energy saving trust

EST Fleet Review – Electric Refuse Collection Vehicles

Manchester City Council

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Data Analysis & Model Report Author	Tom Endacott
Project Manager	Chris Endacott
Peer Review Report	Helen Acott

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The Energy Saving Trust (EST) is an organisation providing a Fleet Support Programme funded by the Department for Transport (DfT). Our remit is to provide unbiased, pragmatic "best practice" advice that enables fleets to become energy efficient, reducing both costs and emissions.

Glossary of Terms

Abbreviation	Meaning
4WD	Four Wheel Drive
AfC	Agenda for Change – NHS grey fleet payments
ANPR	Automatic Number Plate Recognition
BEV	Battery Electric Vehicle
BIK	Benefit in Kind – taxation of company cars
CAZ	Clean Air Zone (England and Wales, excluding London)
CCC	Committee on Climate Change
CDV	Car Derived Van e.g. Ford Fiesta van
CHP	Combined Heat and Power generation
CNG	Compressed Natural Gas
DBEIS	Department for Business, Energy and Industrial Strategy
DVSA	Driver and Vehicle Standards Agency
eRCv	Electric Refuse Collection Vehicles
ESOS	Energy Saving Opportunity Scheme
EV	Electric Vehicle
GHG	Greenhouse Gas - Not just carbon dioxide
GTW	Gross Train Weight
GVW	Gross Vehicle Weight (see also MAM)
HCV	Heavy Commercial Vehicle
HDV	Heavy-Duty Vehicle
HGV	Heavy Goods Vehicle
ICE	Internal Combustion Engine – Petrol/Diesel/Gas
LCV	Light Commercial Vehicle – a van
LEZ	Low Emission Zone (Scotland)
LNG	Liquid Natural Gas
LWB	Long Wheel Base
MAM	Maximum Authorised Mass (new version of GVW)
MID	Motor Insurance Database
mpa	miles per annum
MPV	Multi-Purpose Vehicle

Abbreviation	Meaning
NCAP	New Car Assessment Programme - Safety
NEDC	New European Driving Cycle (replaced by WLTP)
NG	Natural Gas
NPV	Net Present Value
NTS	National Travel Survey
OEM	Original Equipment Manufacturer
OLEV	Office of Low Emission Vehicles
PHEV	Plug-in Hybrid Electric Vehicle
PSV	Public Service Vehicle (e.g. buses)
PTO	Power Take-Off
PV	Photovoltaic (electricity generation)
RCV	Refuse Collection Vehicle
RDE	Real Driving Emissions (RDE1 and RDE2)
REEV	Range Extended Electric Vehicle
SECR	Streamlined Energy and Carbon Reporting
SWB	Short Wheel Base
TTW	Tank to Wheel
ULEV	Ultra-Low Emission Vehicle
ULEZ	Ultra-Low Emission Zone (London only)
UW	Unladen Weight
VCA	Vehicle Certification Agency
VED	Vehicle Excise Duty
VRM	Vehicle Registration Mark
VRU	Vulnerable Road User
WLC	Whole Life Cost
WLTP	Worldwide Harmonised Light Vehicle Test Procedure
WTW	Well to Wheel
ZEZ	Zero Emission Zone

1 Executive Summary

This report was sought by Manchester City Council (MCC) to assess a proposal by vehicle manufacturer Electra and the council's waste collection operator Biffa to supply and operate twenty-seven 27 tonne electric Refuse Collection Vehicles (eRCVs) for ten years from 2020. This analysis was undertaken by the Energy Saving Trust (EST).

The work was focused on the cost and carbon savings over the period as well as the impact on other environmental factors such as energy consumption and air quality.

Based on the data supplied we estimate that:

- Greenhouse gas emissions will be reduced by between 7,069t and 9,354t
- Energy consumption would fall by between 27.8 MWh and 37.1 MWh
- Nitrogen oxide emissions will be reduced by up to 34,801kg
- Particulate emissions will be reduced by up to 71kg
- The eRCV fleet will cost from £0.25m and £1.29m more to operate (10 years).
- CAZ charges at 2020 prices could cost a diesel RCV fleet £700,000 each year.

Vehicle data was provided by Electra, operational data by Biffa and supplemental data by MCC.

The main uncertainty in the data set provided related to the amount of fuel used by the current Euro V refuse vehicles in a year; Biffa put this figure at close to 14,700 litres and MCC data suggested a lower figure of about 12,000 litres.

This difference impacts on the total carbon emissions as well as the total cost of fuel and is multiplied by the size of the fleet and the 10-year operational period. To accommodate this uncertainty, we have modelled both rates of consumption which is why a range of carbon savings, energy savings and costs have been given.

Other uncertainties include the future price of both diesel and electricity. Diesel pricing is very volatile and in the last ten years has been as low as £0.90 per litre and as high as £1.22 per litre (prices exclude VAT). The electricity price is less volatile and is not so influenced by international events. For both fuels, we have modelled an average annual increase based on price data from the last ten years.

Finally, there is considerable uncertainty about the future acceptability of Euro VI diesel engines operating in Clean Air Zones (CAZ). The HCV Euro VI standard is old (January 2013) and may not deliver the reductions in emissions hoped for. If that is the case it may be necessary for regulators to require a higher emission standard or to ban all diesel vehicles from the CAZ at some point in the period 2025 to 2030. This would clearly add significantly to the cost of operating a Euro VI diesel fleet as it must either be replaced early or pay zone entry fees.

