Fleet Decarbonisation Review

West Lindsey District Council

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Contents

1. Executive summary

West Lindsey District Council (WLDC) is committed to reducing its greenhouse gas (GHG) or ‘carbon’ footprint to net-zero by 2050. WLDC commissioned Energy Saving Trust to produce a detailed assessment of current fleet operations and understand what the optimum route to deliver fleet emissions reductions would look like, based on a thorough assessment of WLDC’s fleet operations, data and available technologies.

WLDC operate a mixed fleet based mainly from the Caenby Corner depot, including light commercial vehicles (LCVs), heavy goods vehicles (HGVs), refuse collection vehicles (RCVs) and a small amount of plant.

Key findings and opportunities

There is much to be commended about the current WLDC fleet operation, which is run from a well organised, modern depot and maintained and presented to a high standard.

There are some opportunities to reduce CO$_2$e emissions prior to any major fleet renewal. The following are covered in more detailed within this report:

- Specific improvements to telematics and data processes to allow consistent reporting and communication of efficiency. **(Section 3)**
- Actions to improve driver performance, such as telematics scoring and benchmarking to target training and efficiency incentives **(Section 3 & 4).**

Together, these measures would typically achieve 5% fuel savings, although where there have been no previous interventions, this can be as high as 15%. This would be equivalent to a range of 45t-135t annual emissions reductions and £22,500 to £67,500 cost saving for WLDC.

Larger emissions reductions could be made from switching to a less carbon intensive fuel type. Having comprehensively evaluated the WLDC fleet, we have concluded that battery electric will be the most suitable alternative in many cases and may be suitable for all from 2029. This is due to its high energy efficiency and zero tailpipe emissions and suitability to current usage patterns. However, this must be cost-effective and practical. We have reviewed the fleet in detail to establish where and when this approach is likely to be best applied. We expect this to emerge as a viable solution for all remaining fleet vehicles by 2030 as battery density and charging capacity improves. A key influencing factor is the amount of time available within this fleet to charge every night. Consideration of other alternatives is detailed in **Section 5.**

It is important to align plans, policies, procurement, finance and team efforts to a transition of this nature **(Section 6).** ‘Whole life costing’ methods will help justify additional capital expenditure, as they reflect subsequent savings on fuel and maintenance. Carbon pricing is relevant **(Section 6.7).**

Our evaluation of the fleet data and energy consumption **(Sections 7-9)** shows that with some changes to how vehicles are allocated, that would not affect overall operational outcomes, most vehicles on this fleet could be replaced by existing battery electric products that would be at least as operationally effective as diesel models. The financial case varies, so whilst battery electric vehicles (BEVs) are always cheaper to run if charged at the depot, whole life costs (WLC); which include capital and running costs combined; vary from being cheaper than diesel to more expensive than diesel (depending on vehicle category and mileage and retention cycle). However, comparisons between electric and using HVO

In 12 months, the WLDC fleet:

Drove around **454,000 miles**

Consumed over **3,307 megawatt hours** of fossil fuel energy

Produced **989t** of GHG emissions

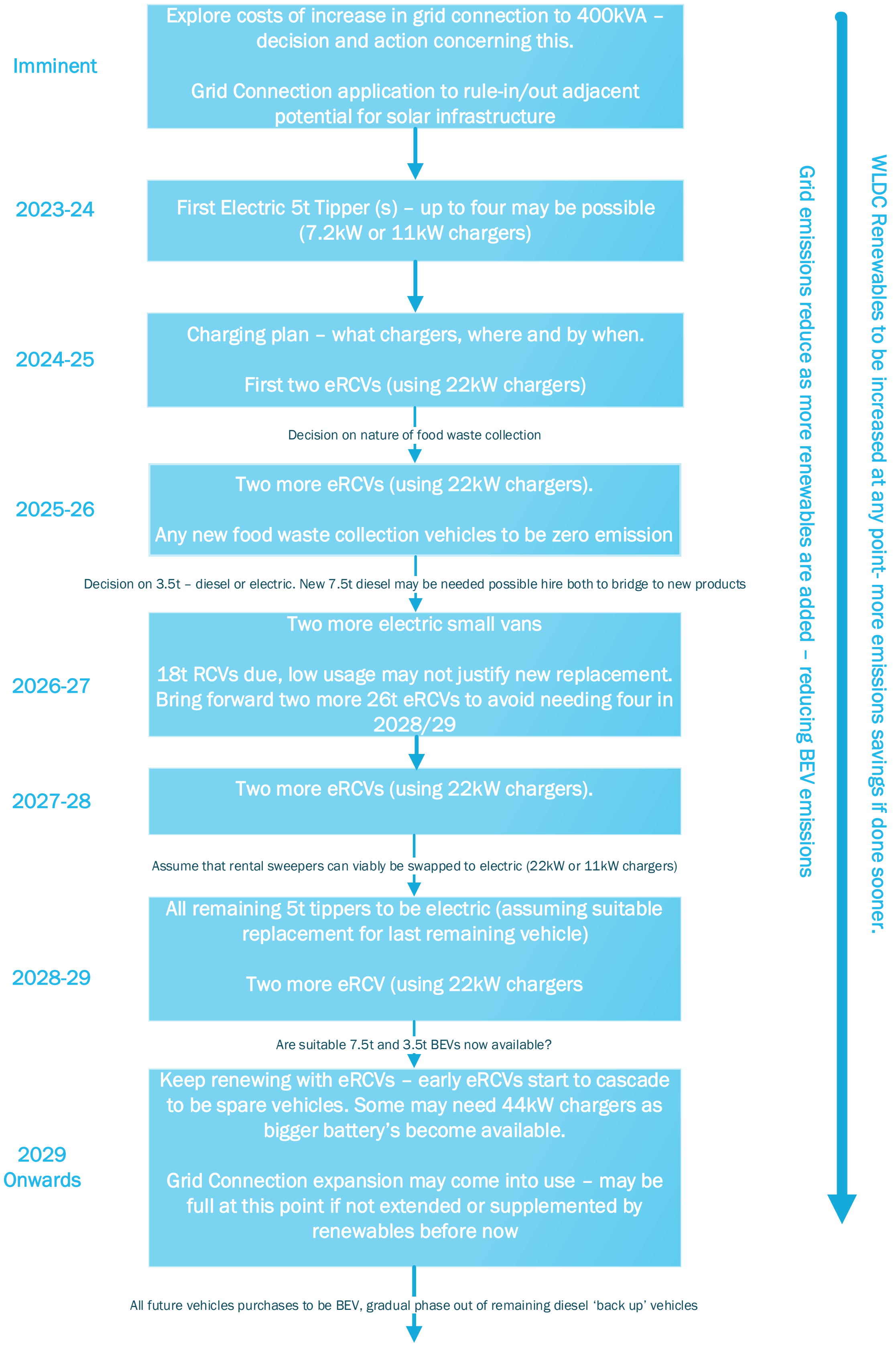
There is opportunity to reduce annual GHG emissions by up to **526t** with currently available electric vehicles are typically more financially favourable to BEVs. The initial outlay will be substantially higher for an electric HGV or RCV. Figure 1-1 provides a road map for this transition. Table 1-1 summarises annual impact of BEVs on whole life costs, based on latest pricing information. We expect BEV purchase costs to converge more with diesel vehicle costs every year, and as such BEV WLCs to improve.

Table 1-1 *Likely* ***annual*** *cost and emissions savings from electrification based on existing products (WLC).*

Fleet Category	No. currently suited to BEV replacement	Ave est cost (saving) per BEV	Ave est emissions saving per BEV	Annual CO_2e saving in this category	Cost (saving) per tonne of CO_2e emissions saved
Small Van	2 of 2	Saves £200	2.7t	5.4t	Saves £74 per t
5t Cage Tippers (BEV)	4 of 5	Costs £3,500	15.5t	62t	Cost £225 per t
5t Tipper (hybrid Conv)	5 of 5	Costs £1,400	12.9t	64.5t	Cost £109 per t
26t RCV (7 Year Vs Diesel)	12 of 16	Costs £7,700	38.3t	459.6t	Cost £201 per t
26t RCV (7 Year Vs HVO)	12 of 16	Costs £1,200	n/a	n/a	n/a
26t RCV (10 Year Vs Diesel)	12 of 16	Saves £1,600	38.3t	459.6t	Saves £42 per t
26t RCV (10 Years Vs HVO)	12 of 16	Saves £11,150	n/a	n/a	n/a
3.5t Box Van	0 of 1	These vehicles do not yet have suitable BEV replacements and may need to be replaced by diesel for this cycle.			
Sweepers	0 of 3				
7.5t HGV	0 of 1				

The Caenby Corner depot has spare grid capacity of 240KVa available at all times. This is sufficient for at least nine eRCVs and replacement electric LCVs to charge overnight. There is also potential to unlock more capacity from this grid connection through battery storage. We estimate the equivalent of around 400kVa is needed for a fully electric fleet. This could also be obtained by increasing the grid connection size (this should be priced and assessed immediately). Wind and solar generation (on site or off site) could be used instead but the latter may need some battery storage to deliver energy effectively for the fleet. Increasing the grid connection size will not prevent other means of generating electricity and could allow for more 'sleeved' electricity to be purchased from an AD plant. Vehicle chargers will need to be in place prior to electric vehicles arriving so trunking should be put in place in one installation project, in order that chargers can be fitted easily into place when needed. It is important that chargers are not over-specified and a demand management system should manage charging load across points. **(See Section 11).**

Figure 1-1 Roadmap to emissions reduction for WLDC



Imminent

Explore costs of increase in grid connection to 400kVA – decision and action concerning this.

Grid Connection application to rule-in/out adjacent potential for solar infrastructure

2023-24

First Electric 5t Tipper (s) – up to four may be possible (7.2kW or 11kW chargers)

2024-25

Charging plan – what chargers, where and by when.

First two eRCVs (using 22kW chargers)

Decision on nature of food waste collection

2025-26

Two more eRCVs (using 22kW chargers).

Any new food waste collection vehicles to be zero emission

Decision on 3.5t – diesel or electric. New 7.5t diesel may be needed possible hire both to bridge to new products

2026-27

Two more electric small vans

18t RCVs due, low usage may not justify new replacement. Bring forward two more 26t eRCVs to avoid needing four in 2028/29

2027-28

Two more eRCVs (using 22kW chargers).

Assume that rental sweepers can viably be swapped to electric (22kW or 11kW chargers)

2028-29

All remaining 5t tippers to be electric (assuming suitable replacement for last remaining vehicle)

Two more eRCV (using 22kW chargers

Are suitable 7.5t and 3.5t BEVs now available?

2029 Onwards

Keep renewing with eRCVs – early eRCVs start to cascade to be spare vehicles. Some may need 44kW chargers as bigger battery's become available.

Grid Connection expansion may come into use – may be full at this point if not extended or supplemented by renewables before now

All future vehicles purchases to be BEV, gradual phase out of remaining diesel 'back up' vehicles

Grid emissions reduce as more renewables are added – reducing BEV emissions

WLDC Renewables to be increased at any point- more emissions savings if done sooner.

Conclusion

WLDC are well placed to start the transition to an electric fleet, due to vehicles typically being available to charge for 14 hours a day, a favourable grid connection and operations that would only need minor adaptation for all but four RCVs to be electric. Some additional work is needed to ensure the grid connection is ready for the final stages of the transition, and whilst this seems a long way off, beyond 2029 it will be most cost effective and expedient to have a plan in place at the earliest stage, based on the likely assumption that products available by then will have full capability for all WLDC operational needs on a single charge.

In most cases the transition will increase vehicle capital requirements, but with some changes to replacement cycles, whole life costs will be reduced due to energy efficiency, and even more so if renewable generation or zero emission electricity sourced from AD can be achieved. Whilst, with grid electricity, emissions could be reduced by 526t, using renewables could take fleet emissions to zero and reduce electric vehicle operating costs to deliver large WLC savings.

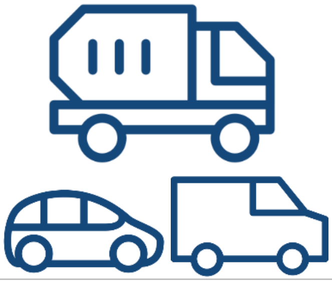
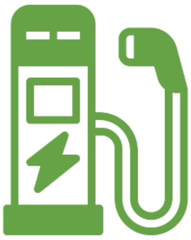
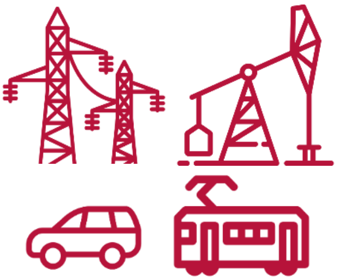
New food waste collections should all be powered by electric vehicles, from the start, which also offers the exciting possibility of operating vehicles on electricity generated by gas from the waste itself, (although this will need to be cost effective when compared to other renewables to be justified).

2. Emissions and energy use

2.1 Greenhouse gases (GHGs)

The carbon dioxide (CO_2e) footprint (often shortened to carbon footprint) details an estimate of the tonnage of carbon dioxide that WLDC's fleet has emitted in 2022-2023, based mainly on the fuel data provided.
The 'e' in CO_2e stands for 'equivalent' and indicates that the estimate includes the other reportable GHGs emitted by the fleet (nitrous oxide and methane) expressed in terms of their carbon dioxide equivalence over 100 years. For example, nitrous oxide (N_2O) has a global warming potential (GWP) 265 times that of carbon dioxide and one tonne of N_2O is therefore equivalent to 265 tonnes of CO_2 (GHG Protocol, GWP Values, AR5). The GWP of methane (CH_4) is 28. In the UK, GHG emissions are usually reported under Scopes 1 to 3 (**Figure 2-1**).

Figure 2-1 *Summary of GHG reporting - Scopes relevant to road transport emissions*

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

Summary of WLDC fleet GHG Emissions

Table 2-1 *WTW GHG reporting: fleet size, mileage, GHG emissions and energy consumption*

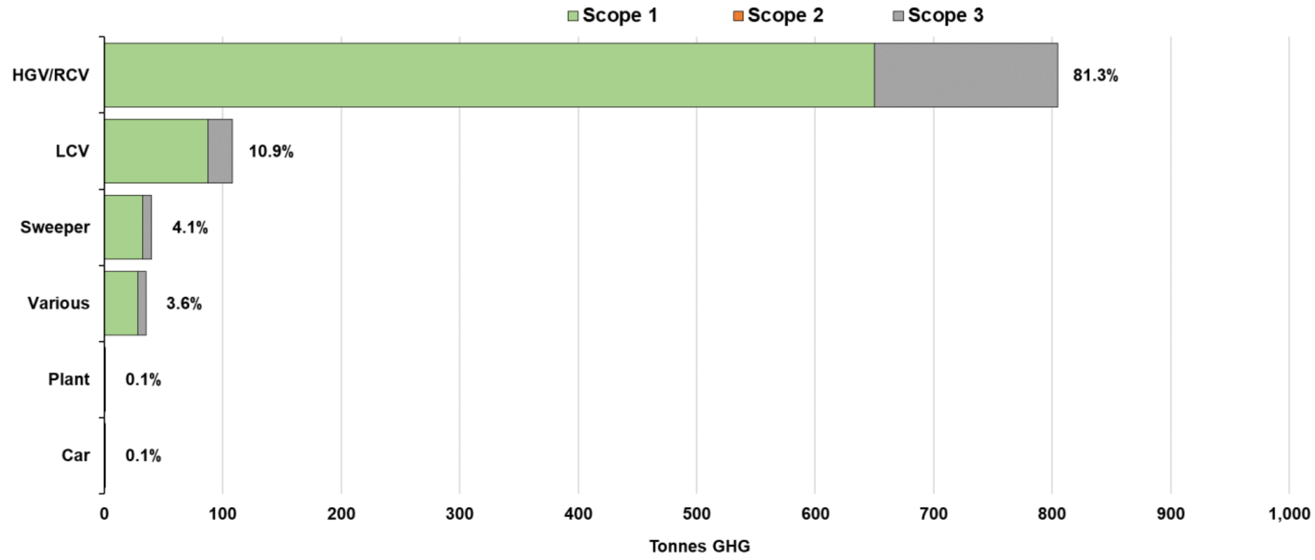
Fleet Category	Vehicles	Annual mileage	WTW GHG (tonnes)	Energy (MWh)
HGV/RCV	22	285,691	805	2,687
LCV Up to 5.2t	13	150,886	108	362
Sweeper	3	15,847	40	134
Plant	3	12	1	2
Car	1	2,097	1	2
Various	1	0	35	120
Totals	43	454,533	989	3,307

The WTW GHG footprint of the fleet (**Figure 2-2** and **Table 2-1**) is based on the fuel and mileage data provided by WLDC. We have calculated this footprint using the year-appropriate GHG conversion factors published by BEIS. It also includes an estimate of the GHG emissions from burning adBlue in the diesel exhaust systems of HGVs. The methodology used complies with international GHG reporting standards (WRI GHG Protocol) and with UK's SECR Reporting Guidelines which apply to UK public bodies. We have not included the lifecycle GHG emissions associated with the manufacture and disposal of the vehicles, which are classed as out of scope.

