have a long second-life as a static battery in an energy storage array. The large batteries are modular in design and can be refurbished. No residual value is assigned to the chassis and rig but that may be unduly pessimistic when the long lifecycle of electric drive components is considered.

We have modelled the WLC of eRCVs on a ten-year lifecycle and compared that with a seven plus three-year lifecycle for the diesel RCVs. Based on the 27 newer vehicles (all supplied with Dennis Eagle telematics) CBCs waste fleet is essentially split between two mini fleets. The first comprises of twelve 26t Twinpack Dustcarts driving low mileage (c.4,600 average) and achieving average mpgs of c2.6 mpg, and the second comprising of fifteen 26t Dustcarts with various different backs multiple averaging c.11,500 miles and achieving just over 4mpg.

If all 27 vehicles were converted to eRCV and using best estimates for the cost of fuel and energy for the next ten years, we believe the eRCVs would save at least £612k and reduce carbon emission by up to 6,360 tonnes (80%) over their lifetime. By 2030 the eRCV GHG emissions will be 90% less than an equivalent diesel, as carbon produced from the generation of electricity to charge the vehicles reduces.

We have input the results from the eRCV model into the HM Treasury Green Book tool for assessing the net present value (NPV) of projects in terms of GHG reduction, energy reduction and air quality improvement. The results of this suggest that the overall benefit to society of introducing eRCV over its lifetime could be £700k. When combined with a cost saving of between £612k the overall lifetime benefit is significant and could be up to £1.3m.

Electric Vehicle Charging Infrastructure (EVCI) at the depot (or other sites where charging may occur) and the site's power supply capacity is critical to the ability to charge such a large fleet of vehicles equipped with 300 kWh batteries. Using RCV tracking data we believe it will be possible to charge the RCV fleet at one site if the capacity of that site is at least 526 Kilo-volt-amperes (kVA). An accurate assessment can only be made once the first electric RCVs are on site and in regular use – they will need to be closely monitored.

The bulk of the RCV fleet has recently (2019 and 2020) been renewed and so there is time to resolve EVCI issues and build towards an all-electric fleet when the next cycle of replacement occurs in 2026/27.

In the future, managing the fleet will involve playing a role in the management of the site electricity supply and possibly even the local grid. Systems that predict when it will be best to charge EVs, based on surplus renewable generation, and provide a financial incentive for doing so, are already being piloted in the consumer market (e.g. Octopus Agile tariff). On a few occasions in 2019, consumers have been paid to charge their vehicles because it costs less than paying wind farms to curtail generation. Well-integrated data systems, fully integrated into the operation of electric vehicles and that are able to fully report on charging and battery data, will be critical to running a low-cost, low-emission electric vehicle fleet

The whole CBC fleet could be well placed to take advantage of the emerging market in electric cars vans and heavy vehicles providing it can ensure a good power supply at its main depot and other sites it wishes to charge at. If it cannot, CBC should explore its options such as adding additional sites and capacity or even consider allowing appropriate (smaller) vehicles to be taken home, in order to free up capacity at its own sites for the larger vehicles. From 2026, we would expect all replacement vehicles in all but the most specialist sectors to be battery electric powered.

2. Summary of recommendations

Item	Recommendation	Difficulty	Risk	Estimated % CO_2e reduction	Estimated annual £ saving (cost)	Estimated annual emission reductions[1]		
						CO_2e (tonnes)	NO_X (kg)	PM_{10} kg)
1	Establish available power supply and current baseline usage on a half hourly basis at each site where charging is planned	Low	Low					
2	Replacement of diesel RCVs with electric RCVs at next replacement cycle. Monitor energy consumption and charge times.	Moderate	Moderate	70% to 90%	Full fleet £61.2K	Full fleet 636t	COPERT 5[2] 2,681 kg NO_X 5.45 kg PM	
3	From 2022: Replacement of 7.5 tonne and all other HCVs as models become available. GHG reduction increase over time as grid decarbonises.	Moderate	Moderate	70% to 90%	Full Fleet Cost Neutral	Full Fleet 110t		

[1]CO_2 Carbon dioxide, NO_X Nitrogen oxides, PM_{10} Particulate matter under 10 microns. Air quality emissions are based on performance of average vehicle in an urban area and are indicative only.

[2]COPERT is the EU standard vehicle emissions calculator, developed for the calculation of road transport emissions. It has been used for the RCV fleet emissions analysis. https://www.emisia.com/utilities/copert/

3. Emissions and energy use

The carbon dioxide (CO_2e) footprint (often shortened to carbon footprint) details the tonnage of carbon dioxide that Colchester Borough Council (CBC) road transport has emitted during 2019. The 'e' in CO_2e stands for 'equivalent' and indicates that the estimate includes the other reportable greenhouse gases (GHG) emitted by the fleet (methane and nitrous oxide) expressed in terms of their carbon dioxide equivalence. For example, one tonne of nitrous oxide (N_2O) has a global warming potential (GWP) 265 times that of carbon dioxide and is therefore equivalent to 265 tonnes of CO_2. The GWP of methane (CH_4) is 28 (GHG Protocol, GWP Values).

The CO_2e estimate is based on tank to wheel (TTW) factors. This means that it does not include CO_2e emissions relating to the extraction, refining and distribution of the fuels, known as well to tank (WTT) factors, nor does it include the manufacture and disposal of the vehicles. No matter what type of vehicle, or engine technology is used the carbon emissions from burning a litre of diesel (for example) will always be the same. WTT and TTW factors can be combined to give well to wheel (WTW) values.

The footprint for the fleets (Table 3-1) is based on the fuel and mileage data CBC have provided. We have calculated this footprint using the 2019 GHG conversion factors published by the Department for Business, Energy & Industrial Strategy (DBEIS). The methodology complies with international GHG reporting standards. The average gCO_2e/km has been omitted for fleets where mileage and fuel or kWh data was missing.

Table 3-1: *GHG reporting: scope, fleet size, mileage, CO_2e emissions and energy consumption*

Vehicle Fleet	GHG Scope	Fleet size	Annual mileage	CO_2e (tonnes)	Energy (MWh)	Average gCO_2e /km
RCV – Refuse vehicles	1	31	217,014	715	2,911	2,443.8
HCV ≤ 7.5 tonne	1	11	69,515	139	564	1,176.8
Plant – Sweepers / Tractors etc	1	9	2,813	66	271	-
Totals		**51**	**289,342**	**920**	**3,746**	**1,810.3**

Table 3-2 shows the methodology we have used to determine the carbon dioxide emissions and energy used. This is an indicator of the quality of the data: Method 1 is the most accurate and Method 5 the least accurate. A full description of GHG Reporting and the EST Transport Methodology is available on request.

Table 3-2: *Method used for calculating the carbon footprint as a percentage of fleet size*

Vehicle Fleet	Method 1	Method 2	Method 3	Method 4	Method 5	No Data
RCV – Refuse vehicles	100%	0%	0%	0%	0%	0%
HCV ≤ 7.5 tonne	100%	0%	0%	0%	0%	0%
Plant – Sweepers / Tractors etc	100%	0%	0%	0%	0%	0%

A full description of the EST GHG emissions and energy use calculation methodology is available on request.

The expectation is that the analysis of all directly operated fleets including trucks, vans and fleet cars is based on fuel burnt (Method 1).

Air quality

Every litre of fuel burnt or mile driven is also associated with emissions of nitrogen oxides and particulates. These are much harder to measure as they depend on the vehicles average speed, load, its usage cycle, its fuel type, the Euro emission category, the engine technology, and the effectiveness of the exhaust clean-up system.

We have determined the data in Table 3-3 using the average emissions of a 2018 UK car, LCV (van) or HCV (including the RCVs) adjusted for the area of operation (urban) as published by the National Atmospheric Emissions Inventory. This analysis is based on fleet mileage and cannot be determined from fuel data.

Table 3-3: *Estimated annual emissions of nitrogen oxides (NO_X) and particulate matter (PM)*

Vehicle Fleet	NO_X (kg)	PM (kg)
RCV – Refuse vehicles	644.4	6.68
HCV ≤ 7.5 tonne	191.2	2.04
Plant – Sweepers etc	8.4	0.09
Total	**843.9**	**8.81**

A more accurate assessment of the air quality impact would require the use of the COPERT V5 model and much more detailed usage data. Specific fleets such as the RCVs will have very high emissions due to their slow operating speed, low engine temperatures and stop/start operation; this is not reflected in the above figures. The data also assumes an average fleet profile and the CBC fleet is much newer than the UK fleet average with far more Euro 6/VI vehicles in the van and heavy good fleets so, with the exception of the RCVs, it is likely the rest of the fleet will have lower emissions than estimated above.

Overview of the Emissions and replacement strategy for the whole fleet

Whilst this report focuses on the heavier vehicles and items of plant operated by CBC and a separate report detailing the emissions of the sub 3.5 tonne fleet has already been issued, it is we believe useful for CBC to have a view of the fleet where both sections of the fleet are summarised together.

Table 3-4: *GHG reporting: scope, fleet size, mileage, CO_2e emissions and energy consumption*

Vehicle Fleet	GHG Scope	Fleet size	Annual mileage	CO_2e (tonnes)	Energy (MWh)	Average gCO_2e /km
RCV – Refuse vehicles	1	31	217,014	715	2,911	2,443.8
HCV ≤ 7.5 tonne	1	11	69,515	139	564	1,176.8
Plant – Sweepers / Tractors etc	1	9	2,813	66	271	-
LCV - Large	1	30	238,174	139	567	377.1
LCV - Medium	1	11	65,480	21	87	210.4
LCV - Small	1	7	35,292	12	51	150.1
Car	1	29	231,571	75	307	213.5
Totals		**128**	**859.859**	**1,167**	**4,758**	**1,666.4**

If a local authority has responsibility for refuse collection, the RCV fleet is usually a significant source of transport GHG emissions. Typically, it is between 30% and 40% of the fleet total, with the remaining two thirds split equally between the grey fleet and the rest of the council's fleet. We have not been given the data on the grey fleet so this has not been included in the Table 3-4 above or in figure 3-1 (overleaf). Based on the data supplied by CBC the split between RCV and the rest of the council's fleet is approximately 60/40, but CBC should consider the grey fleet when looking at its transport emissions to understand the whole picture.