Based on the data provided by Electra, Biffa and MCC and considering all the uncertainties, it would appear there is a strong case in favour of procuring electric RCVs. An eRCV has been operated by Biffa on all the routes proposed for the new vehicles and the operator is confident the eRCVs can deliver the service. The electric vehicle has also proved popular with the drivers and operatives.

The proposal will introduce a large fleet of electric vehicles to the council's operations and prepare the way for a future all-electric MCC refuse fleet which could be achieved by 2025.

In the worst-case scenario – low diesel usage and low diesel prices – the eRCV fleet costs £1.29m more over 10 years or £4,800 per vehicle per year. However, with high diesel use, the project would almost break-even over ten years and there is a strong possibility that future emission controls, higher diesel prices, carbon taxes and lower off-peak electricity prices would result in large costs savings.

The existing Euro VI diesel RCV fleet could continue to operate until 2025 covering collections on the green waste routes, the only service that proved a challenge for the evaluation eRCV because of the 20-mile trip to the tipping point. By 2025 battery prices will have fallen further, energy densities improved and eRCVs capable of servicing the green waste routes will be available. The Euro VI diesel fleet's chassis could be converted to electric, or new eRCVs purchased.

The projected additional costs of the project are lower than the net present value of the predicted energy and carbon savings (HM Treasury methodology), this is true with both high and low diesel usage. The project therefore represents value for money in terms of the carbon reductions achieved.

Introducing a large eRCV fleet is in line with the commitments made when MCC declared a "Climate Emergency" and, if combined with on-site photovoltaic (solar) electricity generation and battery storage, could result in zero-emission waste collection by 2030. The adoption of the eRCV fleet would be a significant step on the "Road to Zero" for MCC tacking a major component of the council's road transport emissions - both GHG and air quality.

2 Project background

Biffa has operated MCC's refuse collection fleet since 2015. When Biffa took over the operation of the fleet, it replaced approximately half of the RCVs with diesel Euro VI compliant vehicles.

The other half of the fleet is now nearing the end of its operational life and needs to be replaced in 2020. Biffa approached MMC with a thorough proposal to use electric RCVs (eRCV), supplied by Electra, instead of conventional diesel RCVs.

The proposed introduction of eRCVs is in line with several of MCCs aims and objectives, including acting to improve air quality and reduce greenhouse gas (GHG) emissions.

To support its proposal Biffa operated a fully electric RCV, manufactured by Electra, on a six-month-long trial. The trial covered all three refuse collection types (organic, recycling, and residual) and was very successful. The vehicle was able to complete all the rounds although it was at the edge of its range with organic waste collection due to the longer distance required to tip. Feedback from drivers and operators was very positive, despite initial scepticism.

Biffa engaged an electrical engineer to survey the two depots eRCVs would be based at to ensure charging would be possible. They then produced a detailed and well thought out cost model for the operation of the electric RCVs, and identified several key points for further discussion:

1. Euro VI is an old standard and may have a limited life in Clean Air Zones.
2. Vehicles could be leased avoiding high initial capital costs.
3. Existing Euro VI fleet could be retrofitted with an electric drivetrain.
4. External funding could be sought to support the project.

The Energy Savings Trust (EST) was asked to review the proposal, and to comment on the project. In order to do this, the impacts of adopting electric RCVs has been compared to the "business as usual" case of using conventional diesel RCVS.

3 Methodology

3.1 Overall approach

Biffa has identified 27 RCVs that need replacement, the two options for replacing these are either electric RCVs or Euro VI diesel RCVs. The whole life cost, carbon emissions, and air quality implications have been modelled for each option based on a 10-year operating period. Whole life cost modelling aims to account for the whole cost of operating a vehicle excluding staff and allows for high initial capital cost of eRCVs to be offset by reduced running costs. A full list of all the factors in the model can be found in Appendix A.

3.2 Capital costs

The capital cost of an electric RCV is approximately £200,000 higher than that of an equivalent diesel, as shown in Table 3-1. This cost model includes a £20,000 grant from the Office for Low Emission Vehicles [1]. Electra is currently in the process of gaining approval for this grant.

Table 3-1 – Initial capital costs of an electric RCV & diesel RCV.

Diesel RCV		Electric RCV	
Drivetrain and chassis	£90,000	Glider chassis	£65,000
		Electric drivetrain	£130,000
		Battery (287kWh) [2]	£120,000
RCV body	£46,000	RCV body	£46,000
Split lifter	£16,500	Split lifter	£16,500
Grant funding	£0	Grant funding	-£20,000
Total cost	£152,500		£357,500

Biffa engaged an electrical engineer to survey both the Hammerstone and Longley Lane depots who estimated costs of the required charging infrastructure at £150,000. There is also a cost in maintaining the bulk diesel tanks and associated management software required for the diesel fleet, this cost has not been included in the analysis.

At the end of these vehicles' predicted life, the batteries will still have a commercial value for use in other applications such as static energy storage where requirements for energy density (kWh per kilogramme) are not so high. Electra have agreed that they will repurchase the batteries at 30% of their initial cost (£36,000 each).