It should be noted that fuel recorded in the 'various' category was used across the vehicle categories, but no registration data was recorded to identify the specific vehicle.

Fleet numbers in table 2-1 reflect the number of vehicles contributing to emissions in 2022/23 rather than the current active fleet size.

Figure 2-2 *Greenhouse gas emissions (tonnes) by Scope*



Because, in 2022/23 nearly all WLDC vehicles were fuelled by diesel, the distribution of energy consumption between vehicle types is almost identical to the distribution of emissions. This balance would change if more alternative fuels were used.

Table 2-2 provides a breakdown of the WTW GHG emissions by reporting Scope. Scope 1 is the most important because it is the fossil-fuel GHG emissions for which WLDC are directly responsible. The vehicles burning the fuel are fully controlled and operated by WLDC and all aspects of their use from specification, usage, driving standards and monitoring are its direct responsibility. No other organisation can reduce these emissions. Grey fleet emissions are not included in this report.

Table 2-2 *GHG Reporting by Scopes – Scope 1 and Scope 2 are mandatory; Scope 3 is discretionary.*

Fleet category	Scope 1 GHG fossil fuel burnt (tonnes)	Scope 2 GHG electricity consumed	Scope 3 GHG extraction/distribution (tonnes)
HGV/RCV	650	0	155
LCV Up to 5.2t	87	0	21
Sweeper	32	0	8
Plant	0	0	0
Car	0	0	0
Various	28	0	7
Totals	**799**	**0**	**190**

Table 2-3 shows that 81.3% of GHG emissions come from the RCV/HGVs which undertake 62.9% of the fleet's mileage. LCVs contribute only 10.9% of fleet emissions despite covering 10.9% of mileage.

This shows the greatest potential for emission reductions is in the heaviest vehicles, and so it may be worth the higher level of investment to achieve this. In a fleet of this nature, relatively small improvements in efficiency can also result in several tonnes of GHG emissions saved.

Table 2-3 *Analysis of fleet size, mileage, GHG emissions and energy use*

Vehicle Fleet	% Number	% Mileage	% WTW GHG	% kWh of energy	WTW $kgCO_2e$ per Vehicle	S1 $kgCO_2e$/km Per Vehicle
HGV/RCV	52.4%	62.9%	81.3%	81.3%	36,570	1.414
LCV Up to 5.2t	30.9%	33.2%	10.9%	10.9%	8,322	0.360
Sweeper	7.1%	3.5%	4.1%	4.0%	13,357	1.269
Plant	7.1%	0.0%	0.1%	0.1%	204	25.562
Car	2.4%	0.5%	0.1%	0.1%	594	0.137

Vehicle Fleet	% Number	% Mileage	% WTW GHG	% kWh of energy	WTW kgCO_2e per Vehicle	S1 kgCO_2e/km Per Vehicle
Various	-	-	3.6%	3.6%	-	-

Battery electric vehicle (BEV) emissions (Scope 2 and Scope 3 GHG Reporting)

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

There are currently two BEVs, but they were not introduced until after the 2022 – 2023 financial year, so are not included in the data in this section. When Scope 1 emissions are reduced through electrification of any subsequent vehicles, there will be an addition of Scope 2 and Scope 3 emissions as vehicles transition to BEVs, albeit at a small fraction of current Scope 1 levels.

2.2 Emissions that affect air quality

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

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

We have determined the data in table 2-4 using the average emissions of a 2018 HGV adjusted for the area of operation as published by the National Atmospheric Emissions Inventory. This analysis is based on vehicle mileage and cannot be determined from fuel data alone, so where mileage driven is missing, emissions cannot be calculated.

Table 2-4 *Estimated annual emissions of nitrogen oxides (NO_X) and particulate matter (PM_{10} and $PM_{2.5}$)*

Fleet Category	NO_X (kg)	PM (kg)
HGV/RCV	582	8.8
LCV Up to 5.2t	261	3.5
Sweeper	32	0.5
Total	**875**	**12.8**

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

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

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

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

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

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

Nitrogen dioxide (NO_2) emissions which originate primarily from transport have a direct impact on public health, something that should be considered in broader corporate social responsibility policies and influence decision making beyond the immediate financial case. Air quality presents a very strong argument for any decarbonisation transition to focus on vehicles with zero tailpipe emissions, wherever possible.

3. Fleet data management

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

For commercial vehicles, it is also important to have information about the work completed (eg load carried, jobs completed, etc) so that the performance of a fleet and its environmental impact can be linked back to the service it delivered and form part of a suite of driver, vehicle and fleet performance indicators.

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

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

3.1 Description of data set at WLDC

The WLDC fleet team provided a list of vehicles, alongside their role and estimated replacement dates. The list also contained any vehicle disposal details since the start of 2022. Some other vehicles were evident from insurance and fuel datasets, that operated outside of the immediate remit of the fleet department. Further discussions with the fleet manager enabled a clearer understanding of any pending vehicle orders and disposals.

Direct access to the VecTec fuel system was provided. This provided easy access to reporting for fuel transactions based on drawings from an on-site diesel tank at Caenby Corner depot. There is a clear policy of refuelling vehicles to full and submitting an odometer reading at this point. With the refuse fleet, the expectation is that the vehicle is refuelled at the end of every shift, which should give a measure of efficiency and energy consumption for each shift undertaken. In general, this system was well adhered to for the RCVs, although it is clear that a small number of RCVs were sometimes refuelled up after two or more days of operating. Odometer readings were mostly recorded consistently and reliably. However, there were some 5t vehicles where it was hard to clarify whether readings were in miles or kilometres from this system and there were some clearly inaccurate readings (many of which were easy to correct with the context of a full year's dataset).

The main flaw within the fuel data was that the 'spare' fob was frequently used to refuel vehicles without their own fobs. In some cases this was evidently for new vehicles and could be attributed accordingly. However, even after this, there were still over 11,000 litres which were not allocated to a specific vehicle. Given that there were at least five vehicles with no fuel records of their own, based on discussions with the fleet team it is reasonable to assume that this fuel was shared between them. However, it is not clear how much fuel individual machines had used, or if any of this fuel had been also deployed in vehicles with their own fob, if for example it's fob was temporarily missing or broken.

There were some fuel cards in circulation that were used as a back-up for emergencies and at one stage used for off-site vehicles. It is understood that these were not used during the 2022-23 financial year, due to the 'Spare' fob providing fuel in cans for vehicles and plant in other locations. The mayoral car was a petrol vehicle, subject to very low use in 2022-23, with no fuel data available.

Compliance with recording odometer readings was ordered and consistent, with well over 90% of the records appearing to be complete and accurate. This also meant that a clear calculation could be made based on each vehicle's annual fuel efficiency, in most cases. Regarding daily energy consumption, close inspection of the RCV fuel records suggests that vehicles were routinely filled to full, although this was occasionally after more than one day of operating. We have been able to use refuelling times and dates to understand where two days operating for one refuel has taken place. With some additional processing, the data has provided a high level of confidence that daily energy consumption is well understood, and as such predictions for future energy requirements of alternatives can be made with confidence, in most cases.

For plant and machines, fuel allocations were less visible. It is not always clear how much fuel individual machines had used. This means understanding energy consumption is not possible for each machine where the spare fob was used.

RCV telematics

Most of the RCVs were fitted with 'Vision techniques' telematics units. This did not include any CANbus or fuel data. WLDC's main purpose for this system is live tracking and connectivity with camera systems that are used to monitor incidents and activities. The system attempted to record mileage, with limited success. Indexes such as driver performance were displayed on the interface, but not populated with any data, so appeared to be of no use at this stage.

Reporting facilities on this system were efficient and accessible. Mileage data from a long time period was easy to download. However, it was immediately apparent that the data on this system was not consistent with the mileage figure provided when fuel drawings were made. This system always reported less mileage (an average of 92% of the fuel system total), but for some vehicles it was less than 50%. The variance was different for each vehicle, suggesting that the issue was definitely with the telematics and not with the fuel system data. The conclusion we arrived at is that there was no information reported when the system was out of signal range. The result was that distance data was inherently unreliable and could not be used for the purposes of this review. It would also be of limited value as a resource to WLDCs fleet management processes.

It was also apparent that the infrastructure for telematics was in place on the newest Dennis Eagle vehicles (registered from 2020 onwards). The manufacturer has access to vehicle data for 'maintenance purposes', However, this service was not subscribed to, so no data was available to WLDC.

For vehicles that were not routinely refuelled every day, understanding exact daily energy consumption was not always possible. As such alternative options were explored to attempt to achieve this. WLDC provided manually collected daily mileage read outs for seven vehicles for the whole of September 2023. Mileage totals for some of the vehicles during this month did not always accurately reconcile with the data on the fuel system, so we have had to take a worst-case scenario when considering suitability of electric alternatives. If telematics were installed in these vehicles, then the assessment could be made with greater certainty.

Site energy data

Data relating to site electricity billing, including capacity and usage was provided. Data reflecting standard half hourly metering from energy providers was provided for the depot grid connection, allowing analysis of the grid connection in relation to the demands of a future electric fleet. No data was provided concerning generation totals from solar panels, although evidence of the general positive impact of generation can be clearly seen in the half hourly data for the grid connection, and an approximation of generation capacity could be estimated.

3.2 Improving data at WLDC - Recommendations

It will be of great benefit to WLDC to procure a telematics system that can provide accessible and accurate data, that is calibrated and not interrupted by breaks in the phone signal.

If the current system cannot be corrected or improved to the desired specification, then it should be replaced. Action should also be taken to add telematics units from the 'future system' to any vehicles where data is currently absent.

Ideally the same system should be installed across the whole fleet – all makes and models.

Beyond the short term, there are additional desirable outcomes to achieve from all telematics units fitted and operating within the fleet.

- Accurate live reporting of fuel consumption and efficiency through the CANBUS system.
- Addition of driver scoring metrics.
- Live reporting of performance against KPIs – dashboards (this may be possible directly on the telematics package or from a telematics API feeding into fleet management software). This would include fuel, emissions and driver scores (which are currently absent on the VT system).
- Ease of integration with other systems such as vehicle safety checks, cameras and other data sources (this may or may not require specific external fleet management software for the optimum results).
- A driver interface to ensure drivers are directly aware of their performance at any point making conversations about driver performance easier (Section 4).
- Interaction with BEVs so that state of charge and energy consumption can be viewed in real time.

It would also be beneficial for WLDC to find an automated way to bring different data sources together, rather than having different systems working concurrently, all with separate outputs. Integrated fleet management packages exist (albeit to varying standards) that can combine fuel purchase, driving licences, compliance, vehicle checks, maintenance, CANBUS fuel and driver performance data all in one place, selectable by vehicle registration. When set up correctly, all data sources automatically feed into this one place and automated dashboard reporting can be directed to bring appropriate live feedback to different people within the organisation. FORS, the compliance organisation, has approved software that achieves this (depending on the telematics used) , and many other options exist, although care must be taken to set any new system up to its potential and not to simply just add yet another data source or system to check.

However, for a small organisation such as WLDC, this may not be as important as for a large organisation, as data volumes may still be manageable within several systems.

Subsequent consideration should also be given to how data is presented ‘live’ at different levels of the council, reviewing what dashboard reporting is visible to whom and at what level. This should also include direct communication with drivers.

Action Summary

- **Short Term** – ensure telematics is reviewed and the best system selected.
- **Short Term** – complete the telematics coverage across the fleet to enable consistent reporting and data management. Add in driver performance metrics on systems or investigate alternatives.
- **Medium Term** – consider the best approach to integrate existing data sources into as few streams as possible, maximising automation and including enabling communication with drivers. This may require a specific project to simplify the data and provide live dashboard reporting that is relevant to each level of the business.

4. Improving driver efficiency

Based on the fuel records provided, every 1 % reduction in fuel use for the road-going vehicles in the WLDC fleet would reduce carbon emissions by about 9t CO_2e a year and reduce fuel costs by over £4,500 a year, so investment in the time and technology to promote good driving in this fleet should be cost effective.

We were not provided with details of WLDC's current driver and fleet protocol to review. Typically such documents give a clear guide to ensure that the conduct of drivers is legally compliant, safe and in line with the Highway Code. However, there is not usually reference to efficient driving or advice or suggestion of techniques that may reduce fuel consumption.

Whilst fuel efficiency may be discussed informally or presented at team talks, WLDC should consider explicit policies that recognise and oblige efficient driving and create a pathway for drivers to understand their performance and recognise success in this area.

4.1 Communicating performance to drivers

Monitoring fuel consumption across the fleet is important, because when it is done consistently, in close communication with drivers, it can lead to significant fuel savings. Also, drivers who use less fuel in diesel vehicles will go on to use less energy in future electric vehicles, meaning vehicles will go further on a single charge and less energy will be required for charging. Where there is the practice of 'task and finish', for RCVs, it does not always lend itself to enable efficient driving techniques for obvious reasons, so options around this should be given due consideration.

Establishing background information - driver scores

In the absence of telematics-based measures, there is no apparent background information for driver performance within this fleet. Drivers and crews do swap between vehicles and routes vary from day to day, so (currently) using MPG data will not be suitable unless it is carefully benchmarked.

For effective and sustainable monitoring to take place a more consistent technological solution is required. A new, purpose-built system may prove necessary. Solutions exist that provide either 'live' in cab feedback (eg Lightfoot), or app based systems that can provide retrospective feedback on driving and scoring to driver's mobile devices, or systems that offer a combination of both. Sometimes this functionality forms part of the basic specification of a telematics package. Telematics should be specified and procured accordingly.

Communicating efficiency with drivers

With a consistent and reliable data source established, it becomes possible for procedures and systems to be applied that will allow drivers to understand their efficiency performance and identify where training should be prioritised. Without incentive or additional motivation, not all will engage or identify with the need to reduce emissions and fuel costs.

Whilst good will and competitiveness will work in some cases, this kind of communication becomes much more effective if it can be connected to a driver incentive scheme. It is also important that efficient driving is part of WLDC policy and structured into training and performance targets.

Driver incentive scheme implementation

The working principle (in such a scheme) is that efficient drivers will save fuel and money for the employer, and that part of this saving should be invested in an incentive scheme. More drivers will engage with efficient driving techniques if there is some kind of positive incentive (financial or otherwise).

Understanding the baseline and level of performance to reward requires some understanding of the relationship between current performance and fuel costs across the fleet.

Due to variations in route and load, a consistent telematics-based driver scoring system is the best basis from which to measure performance and as such, determine the level of incentive to offer. The difference in fuel consumption between driver score ratings, needs to be understood, with variables managed, in order that the level of cost saving (and thus potential incentives) can be determined.

Rewards and incentives for efficient drivers could take several forms. It is worth consulting with drivers for which method would provide the greatest motivation. The most effective method will depend on the nature of the employment arrangements and culture within the current operation. We understand that local authority structures and employment conditions can make certain types of incentive harder to achieve than others.

We have seen the following methods used to good effect, generally used in isolation to each other (although there is no reason why some measures cannot be combined):

- Fuel savings above a specified level (ideally based on the current level of efficiency) shared with efficient drivers (usually 50:50) as a form of reward or bonus pay.
- Fuel savings above a specified level shared with either a driver's choice of charity, or all savings across the fleet to a designated charity, which could change periodically to reflect good causes that employees may be passionate about.
- All fleet fuel cost savings are pooled, and an agreed proportion allocated to a fund for which drivers achieving over a specified score, that will depend on the parameters set by the telematics provider (eg 85% or 8.5 out of 10) are entered into a monthly (or weekly) draw to win a share of. This can be a big financial incentive, but not everyone will benefit every month, although the incentive will apply to all efficient drivers. This can even be administered or 'held' by the telematics provider, in the case of some suppliers.
- A driver league table is set up. All fleet fuel saved is pooled and an agreed proportion of the financial savings are allocated to the drivers who finish in the highest league positions, based on their aggregate score over a defined period (a week or a month).

Where driver league tables are concerned, they can work even better if they incorporate a range of factors, such as customer feedback (even if the 'customer' is in-house), punctuality, presentation, vehicle cleanliness, accident rate, minor damage cost, fuel consumption (mpg) and telematics scores. League tables can also be used to identify the best drivers and they could be considered 'lead drivers' or 'fuel champion' and could be asked help to promote good driving and fuel-saving initiatives across the fleet (such as benchmarking, which is discussed in Section 4.2). Similarly league tables can be used to identify training needs and demonstrate progress and improvement amongst those who are performing less well.

Clear, regular channels of communication for achievements and goals will maximise the potential benefits of an incentive scheme. It is very likely that a well-executed incentive scheme would deliver significant fuel savings. Evidence suggests that savings will be between 5-15% where there has been limited or no previous interventions.

For example, if only a 5% saving can be made across the WLDC fleet, this would deliver annual savings of £22,500. If this is shared between the council and drivers, it offers some scope for incentives to improve driver efficiency. On top of this, GHG emissions reductions of 5% equate to 45t a year.

Action Summary

- **Short Term –** establish the best method to measure and communicate driver performance, ideally through an upgraded telematics system.
- **Short Term** – implement an efficiency incentive scheme in consultation with the drivers, taking care to understand before and after data so any improvement can be clearly quantified and the basis for the amount and nature of incentives is transparent and clear.