Table 3-4 shows that the RCV fleet emits five times as much CO_2e as either the large van or HCV ≤ 7.5 tonne and nine times as much as the car fleet. Clearly, the RCVs need to be addressed if CBC wishes to make real progress towards a zero emissions fleet. Figure 3-1 (overleaf) shows this gap graphically.

Figure 3-1: *Carbon dioxide emissions (tonnes) (Scope 1)*

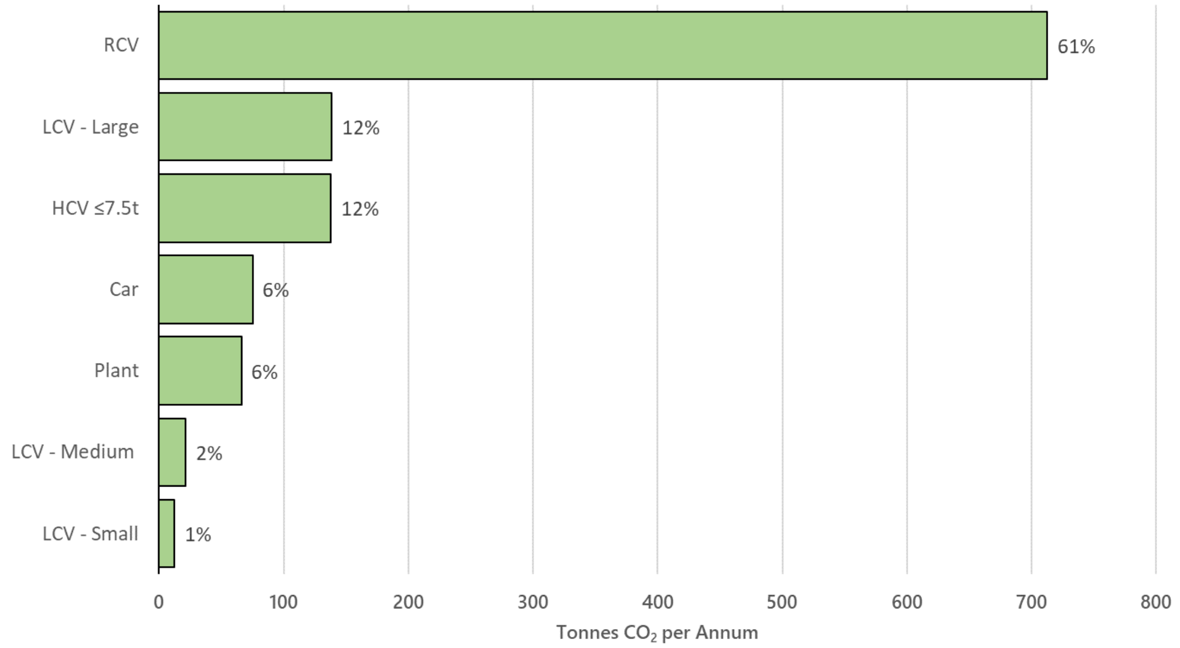


Table 3-5: *Analysis of fleet size, mileage, carbon emissions and energy use.*

Vehicle Fleet	% Size	% Mileage	% Carbon	% kWh
RCV	24.2%	25.2%	61.3%	61.2%
HCV ≤7.5t	8.6%	8.1%	11.9%	11.9%
LCV - Large	23.4%	27.7%	11.9%	11.9%
Car	22.7%	26.9%	6.4%	6.5%
Plant	7.0%	0.3%	5.7%	5.7%
LCV - Medium	8.6%	7.6%	1.8%	1.8%
LCV - Small	5.5%	4.1%	1.1%	1.1%

The biggest environmental impact is from the RCV fleet, which whilst only 24% by number, accounts for 61% of GHG emissions. The sub-fleets with the next largest impact are the HCV ≤7.5t and the Heavy LCV fleet, both of which emit 139 tonnes but the HCV ≤7.5t travels only a third of the distance the Heavy LCV fleet does.

***Figure 3-2**: Targeting fleets for GHG reduction – Average annual GHG emissions per vehicle.*

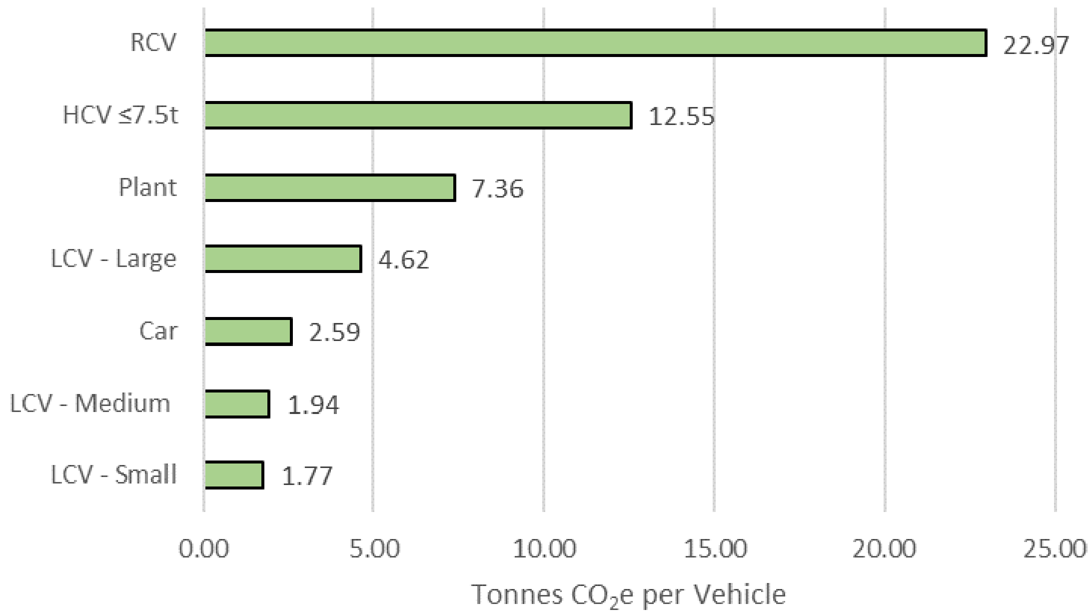


Figure 3-2 shows the average annual emissions of a vehicle in each category and therefore illustrates the annual GHG reduction associated with replacing one vehicle with a zero-emission alternative. Replacing one RCV is equivalent to replacing over five large vans or nine cars. An electric RCV (eRCV) costs about £380,000 while an electric 3.5t van currently costs about £60,000 and a car about £25,000 so five electric 3.5t vans or nine cars would cost £300,000 and £325,000 respectively – so on balance, CBC can achieve a slightly better return on investment by replacing more of the smaller vehicles for less overall expenditure for the same carbon saving. However, given the total CO_2e produced by the RCV fleet, unless CBC does tackle the RCV fleet it is only taking account of 40% of its transport emissions.

So, we would suggest that CBC (if replacement cycles allow,) target the smaller vehicles for replacement first and then once these have been successfully electrified, target the larger fleet beginning with RCVs. we would suggest that planning for the RCV to be replaced by eRCVs begins now, as electrifying the whole fleet will have significant impact on the electricity supply needed, and how/ where it is supplied.

4. Achieving Net Zero Transport by 2030

CBC declared a Climate Emergency (CE) in July 2019 and has set itself the objective of being a "net zero" borough by 2030.

DBEIS data (Appendix B) shows that since 2014, UK electricity grid GHG intensity has fallen from 494 gCO_2e per kWh to 233 gCO_2e per kWh, a reduction of 53% and it is expected to fall much further. The Committee for Climate Change (CCC) and DBEIS suggest that by 2030 the grid GHG intensity could be as low as 100 gCO_2e/kWh and the move to renewables will reduce other generation emissions such as SO_X, NO_X and PM.

Electric vehicles are significantly more energy efficient than internal combustion engine (ICE) vehicles and we estimate that the energy use (MWh) of an all-electric fleet will be at least 75% less than the equivalent ICE fleet. Table 4-1 shows that an all-electric CBC fleet (excludes the grey fleet and plant) charged from the UK Grid in 2030 will reduce CBC transport energy use by 75%, energy costs by 73% and GHG emissions by 91%.

Table 4-1 shows the estimated effect of the electrification of the vehicles under review in this report.

Table 4-1: *Impact of electrification of the CBC Heavy fleet on GHG emissions and energy use (2020 prices).*

Factor	ICE - 2019	BEV - 2030	Change	Reduction
Energy (MWh)	3,746.3	749.3	-2,997.0	-75%
Energy Cost (£)	£367,398	£98,272	-£269,125	-73%
GHG Emissions (t)	916.4	82.4	834.0	-91%

The effect of electrification on the whole fleet, including the sub 3.5t vehicles examined in a previous report would be is shown in table 4-2.

Table 4-2: *Impact of electrification of the whole CBC fleet on GHG emissions and energy use (2020 prices).*

Factor	ICE - 2019	BEV - 2030	Change	Reduction
Energy (MWh)	4,757.8	951.6	-3,806.3	-75%
Energy Cost (£)	£466,564	£124,807	-£341,756	-73%
GHG Emissions (t)	1,163.8	104.7	1,059.1	-91%

If charged from the UK Grid, the fleet will still be associated with about 83 tonnes of GHG emissions for just the heavy fleet and 105 t for the whole fleet, but over the next ten years CBC should evaluate investing in its own "private wire" renewable photovoltaic or wind generation capacity, as well as on-site storage so that the fleet can achieve net zero in 2030.

We believe it should be possible for the whole vehicle fleet to be zero emission by 2030 and a large part of the fleet could move to zero emission by 2025 (see previous report on the sub 3.5t fleet.)

The urban heavy commercial vehicle (HCV or HGV) market has developed more rapidly. By the end of 2020 it is possible that at least two and possibly three UK local authorities will be collecting domestic waste with fleets of 18/19-tonne and 26/27-tonne battery electric RCVs. Indications are that over a 10-year lifespan they are cost neutral and in clean air zones, where Euro VI diesels may incur access charges later in the decade, electric RCVs can make significant savings.

Specialist electric vehicles like gritters, road sweepers, welfare buses and fire tenders are also available or being developed and at least three electric fire engines will be trialled in Europe in 2020. Thousands of single and double deck electric buses are already in use in the UK, Europe and around the world.