3.3 Tax and maintenance

The RCVs will be required to pay both vehicle excise duty (VED) and the road user levy (RUL). For a diesel RCV these are £300 & £315 a year respectively, for the electric RCVs these are both £0, as all zero (tailpipe) emission vehicles in all size categories are currently zero-rated.

Biffa report service, maintenance, and repair (SMR) costs for a diesel RCV to be an average of £5,000 per annum, this expenditure is weighted towards the latter part of the vehicle's life. Electric RCVs should cost less than this, in part due to a drastic reduction in the number of moving parts in the drive train of an electric vehicle. The reduction in eRCV SMR is conservatively estimated at 30%, which Electra agree is a reasonable figure, putting an electric RCV's average annual SMR at £3,500.

3.4 Electricity and fuel consumption

Electricity use is based on each eRCV using 80% of the charge in its 200kWh battery each day, and each RCV operating for 260 days a year. This usage is consistent with the trial data supplied by Biffa and represents a conservative estimate of the requirements for the test routes.

Biffa report the current annual fuel consumption of the diesel fleet is 14,774 litres annum. Data supplied by MCC shows the average fuel consumption of an RCV in 2018/19 was 11,492 litres, although Biffa believes this is due to a problem with the dataset itself. To account for this the model is run for two scenarios, one with Biffa's reported consumption of 14,774 litres per year, and one with 12,000 litres per year to represent the lower consumption in MCCs dataset.

The current Euro VI RCVs at MCC consume 17% more fuel than the Euro V RCVs they replaced so the fleet of new Euro VI diesel RCVs would see the same increase in fuel consumption.

[1] https://www.gov.uk/government/publications/plug-in-van-grant.

[2] A smaller 225kWh battery is available for £105,000.

3.5 Fuel price

The price of both electricity and diesel has been based on current rates. This is £1.05 ex. VAT per litre for diesel, and 10.35 pence per kWh for electricity (MCC cost at Hammerstone Road). The climate change levy has been added to electricity at 0.775 pence per kWh, which is the rate for 2021/22.

3.6 Fuel price increases

The cost of a litre of diesel and a kWh of electricity is can be expected to rise over the next 10 years. AA road fuel price data and QEP 3.1.2 were used to determine that the average annual price increases over the past 10 years of 1.79% for diesel, and 2.73% for electricity. The resulting prices, shown in Table 3-2, represent one of the largest sources of uncertainty in this project.

Table 3-2 - Predicted cost of electricity and diesel to MCC.

Year	Diesel £ per litre	Diesel £ per kWh	Electricity £ per kWh
2020/21	£1.069	£0.101	£0.114
2021/22	£1.088	£0.103	£0.117
2022/23	£1.107	£0.104	£0.120
2023/24	£1.127	£0.106	£0.123
2024/25	£1.147	£0.108	£0.126
2025/26	£1.168	£0.110	£0.129
2026/27	£1.188	£0.112	£0.133
2027/28	£1.210	£0.114	£0.136
2028/29	£1.231	£0.116	£0.140
2029/30	£1.253	£0.118	£0.143

The price of energy is subject to significant variation and diesel fuel is impacted by both international events and government taxation policy. Electricity prices are also impacted by factors such as the green levy and world gas prices. Diesel has been both much cheaper and significantly more expensive than it is today (November 2019) and that volatility in price means this is one area of the model that may significantly underestimate future costs.

3.7 Air quality impact

The COPERT5 model estimates that in the UK a 26-tonne Euro VI rigid diesel HCV travelling at an average of 5 km an hour will produce 7.2483 g km^{-1} of NO_x, and 0.0147 g km^{-1} of PM_{10} from the exhaust (data at: naei.beis.gov.uk/data/ef-transport). Non-exhaust PM from tyres and brakes has not been included in this estimate. Resuspension from the road surface is expected to be similar for both vehicle types and although tyre wear may increase with weight (the batteries add about one tonne to the unladen weight) the eRCVs should produce less brake dust due to the use of regenerative braking.

3.8 Greenhouse gas (GHG) footprint

GHG emissions from diesel RCVs are based on the litres of diesel consumed, the CO_2e emissions from burning a litre of diesel are relatively constant so there is no need to change this over the 10-year life of the RCVs. It is currently 2.594 kg CO_2e per litre of diesel. (see Appendix B)

Conversely, GHG emissions from a kWh of UK grid electricity are expected to continue to fall over the next 10 years. In order to address this reduction, we have used predicted emission factors from BEIS Energy and Emissions Projections (EEP) 2016 which we have corrected to bring 2019 in-line with the BEIS GHG factor for UK grid GHG emissions. This methodology puts the 2030 Scope 2 GHG emissions for UK grid electricity at 135.5 g CO_2e per kWh (see Appendix D).

All Euro VI diesel RCVs are fitted with a selective catalytic reduction (SCR) system in the exhaust to remove nitrogen oxides (NO_X), these use an additive known as AdBlue® (also referred to as Diesel Exhaust Fluid – DEF) which is a formulation of Urea. Diesel RCVs will release CO_2 from the reduction of NO_x by AdBlue®. Actual consumption of AdBlue® by MCCs Euro VI RCVs was not available so it's estimated at 3.5% of the diesel used by volume (this follows the current GHG reporting methodology), so for every 100 litres of diesel burnt we would expect a diesel Euro VI RCV to consume 3.5 litres of AdBlue® producing 0.762 kg of CO_2.