4.2 Undertake route benchmarking

Many of WLDCs vehicle operations involve repeated rounds and routes. In these cases a similar route pattern may occur on a two-week rotation.

Regular rounds do give an opportunity to understand how much fuel is typically consumed on each route, especially if all potential variables such as load and mileage are relatively constant (also assuming no exceptional traffic events). Direct comparisons can be made if the same vehicle is operating on the same route over a specified period with any difference most likely attributable to the driving style.

In most fleets, there are some drivers who are inherently more fuel efficient than others. The difference between best and worst can sometimes be as much as 40% where no previous interventions have taken place, although we would expect this to be less, given the positive management style at WLDC.

WLDC may already have a good idea of who the most efficient drivers are. However, if not, driver scores from telematics can be used to determine which drivers are likely to be the most efficient and these should be asked to drive all the established routes with an allocated regular vehicle for that route (for a fixed period). Exact fuel consumption should be noted from the telematics, taking full account of the normal loads and duties of the vehicle. This will then provide a contrasting 'target' figure to regular drivers for that route, using the same vehicle. If the regular drivers continue to consume significantly more fuel than the benchmark, then there is a clear focus for training and improvement that can be administered in a targeted way (and this can be further monitored with the help of the telematics driver scoring system).

This approach relates closely to the need to communicate fuel efficiency to drivers, and with the right driver KPIs, will help to maintain high levels of fuel efficiency. There is no reason why this approach cannot be combined with a driver incentive scheme.

5. General vehicle recommendations for decarbonisation

Where BEVs are operationally viable and a solution for their charging is available, the outright efficiency of this technology and the benefit of zero tailpipe emissions, means that it will always have an advantage over other existing technologies. This technology uses between a quarter and half of the energy of internal combustion (depending on the use case), and where grid technologies are clean, the emissions reduction is hard to beat, even allowing for carbon embedded in the manufacturing of batteries and vehicles.

At present it is not possible for every existing diesel vehicle to be replaced by a BEV, without some additional in-shift charging strategy, and BEVs do represent a significant additional capital cost. Therefore it is sensible for WLDC to question what other alternatives or approaches may be viable now or in the future. This section covers the positives and negatives of other prominent low emission alternatives that exist, even where they might not be practical for WLDC to employ.

5.1 Hydrogen fuel cell electric vehicles (H_2FCEVs)

A common question is whether H_2FCEVs will be suitable for future vehicle replacements on fleets like WLDCs. H_2FCEVs offer potentially convenient rapid refuelling, and zero harmful air quality emissions where vehicles are operating.

Whilst there is a potential role for ‘green’ hydrogen in decarbonising heavy transport (distinct from the carbon intensive ‘grey’ hydrogen and methane-derived ‘blue’ hydrogen), it is not yet clear whether this will be the best pathway for any WLDC vehicles for the following reasons:

- A hydrogen fuel cell uses more than three times the electrical energy of charging a battery for the same amount of energy to arrive at the wheels of an equivalent BEV. This means more than three times the energy needs to be generated and this comes at both a financial and environmental cost.
- When well to wheel factors such as distribution and transport of the hydrogen are taken into account, the energy use of the fuel cell is likely to be between four to six times that of a battery electric equivalent (Zemo Partnership, 2021).
- The lower efficiency of producing hydrogen for fuel cells not only means extra cost but is likely to divert renewable power away from the grid (as growing off peak demands of a national battery electric fleet are emerging), thus slowing broader decarbonisation.
- Using H_2FCEVs simply adds inefficient processes to energy generation and costly additional components and maintenance requirements compared to a BEV. It is highly likely that there will viable high-capacity battery / rapid charging alternatives emerging within this decade that will cover all WLDC’s operations.
- H_2FCEVs cost significantly more to purchase than BEVs and unlike them, do not offer any operating cost savings from reduced energy consumption to offset the higher costs when compared to diesel vehicles.
- Fuel cell vehicles are more technically complex than BEVs and thus will require more maintenance expenditure.
- WLDC would ideally need reliable local third-party green hydrogen refuelling infrastructure if investing in a fleet of that nature, along with a back-up plan if the refuelling supply becomes unavailable.

For some hard to electrify vehicles, hybrid solutions that work primarily using a battery and use fuel cells as a range extender may well be helpful options that emerge later in the decade, but these are not yet commercially available from any OEMs, and local refuelling infrastructure remains critical to their usefulness.

Summary

It does not appear likely that hydrogen fuel cells will provide a financially viable pathway to emissions reduction for WLDC. Furthermore, it appears unlikely that (green) hydrogen-fuelled vehicles will even be operationally viable from an infrastructure point of view, and investing in this provision would be at a far greater premium than EV charging infrastructure to achieve the same operational results.

5.2 Compressed Natural Gas (CNG) and Bio-CNG

Some vehicle manufacturers offer CNG powered vehicles as an alternative to diesel. Vehicles are powered by spark ignition engines (similar to petrol engines) and fuel is often grid gas that is compressed at a suitable facility, which relies on a sufficiently high-volume gas supply.

Advantages of this approach are:

- Favourable road fuel duty (half that of diesel, fixed until 2032).
- This can result in a favourable WLC for some intensively used vehicles if gas prices are at reasonable levels.
- Better air quality performance than diesel (but poorer than BEV or hydrogen).

However, the downsides could include:

- Operational vulnerability if there is only one local supply (or costly infrastructure installation) – sites will need to shut down at times for maintenance.
- Limited choice and supply of vehicles.
- Low consumption across a fleet or small part of the fleet makes it difficult to find cost effective supply of fuel.
- Gas price volatility in recent times has led to higher than expected refuelling costs.

Biogas is an attractive low carbon fuel, that yields genuine emission reductions, with many transparent waste sourced feedstocks available in the UK and Europe. For most UK vehicle use cases biogas is not put directly into vehicles but is the result of paying a premium when refuelling with mains sourced gas for substitute biogas to be injected into the grid in a remote location (often in Holland or Belgium, who are connected to our grid). Whilst substantial carbon emissions reductions are achieved, these are also counted within the mains gas carbon intensity factors. This means that mains emissions have to be reported alongside the savings to avoid double counting. Further planned changes to GHG reporting protocols could mean that the savings produced when refuelling on mains gas but paying for remote biogas injection, are not attributable to the fleet in future.

If a hypothetical locally produced supply, is available, separate from the mains, then biogas related emissions savings can all be claimed in full by the fleet operator. We understand that there may be the prospect of a local supply becoming available, produced from food waste, including some that has been collected locally.

In these circumstances several questions will need to be asked before committing to use:

- What is the likely cost per unit and potential for cost volatility?
- How reliable is the supply and is there a locally accessible alternative if it fails?
- Is it more efficient to use the biogas to simply generate power for battery electric – The process of production, cleaning and compressing gas, then burning it at 30-35% efficiency in a vehicle needs to be compared to the cost and efficiency and emission profile of using the same gas to generate electricity at >90% efficiency, then using it to power a BEV at 85% efficiency.

CNG In local authority fleets

Currently we have identified four local authority fleets in England that use CNG or Bio-CNG powered vehicles.

The London Borough of Islington and Leeds City Council have both nearly completed the process of phasing out these vehicles, having had much larger CNG fleets in the past. Issues with travel to refuelling and increasing fuel costs have been significant obstacles to Islington. Leeds initially planned to have 200 CNG vans in 2015 but have moved away from this trajectory and only two now remain, with the fleet now moving to BEVs.

London Borough of Camden currently operate 32 biomethane vehicles including vans and buses. Current costs are expected to escalate substantially with the end of a long-term supply contract which may affect how long these vehicles are retained for or may see them retrofitted with other technologies.

Liverpool City Council run 20 Biomethane RCVs and Veolia operate ten CNG vehicles on behalf of Sheffield City Council. Both were introduced in the last few years, so still appear to form part of the current fleet arrangements.

In Summary

Whilst CNG in distribution is growing, it is in decline as a fuel used by local authorities. When grid gas is used there are some downsides to consider, even if biogas is injected into the grid elsewhere.

Powering food waste collection vehicles with energy harvested from food-waste is an attractive proposition. Whether there would be a sufficiently reliable and cost-effective local solution is yet to be seen. However, the end of combustion engine sales will mean that even if this can prove viable, it will only be a transition fuel over a small number of replacement cycles. The most likely niche would be for vehicles that cannot currently be replaced with BEVs, but this may not be enough to deliver value for money with the gas supply.

5.3 HVO and other ‘drop-in’ fuels

There has been growing interest in use of this ‘drop-in’ diesel replacement fuel. Much of the demand is based around its very low BEIS TTW CO_2e conversion factor, 0.0356 $kgCO_2e$/litre[1], versus 2.478 $kgCO_2e$/litre for (average biofuel blend) diesel. While we recognise the theoretical benefits of HVO, there are remaining concerns about the source of its principal feedstock, Used Cooking Oil (UCO) and the use of this fuel under the current sustainability assurance regime. We expect and hope that one significant positive outcome of the DfT’s low carbon fuels strategy consultation is to improve the robustness of the assurance process for this fuel and its feedstock.

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

The high price that UCO suppliers are achieving because of its ‘waste’ classification in Europe, is resulting in a distortion of the world market: UCO is diverted from the less financially rewarding markets and is replaced with other farmed crops which may include palm oil. In instances where palm oil cannot be harvested, soy is grown instead but this crop has a lower energy yield than palm oil and so even more land must be used for crop planting. The greater demand for palm oil and other types of crop-derived oil contributes to further global deforestation, and other indirect land use change (ILUC) leading to reduction in biodiversity, a loss of ecosystem and further increases in GHG emissions (also see **Figure 5-1).**

According to the DfT’s (2020) complete RTFO data[2], 100% of UCO feedstock for UK HVO came from outside Europe and none of the HVO sold in the UK was produced using UK UCO. 104 million litres of UCO were produced in the UK in 2020 but none of this was used to make HVO for domestic use. In 2021, the provisional figures show only 9% of UCO was European in origin (Spain, Italy and Czech Republic). This contrasts with 100% of biomethane feedstock coming from Europe in both years.

As quoted on the BEIS conversion factors, “All fuels with biogenic content, such as (average biofuel blend) diesel and petrol and all electricity consumption should have the biogenic CO_2 emissions reported, to ensure a complete picture of an organisations emissions is created”. Instead of the 80-95% carbon reduction sometimes quoted from adopting HVO, the combined TTW, WTT and out-of-scope emissions figure, shows a much more modest reduction in carbon intensity (around 18%).

However, it is less energy intense than diesel so a slightly quantity HVO will be needed to deliver the same energy as diesel.

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[1] https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2023

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

Figure 5-1 Potential links between UCO and deforestation

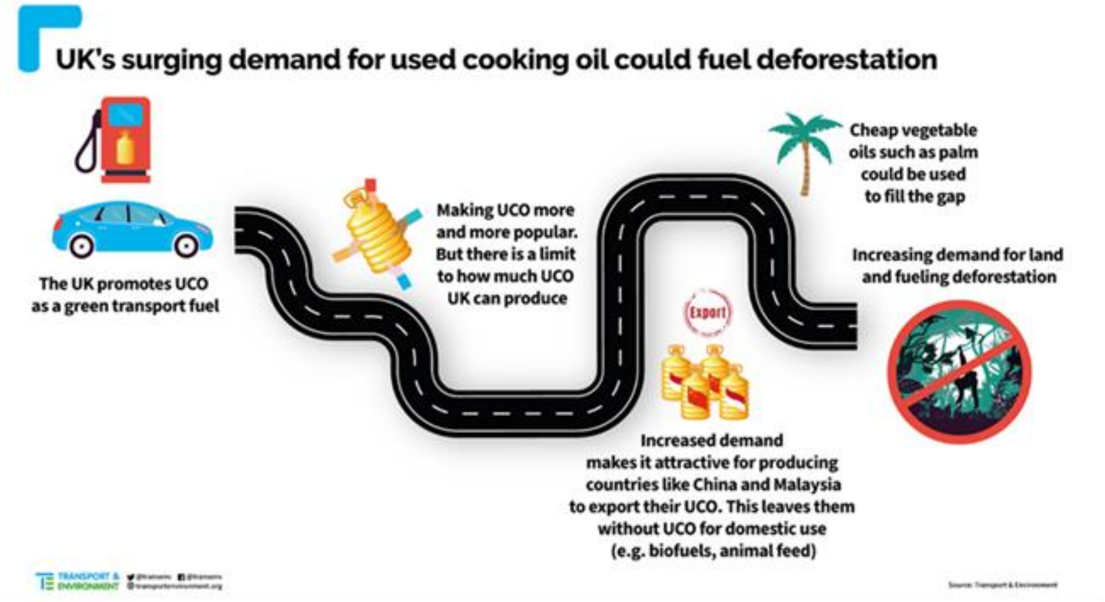


Table 5-1 *Carbon intensity of HVO, diesel and electricity (BEIS Conversion Factors, 2023)*

Fuel or energy	Unit	TTW (Scope 1 kg CO_2e)	Scope 2 kg CO_2e	WTT (Scope 3 kg CO_2e)	T&D Scope 3 kg CO_2e	Out-of-scope kg CO_2	Total WTW
Biofuel HVO (UCO)	kg/litre	0.03558	-	0.35698	-	2.43	0.39256
Diesel (average biofuel blend)	kg/litre	2.4788	-	0.61101	-	0.14	3.08981
Electricity	kWh	-	0.207074	0.0459	0.0397	-	0.29264

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

The BEIS Conversion Factors Methodology points users to the DfT RTFO data when determining GHG emission reductions from HVO. Users must be clear about the source of the claimed reductions in GHG emissions, what these figures include in and out of scope and make sure they use the right factor for the year in question.

Finally, after recent events, there is the issue of security of supply with some of the countries from which the UCO is now being sourced having been subject to sanctions by either the UK, EU, or USA. This further undermines our confidence as to the sustainability of HVO made from UCO sourced from outside Europe. In the context of grain shortages, the drive for increased consumption of fuel that is grown from crops, should also be questioned before committing to its use.

6. Using BEVs to achieve a zero-emission fleet

Where a large proportion of a fleet is operationally viable for replacement with BEVs, this will provide the most energy efficient, zero tailpipe route to large emission reductions. Their implementation may bring challenges from an infrastructure and capital point of view. Help with processes to maximise their uptake in a fleet such as WLDC is described in this section.

6.1 Establish a transition team

The successful transition of the WLDC road transport fleet to a zero-emission fleet will require WLDC to establish a small working group encompassing fleet management and any relevant vehicle operating departments; estates, energy management (or sustainability), human resources (for grey fleet), procurement and finance. The robust appraisal of need and utilisation, changing vehicle procurement to a WLC model, funding the new fleet and installing the charging infrastructure to support new BEVs, will require input and resources from all the groups identified above, as well as a governance and reporting structure with full senior management team engagement.

The move to zero tailpipe emissions is a once in a generation transformation and is not just a project for the fleet team. The decarbonisation of the fleet should be occurring in parallel with a move away from the use of fossil fuels, such as natural gas or oil for heating buildings and this will usually involve a move to electric heat pumps. The two projects need to be integrated, as site supplies and infrastructure will need to cope with the demands of heat pumps, PV generation (and possibly export), battery storage and vehicle charging.

6.2 Identify suitable BEV options

The factors to consider when selecting a suitable BEV include:

- typical daily journey length and load – longest daily trip, maximum load.
- single-charge range – avoiding charging during the working day, if possible, due to lower costs overnight and operational inconvenience.
- opportunities to charge during the day – useful for top up charging if battery range is occasionally exceeded by a small amount.
- carrying capacity – weight and volume in LCVs and HCVs.
- towing capacity – with BEVs under 3.5 tonnes, this can be limited in some cases.
- WLC – cost over the operational lifetime.
- grant funding available – any funding to cover WLC difference.

We have undertaken an initial analysis of the principal elements of the WLDC fleet using the data provided (see Sections 7 to 9). Using 2022/23 as a guide to likely future fleet usage and activity, there is some good and immediate scope for the phased transition to BEVs to begin within upcoming vehicle replacement schedules.

6.3 Review vehicle utilisation

WLDC have already been pro-active in identifying commercial vehicles with low levels of usage and have reduced the fleet size of the small vans and RCVs accordingly. Most of the remaining low usage vehicles are simply older vehicles that are retained to cover if part of the main fleet is in the workshop for maintenance or repair. It continues to make sense to select the best outgoing vehicle(s) when replacements are made to undertake this back-up role. There would be no value in replacing these with new zero emission alternatives, although this will eventually happen in the long term, as low emission vehicles reach the end of their front-line service life.

The most prominent low usage vehicle on the fleet is YT20GOP, a Skoda Superb, which has been used for occasional mayoral duties. There would currently be no GHG benefit to replacing this with a low emission alternative, due to the low mileage meaning that the GHG emissions from manufacture of a BEV would not be recovered by the fuel emissions savings.

Normally, we would recommend that such a low usage vehicle is routinely sold and replaced with spot-hired or pooled vehicles. However, in recognition of the special circumstances of the role this vehicle potentially plays, we would advise close collaboration with local service providers to understand if there is a flexible, reliable zero emission, or low emission private hire option. If there is a viable service, then disposing of this vehicle will be possible.