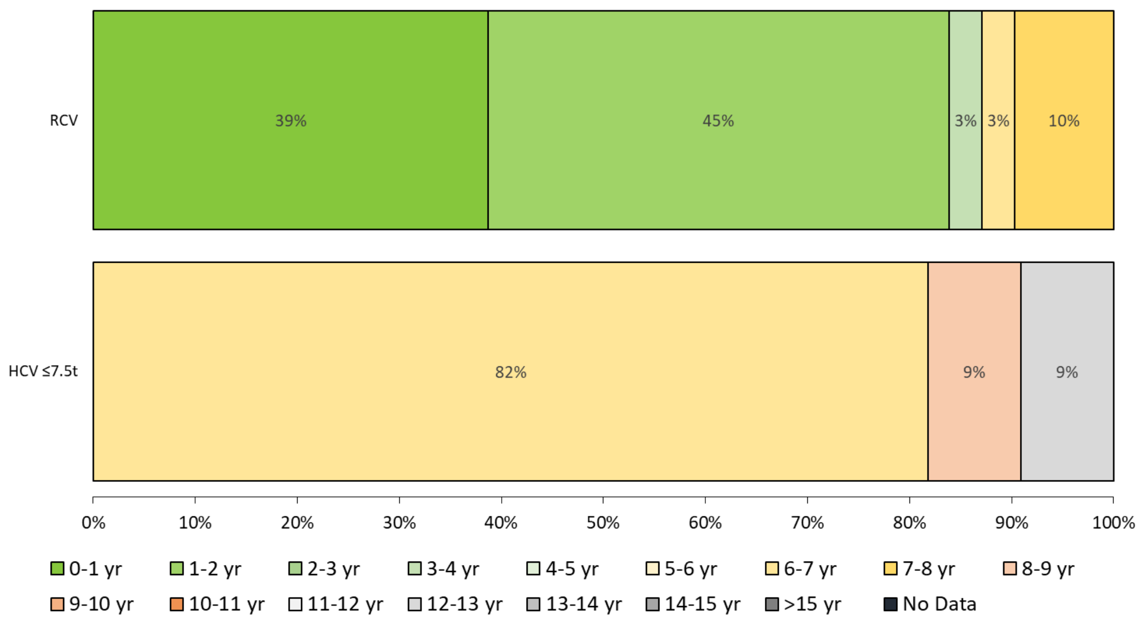
CBC should plan on having an all-electric fleet by 2030 and this has significant implications for the charging infrastructure at depots, offices and at employees' homes where vans may be parked overnight.

5. HCV Fleet profile

This section focuses on CBC heavy fleet (which is comprised of the HCV ≤7.5t fleet and the RCV Fleet. It excludes all vehicles on the CBC fleet under 3.5 t, (details of which may be found in our previous report of June 2020,) and items of plant, as the DVLA does not record the necessary data for us to undertake profiling.

5.1 Age distribution

Figure 5-1: *Age Distribution of CBC heavy fleet*



Vehicle age matters because it impacts adversely on:

- fuel consumption – old engines are less efficient,
- air quality – old engines are significantly more polluting,
- safety – not equipped with modern accident avoidance technology,
- reliability – much more likely to break down,
- service delivery – when they break down it can be very disruptive.

Table 5-1: *Table to show age distribution of CBC Fleet*

Fleet	Fleet size	Newest	Average	Oldest
RCV	31	0.2	1.8	7.4
HCV ≤7.5t	11	6.4	7.2	12.6

CBC operates its vehicles on a 7-year replacement cycle and clearly it also largely replaces different sections of the fleet in one transaction. The bulk of the RCV fleet has been replaced over the last 18 months and that the bulk of the HCV ≤7.5t fleet is due for replacement shortly. However, until they are replaced, this older section of the fleet is a concern for the reasons listed above.

5.2 Fuel types

Fuel type, in conjunction with the Euro emission standard, affects the emissions of two key pollutants: nitrogen oxides (NO_X) and particulate matter (PM). Both have a negative impact on air quality and public health.

The CBC RCV and HCV fleet is all diesel and this fuel type is usually the lower carbon, more energy efficient option, when compared to petrol, but for many years there have been significant concerns regarding the NO_X and PM emissions of diesel vehicles especially when they are used at low speeds in urban areas. The failure of the Euro 6/VI standard to reliably address those concerns means that in urban areas diesel is not the fuel of choice, especially if a zero-emission option is available. Across Europe city administrations are considering or planning diesel bans and, in the UK, Bristol (amongst others) has announced a ban on diesel cars. These restrictions will ultimately impact on all diesel vehicles including those complying with the Euro 6/VI standard and may adversely affect their residual value.

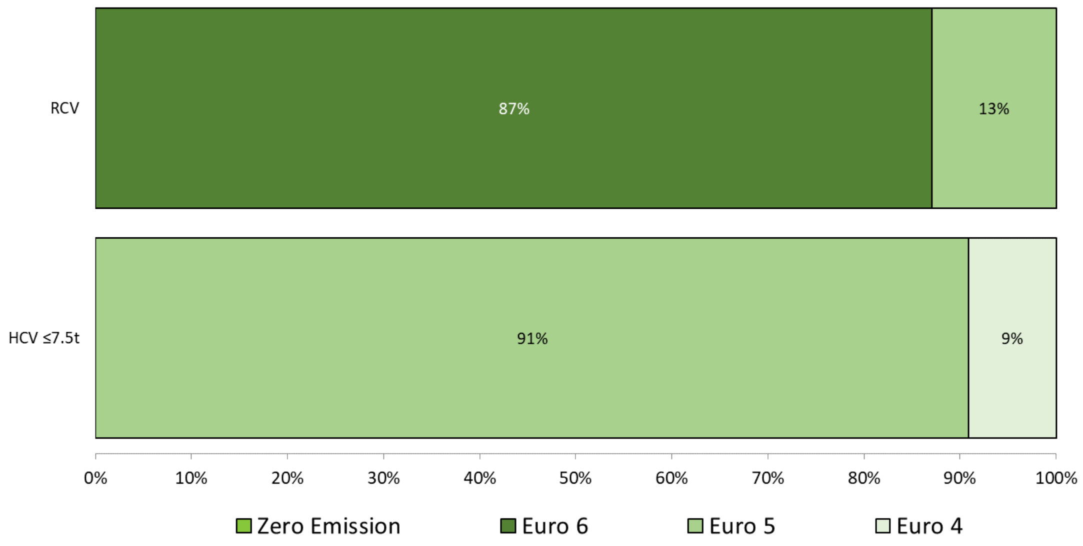
A range of "alternative" commercial vehicle energy sources are now available including battery electric, compressed natural gas, liquid natural gas, natural gas-diesel dual fuel, liquid petroleum gas, gas to liquid diesel, hydrogen-diesel dual fuel, hydrogen ICE and hydrogen fuel cell.

All have their strengths and weaknesses and very careful consideration must be given to all the environmental impacts, independently assessed "well-to-tank" GHG footprint, real world carbon intensity, indirect land use change, energy efficiency and cost associated with each fuel source before making a switch.

Whilst all of the vehicles profiled in this report are currently diesel, in the medium to long term, the heavy fleet could all be transitioned to battery electric vehicles, in some cases achieving cost savings as well as emission reductions.

5.3 Euro emission standard

Figure 5-2: *Euro Emissions distribution of CBC heavy fleet*



The Euro standard is a measure of the air pollution emissions from a vehicle; the Euro standard scheme does not regulate the GHG emissions. From a public health perspective, the two key vehicle pollutants are NO_X and PM but emissions of carbon monoxide (CO) and volatile organic compounds (VOC) are also regulated and these can have a significant impact on health if used in confined spaces, carbon monoxide can be fatal.

There are different Euro standards for petrol and diesel engines with diesel engines consistently permitted to be more polluting. As a result, a 2006 Euro 4 petrol car meets the same emission standard as a new (2020) Euro 6 diesel. Standards for cars and LCVs are numbered Euro 1 to 6 and emissions are measured in milligrams per kilometre driven, standards for HCVs are numbered Euro I to VI and the emissions are measured in milligrams per kWh of engine output because of the different vehicle configurations available.

LCVs (vans) were the last market sector to be required by regulation to meet the Euro 6 standard in September 2016 so this is the sector which often has the lowest proportion of Euro 6 vehicles.

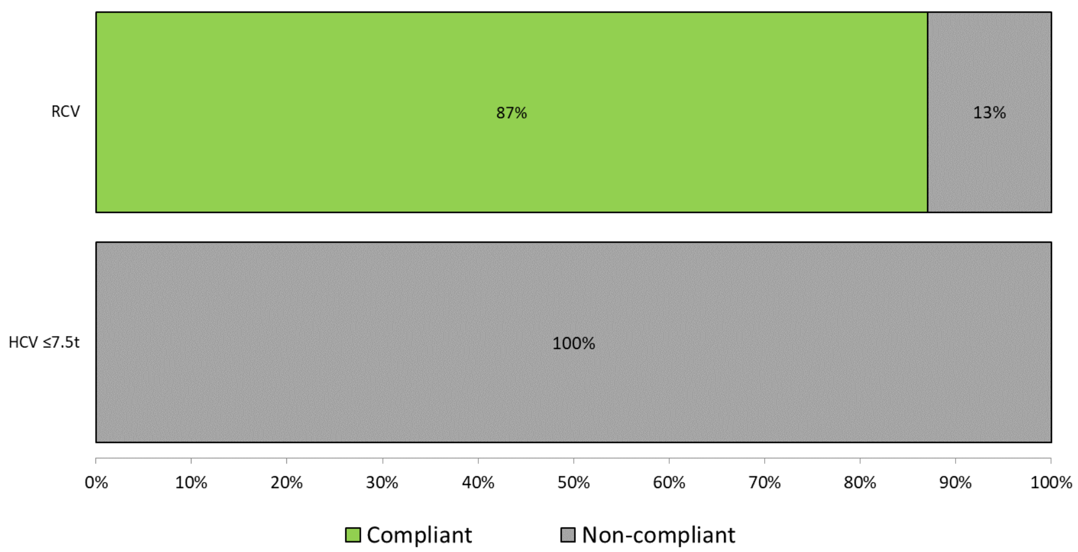
Battery electric vehicles are zero emission (DVLA still records them as Euro 6/VI but we show them separately as ZE) however, like all vehicles, they will produce particulates from both tyres and brakes as well as recirculated road surface debris. Brake dust production may be reduced by regenerative braking, but this could be offset by the greater weight of the BEV's batteries increasing tyre wear. In the future the expectation is that non-exhaust emissions will become the main source of air pollution in urban areas.