3.9 Clean air zone (CAZ) compliance

Manchester's councils are introducing a CAZ across the whole of Greater Manchester in 2021, both replacement options will meet the charge-free entry requirements for the 2021 CAZ. However, there is a significant risk that before 2030 the entry requirements for vehicles will need to be much stricter and, if diesel vehicles are still permitted, they will have to meet a more stringent emissions test than Euro VI which was first introduced for heavy commercial vehicles in January 2013. Therefore, there is a risk that 2020 Euro VI diesel RCVs may have to pay to enter the CAZ in the later part of their operating life, possibly from 2027 onwards.

4 Outcomes

4.1 Whole life cost

Under the two scenarios(Table 4-1), Biffa and MCC (see Section 3.4), the additional cost of the eRCV fleet varies between £0.25 million and £1.29 million respectively.

Under the Biffa scenario, the diesel RCVs consume an extra 878 thousand litres of diesel and 31 thousand litres of AdBlue®, increasing the WLC of the fleet by just over £1 million.

Table 4-1: Whole life cost of the electric and diesel RCV options.

Scenario	Fleet	Capital Cost [1]	VED & RUL	Grant funding & RBV [2]	Energy/Fuel Cost [3]	SMR	Total Cost
MCC	Electric	£10,342,500	£0	-£1,512,000	£1,598,877	£945,000	£11,374,377
	Diesel	£4,117,500	£166,050	£0	£4,448,440	£1,350,000	£10,081,990
Biffa	Electric	£10,342,500	£0	-£1,512,000	£1,598,877	£945,000	£11,374,377
	Diesel	£4,117,500	£166,050	£0	£5,476,771	£1,350,000	£11,110,321

[1] Includes infrastructure costs. [2] RBV = Residual Battery Value. [3] Includes AdBlue® used in diesel exhaust systems.

4.2 Greenhouse gas emissions

Table 4-2 details the predicted emissions of the 27 RCVs during their operating life. GHG emissions are given in tonnes of CO_2 equivalent, or CO_2e, and include the other GHGs emitted by the fleet (methane and nitrous oxide) expressed in terms of their carbon dioxide equivalence.

Operating the electric fleet saves between 7,069 and 9,354 tonnes of GHG emissions over the 10-year life of the vehicles. There are also significant NOx and PM_{10} savings, although these are likely to be an underestimate as they are based on average emissions for rigid 26-tonne HCVs not RCVs. This project presents opportunities for significant carbon savings, costing between £130 and £22 per tonne of GHG saved (MCC and Biffa scenarios respectively).

Although we have no reason to doubt either model, the energy consumption of the fleet under the Biffa model is closer to that seen in other urban refuse collection fleets.

The estimate is based on Tank to Wheel (TTW) factors and does not include other lifecycle CO_2e emissions relating to the extraction, refining and distribution of the fuels, known as Well to Wheel (WTW) factors, nor does it include the manufacture and disposal of the vehicles. The methodology is compliant with international GHG reporting standards.

Table 4-2: Fleet emissions and energy consumption.

Scenario	Fleet	Scope [1]	GHG emissions (tonnes CO_2e)[2]	Tailpipe NO_x (kg)	Tailpipe PM10 (kg)	Energy Consumption (MWh)
MCC	Electric	2 & 3	2,814	0	0	12,480
	Diesel	1	9,883	28,266	57	40,283
Biffa	Electric	2 & 3	2,814	0	0	12,480
	Diesel	1	12,168	34,801	71	49,595

[1] GHG reporting Scopes. [2] Includes 1 tonne of GHG emissions arising from the use of AdBlue in diesel exhaust systems.

4.3 Cost of savings

HM Treasury working with DBEIS, DEFRA, & DfT publish a toolkit that can be used assess the value of marginal (judged at national scale) changes in greenhouse gas emissions due to changes in energy use. Using this toolkit, the Biffa scenario has a net present value (NPV) of £2.021 million, the MMC scenario has an NPV of £1.431 million. Given the costs are below the NPV, this project represents good value for money. (see Appendix E)

5 Discussion

5.1 Uncertainty in the model

Price of fuel.

The predicted cost of diesel RCVs varies significantly with the cost of fuel; a one pence increase in the starting price of fuel results in a £51,000 increase in the cost of the diesel RCVs over the lifetime of the project.

This is also true for the eRCVs, the current depot electricity price (10.35 pence per kWh) was negotiated when the main demand at the site was during operational hours (9-5, Mon-Fri) – it is a low daytime rate. MCC staff and EST believe that this cost could be significantly reduced: a more typical overnight, off-peak, rate would be £0.08 per kWh – a reduction of one fifth on current daytime prices.

Carbon intensity of electricity

MCC plan to redevelop the Hammerstone depot, part of this redevelopment could include installation of photovoltaic (PV) electricity generation and battery storage. If the electric RCVs are partially charged from this their GHG emissions could be significantly lowered as this would be counted as a zero-emission power source. The time of charging also matters – see Appendix C for a full discussion of this issue.