WLDC should also consider how much grey fleet mileage is undertaken on council business from key council locations and whether there is the potential to reduce emissions by transferring some of this mileage to low emission pool cars or car club cars. The grey fleet is out of the scope of this review but is still worth considering for emission reduction potential.

6.4 Adapt the fleet replacement cycles to BEVs

WLDC have a planned replacement schedule for fleet vehicles, with only ‘back-up’ vehicles over seven years old. All vehicles are now at least Euro VI/6 emissions standard. Ongoing improvements in emission technology and standards mean that today’s Euro 6/VI(d) fossil fuel ICE vehicles will be superseded by cleaner ICE models with (Euro 7/VII) which is now under consideration for introduction in 2025/26. Typically, WLDC replaces vehicles every six years.

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

With electric RCVs and HCVs, it may be necessary to take a different approach to the replacement cycle with the chassis, drive train, battery and rig all being treated as separate and independently replaceable components. This approach will be discussed further in Section 9.

To maximise the return on the investment in BEVs, we recommend aligning replacement cycles with the vehicle’s battery warranty, although if a battery is well maintained, its life could be a lot longer than its warranty period. This may mean planned replacement cycles of eight or, in some cases, ten years.

6.5 Introduce a BEV prioritised procurement policy

The assumption should be that from now, all ICE vehicles will be replaced with zero emission BEV models as part of the standard fleet replacement programme. It is occasionally appropriate to use a plug-in hybrid electric vehicle (PHEV) or an ICE range-extended electric vehicle (REEV) where a BEV is not practical, and the PHEV or REEV offers real GHG reductions because there is a significant opportunity to use it in electric-only mode.

However, PHEVs must be applied and managed carefully to avoid poor emissions performance caused by limited battery size and petrol engines being used to carry the extra weight of the electric motor and battery system.

Other technologies such as Hydrogen Fuel Cell (H2FC), Hydrogen ICE (H2ICE), Hydrogen-Diesel Dual-Fuel, Biomethane (BioCNG/LNG) and HVO (BioDiesel) should only be considered where there is no suitable BEV technology available; or expected to be available.

It is recommended that procurement follows the process in Table 6-1 .

***Table 6-1** BEV procurement process*

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

Where current assets are underutilised, replacements should be robustly challenged because of the high capital cost of BEVs. A well utilised, right-sized BEV can save money. An underutilised, overweight BEV costs extra money.

6.6 Use a Whole Life Cost (WLC) selection model

A WLC model calculates all of the predicted costs of owning and operating a vehicle over its operational life, including the capital, servicing, vehicle excise duty and the fuel or energy cost. Fixed costs such as fleet management overheads, telemetry and fleet insurance could also be included, although they do not vary based on fuel or energy type.

Over a BEV's operational life, the reduction in energy cost compared to diesel vehicles may partially or completely offset the higher purchase cost and can result in an overall WLC saving. The current disruption in the energy markets caused by high gas and oil prices means it is very difficult to predict the long-term price of electricity, gas, petrol and diesel to 2030 and beyond. To mitigate for this, we advise the use of conservative figures and using long run averages of energy cost increases when predicting costs in future years. It appears unlikely that prices will remain at the current elevated levels on mid or long-term horizons.

BEVs are mechanically simpler than diesel vehicles, with significantly fewer components in the drivetrain and without a complex transmission and exhaust system. As a result, maintenance costs are much lower – often quoted at 20-30% less. Over an extended operational life of eight to ten years, the saving may be even greater, as ICE vehicles can incur significant costs in later years. The failure of even one ICE vehicle component can be very expensive - for example, replacing a gearbox, or an exhaust catalyst system. The saving from reduced maintenance costs can further help to offset the higher purchase cost or add to overall cost savings.

This approach is also valid for investment in vehicle improvements that may yield CO_2e emissions savings, for example, electric bin lifters.

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

6.7 Putting a cost on GHG emissions – carbon accounting

Implementing GHG emission reductions may have associated costs and deciding what costs are acceptable and where to invest, to achieve the maximum and best value GHG reductions, can be achieved by putting a price, or value, on every tonne of GHG (tCO_2e) emitted (or saved).

Many companies use a carbon price for project appraisal, including ASDA, Novartis, BP, and Shell. Some also use an 'internal price' or 'carbon fee' charged to departments based on their GHG emissions. Companies in this group include Microsoft, Apple, Disney, and Ben & Jerrys. The funds raised are then used to reduce GHG emissions, either by funding GHG reduction schemes within the same company, or by the purchase of independently accredited carbon offsets.

A shadow price for carbon can reflect the societal cost of GHG emissions (externalities) or it can assess the mitigation cost linked to specific targets. A review published by BEIS: "Carbon values literature review (2021)" concluded that, for the UK, the use of a "target consistent price path" was most appropriate because the country has stringent GHG reduction targets and there are significant uncertainties over the use of a price linked to societal cost. As a result, BEIS and Her Majesty's Treasury (HMT) have produced a target consistent shadow carbon price to be used in policy appraisal at a national level.

Following the announcement by the UK Government of new, more ambitious, Nationally Determined Commitments (NDCs), a review of the target consistent UK shadow carbon price was carried out by BEIS and HMT (October 2021).

That review resulted in a significant increase in the UK shadow carbon price from £72 a tonne to £248 a tonne in 2022 and from £81 a tonne to £280 a tonne in 2030 (see Appendix C, Table C-1: Central Carbon Value (BEIS 2021)). The increase between 2022 and 2030 reflects the greater impact of emitting a tonne of GHG in 2030 on the UK's ability to reach its new NDCs.

7. Moving to a zero emission LCV fleet

7.1 Overview of the LCV fleet

WLDC currently have 10 LCVs as shown in Table 7-1. The fleet size has been reduced since the 2022/23 financial year. There are now two electric Nissan Townstars within this section of the fleet, which have commenced operations since April 2023, and numbers of small vans have been reduced. Data is from vehicles operated in 2022/23. However, any subsequent discussions of replacements will reflect the current make-up of the fleet.

***Table 7-1:** Categories of ICE LCVs on the fleet (2023), their energy efficiency and annual mileage*

Fleet Category	Qty Oct 23	Qty 22/23	Example Make	Example Model	Average mpg	Average annual mileage	Min annual mileage	Max annual mileage
Small Van*	4	5	Peugeot	Partner	46.8	6,934	5,571	8,185
3.5t (inc Luton Van)	1	2	Iveco	Daily	18.2	13,635	Na	Na
5.2t Cage Tipper	5	6	Man	Cage Tipper	16.7	19,352	17,104	22,712

**We expect average mileage to increase with reduced fleet size*

Usage levels are within a relatively small range compared to many similar fleets, suggesting that vehicle planning is well balanced. Usage levels are also relatively high, which reflects some of the actions taken already to ensure a well-utilised fleet and de-fleet unnecessary vehicles.

There were no telematics units installed in this part of the fleet. However, daily mileage logs are kept and WLDC provided daily mileage totals for all 5t vehicles, covering all of September 2023.

7.2 Small LCVs

WLDC will be very familiar with the Nissan Townstar small electric van which features a 45kWh battery. A similar specification is also available with the Renault Kangoo E-Tech.

Versions of the Stellantis group Peugeot e-Partner, Citroen e-Berlingo and Vauxhall Combo-e Cargo, with 50kWh batteries, are also available. Maxus offer the eDeliver3 with 35kWh and 50kWh battery options.

Ford are soon to launch the electric version of their smaller van and more options are emerging from manufacturers that are new to the market. These are all practical BEVs, mostly with competitive payloads and load volumes, all of which achieve real world GHG emission reductions, and which can also reduce WLCs. Table 7-2 provides a summary of some of these statistics as well as an indication of likely 'Real World range.

***Table 7-2** Payload (kg) and load space (m^3) of electric LCVs up to 2.6 tonnes*

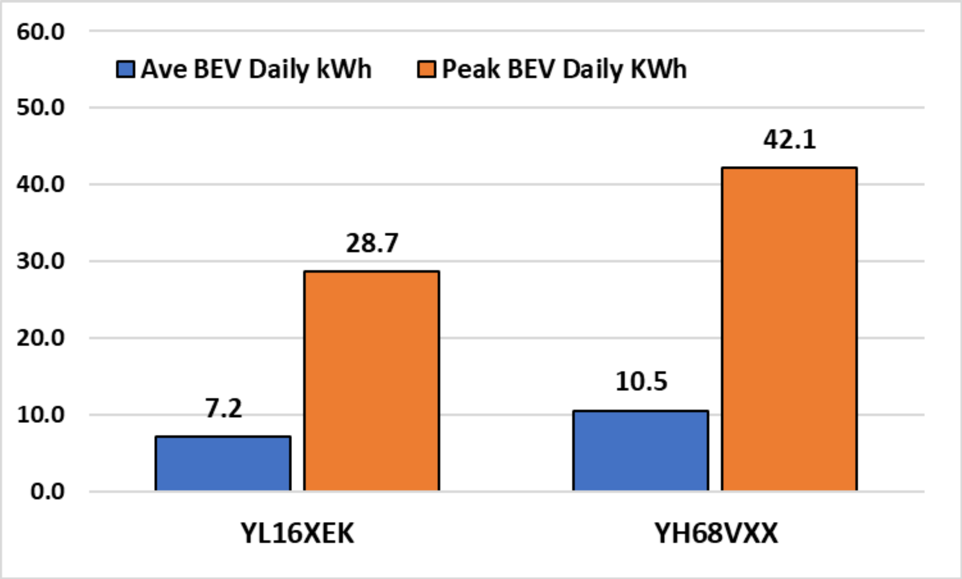
Make	Model	Battery (kWh)	RW Range[1] (Miles)	Maximum payload (kg)	Capacity Cubic m^3
Renault	Kangoo E-Tech	44	130	608-764	3.6
Nissan	Townstar L1 or L2	45	130	612-781	3.3-4.3
Maxus	eDeliver 3	35 or 53	90 - 150	865-1020[2]	4.8
Stellantis	e-Berlingo/e-Combo Cargo	50	125	800	3.8/4.4

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

This part of the fleet has been downsized from five to four vans. The two vans in this part of the fleet that have not yet been replaced by BEVs are the wardens van (YH68VXX), which undertook 7,645 miles in 2022/23 and the managers van that is used for 'call-outs'. Whilst the vehicle, YL16XEK undertook 5,571 miles in 2022/23, we would expect annual mileage to be higher going forward, due to the reduction in vehicle numbers.

No daily mileage records were available for the small vans, so the numbers in Figure 7-1 are based on an estimate. Energy is presented as an average across 240 operating days using the prevailing efficiency of individual vehicles (alongside an assumption that a BEV will use 30% of the energy of the diesel in unfavourable conditions). In the absence of data around peak usage levels, this is presented at four times the average (which considers that the vans do not typically travel far). It is not possible to confirm this without telematics data or daily records.

Figure 7-1 *Average predicted daily and peak energy consumption of WLDC BEV small vans*



Average daily mileages for these vehicles vary from 23 to 32 miles. WLDC may wish to collect further data to verify peak mileages for these vehicles, to understand which battery size is best and if top-up charging may be required. There is due consideration that the on-call van may need to be charged within the day, so consideration of suitable charging in typical daytime locations and subsequent provision needs to be made before a BEV can be procured with confidence that it can operate effectively.

Assuming the warden's van can fully charge at a WLDC location when not in use, it is highly likely that both remaining diesel small vans could be replaced by a BEV, with manageable operational changes. Based on data provided, replacement is not due for a few years. At this point, longer single charging ranges and improved off site charging infrastructure is expected, further minimising any likely concerns for the transition of these vans.

7.3 WLC – small LCVs

We have compared the cost of small vans with typical BEVs using a public sector framework prices at 8,000 miles a year, over eight years (eight years or 100,000 miles is the battery warranty period for several of the models). The comparison is based on current average WLDC small van efficiency, diesel at £1.40 a litre and electricity costs of £0.32 per kWh. Vehicle residual value is assumed to be 10% of the original cost of the vehicle. Pence per mile is shown on the 'y-axis'.

Figure 7-2*: Comparison of ICE and BEV small van options – 8 years, 64,000 miles, purchase*

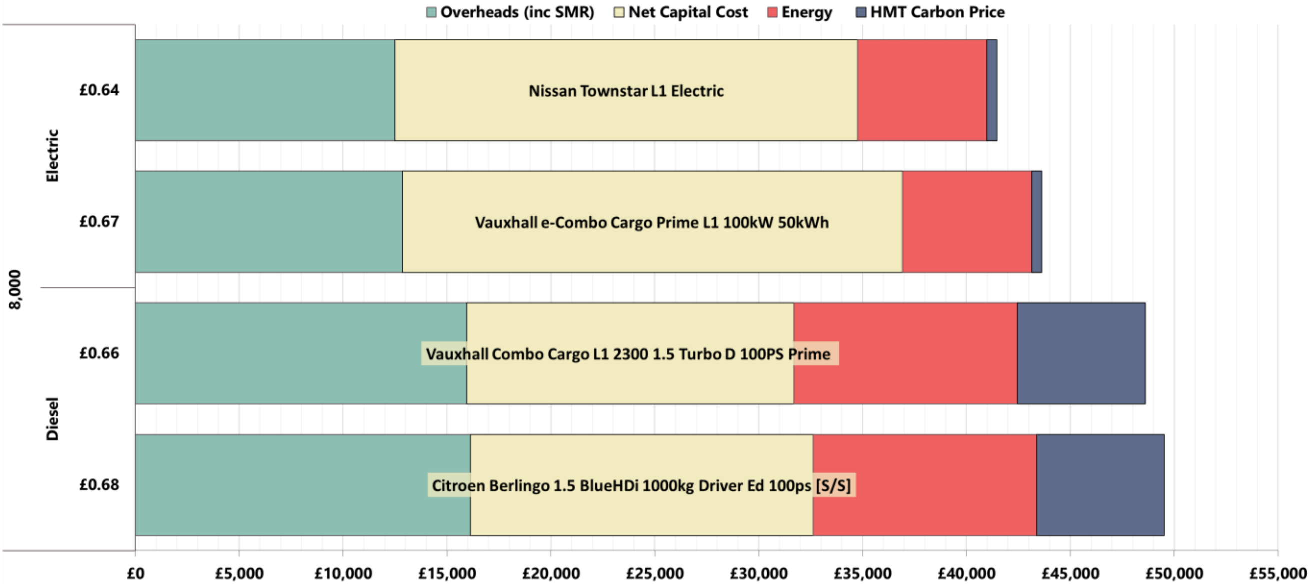


Table 7-3 *Whole life cost and GHG emission comparison, small Vans at 8,000 mpa, 8 years*

Make and Model	Power	Discount purchase price	£/mile	Annual GHG (t)	WLC excluding carbon price	HMT shadow carbon price
Nissan Townstar L1 Electric	Electric	£28,385	£0.640	0.2t	£40,989	£486
Vauxhall e-Combo Cargo Prime L1 100kW 50kWh	Electric	£30,636	£0.674	0.2t	£43,148	£486
Vauxhall Combo Cargo L1 2300 1.5 Turbo D 100PS Prime	Diesel	£18,348	£0.663	2.9t	£42,461	£6,144
Citroen Berlingo 1.5 BlueHDi 1000kg Driver Ed 100ps [S/S]	Diesel	£19,201	£0.678	2.9t	£43,383	£6,144

Using a BEV will reduce the GHG emissions of each small van by an estimated average of around 2.7t a year or 21t over 8 years and 64,000 miles. This is an average annual emission saving of 5.4t across both remaining small vans.

Replacing current diesel small vans with BEVs would have similar WLCs, saving up to £200 a year per vehicle at current energy prices. If electricity prices reduce from current high levels, or energy can be purchased more cheaply from on-site generation, then BEVs will create bigger savings.

If shadow carbon costs (Section 6.7) are included within price considerations, then the BEV option looks like a significantly better financial option in every case.

WLDC should replace both of their remaining small diesel vans with BEVs as their replacement becomes due within existing plans. Based on our modelling, reflecting current costs, we would expect this to deliver modest savings. In practice, the purchase price of diesel vans is increasing faster than that for BEV vans, so we would expect to see even clearer WLC advantages emerging for BEVs as the decade progresses. Initial outlay may be around £20,000 more for both vehicles, but is offset by cheaper operating costs.

7.4 Large LCVs - 3.5t

The first generation of BE vehicles in this category had limited capabilities because of small battery sizes. Newer vehicles such as Fiat E-Ducato and Maxus eDeliver 9 are now very capable, with a longer range and much greater carrying capacity than earlier vehicles. The Ford E-Transit is available with a comprehensive range of size options. Stellantis Group also produce the e-Boxer, e-Relay and the Movano-e. It is now possible to procure a 3.5t BEV with most body types and specialist applications that may be offered on a diesel vehicle.