The CBC RCV fleet has a very "clean" fleet by ICE standards with only 4 vehicles out of 31 not meeting the Euro VI emission standard. The next step is to transition the fleet from fossil fuel internal combustion engines to zero tailpipe emission electric vehicles which should be achievable over the next five to seven years as the vehicles in the current fleet come to the end of their operational life with CBC.

Though smaller than the CBC RCV fleet, its HCV ≤7.5t is not as "clean" with none of the 11 vehicles currently meeting the fleet the Euro VI emission standard. The next step is (at the very least) to meet the Euro VI emission standards, by the procurement of the latest ICE vehicles, or even to exceed them by either transition of the fleet from fossil fuel ICEs to zero tailpipe emission electric vehicles.

5.4 Low emission/clean air zone compliance

Figure 5-3: Notional Clean Air Compliance of CBC heavy fleet



Across the UK, local authorities have implemented or are considering implementing low emission zones (Scotland), clean air zones (England and Wales) or an ultra-low emission zone (London).

To avoid paying a charge to enter these zones, vehicles must meet these minimum emission standards:

- Petrol engine: Euro 4 (Euro IV HCVs),
- Diesel engine: Euro 6 (Euro VI HCVs),
- Battery Electric or Hydrogen Fuel Cell (zero emission).

According to Public Health England there are 75 premature deaths each year in the CBC area attributable to particulate (PM) pollution with 811 life years lost.

Colchester has also three current air quality management areas all as a result of NOx emissions.

Whilst we acknowledge CBC is not considering introducing a CAZ, the emission standards used in a CAZ are, nevertheless, a useful guide as to what can be considered a clean fleet. CBC compliance in the fleet profiled in this report (RCVs and HCVs) is 65%, whilst CBCs overall compliance (including the sub 3.5 T fleet) is 57%.

6. Fleet data management

Central to any well-managed fleet is good data management. Fleet operators and service managers must have up-to-date, comprehensive, accurate, and accessible data on all the vehicles in use by an organisation, their drivers, their energy (litres or kWh) consumption and the business mileage driven. This applies regardless of the ownership of the vehicles (purchase, lease, spot hire, contracted, private) or the period of use.

Where commercial vehicles are involved, it is also important to have information about the work done (e.g. load carried, waste collected, bins emptied, households serviced, repairs completed, passengers carried) so that the performance of a fleet and its environmental impact can be linked directly to the level of service it has delivered.

Systems have been widely available for some time to monitor bulk fuel tanks, track off-site fuel purchase with fuel cards, manage fleet workshops, manage the fleet itself, and track all vehicle operations. The quality of these systems is variable, some have not kept pace with developments in vehicle technology, and there is often a failure to fully integrate the data from all these different sources. As a result, fleet managers – who are usually not IT specialists – are often "data rich but information poor". Microsoft's Excel is often the tool in which all the information from all these systems is collated and integrated and that can be time consuming, lead to inaccuracies and is dependent on the Excel skills of the user.

In local authorities there is a further level of complication in that the data from fuel card purchase or vehicle tracking may be held by central finance or by the operating department and not the fleet management team and so no one management team has a real-time overview of the fleet, its energy consumption, energy efficiency and GHG emissions.

All the information required for this review should be readily available to the fleet manager, the service delivery manager and, with electrification of the fleet, the energy manager.

The National Gird Electricity System Operator (ESO), working with partners, has already developed and published an open system called the "Carbon Intensity API" which publishes the predicted carbon intensity of the grid up to two days in advance in half hour periods. In the future a forecast like this may be used to adjust the price paid for electricity by lowering the cost when renewable generation is high and increasing the cost when fossil fuel generation is high. This has the aim of modifying consumer behaviour as well as the activity of "smart" appliances and vehicle charging systems. Accurate real-time data will be essential to efficient, low cost, low emission operation of an all-electric fleet.

6.1 Quality of data set at CBC

The fleet team was able to supply both fuel and odometer mileage data for almost all the Heavy fleet and it has been used to determine energy efficiency (miles per gallon or miles per kWh). Where we had concerns over the accuracy of the mileage data (especially in respect to plant) these issues have not impacted on the accuracy of this report in terms of GHG emissions as fuel data was available on which to base the GHG calculations.

CBC was unable to provide telemetry data for either the plant or the HCV ≤7.5t fleets but was able to provide it for the RCV Fleet. This allowed the routes to be mapped and out-of-area journeys to be identified. The council however was unable to supply half-hour electricity consumption data for the depot which, when combined with tracking data, allows an estimate of the required capacity for charging a future all-electric fleet to be made. We recommend that CBC urgently redresses this and begins to monitor it electricity consumption data.

6.2 Fleet energy and mileage data management

Overall CBC has good fleet data systems in place, but consideration should be given to better integration of fleet management, departmental fleet management (e.g. waste vehicle tracking) and energy management systems. This should allow all the key management teams involved: fleet operations, service delivery and council energy management to have a complete overview of transport operations without excessive manual data processing. It is important they can all quickly generate the reports they need to ensure efficient operation of the fleet, reliable service delivery and optimum energy use with minimum cost.

The move to an all-electric fleet will require new monitoring systems such as charge management software and these new systems should be able to exchange data and make reporting on fleet performance a straightforward process providing quick access to management information.

During periods of very high renewable generation and low demand some energy suppliers whose consumers have the required smart metering have offered a negative electricity cost because it is more cost effective to pay consumers to use electricity than to pay wind or solar generators to curtail generation. The electric vehicle charging system must be able to respond to this information so that periods of low carbon intensity that occur outside the normal charging hours can be utilized if the vehicle is parked and plugged in.

A large fleet of electric vehicles, some with 300 kWh batteries, is a large “sink” for surplus renewable generation and could play an important part in balancing the UK’s electricity system as well as absorbing any excess capacity from on-site generation. However, this will only work with good data systems providing accurate real-time data about the fleet and its current “status”.

6.3 Information management review – Recommendation

CBC, like many councils, would benefit from a comprehensive review of all the data systems in place to track and monitor the fleet including bulk fuel tank software, integration of any fuel cards, fleet workshop and fleet management software, EV charging infrastructure, on-board tracking systems and service delivery systems. The review should consider both the operational needs of today’s ICE fleet as well as the future requirements of a ULEV fleet – assumed to be mostly, if not entirely, electric.

7. HCV and RCV fleets

7.1 The RCV Fleet - Electrification

The refuse collection vehicle (RCV) fleet consist of 31 vehicles which average 8,513 miles per annum and achieve 3.4 miles to the gallon with a range from 2.0 to 4.7 mpg. With a gallon costing about £4.72 this means these vehicles cost about £1.39 per mile for fuel alone. Electric RCVs are available and their use is considered in full in this section.

Until very recently the only practical alternative to a Euro VI diesel RCV was a Euro VI compressed natural gas (CNG) vehicle. While natural gas vehicles can achieve GHG reductions (over 80% if fuelled with locally sourced “private” biomethane) and might improve air quality (the published scientific evidence for this is ambiguous) the refuelling infrastructure is expensive and from 2019/20 biomethane drawn from the UK gas grid cannot be counted as low carbon for GHG reporting purposes even if it is supported by Renewable Transport Fuel Obligation certificates (see notes on REGO and RTFO certificates). The same restriction applies to green electricity drawn from the UK electricity grid. In both cases the benefit of the renewable gas or electricity has already been accounted for in the calculation of the UK gas or electricity grid emission factor and it cannot be counted and claimed twice.

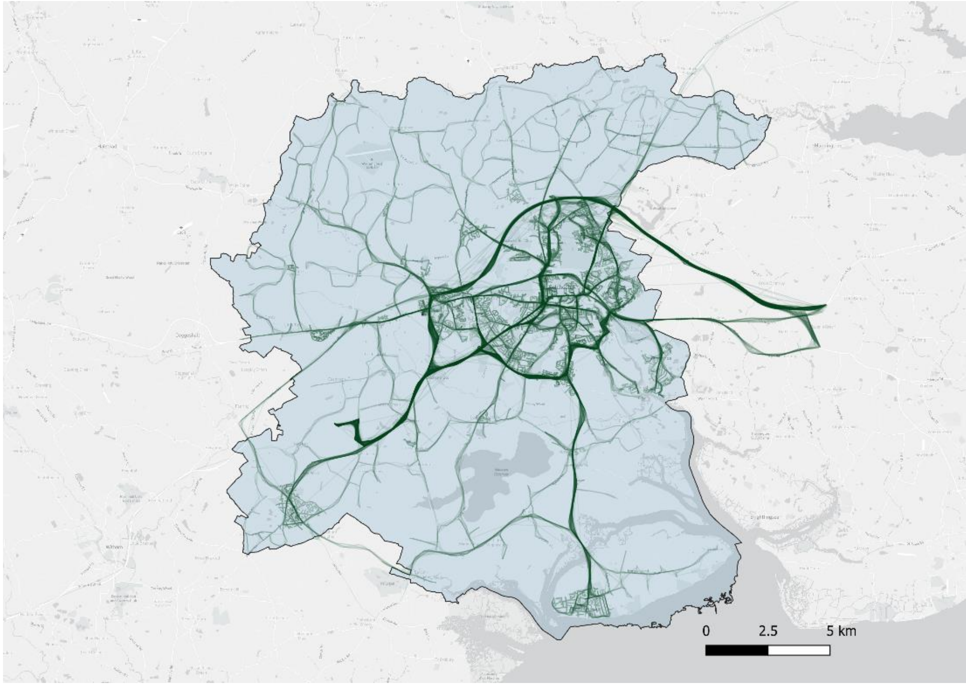
In 2018/19 Electra introduced a prototype all-electric eRCV based on a 26 tonne, three-axle Mercedes Econic chassis. During 2019 the chassis and rig was widely trialled around the UK in several cities. In Manchester it was operated by Biffa on the City Council domestic contract for over six months. There, the Electra eRCV was 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) and all the data was made available to EST. The 200-kWh 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. It is fully supported by Mercedes who provide a glider chassis pre-prepared for the electric power train direct from the factory in Germany.

Also available is the Dennis Eagle eCollect, which is a 300-kWh battery electric version of the company’s popular 26 tonne “Narrow” model. It has been extensively tested with local authorities by Dennis Eagle and will go into limited production in 2020 and full production in 2021. Its capital cost and operating costs are very similar to the Electra model. Two eCollect will go into service with Nottingham City Council in 2020.