Actual performance of the vehicles

There is a small risk, despite the extensive testing carried out by Biffa and Electra, that the electric vehicles will not be able to perform all refuse collection routes required. The organic routes, with longer distances to tip, are likely to be the most difficult for the eRCVs. Given that only half of the fleet is being electrified, these routes may need to be done with the current diesel Euro VI RCVs. When these are up for replacement, MCC will have more than enough data from operating eRCVs to assess if larger batteries are needed in the next group of replacement vehicles.

Changes in tax structure

There are several changes future governments could make that would impact on the cost of running the RCV fleet, these include:

- Re-instating fuel duty escalator.
- Introduce a carbon tax.
- Increase VED/RUL on diesel vehicles.
- Stop zero-rating electric vehicles.
- Introduce road pricing (taxation based on road usage and vehicle metrics).

Predicting change is difficult but in the event of a robust government response to climate change, it is likely that taxes on carbon-intensive fuels will increase in the next 10 years. This would further increase the cost of operating diesel RCVs.

Future clean air zone compliance

Implementing eRCVs is the least expensive option if Euro VI vehicles are charged to enter the Greater Manchester CAZ in the latter part of the decade. Based on current operations the 27 vehicles would be charged £702,000 a year in entry fees, two years of this would more than offset the increased costs in both scenarios.

The London ULEZ only guarantees entry for Euro VI vehicles until 2025, if TfGM use same time frame diesel RCVs would pay from 2027 onwards, costing over £2 million.

5.2 Road to zero emissions

A few years ago, electrifying a fleet of RVCs would have been a challenging proposal. Now, with the help of Biffa and Electra, there is a clear pathway to do so. With this project the "Road to Zero by 2030" is possible – electrifying the entire fleet, starting with these 27 vehicles. Reducing the GHG emissions further will require MCC to install to onsite PV and battery storage.

In electrifying this fleet, MCC and Biffa will hopefully learn a significant amount about the challenges present when implementing a fleet of large electric vehicles. The council can not only use this knowledge within their own fleets, e.g. when replacing the other half of the RCV fleet but may be able to help other large vehicle operators in Greater Manchester electrify their own fleets.

5.3 MCCs climate emergency declaration

On the 10th of July 2019, Manchester City Council formally declared a climate emergency, committing to become a "zero-carbon city" by 2038 if not sooner. Part of the declaration of a Climate Emergency included the commitment to:

"*Become carbon neutral by the earliest possible date."* - Notice of Motion - Climate Emergency, 10th July 2019.

Electrifying 50% of the refuse collection fleet represents a practical option to achieve this aim. Based on the evidence presented to us we believe this to be a low risk and cost-effective way of reducing GHG emissions in the short term and achieving zero-emission refuse collection in the long term if combined with PV and battery storage.

6 Appendices

Appendix A: Factors used in the eRCV model with sources

Variable Description	Model Value	Units	Source
Litres in a Gallon (also now the definition of a gallon)	4.54609	*litres per gallon*	*BEIS UK GHG Factors 2019*
Conversion factor miles to km	1.60934	*km per mile*	*Current definition of a UK mile*
Year of introduction of the new fleet	2020		*MCC*
Quantity of eRCVs to be introduced	27		*Biffa - Current Euro IV & Euro V vehicles.*
BEV RCV Lifespan (years)	10	*Years*	*Biffa*
ICE RCV Lifespan (Years)	10	*Years*	*Biffa*
Operational Days/yr	260	*Days*	*Biffa*
Average Speed Diesel and Electric Vehicles (km/hour)	5	*km/hour*	*Confirmed by Biffa & MCC*
Glider chassis cost	£65,000	*£*	*Electra*
e-drivetrain cost	£130,000	*£*	*Electra*
Battery pack cost	£120,000	*£*	*Electra*
EV Chassis & drivetrain cost	£315,000	*£*	*Calculated*
eRCV Grant (Minimum £8K, Max £20K)	£20,000	*£*	*OLEV - first 200 Zero Emission HCVs*
Diesel chassis cost	£90,000	*£*	*Electra*
RCV body cost	£46,000	*£*	*Electra*
Split lifter cost	£16,500	*£*	*Electra*
Full e-vehicle cost (excluding Grants)	£377,500	*£*	*Calculated*
Full diesel vehicle cost	£152,500	*£*	*Calculated*
Longley Lane Charging Infrastructure	£50,000	*£*	*Biffa*
Hammerstone Road Charging Infrastructure	£100,000	*£*	*Biffa*
Charging infrastructure cost	£150,000	*£*	*Biffa*
Battery residual value %	30%	*%*	*Electra - Second market as Storage*
Climate Change Levy	£0.00775	*£/kWh*	*MCC*
Cost of electricity at depot	£0.1035	*£/kWh*	*MCC*
kWh in eRCV battery	200	*kWh*	*Electra*