Table 7-4 *Payload (kg) and load space (m3) of electric LCVs, 3.5 tonnes.*

Make	Model	Battery (kWh)	RW Range1 (miles)	Maximum payload (kg)	Size[2]
Fiat	E-Ducato	47 or 79	91 - 148	1,900	L1-L4/H1-H3
Maxus	eDeliver 9	50, 72, 88	136 - 150	1,400	L2-L3/H2-H3
Mercedes	eSprinter	55	96	774	L2-L3/H2-H3
Renault	Master E-Tech	52	90	1,000	L2H2
Stellantis	e-Boxer/e-Relay/Movano-e	37 or 70	139	1,260 - 1,890	L2-L4/H2
Ford	E-Transit, 350, 390, 425	70	108 - 126	1,470 - 1,970	L2-L4/H2-H3

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

Luton Van

WLDC currently operate one 3.5t van (FN20XHZ), which was registered in 2020. The vehicle has a Luton body and is primarily used for delivering and collecting bins. Average efficiency is 18.8 mpg. No daily mileage records were provided for this vehicle, but annual mileage for this vehicle is expected to be very close to 18,000 miles based on fuel odometer records. If the vehicle is used for 240 days a year, then this would be an average of 75 miles a day. Based on current efficiency and a BEV using 30% energy of a diesel, this would be equivalent to around 60kWh a day. This would be in the range of several electric alternatives that are currently available.

In reality, usage fluctuates daily as it services varying needs. Knowing the level of variation could accurately determine if a BEV could undertake this role without the need for regular top-up charging and establish the size of battery that would be most suitable.

The fuel data shows the vehicle being refuelled on less than half of the working days in the year, which means that many records could be the amalgamation of several days usage of the vehicle and cannot be used to assess daily peak energy usage. However, some records show where the vehicle is being refuelled at the end of successive shifts, giving a clear indication of daily energy use on those days. On several occasions it appears daily energy consumption would be well in excess of that of a typical BEV's single charge capacity. As such it does not appear likely that there are any current 3.5t vans that offer a suitable alternative.

WLDC should aim to understand the maximum daily energy consumed by this vehicle and how often this would exceed a typical battery capacity if adjusted to likely BEV energy consumption. This will help understand which 'future' battery size would be a viable alternative to diesel, what future in-shift charging needs may be required and so when to make the transition.

There is also a possibility that some of the options explored in section 7.5 for decarbonising the 5t cage tippers may also be relevant to this vehicle if fitted with a Luton body rather than a tipper body. Future purchases could be viable for conversion to hybrid, although more data on the use patterns of this vehicle would be necessary to fully assess viability. It is unlikely to be worthwhile to convert this specific vehicle to hybrid, this may only be worth considering on a subsequent new replacement with a longer expected lifespan.

7.5 5t Cage tippers

Until the recent (2023) launch of the Iveco Daily electric there was no OEM option for zero emission cage tippers within this weight category. Currently factory orders are possible for some variants of the Iveco Daily with a factory tipper body, through a major public sector framework. It is also possible to order a chassis cab in other weight categories and with larger battery sizes, which could be fitted with a tipper body (ex-works).

There are also 3.5t BEV options. Most would involve purchasing a chassis cab and specifying a conversion outside of the framework (table 7-4 gives an outline based on vans of the same size). The Ford Transit was the only electric model specifically offered (or categorised) as a tipper within the procurement framework. Some options are summarised in table 7-5, which is not exhaustive. We understand that a Mercedes Sprinter 5t BEV will also become available in 2024 with a 112kWh battery capacity, which will increase the options available. The emergence of competition is also likely to lead to lower prices in this vehicle category.

Table 7-5 Summary of Electric cage tippers

Make & Model	Variant	Battery (kWh)	Maximum payload (kg)
Iveco Daily	42S14 3450WB Tipper	74 kWh	1,171 kg
Iveco Daily	50C14 3450WB Tipper	74 kWh	2,105 kg*
Iveco Daily	50C14 4100WB Chassis Cab	111 kWh	1,949 kg*^
Iveco Daily	72C14 4100WB Chassis Cab	111 kWh	3,680 kg^
Ford Transit	350 L3 Leader Tipper	68 kWh	1,380 kg
Ford Transit	425 L4 RWD Chassis Cab	68 kWh	1,574 kg^

** diesel 5t equivalent payload is 2,348kg. ^ estimated based on tipper body weighing 500 kg*

WLDC currently operate five 5t cage tippers. Four are MAN vehicles, registered in 2018 and one is an Iveco Daily registered in 2017. Average efficiency appeared to be 16.7 mpg in 2022/23, varying from 15.4 to 17.6 mpg. Daily mileage data was available for September 2023 and fuel data was also provided in full. All vehicles enjoyed relatively good levels of utilisation, with an average of 19,352miles in 2022/23. This varied from 15,508 (WM68HBZ) to 22,712 (WM68HCD).

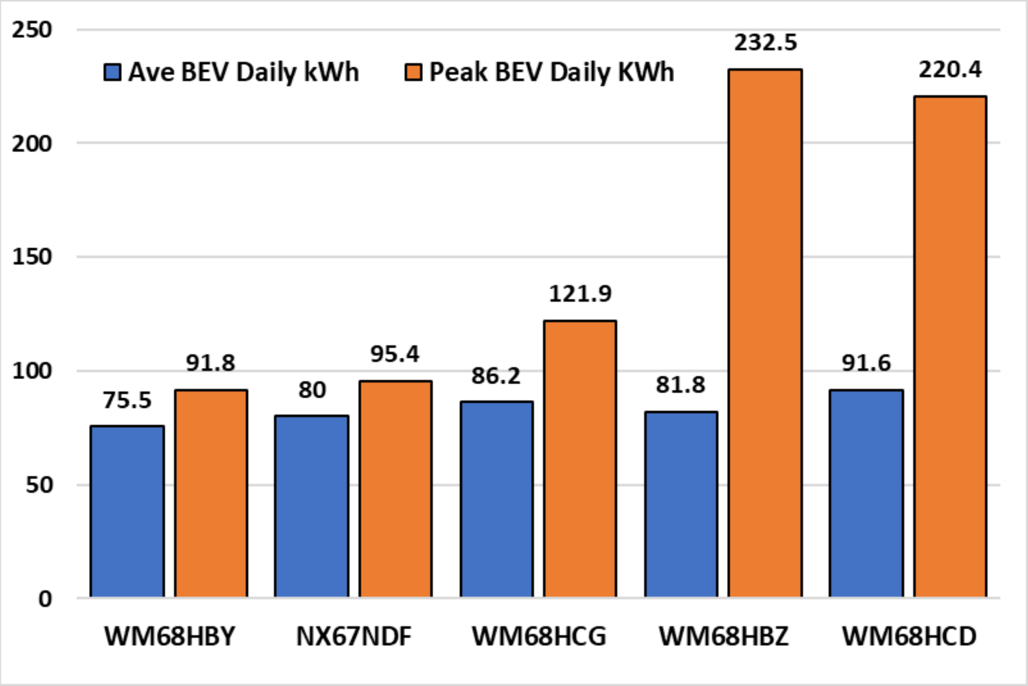
WLDC provided daily mileages of all the 5t tippers for September 2023. When combined with the specific average diesel consumption of each vehicle, and the assumption that a BEV would use 30% of the energy of these vehicles, we were able to conservatively model likely BEV energy consumption for vehicles. We were also able to model what likely energy consumption would be like for a lighter equivalent electric vehicle (3.5-4.25t), using efficiency for this size vehicle although suitability to task would depend entirely upon whether a lighter vehicle would offer sufficient payload or battery capacity.

It appears that all of the vehicles would exceed the 68kWh battery capacity of a lighter vehicle on between 28% and 38% of the days they are operated (even with the energy forecasting reflecting the higher efficiency of the lighter vehicle). They will be close to the single charge capacity on several more days. The situation would be similar with a 74kWh battery, meaning that the only option to electrify these vehicles would be with the largest battery on the market.

If a 5t (or 7t) vehicle with a 111kWh battery was employed (assuming there is sufficient space to fit a tipper body suitable to WLDCs specification with this configuration), then the operation of BEVs looks a lot more operationally favourable.

Figure 7-3 shows the forecast maximum and average energy consumption for each vehicle. Table 7-6 provides context of frequency of days where high energy consumption takes place.

Figure 7-3: *Average predicted daily and peak daily energy consumption of WLDC BEV 5t tippers.*



Based on data from September 2023, it appears that two of the tippers, WM68HBY and NX67NDF would not exceed the single charge range of an Iveco 50C14 with the 111kWh battery. This would make them operationally suitable for replacement with a BEV, requiring no in-shift charging to maintain current operating patterns and only charging overnight at the depot.

Table 7-6 *Number of days 5t tippers would be likely to exceed BEV single charge capacity*

Reg	No. of days used in September 2023	Likely BEV efficiency (miles per kWh)	Number of times BEV will exceed 110kWh	No of times a BEV will exceed 68kWh
WM68HBY	21	1.16	0	6
NX67NDF	18	1.21	0	9
WM68HCG	17	1.13	1	9
WM68HBZ	20	1.07	2	3
WM68HCD	21	1.22	4	14

The three remaining tippers would be likely to exceed the single charge capacity on occasions. Whilst this could be an issue if electrifying the fleet (arguably this would happen at least monthly for each vehicle), it is evident from closer inspection of the data that there is no date where more than one vehicle used more than a predicted 110kWh of battery capacity. The implication of this would be that if there was scope for some flexibility in how the jobs were allocated (or some ability to predict days of high energy use before a shift), it could be operationally possible to operate four out of five electric tippers within the WLDC fleet, leaving just one diesel vehicle. This of course would have capital implications which are discussed fully in Section 7.6.

Retrofit possibility for 5t tippers

Bedeo have launched a new range of retrofit products that have the aim of enabling existing (or new) diesel vehicles to be fitted with electric powertrain equipment that will secure significant emissions savings, whilst retaining an engine to act as a range extender on days when distance travelled is greater than the battery can deliver.

Bedeo is a brand of BD Auto who have manufactured all the electric 3.5t-4.25t vehicles for Fiat in recent years. Powertrains are supplied by Protean, who are well established as a supplier to OEMs. In the Bedeo product, there are in-wheel motors leaving sufficient space to accommodate batteries alongside tipper mechanisms.

The option offered for a 5t vehicle is a range extender configuration which replaces the vehicles original diesel engine with an electric drivetrain and new petrol ‘range extender’ (in contrast to the 3.5t conversion that retains the original Euro 6 diesel engine). This is being made available initially for the Mercedes Sprinter 5t, with the first demonstration vehicle now available with a van body. Battery options are likely to be 37kWh and 74KWh. This configuration will allow the vehicles to continue running for as long as is needed on the range extender engine after the battery becomes depleted.

Given that most of the mileage on this fleet is within a 74kWh capacity of a battery’s capacity, this product would have had the effect of electrifying over 83% of WLDCs mileage if fitted to all cage tipper vehicles in September 2023. This would be the annual equivalent of a 12.5t CO2e emission saving based on 83% of the emissions reduction that would be achieved from switching to a BEV.

7.6 WLC – Tippers

Cost comparisons for 5t tippers have been based on 20,000 miles a year, which is close to the current average for this part of the fleet. We have considered BEV alternatives with a 111kWh battery, and varying payloads as well as an estimate relating to the forthcoming range extender.

Not all vehicles were available to quote as tippers on the framework, so all have been priced as a chassis cab for consistency. The vehicle costings will still be comparable for WLDC because the body conversion costs do not vary with power type and the main difference will be from the drivetrain. On the procurement framework there were fewer BEV tippers listed than BEV Chassis Cabs, which could no doubt be specified with an additional cost conversion to a tipper.

We have assumed diesel will cost £1.40 a litre and electricity costs of £0.32 per kWh (all exc vat). Vehicle residual value is assumed to be 10% of the original cost of the vehicle in all cases. A cost of £0.50 a litre has been added to further compare costs of running diesel vehicles using HVO. We have also considered the benefit of reduced energy costs that could be delivered by investment in renewable energy sources and how that could affect the WLC calculation.

Diesel costs are based on 16.7 mpg, which is the average for WLDC’s caged tipper fleet. Vehicle costs are modelled over eight years, which is closely aligned to battery warranty (155,000 miles and eight years). However, if batteries are regularly charged using overnight AC charging, it is probable that there will be significant residual life beyond eight years, although the residual life of the rest of the vehicle would need to be assessed at that stage.

Figure 7-4 *WLC comparison of ICE and BE tipper options at 8 years, purchase, 160,000 miles*

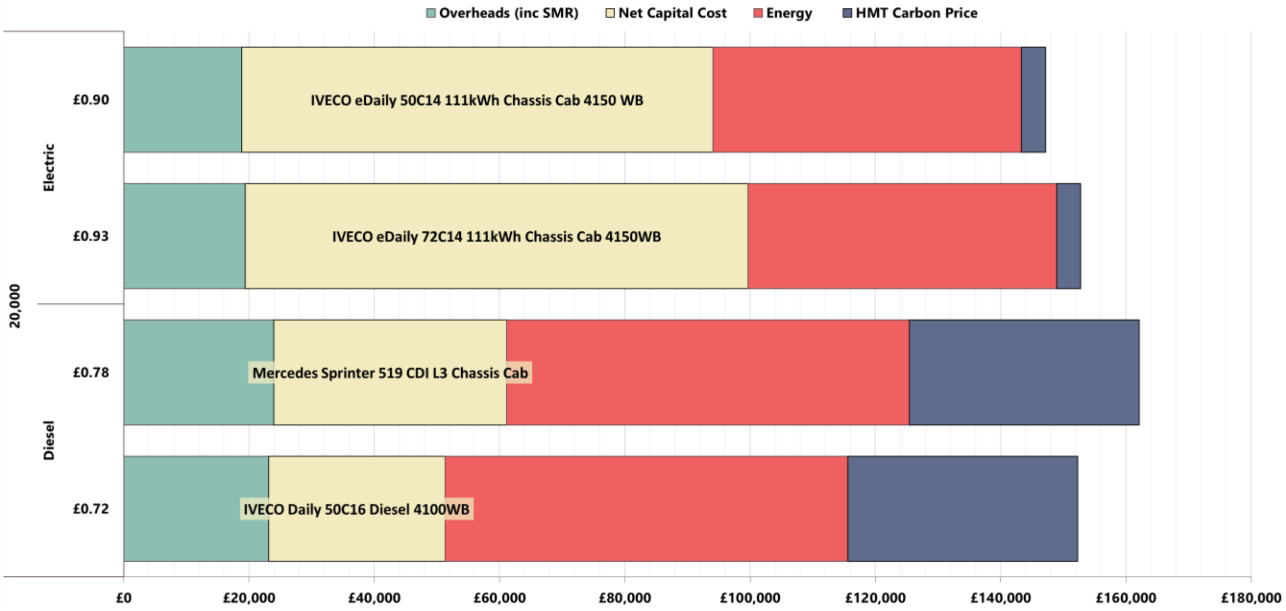


Table 7-7 *5t LCV chassis cab - WLC and GHG emission comparison, at 8 years, 160,000 miles*

Make and Model	Power	Discount purchase price	£/mile	Annual GHG (t)	WLC excluding carbon price	HMT shadow carbon price
IVECO eDaily 50C14 111kWh Chassis Cab 4150 WB	Grid Electric	£86,762	£0.896	1.8	£143,317	£3,842
IVECO eDaily 72C14 111kWh Chassis Cab 4150WB	Grid Electric	£92,518	£0.931	1.8	£148,939	£3,842
Mercedes Sprinter 519 CDI L3 Chassis Cab	Diesel	£43,741	£0.784	17.3	£125,418	£36,700
IVECO Daily 50C16 Diesel 4100WB	Diesel	£34,203	£0.722	17.3	£115,575	£36,700
IVECO Daily 50C16 Diesel 4100WB	HVO	£34,203	£0.892	2.1	£143,303	£4,482
Mercedes Sprinter 519 CDI L3 Chassis Cab with £30k Conversion (74kWh)	17 % Petrol 83% Electric	£73,741	£0.853	4.4	£136,512	£9,427
IVECO eDaily 50C14 111kWh Chassis Cab 4150 WB	50% Grid Electric 50% Renewable* *£0.10 kWh	£86,762	£0.790	0.9	£126,739	£1,921

Options exist to replace up to four of the five 5t tippers, that can deliver substantial emissions reductions of around 15.5t per year per vehicle. However, all these options do come at differing levels of WLC. In the case of electrification, the costs are front-loaded with capital expense, and then running costs are reduced throughout the life of the vehicle, albeit without fully compensating for all additional purchase costs.

Overall, if a 1,950kg payload is sufficient then the Iveco eDaily 50C14 111kWh would be a good low emission alternative to diesel tippers. If not the larger capacity 72C14 would cost £700 a year more over the life of the vehicle and has the same footprint.

When compared to diesel equivalents, an electric tipper would cost around £1,900 less a year to operate if powered by grid electricity. However, when purchase costs are factored in, the WLC is £3,500 a year more than the diesel. This works out at around £225 for each tonne of carbon emissions saved, which is less than the shadow carbon price suggested by the government, and as such may represent a good value investment in emissions reduction.