The City of London (Veolia) and Manchester City Council (Biffa) are planning to use substantial fleets of the Electra eRCV in its 18 tonne (2-axle) and 26 tonne (3-axle) versions from late 2020 onwards. In the analysis of both business cases there was considerable uncertainty about the future cost of diesel, carbon taxation of diesel, the introduction of road pricing and whether Euro VI diesel vehicles would still be permitted to enter a clean air zone without charge beyond 2025 (London) or 2027 (Manchester).

The reduction in GHG emissions from using e-RCVs is substantial even when charged from the UK grid. In the first year (2020) it should be at least 70% but by 2029/30 the decarbonisation of the UK grid is expected to have increased the annual reduction in GHG emissions to at least 90%.

__Figure 7-3__: Tracking of RCV operations



The tracking data for the RVs show that they mostly stay within the CBC boundaries, only travel out of area to visit specialist repair centres. The exception to this is traveling along the A120, apparently to visit Ardleigh South Services.

Because they have a compact area of operations, we have modelled the replacement of all RCVs in use at CBC. These vehicles average 8,500 miles per annum and achieved an average of 3.4mpg. Poor mpg in a RCV fleet is not unusual and 3.4 mpg is in the "normal" range.

After discussion with Dennis Eagle, Electra and the three authorities planning to operate eRCVs in 2020 we now model all electric RCVs on a 10 year life cycle as experience with a range of BEVs suggests they will be significantly more reliable than the diesel vehicles which are usually operated over a seven year lifecycle. The data shown below is based on 10 years of an eRCV fleet and 7 years of a diesel RCV fleet plus another 3 years – so the first three years of average annual costs associated with the next new diesel fleet are added to the seven years. In the attached Appendix C we have also included models of both fleets with a 7 year lifecycle and with a 10 year lifecycle.

***Table 7-1:** eRCV – factors used in cost model*

RCV Factor	Electric	Diesel	Notes/Units
Year of Introduction	2021		
Operational (4.5 days per week)	260		Days per annum
Number of eRCV vehicles	27	27	Vehicles
Anticipated lifecycle	10	7+3	Years
Average annual mileage (eRCV)	8,513	8,513	Miles
Cost of energy in year one	£0.13116	£1.06	£/kWh, £/Litre
Fuel price inflation	3.24%	1.79%	From DBEIS
Residual value of the batteries	10%	-	EST Estimate

All data comes from Electra, Dennis Eagle, DBEIS or DfT national data sets. The eRCV has a significantly higher capital cost but that premium is expected to fall in line with falling battery prices. The batteries make up about £150,000 of the additional cost but Electra claim they will have a 30% residual value at the end of the vehicle's life if used in commercial battery storage arrays, we have used a more cautious 10% residual value.

***Table 7-2**: Capital costs of a fleet of electric refuse collection vehicles*

Capital Costs	Electric	Diesel	EV Cost (-Saving)	Notes
Vehicle Capital Cost	£380,000	£180,000	£200,000	Dennis Eagle
Residual Value (Chassis)	£0	£0	£0	BEV 0%, ICE 0%
ULEV Grant Funding	-£8,000		-£8,000	OLEV £8,000
Residual Value (Battery)	-£15,000		-£15,000	Estimated as 10%
Total Vehicle Cost	£357,000	£180,000	£177,000	
Over 10 year Project	£357,000	£257,143	£99,857	Diesels are 7+3
Fleet Capital Cost	£9,639,000	£6,942,857	£2,696,143	

[1]The OLEV grant for the first 200 ultra-low emission HCVs is £20,000 per vehicle. This then falls to £8,000.

The diesel vehicles using a 7+3 lifecycle still cost nearly £100,000 less to procure than the electric vehicles. The residual value of the battery may be a significant under-estimate as a 300 kWh battery in 2030 will still have a use for energy storage and the modular nature of the battery means it can be fully refurbished and reused on site. Electra has built a 30% residual value into its leasing model and that would reduce the cost of the BEV by a further £30,000. The ULEV grant of £20,000 for the first 200 vehicles over 3.5t is assumed to have been fully utilized by the time a purchasing decision is made and has therefore not been considered.

In Table 8-4, we have summarised the key elements of the WLC calculation. Whilst the initial capital cost of eRCVs is higher, once operating costs are taken into account, they can become more cost effective than diesel RCVs and even if refurbishment work on the waste collection rig is required at seven years there is headroom in the savings being made to fund this.

***Table 7-3**: Comparative whole life costs of an eRCV fleet (10 years eRCV, 7+3 diesel RCV)*

Cost Summary	Electric	Diesel	EV Cost (-Saving)	%
Total Vehicle Cost	£9,639,000	£6,942,857	£2,696,143	39%
Total Energy Cost	£1,323,505	£3,599,845	-£2,276,341	-63%
AdBlue Cost	£0	£56,129	-£56,129	-100%
SMR Cost	£1,215,000	£2,025,000	-£810,000	-40%
VED + Road User Levy	£0	£166,050	-£166,050	-100%
Total Cost	£12,177,505	£12,789,882	-£612,377	-5%
Charging Infrastructure	£324,000		£324,000	

Based on the data available we estimate a 27 vehicle eRCV fleet would save CBC £612,377 over a ten year period (£61,237 per vehicle per year) but this is very sensitive to factors such as the diesel price, introduction of a carbon tax, road pricing, diesel Euro VI CAZ charges and significant reductions in the off-peak cost of electricity including occasional negative pricing and local private-wire generation. The charging infrastructure is shown as a below-the-line cost because the expectation is that it will have a longer lifespan than the fleet and the cost of the diesel refuelling infrastructure is not included in the model.

***Table 7-4**: Energy Use and GHG Emissions of an ICE RCV and eRCV fleet over ten years*

Energy Use & GHG	Electric	Diesel	EV Cost (-Benefit)	%
Energy consumption (kWh)	8,169,148	32,676,591	-24,507,443	-75%
Scope 1 kg CO_2e	0	7,993,348	-7,993,348	-100%
Scope 1 AdBlue kg CO_2e	0	34,920	-34,920	-100%
Scope 2 kg CO_2e	1,535,426	0	1,535,426	100%
Scope 3 T&D kg CO_2e	132,046	0	132,046	100%
Total GHG Emissions	1,667,472	8,028,268	-6,360,796	-79%

Over the ten-year lifetime of the fleet using eRCVs carbon emissions will reduce by 6,360 tonnes and in the final year this reduction will be 90%. The eRCVs have no Scope 1 emissions from burning fuel and all the GHG emissions are Scope 2 from the generation of electricity and Scope 3 from transmission and distribution (T&D) losses

When the increased electricity usage and reductions in diesel consumption are input to the HM Treasury Green Book model for assessing the net present value (NPV) of the project in terms of GHG reduction, energy reduction and improved air quality, the total social benefit is valued at just under £0.7 million. With a potential c.£612k saving and a c.£700k social benefit adoption of eRCVs represents very good value for money.

7.2 Air quality improvements

The diesel RCV engine has significant emissions of both nitrogen oxides (NO_X) and particulate matter (PM) and these must be controlled using a selective catalytic reduction system (SCR) for the NO_X and a particulate trap for the PM. Both these technologies struggle to work well at the low exhaust temperatures associated with low speeds and with intensive stop/start operations. Table 7-5 below has been determined using the COPERT5 model for a Euro VI diesel operating at an average speed of 5 km per hour. This is a vehicle specific model and very different to the "Average UK HCV" values presented in Table 3-3.

Table 7-5: *Air Quality: Emission reduction over the operational life (10 years) of the ICE and BEV RCV fleets*

Factor	Electric	Diesel	EV Cost (-Saving)	Notes
NO_X kg/lifetime	0	26,811	-26,811	NAEI COPERT5
PM kg/lifetime	0	54.5	-54.5	NAEI COPERT5

7.3 eRCV Fleet Recommendation

CBC should actively pursue the option to implement an electric refuse fleet when the current fleet is due for replacement. The whole fleet should then be changed using a phased introduction, which should ensure a smooth transition to zero emission operation. We have assumed in making this recommendation that any potential issues in power supply are resolved by 2026. However, we also recommend CBC revisit the modelling nearer the point they wish to replace the fleet, to take into account any developments in the market.

7.4 The HCV fleet – opportunities for ULEVs

The rest of the heavy fleet (everything over 3.5t tonnes that is not a refuse vehicle) is very varied but includes eight 7.5 tonne Mitsubishi Fuso Canters with plastic tipper bodies operated by Waste and Recycling, three other assorted 7.5t trucks (one of which is used as a gritter) also operated by Waste and Recycling and Hall Keepers.

Mercedes Fuso did have a functional and practical battery electric version of the 7.5 tonne Canter known as the eCanter that worked well in extensive end-user trials offering a 62-mile range. But, in a classic example of "perfectionism is the enemy of progress", the Fuso eCanter is not currently available to order because it is being re-engineered to remove the conventional drive shaft and the rear axle and replaced with in-wheel motors. While this configuration reduces weight, improves efficiency, increases range and creates capacity for more batteries or greater load, it does mean that the vehicle will not be available until 2021 at the earliest and the opportunity to significantly reduce the GHG and air quality impact of the urban 7.5t fleet in 2020 has been delayed by a year. Various other OEMs have plans for launching electric vehicles within this size beyond this timescale.

Whilst there are currently no fully electric OEM models generally available, some small manufacturers currently produce 7.5t to 12t EV chassis that could be adapted to CBC needs. ULEV products exist from companies such as Paneltex and Tevva, that are available now to purchase or lease.

Mileages vary significantly between the HCV ≤7.5t fleet between circa 3,300 and 16,500 miles a year, giving an average across the fleet of 6,951. This is an average of 27 miles per working day, based on a 250-day working year. However, because we do not have telematics data or an accurate daily mileage pattern, we have chosen to model the (range-extended) Tevva REEV, rather than the Tevva EV.

The Tevva Motors Range Extender (REEV) has an OEM stated typical electric range of 93 miles, mated to a diesel engine, in case the vehicle runs out of electric charge. The vehicle can be fitted with any body type that a similar sized diesel chassis could be, with no payload penalty. This means that a box truck, drop-side, or tipper could all be specified. However, EST has seen no independent verification of the stated range, or of the stated power consumption figures supplied by Tevva and so we advise that if this option is explored by CBC, that CBC should test the vehicle thoroughly before any purchase. Similarly, CBC should be aware that the diesel generator (used to extend the range) is not subject to the same emission standards a diesel engine is subject to and so it is possible that it may produce considerably more NOx and PM than a Euro 6 diesel engine for the same amount of fuel burnt. This of course could be avoided by purchasing the EV (only) vehicle, and analysis of the CBC HCV ≤7.5t daily mileage will reveal if this is an option, or what the mix between full EV and REEV vehicles should be.