Variable Description	Model Value	*Units*	*Source*
% Battery used per day	80%	*% Charge*	*Biffa*
Charging Losses (AC/DC conversion)	10%	*% Lost*	*Electra claim 1% but no data available*
Average kWh used per eRCV per year	46,222	*kWh*	*Biffa with charging loss added*
Average annual electricity price increase over the last nine years	2.73%	*% Increase*	*DBEIS*
Average Fuel Consumption of Euro V diesel (mpg)	3.4	*Mpg*	*Biffa*
Average Fuel Consumption of Euro VI diesel (mpg)	2.9	*Mpg*	*Biffa*
Increase in fuel used - Euro V to Euro VI.	17.24%	*% uplift*	*Biffa*
Average litres per RCV per year – current Euro V & IV	12,000 / 14,774	*Litres*	*MCC / Biffa*
Average litres per RCV per year – Euro VI	14,069 / 17,321	*Litres*	*Calculated using uplift*
Annual mileage Diesel and Electric Vehicles (miles)	8,975	*Miles*	*Calculated*
£/litre diesel	£1.06	*£/litre*	*Biffa*
Average annual diesel price increase over the last 10 years	1.79%	*% per annum*	*AA monthly reports*
% Rate AdBlue for Euro VI	3.50%	*% AdBlue*	*BEIS UK GHG Factors 2019.*
AdBlue Cost (£/l)	£0.35	*£/litre*	*Bulk delivery 1000 litres (more is less)*
RCV Road Levy (Band D)	£315	*£/annum*	*DVLA V149/1*
RCV Road Levy (All Zero Emission CVs are Zero rated)	£0	*£/annum*	*Confirmed Pers Comms. CE/DVLA Tel*
RCV VED Diesel (Band D1)	£300	*£/annum*	*DVLA V149/1*
RCV VED Electric (All Zero Emission CVs are Zero rated)	£0	*£/annum*	*Confirmed Pers Comms. CE/DVLA Tel*
Diesel RCV SMR (ex Tyres) – Lifetime Average Cost per Annum	£5,000	*£/annum*	*Electra/NRG*
eRCV % SMR Saving	30%	*% reduction*	*Electra/NRG*
eRCV SMR (ex Tyres) – Lifetime Average Cost per Annum	£3,500	*£/annum*	*Calculated from ICE Cost and % Saving*
CAZ Surcharge for Euro VI diesel HCV	£100	*£/day*	*Based on current CAZ charges*

Appendix B: CO_2e & kWh Methodology

Calculating fleet CO_2e emissions (DBEIS 2019 Dataset)

Expected fuel consumption data was available so the GHG emissions and energy use could be calculated by applying the following factors to the quantity of fuel or energy consumed.

Fuel	Unit	GHG Scope	kg CO_2e/unit	kWh/unit
Diesel*	litre	1	2.59411	10.60465
Electricity	kWh	2	0.25560	
Electricity T&D	kWh	3	0.021775	

*The Diesel factors is for the biofuel blend sold for road transport use in the UK.

Electric Vehicles and Plug-In Hybrids

Because EVs do not directly burn a fuel their Scope 1 emission is zero, hence they are correctly rated by the OEMs as 0 gCO_2/km.

The emissions of a battery electric vehicle (BEV) arising from the consumption of electricity fall under GHG Scope 2 and Scope 3 emission reporting.

The factor to use for an all-electric vehicle (EV) is linked to the source of the electricity. If it is drawn from the national grid, then the current Scope 2 factor for carbon should be used to which should be added the Scope 3 factor for Transmission and Distribution (T&D).

If the electricity is generated from other sources, for example, a combined heat and power (CHP) plant or energy from waste (EfW) plant, then an appropriate factor must be determined for that plant.

If it has come from on-site renewables such as photovoltaic or wind, then it can usually be considered as zero-emission.

If the EVs are charged on-site the GHG emissions may already be reported under the site's Scope 2 and 3 reporting of electricity consumed. Every effort should be made to avoid double accounting.

Renewable Energy Guarantees Origin (REGO) certificates.

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

The carbon emissions of the electricity can be reported in line with the "market-based" (consumer) value calculated by the supplier (e.g. 0 gCO_2e/kWh if 100% renewable) but it should also be reported alongside the "location-based" (national) figure.

This is because the zero-carbon benefit of the electricity has already been accounted for in the national grid figure. The benefit cannot be taken twice, nor can the carbon factor for other consumers be adjusted upwards to compensate.

The requirement to do this is fully documented in:

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

GHG Protocol, Scope 2 Guidance, Corporate Standard, Section 1.5.1, Page 8.

What is permitted is time-specific emission factors. The HM Government guidelines 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, but organisations may have difficulty providing hourly consumption data.

Where a company generates its own renewables on-site or locally and does not supply the grid it can be accounted for as a 0 gCO_2e/kWh supply.

Appendix C: Charging electric vehicles

The time of day a BEV is charged is critical as commercial consumers can have three tariffs “Red”, “Amber” and “Green” that are linked to time bands (see Table 6-1).

Table 6-1: Typical commercial electricity tariffs and time bands

	Red	Amber	Green	Units
Tariff	£0.24	£0.14	£0.08	£/kWh
Time	16:00-19:00	07:00-16:00 19:00-23:00	00:00-0700 23:00-00:00 All Day Sat/Sun	

There is a move to merge bands “Red” and “Amber” to have a weekday daytime and an evening & weekend off-peak rate. It is important to charge the vehicle when the electricity cost is at a minimum.

Table 6-2: Impact of charging band on the cost per mile of a battery vehicle.