If the BEV is compared to running a diesel vehicle using HVO, the WLC would be very similar. The difference being that the HVO vehicle would have much higher running costs than the BEV (close to £4,750 a year). Given that carbon emissions may ultimately be more from HVO, tailpipe emissions remain, and questions remain over supply, feedstock (indirect land use issues) and out of scope emission reporting, it does not appear to be as viable as using an electric vehicle.

BEVs in this category start to look increasingly attractive if calculated with energy costs that are not at current peak levels. Whilst prices could increase of decrease, increasing the renewable energy content used to power the fleet is a good way to secure lower energy prices. If the lifetime cost of solar energy is considered at £0.10 kWh, and this could be installed to provide 50% of the energy a vehicle requires, then an average cost of £0.21 kWh would be achieved, and the WLCs of electric vehicles start to compete with some diesel models. In the example in table 7-7, the WLC gap reduces to just over £1,000 a year, and emissions are reduced further still by the renewable energy that is generated.

The conversion to the range extender hybrid option also looks worthy of further consideration, especially for any vehicle that regularly needs to undertake trips that would exceed the single charge driving range of a battery. Assuming 83% of range can be undertaken in electric mode and a £30,000 conversion cost, this costs marginally more than a diesel over an eight-year life cycle, but still reduces emissions by 12.9t.

If the extra capital can be raised, WLDC should initially consider replacing up to four of the five cage tippers with electric equivalents, which would deliver emissions savings of 62t a year and reduce running costs by approximately £7,500 a year. This would also allow the possibility of further emission and cost savings if renewable energy is successfully produced and capacity increased at the depot. If orders have already been placed for diesel vehicles, it would be worthwhile to understand if some could be rescinded and redirected towards the BEV options (subject to acceptable lead times and body specifications).

Any vehicles that are replaced with diesel vehicles should be considered for conversion to range extender hybrid early in their life in order to maximise potential emission reductions and running cost reductions.

7.7 LCVs that could transition to BEV -summary

Before replacements become due, there is the need to plan for additional capital for BEVs. Even if there are lower operating costs, it is important to acknowledge the new cost profile within financial planning.

Table 7-8 *Estimated total replacement costs of diesel or BEV LCVs*

Fleet category	No. of vehicles	No. of vehicles operationally suited to battery electric	Estimated capital cost of all diesel replacements	Estimated capital cost of buying BEVs where suitable
Small van	2	2	£36,700	£56,800
Luton Van	1	0*	£30,000	Na (or +£25k conversion)
5t	5	Up to 4*	£221,000	£431,250 (inc 1 diesel)

**further consideration of usage case required.*

Lead times mean that new vehicles may need to be ordered well in advance of when they are required for work. WLDC need to plan for sufficient additional capital investment for each year, in line with scheduled vehicle replacements.

7.8 Plant and Machinery

WLDC provided information on two road registered machines – a JCB machine and a New Holland Tractor.

Unfortunately, no data on fuel allocated for either machine was available. Refuelling appears to take place using the ‘Spare’ fob, which means any fuel used by these vehicles is not attributable to the specific vehicle.

Without any knowledge of energy used by each vehicle, it is not possible to quantify emissions, usage, costs and suitability or benefits of lower emission alternatives.

The implications are that energy consumption needs to be clarified for each machine before conclusions can be drawn regarding the suitability of any alternatively fuelled variants. This would need to be achieved by monitoring vehicle-specific fuel efficiency alongside activity to understand the maximum energy consumption from diesel (in kWh). This can be used to predict what the likely maximum will be with an electric alternative, using the efficiency of electric alternatives as a guide. If maximum daily energy consumption is within the single charge capacity of a battery in an available product, then the implication would be that an electric alternative is operationally suitable. Even if this is the case, it should also be considered that usage needs to be sufficiently high to justify a low emission replacement, when emissions from embedded carbon within batteries are taken into account. WLDC would need to be sure that operational emissions savings can offset those from the manufacture of a battery powered alternative.

In practice, the market for such electric machinery is not mature, and there are not yet electric alternatives in every class. However, the potential for reducing air quality emissions is particularly high, given the generally lower standard of emissions controls on such machines.

WLDC should quantify fuel use, and when usage is understood, and the need for emission reduction is established, progress to test and assess available products.

8. Moving to a zero emission HGV fleet

8.1 Overview of the HGV/RCV fleet

WLDC have 22 HGVs (including RCVs and Sweepers) as shown in Table 8-1. The list does include some RCVs that are subject to lower levels of usage due to them being spare vehicles for when the primary fleet is being repaired or serviced.

Table 8-1 *Categories of HGV/RCVs on the fleet (2022-23), their energy efficiency and annual mileage*

Fleet category	Qty	Example make	Example model	Average mpg	Average annual mileage	Min annual mileage	Max annual mileage
7.5t	1	MAN	Curtain Side	14.7	20,733	n/a	n/a
4.5t Sweeper	2	Scarab	M25H	3.8*	5,646	n/a	n/a
15t Sweeper	1	DAF	15t Sweeper	7.9	10,201	n/a	n/a
18t RCV*	2	Dennis	Elite 18t	5.6	8,576	n/a	n/a
26t RCV	16	Dennis	Elite 6	4.8	15,347	11,348	21,439

** Data only available for one vehicle*

For some vehicles, it was not possible to identify exact patterns of usage where no telematics units were present and refuelling did not always occur daily. There are variations in mpg between similar vehicles within all sectors of the WLDC fleet. Some of this will undoubtedly be attributable to usage cycles, but some may also reflect varying driving styles, although vehicles are not allocated to one driver/operative.

Where we can confidently understand daily energy consumption from fuel records, more accurate conclusions have been drawn about the operational suitability for replacement with BEVs. Where daily energy consumption is less visible assumptions based on average efficiency and daily mileage have been made. Where no information on daily mileage is available, more assumptions have to be made.

8.2 7.5t HGVs

Mercedes, through its Fuso subsidiary, has its 7.5-tonne eCanter model in full production. The specification offers three battery options with gross weights ranging from 6.5t to 8.5t, providing from 40kWh to 120kWh battery capacity, with the latter claiming up to a 120-mile range from mixed use (the smaller battery would be closer to 40 miles). However, the larger battery model is likely to require a C category driving licence and will be restricted from roads where there is a 7.5t weight limit.

There is currently a payload impact from transitioning to battery electric 7.5t HGVs. It appears likely that a 12t electric HGV will be typically presented as the alternative to a 7.5t diesel vehicle by some manufacturers, especially where operations are payload critical.

Some smaller manufacturers currently produce a 7.5t BEV chassis that can be fitted with the correct body for WLDC's needs. BEV products exist from companies such as Electra and Magtec and these are available now to purchase or lease. Electra use 'gliders' (chassis without engines, gearbox or exhaust), provided by Isuzu as a basis to build their 7.5t BEV upon. The chassis is warranted by the OEM and Electra have their own dealer network under the banner of NRG fleet. With a 140kWh (useable) battery capacity, range is expected to around 120 miles. However, the weight of the batteries in small trucks limits payload.

Another alternative could be the Iveco Daily chassis with a curtain-side body. These vehicles were covered in depth in Section 7.5 in the context of tipper bodies. Longer wheelbases are available, and payload may be sufficient, depending on the weight of the body specified, but largest batteries are only 110kWh.

Decarbonising WLDCs 7.5t curtain-side

There were no daily mileage records provided for this vehicle. It was also not refuelled routinely every day. However, it was sometimes refuelled on successive days, and it was also frequently refuelled after two days work.

On these occasions it was possible to use the daily energy consumption or the average of two days to understand if the likely future energy consumption of the vehicle would fit with the available BEV products. In practice this would be an optimistic outlook, as the combination of two days would not usually be evenly split, so there are probably more high usage days than are indicated in table 8-2.

Table 8-2 Summary of 7.5t HGV likely BEV daily energy consumption.

Reg	No. of days use BEV would exceed 110kWh	No. of days use BEV would exceed 120kWh	No. of days use BEV would exceed 140kWh	Maximum likely daily BEV energy
NX70PCF	40+	31+	13+	172kWh

This analysis would point to a replacement BEV 7.5t vehicle needing in excess of a 170kWh battery to operate effectively with just overnight charging.

In practice, such an energy capacity is unlikely to be possible soon with a 7.5t vehicle. The weight of a high-capacity battery would simply take up too much payload.

A 12t BEV with a 190kWh battery could be used as an alternative, but capital costs would be likely to be close to £200,000, which could be prohibitive. Additionally, driver licensing requirements would be more onerous (C category) and the vehicle would be likely to feel quite ‘over-sized’ for its duties. It is our view that a 12t vehicle is probably an inappropriate replacement for this vehicle.

We would anticipate that a suitable BEV replacement for this vehicle will not be available when it is due for replacement in 2025/26, unless a strategy can be formed to rapid (DC) charge a vehicle in-shift on a regular basis. This would depend on the vehicle being located consistently near to sufficiently high-powered charging infrastructure during a shift (possibly at the depot) and the vehicle being specified to receive DC charge to a sufficiently high level to achieve a sufficient top-up charge in a very short period of time.

By the time the second cycle of replacement for this vehicle is due (circa 2030/31), the possibility of an affordable zero emission alternative is much greater, as is the likelihood of suitable infrastructure for rapid top-up charging. We would expect WLDC to plan for a BEV replacement at that stage. The only action for now is to ensure any future battery charging demand is factored into the depot’s charging infrastructure strategy and grid connection capacity.

8.3 Sweepers

Increasing numbers of options are emerging for electric sweepers. Nottingham City Council is operating a fleet of eight small electric sweepers (Boschung). Companies like Whale (tankers and gully cleaners) and Johnston/Bucher sweepers have used electric drive kits from the Dutch company EMOSS to convert donor vehicles. The Green machine Ze500 is another small fully electric sweeper that has recently emerged on the market with a useable battery capacity of up to 46kWh. Schmidt also offer the e-Swingo 200 for daily duties, suited to inner cities and pedestrianised areas. Battery size is 75kWh.

Also, recently launched from the Fayat group, which owns Scarab, is the ERavo, which is an 11.5t sweeper with a payload of approximately 5t and retail cost of approximately £390,000. The smaller EMC210 electric, is likely to be approximately £225,000, which contrasts with diesel equivalent capital costs of just below £100,000.

WLDC operated three sweepers in 2022/23. We understand that these are hired on a yearly basis, currently from Dawson. One is a 15t DAF truck and two are smaller 4.5t sweepers that are more suited to urban areas. We understand Dawson also hire out equivalent sized electric sweepers.

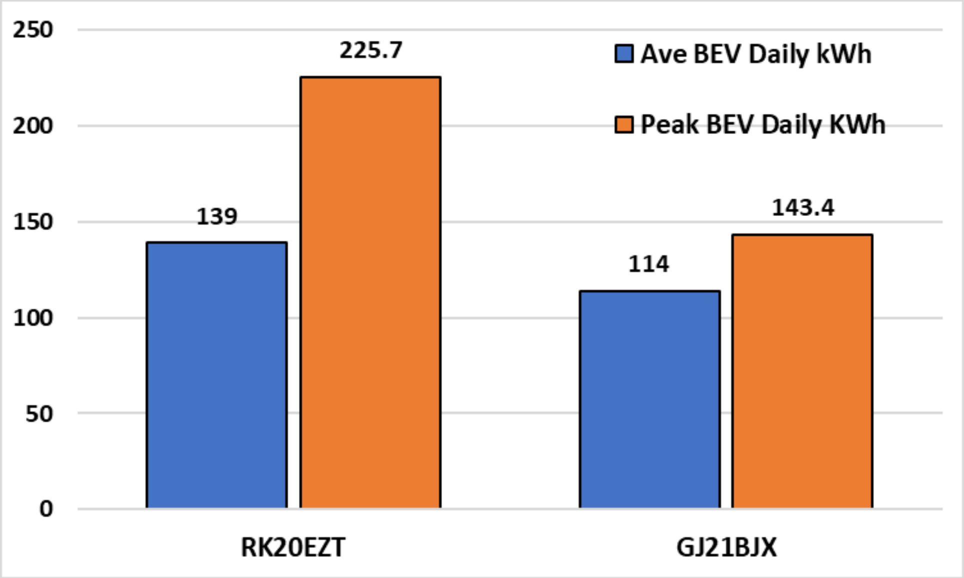
Figure 8-1 *WLDC – two of the leased sweepers currently on the fleet*

Fuel data and mileage was available for two of the sweepers, GJ21BJX (4.5t Scarab) and RK20EZT (15t Johnston). This is sufficient to allow energy modelling for operational suitability of a BEV as well as helping to lower operating costs. However, no data was available for LJ20CJE (which was listed in the vehicle replacement plan). We understand that fuel from this vehicle has been obtained using the ‘spare’ fob and no mileage was reported. We will assume that it has a usage profile that is similar to GJ21BJX for the purposes of the review, although we have no data to confirm anything of the nature and extent of its operation.

GJ21BJX averaged 3.8 mpg, travelling an average of 30 miles per working day (September 2023) and RK20EZT achieved 7.9mpg. This was calculated as 76 miles per working day (September 2023).

Based on current efficiency, Figure 8-2 shows the likely energy use for a BEV equivalent, based on it using 30% of the energy of the ICE version.

Figure 8-2 *Average daily energy consumption and predicted peak BEV energy of WLDC sweepers*



Both refuelling and mileage data for GJ21BJX point to an energy consumption in excess of that which any current BEV sweepers of that size can offer. Typical daily use would amount to around 114 kWh. Even using a lower (less BEV pessimistic) energy conversion factor of 25% to reflect the usage type, would still indicate likely energy consumption of 95kWh a day. This means that the 4.5t sweepers at WLDC are not yet suited for electrification if only overnight charging is available.

The only solution with current products would be for rapid charging during the driver breaks. However, if locations for breaks change, then this would be an unlikely outcome, and would point to small sweepers at WLDC only being suitable for electrification after significant improvements in battery density and single charge capacity, which would be closer to the end of the decade to make this change.

For the 15t sweeper, RK20EZT, it is understood that an electric alternative is available, advertised with a 200kWh battery capacity. However, it appears that only 170kWh is useable capacity. Annual fuel data does not show the vehicle being refuelled every day, but there are twelve occasions where it is clear that more than 170kWh electric energy would have been needed in a day to power an electric sweeper of this size at WLDC. In practice this could be more, but there was not sufficient granularity of fuel data to confirm. Using September's daily mileage for the same vehicle and the average mpg, this looks like it would be between two and four occasions in that month. In all but a few of these cases, energy use would be close to the 170kWh capacity, so top up charging needs would be minimal. WLDC would need to understand if this is a practical and acceptable operational compromise, once or twice a month to enable decarbonised sweeping from this kind of vehicle. The alternative would be to delay procurement until later in the decade, when improved battery capacity is expected to be achieved by manufacturers.

The economic case for electrification will depend entirely on the differential between hire rates for electric and diesel vehicles (as these include maintenance). We did request a quote for hiring an electric sweeper from Dawson but did not receive a response. We would expect the electric version to save around £187 a month at current fuel rates compared to diesel and £480 compared to HVO. Table 8-3 provides a brief summary of possible cost scenarios for a 15t Sweeper. With 50% renewable energy, fuel savings could be even greater.

Table 8-3 *Anticipated fuel costs for a hired 15t sweeper*

Power Source	Energy Unit Cost	Energy cost per year	£/mile	Monthly energy cost
Grid Electricity	£0.32 / kWh	£5,973	£0.59	£498
50% Renewable 50% Grid Electricity	£0.10 / kWh £0.32 / kWh =£0.21 / kWh	£3,919	£0.38	£327
Diesel	£1.40 exc vat	£8,218	£0.81	£685
HVO*	£1.90 exc vat	£11,740	£1.15	£978

**slightly larger quantity due to lower energy density*

The maintenance-intensive nature of sweeping ancillaries means that buying and retaining a vehicle like this may not deliver any significant savings, even if it operated for longer. However, hiring these vehicles does allow WLDC the flexibility to move to a zero-emission alternative when the time is right, without capital outlay, and understanding energy costs will help inform decarbonisation strategies and compare total running costs with hire costs.

9. Moving to a zero emission RCV Fleet

9.1 Battery electric refuse and recycling vehicles

The City of London (Veolia) and Manchester City Council (Biffa) now have substantial fleets of the 18t (2-axle) and 26t (3-axle) Electra RCVs (Figure 9-1) in operation. The Electra vehicle has also entered service with several other councils and boasts a 270kWh useable battery capacity.

The Dennis Eagle eCollect, is a 300kWh battery electric version of the company's popular 26 tonne 'narrow' model. Well over 100 are already in service with many councils including Nottingham, Newport, Cardiff, Oxford, Powys, Dundee, York, Cambridge, Sunderland, and Islington. However, this vehicle is limited to a 40mph top speed which may disadvantage its operation on many of the routes undertaken by WLDC.

Renault's 26t eRCVs (D Wide ZE), has proved popular, with Enfield Council, Peterborough Council and North Lincolnshire Council having purchased several. Renault provide a low entry cab for the electric RCV range. Batteries were initially 265kWh (four 66kWh units), which are adequate for many applications, however, we understand that 90kWh batteries can now be specified, with no weight or space penalty. This gives a total of 360kWh, quoted as a useable capacity of over 300kWh when new.