Whilst not a typical OEM product, this option warrants further investigation and discussion with the manufacturer, based on the following assumptions and table 7-6 shows a broad estimate of variable costs.

- VED is constant between vehicles and excluded from table
- Body costs are constant between vehicles and excluded from table
- Vehicles are operated for 10 years, but diesel vehicles are currently replaced after 7 years.
- Zero retained value after 10 years on the EV and 7 years on the diesel.
- Average diesel cost is £1.04/litre.
- Average electricity cost is £0.13116 p/kWh and REEV vehicle runs on battery power 80% of the time.
- Mileage is 7,000 per year, diesel fuel consumption is 5.9 mpg (CBC average)
- Electricity consumption for range extender in EV mode is estimated at 1.6 kWh / mile
- Assumed that 10% of Tevva's mileage is driven on diesel extender for purposes of maintaining the engine
- We have excluded maintenance from the table below, and whilst maintenance on a full EV is usually lower on a REEV, (based on our experience of REEVs in the sub 3.5t market) we have chosen to be conservative, assumed to be constant between the vehicles and have not shown it.

***Table 7-6**: Approximate cost comparison for 7.5t chassis (one vehicle)*

	Range Extender Chassis	Diesel Chassis	EV Cost (-Benefit)	%
Term	10	7+3		
Approximate Capital Costs (Chassis Only)	£80,000	£64,285	£15,715	19.6%
Est. Diesel Costs (10years)	£5,609	£56,093	-£50,484	-900%
Est. Electricity Costs (10 Years)	£13,218	£0	£13,218	100%
Est. Total Costs (10 years)	£98,828	£103,551	-£4,723	-4,8%
Annual Fuel / Depreciation Costs	£9,883	£10,355	-£472	-4.8%
Annual CO_2e emissions	4t	14t	-10t	-251.5%

Based on these broad assumptions, the use of a ULEV range extender appears to be slightly cheaper than using a diesel vehicle over a 10-year life span, at approximately £472 per year. However, this is very sensitive to changes in the cost of fuel or in diesel consumption. If the 7.5t diesel chassis was operating at the best mpg on the CBC fleet, it would be cheaper than the range extender over its lifetime by around £6,500 (£650 a year).

Based on these assumptions. CO_2e emissions could reduce by 10.0t per vehicle per year, but until we have more information about the diesel generator, we are unable to predict the impact on air quality emissions.

Tevva offer a short 3-6 month lease option to help prospective buyers evaluate the use of these vehicles in service. CBC could investigate this option and if possible, undertake a trial to better understand any operational issues and true running costs.

In the long term, increasing numbers of HCVs will be suited to replacement with EVs, from OEMs, especially where mileage profiles are not excessive and where vehicles return to a depot each night. Prices are expected to fall as products become more mainstream. Battery energy density and vehicle range is also expected to increase in the coming years.

7.5 HCV Fleet Recommendation

Subject to establishing that sufficient power is available, CBC should actively pursue the option to implement an electric HCV ≤7.5t fleet when the current fleet is due for replacement. CBC may choose to wait until the launch of OEM vehicles in 2022, but from that date the whole fleet should then be changed using a phased introduction should ensure a smooth transition to zero emission operation.

7.6 Plant

The CBC fleet includes one Schmidt Cityjet compact sweeper, three Johnson 201 compact sweepers and three medium Johnson 401 sweepers. There are also two waste loaders and two John Deere Gators (a small 4x4 quadbike style vehicle). The gators were not included in the Carbon Footprint, as neither mileage nor fuel data was supplied for them.

Whilst battery electric replacements for most of these vehicle types have become available, they are yet to become cost effective. Nottingham City Council operates a fleet of eight compact Boschung sweepers and Oxford Direct Services have just taken delivery of one. In both cases, the increased purchase costs of the electric sweepers (compared to the diesel models) were covered by grant funding. We have modelled the pricing below without any grant funding. We understand that because of the nature and use of the vehicle, it is usual for a council to operate them for a maximum of 5 years. CBC provided its utilisation figures in miles but it is usual for Sweepers to be assessed in operational hours. We have therefore modelled using hours.

- VED is constant between vehicles and excluded from table
- Retained value after 5 years is 5%.
- Average diesel cost is £1.04/litre.
- Average electricity cost is £0.13116 p/kWh
- Fuel use is 5.0 litres per hour for diesel and energy use is 10 kWh/hour for the electric version.
- Annual operational hours per year are 7,000 over the 5-year lifetime (5.6 hours a day for 250 days a year)
- Schmidt estimate the maintenance costs of an electric model being between 60% to 80% less than the equivalent diesel. We have estimated maintenance figures using the maintenance figure supplied for a compact sweeper by CBC for their diesel and reducing that by 60%.

Table 7-7 - *Approximate cost comparison for a Compact Sweeper (one vehicle)*

	Electric Compact	Diesel Compact	EV Cost (-Benefit)	% Increase
Term	5	5		
Approximate Capital Costs	£213,750	£66,500	£147,250	221%
Estimated Maintenance costs (5 years)	£14,640	£36,600	-£22,000	-60%
Est. Diesel Costs (5 years)	n/a	£36,400	-£36,400	
Est. Electricity Costs (5 Years)	£9,181	N/A	£9,181	
Est. Total Costs (5 years)	£237,571	£139,500	£98,071	70%
Annual Fuel / Depreciation Costs	£47,514	£27,900	£19,614	70%
Annual CO_2e emissions	3.58t	18.15t	-14.57t	-80%

John Deere produce an electric version of the Gator and details can be found here.

7.7 Plant Recommendation

CBC should actively pursue the option to implement electric vehicles across the rest of the fleet before attempting to adopt electric items of plant such as sweepers, unless they are able to obtain grant funding to offset the addition cost. For the smaller items of plant, CBC needs to begin to collect mileage and fuel data, so that a whole life cost analysis can be performed on the electric alternatives.

7.8 Maintenance training

For organisations with their own workshops, the Institute of the Motor Industry (IMI) provides an EV technician training programme. A full series of eLearning across two-day courses cover the key elements and the total cost is about £1,800 (less a discount for IMI members):

More information on EV technical training: Institute of the Motor Industry

8. Electric Vehicle Charging Infrastructure (EVCI)

8.1 Charging electric vehicles

On many sites, small-scale “fast” charging (7.4 kW) can use spare overnight site capacity to charge small fleets of battery electric cars and vans without the need for complex charge management systems. The use of in-vehicle timers, where fitted, can ensure that the local grid connection is not overloaded, and full advantage can be taken of lower, off-peak tariffs.

Ideally, vehicles should be charged overnight from 20:00 to 08:00 hrs, to avoid a negative impact on the local and national grid by charging during periods of peak use. It is therefore important that CBC negotiates low overnight and weekend off-peak tariffs for electricity at all sites, where electric vehicles may be based. It is also important to avoid charging weekdays during the 16:00 to 19:00 hrs peak period, when grid demand is at its maximum, grid GHG emission intensity is high, due to the use of gas generation, and the unit cost per kWh is also at its peak. However, if there is on-site generation for photovoltaic, that should be used if available.

With several battery electric vehicles on the fleet, the infrastructure cost can be spread, and it is very likely that large parts of the charging infrastructure will outlive the vehicles, especially the expensive cabling and groundworks. It is unusual for ICE vehicle whole life cost models to include the cost of onsite bulk tanks, the dispensing systems, the monitoring software, and their annual maintenance.

There are over thirty suppliers of charging infrastructure; ESPO offer a framework but it has a limited number of suppliers, Crown Commercial Service (CCS) have also released a framework https://www.crowncommercial.gov.uk/agreements/RM6213 and Nottingham City Council is also believed to be entering the market, based on its considerable experience of EV charging and vehicle operation.

A simple 7.4kW AC charger can be purchased for under £400 but the most sophisticated charge points with card scanner, 3G network connection, management software and full barrier protection cost about £1,800 for a two-port pillar. To this should be (typically) added a further £1,000 for installation, management software, billing systems and on-site support with about £250 of that cost being an annual expense.

Cars and vans up to 60 kWh battery size can be charged overnight in less than 12 hours with 7.4 kW AC chargers but eRCVs will require more expensive 40 kW DC chargers, or 3-Phase AC supplies for on-board AC chargers.

See the EST Guide to chargepoint infrastructure for more detailed information on EV charging systems.

8.2 Meeting the demand for EV charging – tracking data

Using the tracking data from the CBC fleet, we have been able to estimate the charging capacity needed to meet peak demand. That peak occurs when several vehicles return with a low State of Charge (SoC) which will happen on the longer trips, or trips with high energy use due to a large load (tonnes collected) or a large number of hydraulic movements (bin lifts and compactions).