Factor	Red	Amber	Green	Units
Cost of kWh to charge	£0.24	£0.14	£0.08	£/kWh
Vehicle energy consumption	3.5			Miles/kWh
Electricity Cost per mile	£0.069	£0.040	£0.023	£/mile

The importance of a low overnight tariff and the ability to restrict charging to the off-peak period is apparent from Table 6-2.

GHG emissions

Charging time-of-day will also impact on the GHG emissions associated with the electricity as the carbon intensity of the grid is at its worst during periods of peak use.

Figure 6-1: UK Grid Carbon Intensity – Daily Variation, 2018

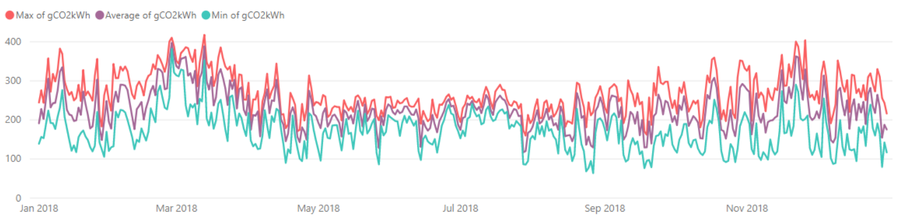
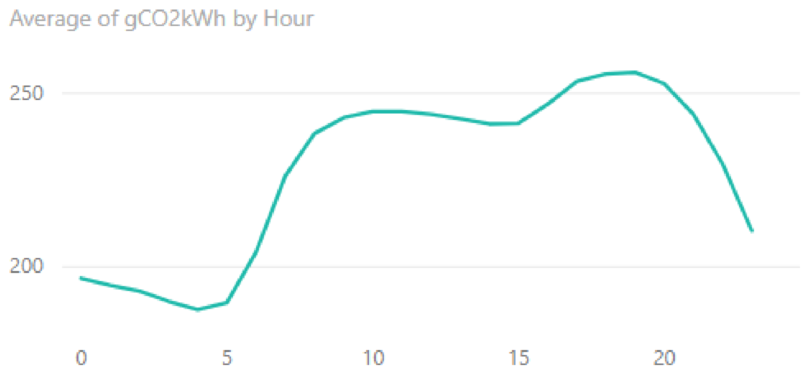


Figure 6-1 demonstrates how the carbon intensity of the UK grid varies from month to month, day to day and during the day with demand, temperature, wind and sun all having a part to play. On the 27th August 2018 (lowest point on the green line) the grid minimum during the day was 64 gCO_2/kWh while on the 13th March 2018 (highest point on the red line) the grid peaked at 418 g/kWh.

Figure 6-2 shows how the carbon intensity of the grid, and therefore the electric vehicle charged from the grid, depends on the time of day. In 2018 average daily emissions ranged from a low of 188 g/kWh at 04:00 to a high of 257 g/kWh at 19:00.

Figure 6-2: UK average GHG emission per kWh by time of day (2018)



When to charge a BEV

It is not possible to predict when the grid will be at its minimum and in any case that might not be a good time to charge the vehicle. What we can do is look at how the carbon intensity of the grid varies during the average day and adjust the charging regime to fit that.

As can be seen in Figure 6-2 the best time to charge a vehicle during 2018 was from 23:00 to 06:00 hours. Fortunately, high carbon intensity is usually linked to demand which is linked to price so the best time to charge a BEV from a GHG perspective is also the best time from a price perspective.

In 2018 the worst time to charge was mid-morning and late afternoon/early evening when charging BEVs could make the grid worse by adding to high demand and forcing additional high-carbon generation to be brought on-line.

Driving back to the depot at the end of the working day (Monday to Friday) and just plugging in would leave the vehicle charging when the carbon intensity of the grid is at its worst (15;00 to 21:00) and the cost is usually at its maximum.

This would not only cost more and produce more carbon. The knock-on impact of EV users just plugging their vehicles in at the end of the day would be to increase peak demand and the grid would respond by adding more generating capacity; initially storage but then gas and finally coal. The EV would have had the effect of increasing UK electricity carbon emissions.

As more wind and solar generation comes on-line, there may be other times during the working day when it is optimal to top-up BEVs but they may not fit with operational requirements.

Implementing a BEV fleet is not just about buying electric vehicles and putting a charging infrastructure in place. It is also important to understand when it is best to charge the vehicle to minimise cost, GHG emissions and the impact on the grid.

Vehicle to Grid (V2G)

In the future smart metering and a dynamic link between the grid and the EV may allow owners to automatically charge their vehicle when the cost of electricity falls below a certain price, or the carbon intensity is low.

It may also be possible to sell electricity back to the grid (Vehicle to Grid – V2G) when demand is high. Ovo and Nissan are operating a project in the North East to test this technology which started in April 2018 and ends in March 2020. One of the factors to determine is the impact of rapid discharge of the car battery to the grid on battery life. The work is funded by UK Research and Innovation (Innovate UK) as project “Sciurus”.

A fleet of HCVs with 200 kWh or 300 kWh battery packs returning to the depot at 17:00 with 20-30% battery capacity represents a significant store of electricity. In the future, this could be sold back to the grid to cover peak demand at a price higher than that paid for it when the vehicle was charged.