The first DAF 6x2 eRCV has been supplied to the Dutch waste company ROVA (it has a 170kWh useable battery and a 30 minute rapid recharge time).

***Figure 9-1**: One of the City of Manchester's 27 Electra/Mercedes 26 tonne 300 kWh electric refuse vehicles*

An alternative to buying a new electric RCV is offered by the UK company Refuse Vehicle Solutions (RVS) who have entered into an agreement with EMOSS to use its technology to convert donor RCVs from diesel to electric. The old vehicle chassis, cab and waste collection rig are refurbished, new electric bin lifts are fitted, and the diesel drive train is replaced by an EMOSS electric drive, with the option of a 200kWh or 280kWh battery. Examples are in service with Islington Council and Chichester District Council.

The Geesinknorba group have also developed an electric RCV in collaboration with GINAF, using a DAF LF chassis. The vehicle has a 200kWh battery and a 44kW on-board AC charger. Lunaz offer a comprehensive upcycling solution which claims to deliver a 21 tonne saving from the embedded carbon in the chassis and prevents the further sale and emissions of an old vehicle after it has finished service. So far this has mainly been focused on Mercedes Econic chassis, which can be supplied by Lunaz, if needed. Battery options are 260kWh and 380kWh. However, whilst this does cost more than some new vehicles, it is confirmed that discounts apply with volume.

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

9.2 Moving to a zero emission RCV fleet at WLDC

WLDC have a fleet of 17 Dennis Eagle 26t RCVs and one 18t RCV. Several of the older vehicles could be considered ‘secondary’ or spare, so they are used to cover other vehicles if they break down or are needing maintenance. These do not feature in planned replacements, as they will themselves be replaced by other ‘semi-retired’ vehicles through cascading the best of the vehicles that are replaced by new.

Average efficiency is recorded at 4.8mpg based on data from fuel drawings. A detailed analysis of energy use has taken place for every vehicle, assessing the fuel data sources, and identifying where refuelling has and has not happened daily, so that the most accurate possible conclusion on maximum daily energy use is arrived at. Data has been checked in order that our conclusions regarding suitability for eRCVs should be realistic in all likely conditions.

4.8mpg is an impressive efficiency figure for an RCV fleet and whilst some of this will be due to the rural nature of the routes, factors such as electric bin lifts and the installation of solar matting on some of the vehicles will have made significant contributions to this. Aside from the potential for driver improvement, WLDC have certainly worked well to maximise the base efficiency of the diesel vehicles. Daily utilisation is also comparatively good, due to the longer shift and relief crew operating model.

Figure 9-2 *WLDC diesel RCVs parked in the depot*

Replacing the refuse fleet with zero emission vehicles is very important moving forward, as at WLDC, the RCV fleet accounts for over 80% of fleet emissions, with a large WLDC RCV producing an average annual 46 tonnes of GHG, which is about three times the GHG produced by one of the 5t tippers.

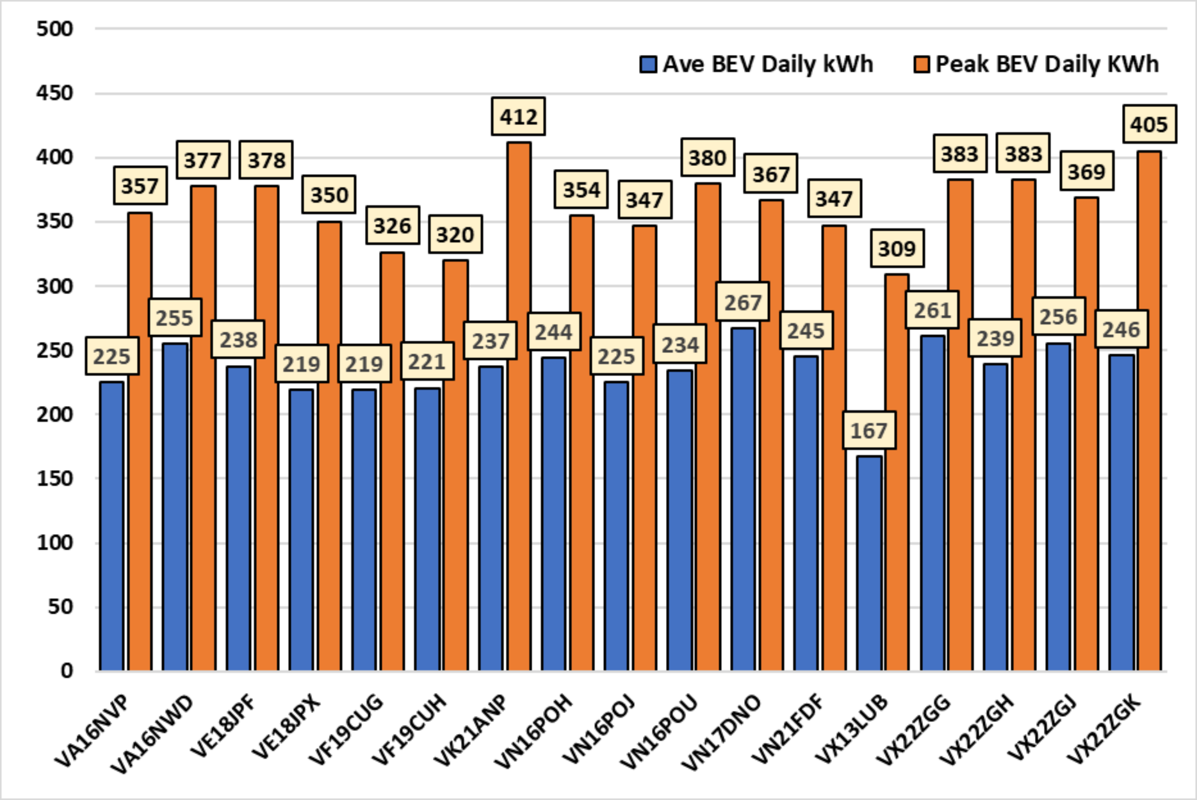
An eRCV is likely to use between 25-30% of the energy of a diesel equivalent during operation (the latter is more likely in colder conditions and at speeds where a diesel vehicle would be more efficient). We have used the 30% figure, to make allowances for adverse conditions and ensure some caution within our conclusions.

All of the WLDC RCVs usually exceeded 200kWh of equivalent likely BEV energy consumption during a typical working day. Refuelling data suggested that average daily electric energy use would be somewhere between 220 kWh and 273 kWh for all RCVs. These figures are likely to be slightly inflated due to a small number of days when vehicles were not refuelled daily and two days data was amalgamated into one refuelling event. This occurred more in some specific vehicles than others.

WLDCs RCVs are not allocated to specific routes or sets of routes, so there are no consistent patterns of energy consumption visible for each vehicle. This also means that all vehicles have relatively high peaks of energy consumption, as they all may be used on longer or more energy intensive routes, on some occasions.

Figure 9-3 sums up registration numbers, and the likely average and maximum energy consumption of eRCV replacements of the current RCV fleet. This assumes that a BEV will use 30% of a diesel vehicle’s energy and that 2022-23 operations offer a sufficiently accurate indication of future activity.

Figure 9-3: *Potential peak and average daily energy use (kWh) of an all-electric heavy RCV fleet (30% ICE energy use, average from 2022-23 data), in place of current ICE RCVs*



If taken at face value, it is possible to look at maximum energy consumption and dismiss the use of OEM eRCVs because all vehicles are likely to exceed a single charge of 300kWh during a shift at some point (this is the ‘useable capacity’ figure offered by Renault Trucks, with Dennis Eagle lower, at 270kWh). The ‘upcycled’ Lunaz vehicle with the larger 380kWh battery would be viable to replace eight of the RCVs, allowing for some battery degradation over the life of a vehicle. A further three may also be suitable, but this does not allow for any battery degradation.

However, if the fleet is viewed holistically and the possibility of allocation of vehicles to more specific routes is considered then the possibility of transition to an OEM eRCV looks more favourable than the data in Figure 9-3 initially suggests. Table 9-1 provides an evaluation of individual vehicles high energy consumption days and table 9-2 considers the amount of times 300kWh on eRCV energy would be likely to be exceeded on any given day across the fleet.

Table 9-1 *Further analysis of BEV suitability of high energy consumption of RCVs by registration*

Vehicle Registration	Peak daily eRCV energy (kWh)	Days over 270 kWh eRCV energy	Days over 300 kWh eRCV energy	Days over 360 kWh eRCV energy	Days over 380 kWh eRCV energy
VA16NVP	357	27	4	0	0
VA16NWD	377	62	29	2	0
VE18JPF	378	38	18	3	0
VE18JPX	350	31	12	0	0
VF19CUG	326	20	4	0	0
VF19CUH	320	22	3	0	0
VK21ANP	412	57	29	5	3
VN16POH	354	59	22	0	0
VN16POJ	347	29	6	5	0
VN16POU	380	26	9	1	0
VN17DNO	367	108	40	2	0
VN21FDF	347	50	17	0	0
VX13LUB	309	3	1	0	0

Vehicle Registration	Peak daily eRCV energy (kWh)	Days over 270 kWh eRCV energy	Days over 300 kWh eRCV energy	Days over 360 kWh eRCV energy	Days over 380 kWh eRCV energy
VX22ZGG	383	85	45	3	1
VX22ZGH	383	41	24	2	1
VX22ZGJ	369	79	45	1	0
VX22ZGK	405	26	12	4	2
Total	**412**	**763**	**320**	**23**	**7**

Vehicles highlighted in red italics are spare / secondary to main fleet.

Table 9-1 Shows the number of times each of these vehicles exceeds typical eRCV product battery capacities in a year, during one working day (according to the available data).

All but one of the vehicles would regularly (more than once a fortnight) exceed 270kWh eRCV equivalent energy consumption, which effectively rules out the current Dennis Eagle product for the WLDC fleet as it does not come with an on-board charger and cannot recharge off site.

At 300kWh (the daily charge capacity of both the Renault and Electra models), there are eight vehicles that would need an in-shift charge between once a month and once a year. Only four vehicles would require this more than once a fortnight if vehicle allocation carried on exactly as in 2022-23. However, table 9-2 shows the true potential for eRCVs with a 300kWh battery if some level of strategic route allocation were to take place based on battery capacity.

At 380kWh (which is the claimed battery capacity available with a Lunaz up-cycled vehicle, there were only seven ‘vehicle days’ across the whole fleet in 2022/23 where the eRCV could not have fulfilled all duties on a single charge. Even if this is adjusted to 360kWh to allow for some battery degradation as the vehicle ages, this still only equates to 23 vehicle operating days annually. We can only identify one day where this happens to more than one vehicle simultaneously and the second vehicle would be expected to consume 360.1 kWh during that day. This would suggest that a fleet of 380kWh eRCVs would only need to be supplemented with one diesel vehicle to fulfil all operations. The viability of this will depend on how predictable the days where energy consumption is at its greatest are. The 380kWh eRCV option is a non-OEM refurbished product, that appears to be both robust and high quality, but cannot be seen in operation anywhere at more than several ‘months’ old. Whilst this brings its own risk factors, it is also substantially more expensive than some of the OEM products, which provides significant reasons why a straightforward transition to upcycled vehicles isn’t the primary recommendation from this review.

Table 9-2 *Number of dates and ‘vehicle working days’ when a 300kWh eRCV battery would be insufficient*

Scenario	Number of dates	Number of vehicle operating days
Weekdays when no vehicles exceeded a likely 300 kWh eRCV energy consumption	66	66
Weekdays when one vehicle exceeded a likely 300 kWh eRCV energy consumption	94	94
Weekdays when two vehicles exceeded a likely 300 kWh eRCV energy consumption	45	90
Weekdays when three vehicles exceeded a likely 300 kWh eRCV energy consumption	31	93
Weekdays when four vehicles exceeded a likely 300 kWh eRCV energy consumption	14	56
Weekdays when over four vehicles exceeded a likely 300 kWh eRCV energy consumption	0	0

When the entire RCV fleet operation (including retired vehicles) is taken into consideration, it is apparent that there only 66 calendar days when 300kWh would not be exceeded by any RCV on the fleet if substituted by an eRCV. This means that there would be a majority of days (184) where at least one RCV would exceed the eRCV equivalent of a 300kWh battery charge. This happens between one and 45 days in the year for every vehicle. However, if all data is put together, there are 333 occasions where an RCV would exceed 300kWh eRCV equivalent energy consumption. However, this is usually only one or two vehicles on the same day and there were no days when more than four vehicles exceeded this energy consumption on the same day as each other.

It would therefore be reasonable to assume that a maximum of all but four RCVs on the fleet could be electric without any impact on operations, beyond the addition of changes that require some planning and parameters in how specific vehicles are allocated to routes that demand the highest level of energy consumption.

To reliably achieve a greater level of electrification, without compromising operations with in-shift charging, becomes progressively more challenging with each of the last four vehicles to transition. Based on earlier discussions, three could be replaced with upcycled vehicles with a 380kWh battery and at least one would need to remain either as diesel, or a plan would be needed to top-up charge during the busiest working days (occasions where top-up charging will create the greatest level inconvenience).

However, it is also important to remember that 2022/23 operations will not be exactly the same as the future's. New housing and population growth may create demand for additional vehicles and changes to routes could increase or decrease the energy consumption of the individual vehicles. There will need to be some flexibility built in. There will also need to be consideration of how food waste collections will interact with current fleet demands (Section 10).

We would expect any transition to be phased in gradually, and by the time the final four vehicles need replacing, there may well be suitable OEM products or new solutions that smoothly overcome any energy capacity shortfall presented by current products. Therefore, operationally, there is no reason why the transition to eRCVs should not start now.

9.3 WLC model for electrification of RCVs

We have estimated costs for the replacement of a typical diesel RCV with an eRCV and have used the average energy efficiency data (mpg) from WLDC's RCVs in 2022/23 to determine the energy cost savings and GHG emissions. Any new diesel vehicles are not expected to have significantly better energy efficiency than current models, as both old and new fleet meet the Euro VI emission standard and the engine technology is very similar.

Because a BEV drive train has far fewer wearing, parts it is expected to be inherently more reliable. Some manufacturers even offer a ten-year battery warranty. Therefore, we have modelled the life of the BEVs over both seven and ten years and the ICE vehicles over seven years (based on the fact WLDC retain some RCVs for six years and some for longer than seven years) and also with a second new ICE fleet for the last three years (costs are proportionate to this). What is not included in this model is the additional cost of future diesel RCVs associated with meeting the new Euro VII emission standard in 2026/27.

Table 9-3 *Electric 26 tonne RCV fleet – factors used in the WLC energy model*

RCV factor	Electric	Diesel	HVO	Notes/units
Annual mileage/vehicle	15,400	15,400	15,400	Fleet data
Energy efficiency	3.01 kWh/mile	4.8 mpg	4.1 mpg	BEV and HVO calculated from diesel.
Cost of energy/fuel	£0.32	£1.40	£1.75	Base cost Aug 2023 (ex VAT)
Annual inflation to 2030	3.24%	1.79%	1.79%	Based on BEIS 2009-19

The cost savings from eRCV chassis maintenance are significant but the cost of maintaining the rig will be similar for both vehicle types. The energy/fuel costs for August 2023 are used as the base year but an annual inflationary increase has been applied. Future carbon taxes have not been considered but may be significant. Reductions in electric energy costs may be achieved through self-generation and may be likely given the current 'spike' in energy prices.

Table 9-4 *Seven and ten-year net capital cost of an electric and diesel RCV*

Cost summary	Renault D-Wide electric 376kWh	Dennis Eagle Elite diesel	Dennis Eagle Elite HVO	BEV cost (-saving)	Notes
Vehicle capital cost	£422,000	£232,000	£232,000	£190,000	OEM data
Residual value (chassis)	-£11,000	-£11,600	-£11,600	0	
OZEV grant funding	-£25,000			-£25,000	*First 100 UK vehicles, after which, £16,000
Residual value (battery)	-£30,000			-£30,000	Estimated as 20% of battery
Total vehicle cost	£355,500	£220,400	£220,400	£135,100	
Over 7-year project	£355,500	£220,400	£220,400	£135,100	
BEV retained for 10-years	£355,500	£314,857	£314,857	£40,644	7/3 for ICE vehicle

The higher capital cost of the eRCV fleet is apparent in Table 9-4 and even if the ICE fleet is renewed at seven years and the costs associated with the additional three years included over ten years, the BEV vehicles still have a significant additional capital cost of over £40,000. The residual value of the batteries could be higher than our estimate (they should have a second life in energy storage and may even have the potential to be refurbished for longer use in a vehicle) and it is quite possible that in 2030 (and 2033), an electric chassis will be worth much more than a diesel chassis, and possibly even have significant residual life.

Table 9-5 and

Table 9-6 show estimates comparing the total costs of ownership of RCVs over seven and ten years respectively.