Figure 8-1*: Profile of RCV journeys*

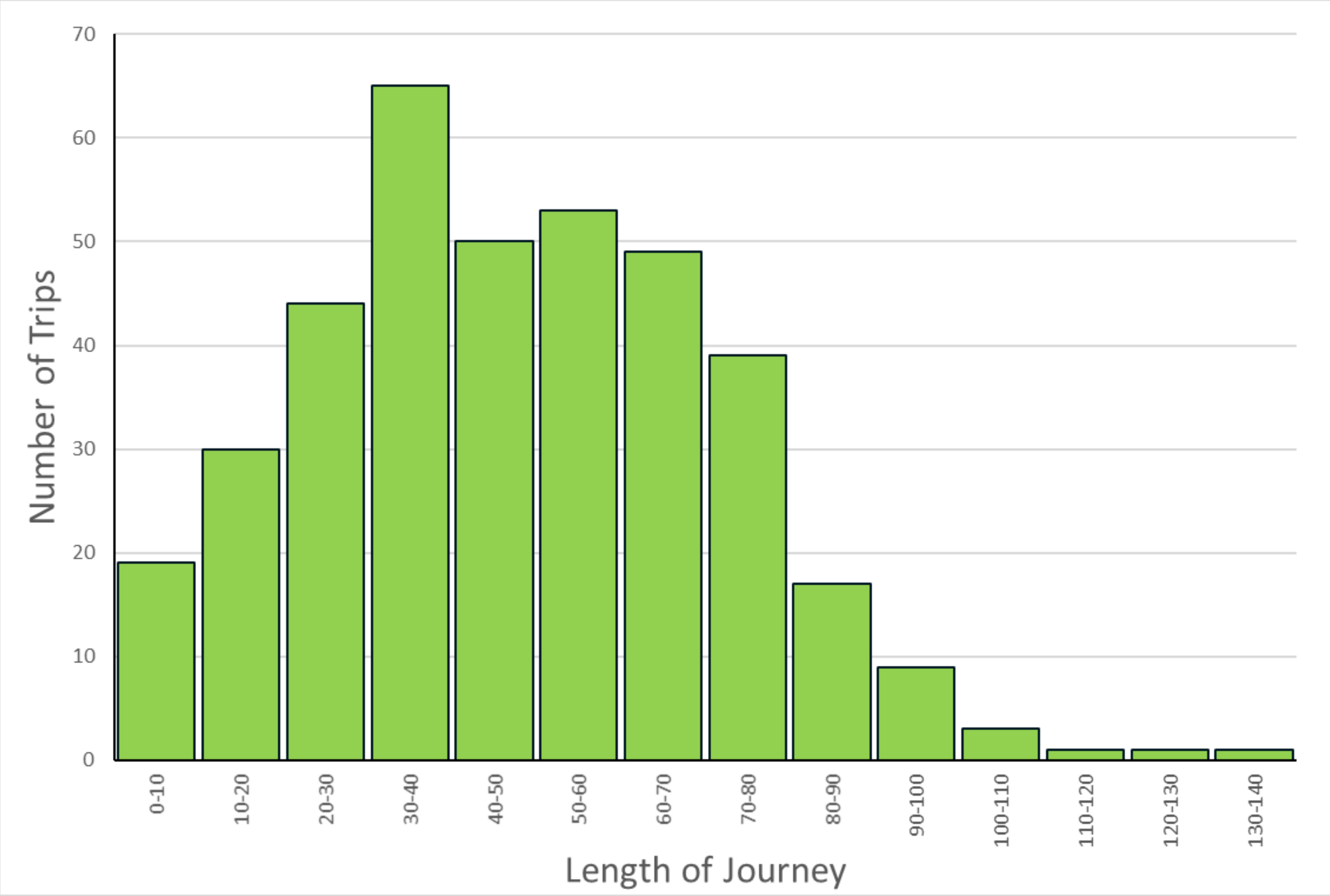
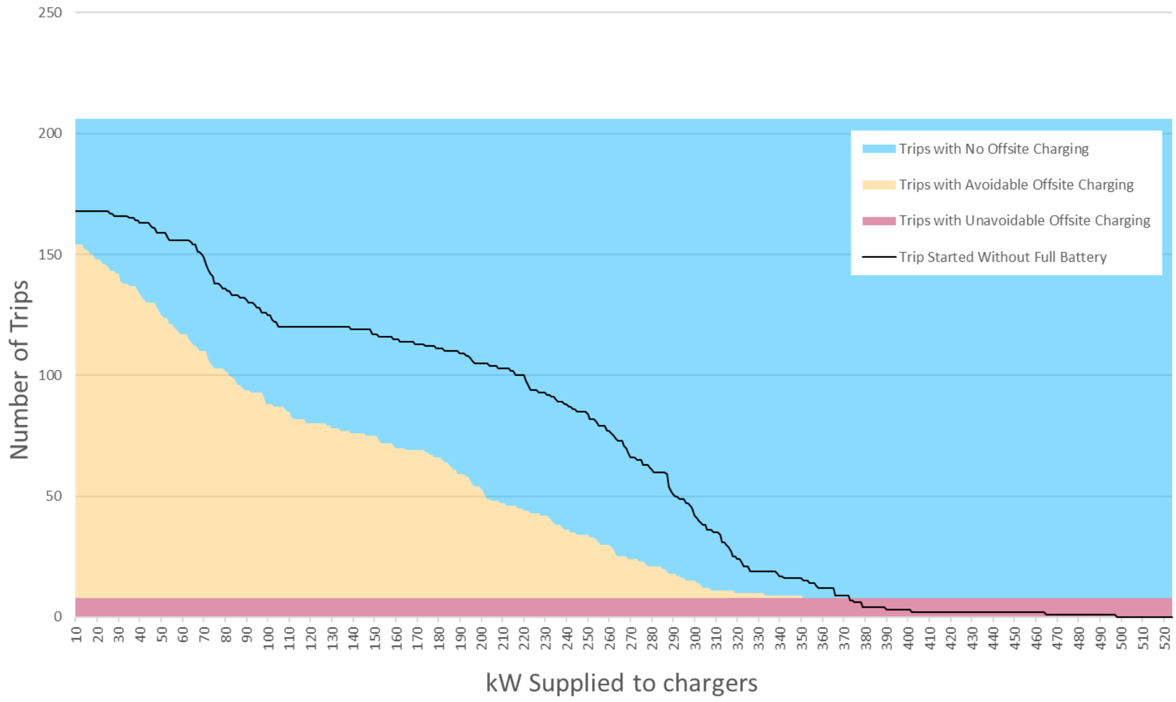


Figure 8-1 shows that there are a small number of trips that may be too long for a 300 kWh eRCV: including some by vehicle VX69YGG, which appeared to spend a long time at the Dennis Eagle factory, so it's trips may not be representative of normal use. These longer trips can be seen in Figure 8-2 which has a small number of "Trips with unavoidable off-site charging". These long-distance routes will require further investigation and it may be that with fewer stop/start operations, energy consumption would have been less than when making door-to-door street collections.

Figure 8-2: *Meeting the charge requirements by increasing the kW capacity of the site supply*



In the model vehicles were not permitted to charge between 16:00 and 20:00 weekdays but if they returned to the depot in the afternoon before 16:00 could charge up until that time. In the summer, if PV was available, there would be no reason not to allow vehicles to continue charging providing the capacity was coming from the PV – this will require a very smart management system and we have not tried to model this scenario.

There are several options for charging EVs. The simplest is to build sufficient site capacity (kW or kVA) to meet the simultaneous maximum demand for charging all the EVs from the grid connection at the full rate, supported by the charger regardless of the local "domestic" site load. This can be expensive, especially if it requires significant upgrades to the local grid infrastructure.

The alternative is to use some method of moderating the supply available to the chargers. This could be achieved by simply restricting the time when banks of chargers are operational or, with more sophisticated controls, limiting the power available to each charger and reallocating that capacity as vehicles are fully charged.

The issue with timed charging, which must be based on predicted need, is it that there is a higher risk of some vehicles not having an adequate charge to complete the follow day's workload if they return with a much lower than anticipated SoC.

It is also possible to link the management of the energy available for charging EVs to the site's "domestic" load so that the charging control system can maximise the current it draws as the load from the rest of the site falls. Each step-up in charger management requires more investment in the charging system but should avoid even more expensive capacity upgrades in the local grid and gives the fleet team greater visibility around demand and driver behaviour.

Using the model, we have determined the capacity required from four possible charging strategies. The first is the capacity required for all the chargers to operate simultaneously at full power – this is the simplest option and many vehicles will be fully charged in less than eight hours leaving unused capacity throughout the rest of evening. The second strategy considered assumes that all the vehicles return with 10% battery capacity and there is a charge management system in place to spread charging over the whole overnight period by restricting the capacity available to the chargers.

The third strategy uses the tracking data, considers the mileage driven by the vehicles during the day and determines the electricity (kWh) required to return the vehicles to a fully charged state. The fourth and final strategy is much riskier. It allows the vehicle to run down throughout the week by ensuring that each vehicle has enough power to complete the next day's workload and is only fully recharged over the weekend. This final strategy only works with a very predictable daily workload and does not accommodate changes made at short notice. It is a high-risk strategy and should only be considered if the site capacity is severely constrained, upgrade is very expensive, and the vehicles have a very predictable work pattern.

***Table 8-1**: Site capacity required by different charging strategies*

Strategy	Description	kW	Notes
1	Simple maximum capacity – all 100% charged	1,040	Very expensive
2	Smart - worst case – all 100% charged	533	Expensive as over 400 kVA
3	**All departures 100% charged**	498	**Optimal**
4	No unnecessary off-site charging, not all 100%.	351	High risk

It may be difficult to create the 500 kW of headroom predicted to be needed to fully charge the eRCVs overnight. We believe this may be a worse case estimate but only a long-term detailed on-site evaluation of an eRCV across all the CBC routes will determine that. Dennis Eagle have a policy of limiting the initial number of eRCV to two and these will provide all the data needed to confirm the impact of an eRCV fleet.

8.3 EVCI Recommendation

CBC will need at least 526 kVA capacity to charge a large fleet of electric RCVs (assuming a power factor of 0.95).

If the entire fleet (including the smaller vehicles covered in our earlier report) is moved to electric power, then even that capacity may not be sufficient and consideration should be given to other options like installing on-site battery storage or charging some of the fleet at other council sites, or, (for the smaller vehicles at least,) whether charging at employee homes is practicable and finally - probably as an option of last resort - a further upgrade of the site capacity which will be expensive.

Careful monitoring of new electric vehicles as they join the fleet will allow the estimate of future demand to be refined and a strategy developed long before the whole fleet has switched to electric power. All CBC EVs should all be equipped with on-board telemetry that is “EV-aware” and can report battery state of charge as well as total kWh received from charge points and distance travelled. This data needs to be linked to good fleet data management systems.

Appendix A: Renewable electricity and gas

Electricity Renewable Energy Guarantees of Origin (REGO) and Gas Renewable Transport Fuel Obligation (RTFO) certificates.

Many organisations have opted to have their grid electricity supplied from renewable sources backed by REGO certificates or grid biomethane backed by RTFO certificates.

The GHG emissions of the electricity or gas can be reported in line with the "market-based" (consumer) value calculated by the supplier (e.g. Zero gCO_2e/kWh if 100% renewable electricity) but it should be reported alongside the "location-based" (national) figure which is the actual GHG impact of the energy used.

This is because the zero-carbon benefit of the electricity or gas has already been accounted for in the national UK grid figure. The benefit cannot be taken twice as the grid carbon factor for other consumers would need to be adjusted upwards to compensate.