Appendix D: Grid carbon intensity, 2016 to 2030

Year	DBEIS Actual GHG Factor	CCC cost-effective path projection	BEIS Energy and Emissions Projections 2016	BEIS % Reduction	Corrected GHG Projection Factor Used
2016	412.1	238.8	238.8		412.1
2017	351.6	234.8	226.4	5.2%	351.6
2018	283.1	226.8	214.0	5.5%	283.1
2019	255.6	218.8	201.5	5.8%	255.6
2020		**210.8**	**189.1**	**6.2%**	**239.8**
2021		199.5	184.3	2.5%	233.8
2022		188.3	179.5	2.6%	227.7
2023		177.1	174.7	2.7%	221.6
2024		165.9	170.0	2.7%	215.5
2025		154.6	165.2	2.8%	209.5
2026		142.5	153.5	7.1%	194.7
2027		130.3	141.8	7.6%	179.9
2028		118.2	130.2	8.2%	165.1
2029		106.1	118.5	9.0%	150.3
2030		**93.9**	**106.8**	**9.8%**	**135.5**
2031		86.6	99.5	6.8%	126.2
2032		81.0	82.8	16.9%	105.0

Predicting the future is an inexact science and predicting the carbon intensity of the grid in 10 years' time has many variables associated with it ranging from the growth in renewables to the completion of nuclear power plants currently under construction.

The DBEIS EEP 2016 projections are already out of step with the DBEIS published GHG factor for the year. This may reflect the fact that the grid GHG factor is two years behind the published emission factor for the year.

To maintain consistency with the fleet GHG footprint, we have adjusted the DBEIS GHG reporting factor for 2019 to be in line with the annual percentage reduction as projected by the DBEIS.

We have also displayed the Committee for Climate Change (CCC) prediction which is less optimistic than the DBEIS in the early years but predicts much lower emissions in 2030.

Appendix E: Output from UK Government NPV Model

More detail on the model, its uses and methodology can be found at: https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal.

Results for predicted energy use changes under Biffa scenario:

Initial Inputs → Changes in Energy Use → Additional Assumptions → Results → Cost-Effectiveness / Sensitivity Analysis

MCC eRCV

Results Summary

(£, 2018)

Energy price scenario:	Central
Carbon price scenario:	Central
Base year:	2020

CLICK TO ADD OTHER POLICY COSTS AND BENEFITS

This allows you to calculate the Cost-Effectiveness Indicator

Net change in energy use	£850,686			
Net change in emissions	£676,105			
Net air quality impact	£494,450		Appraisal period (years):	10
NPV (Net Present Value)	**£2,021,241**	→	Annualised NPV	**£234,818**
Total other costs (including policy costs)	£0			
Total other benefits	£0			
NPV inc. other costs/benefits	**£2,021,241**	→	Annualised NPV	**£234,818**

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CLICK TO CONDUCT SENSITIVITY ANALYSIS

You can test for sensitivities in energy and carbon prices here

CLICK TO CREATE CUSTOMISED DETAILED OUTPUTS

You can use this tool to create customised tables from this spreadsheet to input directly into Impact Assessments.

CLICK TO GO BACK

Other Major Outputs

CHANGES IN CO_2e EMISSIONS

(minus indicates an emissions saving)

	Total appraisal period *(Mt CO2e)*
Net emissions CO_2e in the traded sector	0.001
Net emissions CO_2e in the non-traded sector	-0.011

Carbon Budgets

UK GHG EMISSIONS

(minus is a reduction in emissions) *(Mt CO2e)*

	2008-2012	2013-2017	2018-2022	2023-2027	2028-2032
Net change in CO_2e (traded)	0.000	0.000	0.000	0.001	0.000
Net change in CO_2e (non-traded)	0.000	0.000	-0.003	-0.006	-0.002

Results for predicted energy use changes under MCC scenario:

Initial Inputs → Changes in Energy Use → Additional Assumptions → Results → Cost-Effectiveness / Sensitivity Analysis

MCC eRCV

Results Summary

(£,2018)

Energy price scenario:	Central
Carbon price scenario:	Central
Base year:	2020

Net change in energy use	£499,860			
Net change in emissions	£540,478			
Net air quality impact	£390,762		Appraisal period (years):	10
NPV (Net Present Value)	**£1,431,099**	→	Annualised NPV	**£166,258**
Total other costs (including policy costs)	£0			
Total other benefits	£0			
NPV inc. other costs/benefits	**£1,431,099**	→	Annualised NPV	**£166,258**

CLICK TO ADD OTHER POLICY COSTS AND BENEFITS

This allows you to calculate the Cost-Effectiveness Indicator

CLICK TO CONDUCT SENSITIVITY ANALYSIS

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Other Major Outputs

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	Total appraisal period *(Mt CO2e)*
Net emissions CO_2e in the traded sector	0.001
Net emissions CO_2e in the non-traded sector	-0.009

Carbon Budgets

UK GHG EMISSIONS

(minus is a reduction in emissions) *(Mt CO2e)*

	2008-2012	**2013-2017**	**2018-2022**	**2023-2027**	**2028-2032**
Net change in CO_2e (traded)	0.000	0.000	0.000	0.001	0.000
Net change in CO_2e (non-traded)	0.000	0.000	-0.003	-0.005	-0.002