The requirement to do this is fully documented in:

HM Government: Environmental Reporting Guidelines (ERG): Including streamlined energy and carbon reporting guidance. March 2019, pages 48-49

"Where organisations have entered into contractual arrangements for renewable electricity, e.g. through Power Purchase Agreements or the separate purchase of Renewable Energy Guarantees of Origin (REGOs), or consumed renewable heat or transport certified through a Government Scheme and wish to reflect a reduced emission figure based on its purchase, this can be presented in the relevant report using a "market-based" reporting approach. ***It is recommended that this is presented alongside the "location-based" grid-average figures*** *and in doing so, you should also look to specify whether the renewable energy is additional, subsidised and supplied directly, including on-site generation, or through a third party.* ***A similar "dual reporting" approach should be taken for biogas and biomethane (including "green gas")."***

GHG Protocol, Scope 2 Guidance, Corporate Standard, Section 1.5.1, page 8

"Companies with any operations in markets providing product or supplier-specific data in the form of contractual instruments shall report scope 2 emissions in two ways and label each result according to the method: one based on the location-based method, and one based on the market-based method. This is also termed "dual reporting."

What is permitted is time specific emission factors. The HM Government ERG state:

"Where available, time specific (e.g. hour-by hour) grid average emission factors should be used in order to accurately reflect the timing of consumption and the carbon-intensity of the grid."

The carbon intensity of the grid varies throughout the day and the year. The grid data is publicly available in half hourly intervals, but organisations may have difficulty calculating this.

Where a company generates its own renewables on-site or locally, for example by using photovoltaic, wind with "private wire" or an on-site anaerobic digester and does not supply the grid it can be accounted for as a zero or low carbon supply.

Appendix B: UK Grid carbon intensity 2020-2030

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

Table B-1 shows:

- The DBEIS emission reporting factor for the year, which is about two years behind real-time emissions because of the verification process.
- 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 DBEIS projections from 2018.
- The average of the CCC and DBEIS data sets.

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

Year	DBEIS GHG Scope 2 Factor	Year on Year Change	Actual in year from Elexon Portal	CCC cost-effective path projection	DBEIS Energy and Emissions Projections	CCC - DBEIS Average
2014	494.26		415.7			
2015	462.19	-6%	364.2			
2016	412.04	-11%	277.1			
2017	351.56	-15%	247.1			
2018	283.07	-19%	227.8			
2019	255.60	-10%	204.3	218.8	201.5	210
2020	**233.14**	**-9%**	**161.3***	**210.8**	**189.1**	**200**
2021	*211.58*	*-9%*		199.5	184.3	192
2022	*192.51*	*-9%*		188.3	179.5	184
2023	*174.93*	*-9%*		177.1	174.7	176
2024	*159.06*	*-9%*		165.9	170.0	168
2025	*144.58*	*-9%*		154.6	165.2	160
2026	*131.44*	*-9%*		142.5	153.5	148
2027	*119.48*	*-9%*		130.3	141.8	136
2028	*108.62*	*-9%*		118.2	130.2	124
2029	*98.74*	*-9%*		106.1	118.5	112
2030	*89.77*	*-9%*		**93.9**	**106.8**	**100**

*January-June 2020 (includes impact of COVID-19). *211.58 = Projected future emission factors.*

When calculating the future emissions of an EV fleet it is important to use these predictions to ensure the potential carbon saving is fully assessed.

Appendix C: eRCV Lifecycle options

***Table C-1** -- Seven-year life cycle*

BASE DATA (from Model)	Electric	Diesel	Units		Notes
Annual Mileage (Fleet)	229,838		miles		From Fleet Data
Project Life	7		years		Lifespan of BEV - Max 10
Vehicle Lifespan	7	7	years		OEM Advice & Fleet policy
Fleet Size	27	27	vehicles		Fleet data
Annual Mileage/Vehicle	8,513	8,513	miles per annum		Fleet data
Energy Efficency	3.55	3.39	kWh/mile, mpg		EV derived from diesel kWh
Cost of energy/fuel	£0.131	£1.040	£/kWh, £/litre		Cost in 2020 (ex VAT)
Annual Inflation to 2030	3.24%	1.79%	Per annum		Based on DBEIS 2009-19
CAPITAL COSTS	**Electric**	**Diesel**	**EV Cost (-Saving)**		**Notes**
Vehicle Capital Cost	£380,000	£180,000	**£200,000**	**111%**	Electra/DE/Client
Residual Value (Chassis)	£0	£0	**£0**		BEV 0%, ICE 0%
ULEV Grant Funding	-£8,000		**-£8,000**		OLEV £8000
Residual Value (Battery)	-£15,000		**-£15,000**		Estimated as 10%
Total Vehicle Cost	**£357,000**	**£180,000**	**£177,000**	**98%**	
Over 7 year Project	£357,000	£180,000	**£177,000**	**98%**	From Lifespan
Fleet Capital Cost	**£9,639,000**	**£4,860,000**	**£4,779,000**	**98%**	
WHOLE LIFE COST MODEL	**Electric**	**Diesel**	**EV Cost -Saving**		**Notes**
Fleet Capital Cost	£9,639,000	£4,860,000	**£4,779,000**	**98%**	From Capital Costs
Fleet Energy Cost	£881,322	£2,452,259	**-£1,570,936**	**-64%**	Includes inflation
Diesel Fleet AdBlue Cost	£0	£39,291	**-£39,291**	**-100%**	No inflation applied
SMR (ex Tyres) Cost	£850,500	£1,417,500	**-£567,000**	**-40%**	OEM -40% to -60%
VED + Road User Levy	£0	£116,235	**-£116,235**		DVLA V149/1
Diesel Euro VI CAZ Levy	£0	£0	**£0**		Local CAZ Policy
Whole Life Cost	**£11,370,822**	**£8,885,284**	**£2,485,538**	**28%**	**£13,151**
Charging Infastructure	**£324,000**		**£324,000**		**Estimated**
ENERGY AND GHG	**Electric**	**Diesel**	**EV Cost -Saving**	**%**	**Notes**
Energy consumption (kWh)	5,718,403	22,873,614	**-17,155,210**	**-75%**	Model
Scope 1 kg CO_2e	0	5,595,343	**-5,595,343**	**-100%**	DBEIS Factors
Scope 1 AdBlue kg CO_2e	0	24,444	**-24,444**	**-100%**	DBEIS Factors
Scope 2 kg CO_2e	1,177,396	0	**1,177,396**	**100%**	DBEIS Factors
Scope 3 T&D kg CO_2e	101,256	0	**101,256**	**100%**	DBEIS Factors
Total GHG Emissions	**1,278,652**	**5,619,788**	**-4,341,136**	**-77%**	
AIR QUALITY	**Electric**	**Diesel**	**EV Cost (-Saving)**	**Speed km/hr**	**Notes**
NO_x kg/annum	0	18,767	**-18,767**	**5**	NAEI COPERT5
PM kg/annum	0	38.2	**-38.2**	**5**	NAEI COPERT5

Table C-2 – *Ten-year life cycle*

BASE DATA (from Model)	Electric	Diesel	Units	Notes
Annual Mileage (Fleet)	229,838		miles	From Fleet Data
Project Life	10		years	Lifespan of BEV - Max 10
Vehicle Lifespan	10	10	years	OEM Advice & Fleet policy
Fleet Size	27	27	vehicles	Fleet data
Annual Mileage/Vehicle	8,513	8,513	miles per annum	Fleet data
Energy Efficency	3.55	3.39	kWh/mile, mpg	EV derived from diesel kWh
Cost of energy/fuel	£0.131	£1.040	£/kWh, £/litre	Cost in 2020 (ex VAT)
Annual Inflation to 2030	3.24%	1.79%	Per annum	Based on DBEIS 2009-19

CAPITAL COSTS	Electric	Diesel	EV Cost (-Saving)		Notes
Vehicle Capital Cost	£380,000	£180,000	£200,000	111%	Electra/DE/Client
Residual Value (Chassis)	£0	£0	**£0**		BEV 0%, ICE 0%
ULEV Grant Funding	-£8,000		-£8,000		OLEV £8000
Residual Value (Battery)	-£15,000		-£15,000		Estimated as 10%
Total Vehicle Cost	**£357,000**	**£180,000**	£177,000	98%	
Over 10 year Project	£357,000	£180,000	£177,000	98%	From Lifespan
Fleet Capital Cost	**£9,639,000**	**£4,860,000**	£4,779,000	98%	

WHOLE LIFE COST MODEL	Electric	Diesel	EV Cost -Saving		Notes
Fleet Capital Cost	£9,639,000	£4,860,000	£4,779,000	98%	From Capital Costs
Fleet Energy Cost	£1,323,505	£3,599,845	-£2,276,341	-63%	Includes inflation
Diesel Fleet AdBlue Cost	£0	£56,129	-£56,129	-100%	No inflation applied
SMR (ex Tyres) Cost	£1,215,000	£2,025,000	-£810,000	-40%	OEM -40% to -60%
VED + Road User Levy	£0	£166,050	-£166,050		DVLA V149/1
Diesel Euro VI CAZ Levy	£0	£0	**£0**		Local CAZ Policy
Whole Life Cost	**£12,177,505**	**£10,707,025**	£1,470,480	14%	**£5,446**
Charging Infrastructure	**£324,000**		£324,000		**Estimated**

ENERGY AND GHG	Electric	Diesel	EV Cost -Saving	%	Notes
Energy consumption (kWh)	8,169,148	32,676,591	-24,507,443	-75%	Model
Scope 1 kg CO_2e	0	7,993,348	-7,993,348	-100%	DBEIS Factors
Scope 1 AdBlue kg CO_2e	0	34,920	-34,920	-100%	DBEIS Factors
Scope 2 kg CO_2e	1,535,426	0	1,535,426	100%	DBEIS Factors
Scope 3 T&D kg CO_2e	132,046	0	132,046	100%	DBEIS Factors
Total GHG Emissions	**1,667,472**	**8,028,268**	-6,360,796	-79%	

AIR QUALITY	Electric	Diesel	EV Cost (-Saving)	Speed km/hr	Notes
NO_x kg/annum	0	26,811	-26,811	5	NAEI COPERT5
PM kg/annum	0	54.5	-54.5	5	NAEI COPERT5

Energy Saving Trust
30 North Colonnade
Canary Wharf
London
E14 5GP
Phone: 020 7222 0101