Table 9-5 *Seven-year WLC – includes fuel, AdBlue, VED and road user levy*

Cost Summary	Electric	Diesel	BEV cost (-saving)	HVO	BEV cost (-saving)	Notes
Total fleet net capital cost	£355,501	£220,400	£135,101	£220,400	£135,101	From previous table
Total energy cost	£118,330	£153,516	-£35,186	£218,160	-£99,830	Includes inflation, assumes all depot charging
AdBlue cost		£2,501	-£2,501	£2,501	-£2,501	No inflation
SMR (ex-tyres) costs	£67,200	£84,000	-£16,800	£84,000	-£16,800	Estimate with eRCV at 70% of ICE figures
VED + road user levy	£0	£3,990	-£3,990	£3,990	-£3,990	DVLA V149/1 - 2020 Policy
Euro VI CAZ levy from 2027	£0	£0	£0	£0	£0	No local CAZ proposed
Whole life cost	£541,031	£464,407	£76,624	£529,051	£11,980	

Table 9-6 *Ten-year WLC – includes fuel, AdBlue, VED and road user levy*

Cost Summary	Electric	Diesel	BEV cost (-saving)	HVO	BEV cost (-saving)	Notes
Total fleet net capital cost	£355,501	£314,857	£40,644	£314,857	£40,644	From previous table
Total energy cost	£177,699	£225,357	-£47,658	£320,253	-£142,554	Includes inflation, assumes all depot charging
AdBlue cost		£3,573	-£3,573	£3,573	-£3,573	No inflation
SMR (ex-tyres) costs	£120,000	£120,000	0	£120,000	0	Estimate with eRCV at 70% of ICE figures
VED + road user levy	£0	£5,835	-£5,835	£5,835	-£5,835	DVLA V149/1 - 2020 Policy
Euro VI CAZ levy from 2027	£0	£0	£0	£0	£0	No local CAZ proposed
Whole life cost	£653,201	£669,623	-£16,422	£764,687	-£111,486	

The OZEV grant for 26t HCVs is £25,000, which is capped at five vehicles per year per organisation (£125,000), and £16,000 for the next ten vehicles, beyond this it reduces to £5,000. This amount will also vary according to how many vehicles have been sold nationally at the time of the grant application.

We would expect electric RCVs to reduce the energy cost of an RCV by about £35,000 over seven years and £47,500 over 10 years. They would also eliminate the need for 'AdBlue' exhaust additive and would be zero-rated for Vehicle Excise Duty and Road User Levy. Other savings arise from reduced chassis maintenance costs.

There is therefore an estimated cost of about £76,600 (£7,660 a year) extra from operating an eRCV compared to diesel over seven years when capital costs are included (Table 9-5). If vehicles are retained for 10-years (Table 9-6) then this will become a significant saving, even allowing for rig refurbishment (which means no maintenance savings are expected for the eRCV). We would estimate the saving to be between £1,000 and £2,000 a year across the life of the vehicle. Buying an upcycled truck with a larger battery will add around £60,000-£70,000 to the capital costs, but will not deliver any significant additional running cost savings.

With a seven-year replacement cycle, the eRCV WLC is quite close to that of running a diesel vehicle on HVO (our forecast is around £1,200 a year more), and at ten years, the eRCV offers significant savings over HVO, likely to be more than £11,000 a year.

This is all based on an assumption that electricity will only increase from its current high base cost. If grid electricity costs decrease, or if a significant contribution can be made from on site or local renewable energy production, an eRCV will start to deliver significant savings, even if retained for only seven years.

Using eRCVs where possible, taking measures to manage electricity costs and operating vehicles for as long as is reliably possible, will be the most cost-effective way to decarbonise this fleet.

It should be noted that with the current volatility and unpredictability of fuel and energy prices, any modelling of future costs could be subject to significant variation in either direction. However, whilst we remain very close to an all-time high electricity cost there is the strong possibility of a return to more favourable rates, especially as the influence of renewables increases in its contribution to grid generation.

Emission reductions from a transition to eRCVs is summarised below.

Table 9-7 *Ten-year energy use (kWh) and GHG Emissions (kg CO_2e) of an electric and diesel RCV fleet*

Energy use and GHG	Electric	Diesel	BEV cost (-saving)	Notes
Energy consumption (kWh)	464,113	1,547,043	-1,082,930	Assumes 70% reduction
Scope 1 kg CO_2e		366,433	-366,433	BEIS Factors
Scope 1 AdBlue kg CO_2e		1,112	-1,112	Used by SCR - BEIS
Scope 2 kg CO_2e	53,428	0	53,428	UK Grid - Predicted
Scope 3 T&D kg CO_2e	4,728	0	4,728	UK Grid - Predicted
Scope 3 WTT kg CO_2e	15,143	88,950	-73,807	BEIS Factors
WL WTW GHG (kg CO_2e)	73,299	456,495	-383,195	-383 tonnes over vehicle life

Over the ten-year lifetime of an eRCV, total GHG emissions will reduce by 383 tonnes and by at least 90% after ten years. The eRCVs have no Scope 1 emissions and all the GHG emissions are Scope 2, from the generation of electricity and Scope 3 from transmission and distribution (T&D) losses as well as 'WTT' emissions at the generator – all of these will fall over the lifetime of the project, as the UK Grid decarbonises. Local generation of electricity by WLDC using a wind turbine or PV[3] array would help to reduce electrical energy costs (typically to around 10p/kWh equivalent or less) and shield WLDC from future fluctuations in electricity costs.

If WLDC can order operations so that at least the next 10 RCVs are replaced by an eRCV equivalent, then annual emissions would reduce by at least 383t compared to operating diesel vehicles. This figure could increase to 608t if 16 of 17 of the RCVs (which includes 'replaced' spare or secondary vehicles) that are eventually transitioned electric.

This carbon reduction is particularly good value for money in all circumstances. Even using the seven-year figures, the cost per tonne of emissions saved equates to £200 a tonne, which is less than the carbon price quoted in Section 6.7.

Air quality improvements

The diesel RCV engine has significant emissions of both NO_X and 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. The SCR may switch off as it can release ammonia at low temperatures and the particulate trap may need to be regenerated by driving the vehicle at sustained speed.

Table 9-8 below has been determined using the COPERT5 model for a Euro VI diesel operating at an average speed of 20 km per hour reflecting something of the stop-start operation of RCVs in a rural area. This is a vehicle specific model and very different from the 'Average UK HCV' values presented earlier in this report.

Vehicles powered by HVO still emit tailpipe pollutants, possibly at a marginally lower rate than fossil diesel, but an eRCV does not emit anything in this way.

***Table 9-8:** Air Quality: Emissions per vehicle over the 10-year life of an ICE and BEV RCV (kg)*

Air quality (Project life)	Electric	Diesel	BEV emission reduction	Notes
Nitrogen Oxides (NO_X) kg	0	217	-217	NAEI COPERT5 (20 km/hr)
Particulate matter (PM) kg	0	2.0	-2.0	NAEI COPERT5 (20 km/hr)

Offsetting the GHG embedded in the battery

One concern often expressed when evaluating BEVs is the embedded GHG in the battery associated with the manufacture of the battery cells. One option, the Lunaz 'upcycled' vehicle will largely compensate for this by recycling the chassis and body of a used vehicle, which will prevent around 20t of carbon from manufacturing those parts of a new vehicle. However, this is not the case if a new vehicle is purchased.

Research by the Swedish Environmental Research Institute in cooperation with the Swedish Energy Agency has identified the variation in GHG emissions associated with each kWh of capacity (Lithium-Ion Vehicle Battery Production, 2019) depending on the GHG intensity of the manufacturing process.

In 2019, the range was from 61 $kgCO_2e/kWh$ to 106 $kgCO_2e/kWh$. Figure 9-4 demonstrates that even with the most GHG intensive battery (worst battery) the electric RCV offsets the GHG embedded in its manufacture within 18 months - when the yellow line of cumulative diesel emissions crosses the green lines of cumulative eRCV emissions. In the case of the 'best battery' this occurs after about a year of use based on WLDC mileage and current diesel efficiency.

During 2019-2023, many battery manufacturers around the world have moved to using renewable energy for the production process which would place their batteries in the 'best' category. Even if the battery manufacturing plant is 100% net zero, there are still GHG emissions associated with the extraction, processing and transport of the raw materials required for manufacture of the battery.

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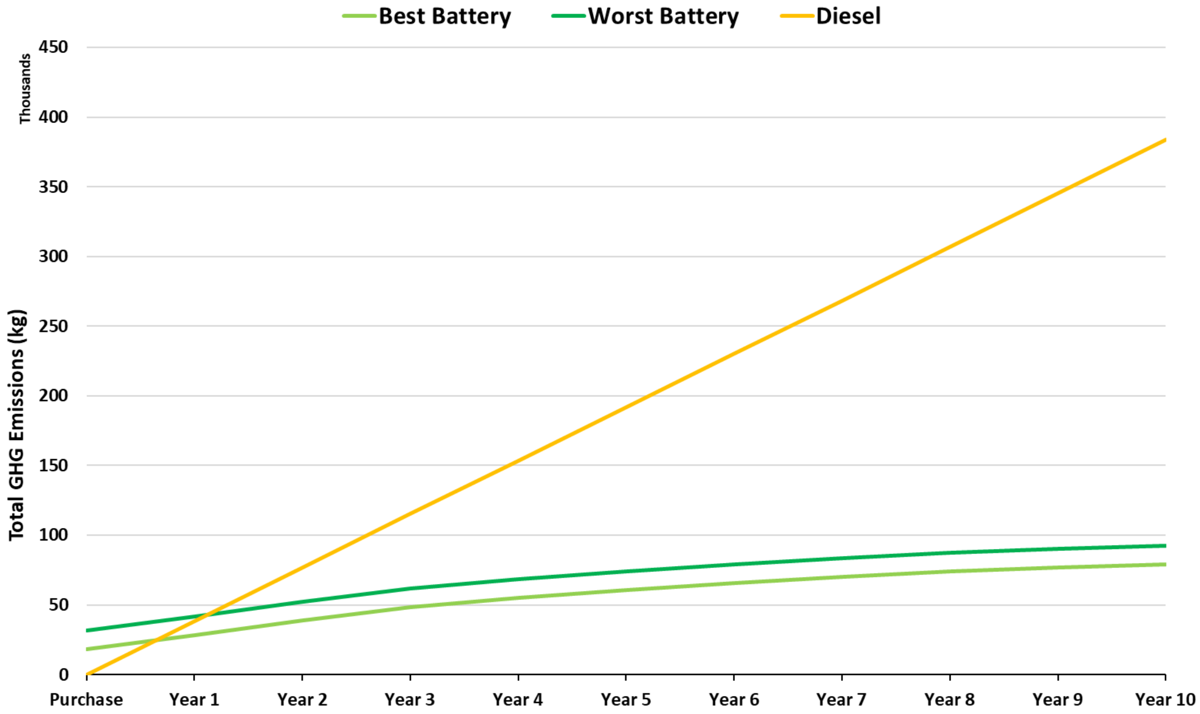
[3] LAPV Article on Solar PV

Figure 9-4 *Cumulative GHG Emissions, 300kWh battery, 10-year life, UK Grid, WLDC RCV operation.*



Treating the principal components as separate assets

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

Batteries can be serviced by replacing faulty cells and, when they are no longer economic to refurbish, they can still be used in a battery storage array as the reduced storage capacity – and therefore range – is not an issue. The chassis and cab can be fully refurbished, and the refuse rig replaced. All of which means that simply replacing the whole vehicle at seven years – common practice for diesel RCVs – is likely not the optimal ownership strategy for an electric RCV fleet. Longer retention may also be complemented by refurbishment and second life of many components. Lunaz state that their upcycled vehicle can be refurbished at least one more time and are looking to build that into agreements with some clients.

10. Fleet options for food waste collection

Details of long awaited reforms to recycling collections have started to emerge through government communications.

Under the new legislation, waste collection authorities in England must arrange a weekly collection of food waste for recycling or composting from households. All non-household municipal premises in England must arrange for the separate collection of food waste and to present their waste in accordance with these arrangements, but they are not required to have weekly collections.

The weekly collection of food waste is likely to need to be in place for most households by early 2026. It is not yet clear if and what the nature of any additional funding settlement to facilitate this collection will be.

This potentially has implications for the future shape and operation of the WLDC fleet. Two likely pathways available would be to (1) use dedicated food waste collection vehicles that would operate in addition to current services, or (2) integrate food waste collection with other recycling using a permutation of a resource recovery (RRV) type vehicle, the likes of which are used commonly by Welsh local authorities but require a more thorough sorting of waste streams at the roadside. We would also expect other options to emerge that may be a hybrid of these ideas or emerge from adaptation of current collection arrangements and vehicles.

WLDC will need to make decisions surrounding broader recycling collections and waste management that go beyond the scope of fleet. However, fleet implications may still be a significant factor in these decisions. Understanding the fleet options will help with the decision making process.

Dedicated food waste collection vehicles

Food waste collection vehicles are typically comprised of a chassis with a dedicated enclosed body, which is watertight and has access doors at a height that food waste can be placed through into the main container(s). Whether the body is required to tip waste, or simply hold removable sub-containers will depend on how the waste is processed at its destination.

Some larger vehicles come equipped with bin lifts, but these are most likely to be only necessary where there is a substantial trade food waste collection element to rounds, as household food waste holders will be relatively small.

Various sizes of chassis have already been adapted for dedicated food waste collections, which means that all the usual diesel or electric base vehicle options should be adaptable. Payload requirements are likely to depend on the density of collection addresses and the ease of access to tip a full load. Some very different options have already emerged between local authorities.

Lewes Council have been trialling the use of 3.5t electric Maxus eDeliver 9 vehicles. This typically offers between 1 and 1.5t payload and up to an 88kWh battery.

Basildon Council have purchased a 12.5 tonne Electra eCargo (figure 10-1), which is based on the on the conversion of an Iveco Cargo chassis. This is specified with a 140kWh battery and has an allowance of 7.9t for payload. Range is claimed at up to 156 miles, although this will no doubt depend on weather conditions and the amount that is being carried.

Figure 10-1 – Electra 12.5t eCargo compact electric waste collection vehicle

Some councils have 7.5t diesel powered vehicles already allocated to this kind of task. The ability to use 7.5t electric vehicles would be very sensitive to range and payload. It would be more likely that those needing such a large volume of collection would opt for the larger payload and battery of the 12.5t vehicle.

It would also be possible to convert a chassis similar to that of the 5t Iveco eDaily (with up to a 111kWh battery), which would be likely to provide a sufficient payload at a similar economic outcome to that covered in Section 7.6 for the caged tippers. It is likely that this would be the option that would provide an optimum balance between range, payload, cost and ability to do the job for a council with widely distributed collections such as WLDC. More choices in this size category will emerge as the 5t Mercedes eSprinter is released onto the market in 2024.

Resource Recovery Vehicles

Rather than simply adding another collection to the current operation, a worthwhile alternative that should be considered is in the form of the resource recovery vehicles, which are typically built on a 12-tonne chassis, with a highly specialised body (see figure 10-2), which can be adapted to an individual service's needs. This is a different approach which would necessitate a rethink of recycling collections by WLDC, in the context of current waste disposal contracts. The food waste would be collected at the same time as other recyclables and deposited into a separate removable pod within the vehicle.

Residents collect various categories of dry recyclables in different containers. It may be possible to specify food and cardboard and food and mixed in different iterations of this kind of vehicle. The vehicles can come equipped with mechanisms to store plastic and cans in the roof space, and also a compacting mechanism which works to optimise space in a large carboard collecting compartment at the rear. The compartmentalisation allows for easy depositing of different waste streams at recycling centres.

This approach has been used to good effect over many years in Wales. A great example, which includes food waste being sent for anaerobic digestion, can be seen in Merthyr-Tydfil. More detail of how the process works can be seen in this example from Anglesey. However, it is acknowledged that both examples see items sorted to a much greater extent than they would need to be in West Lindsey, and they would have a different routine in terms of what needs to be collected, but the vehicles should be adaptable and could be individually dedicated to either cardboard and food, or mixed recyclables and food.

Advantages of this approach are:

- Very high recycling rates can be achieved.
- Residual waste is reduced.
- Waste disposal costs are reduced.
- Food waste collections do not simply become extra mileage.
- Electric vehicles can be used, achieving greater efficiency than a larger vehicle on a lighter weight recycling round. This means batteries can be smaller and capital required for the vehicles might be less.

Figure 10-2 A Romaquip Resource Recovery Vehicle

11. Electric vehicle charging infrastructure (EVCI)

Energy Saving Trust provides guidance on charging infrastructure on the main website, which is a helpful read alongside this report. Appendix B also provides further generic information on charging.

11.1 Number of charge points

Generally, we expect every electric vehicle should have a parking bay and charge point of sufficiently high power during its ‘down-time’. If different vehicles are off duty at consistently different times, then bays and chargers can be shared, it does not appear this will be the case at WLDC. However, some low use vehicles that do not need a daily charge could be charged on alternate days.

Charging heavy goods vehicles

HGVs, with very large batteries need a powerful charging infrastructure if they are to recharge in time for the next shift. This can be 22 kW three-phase AC (400V, 32A) units which can be doubled up if needed (two per vehicle), or more sophisticated 50 kW+ DC chargers. For WLDC, most RCV activity would not need more than a 22kW AC charger available for 14 hours every day. Where daily energy consumption exceeds 300kWh a higher charge rating may be needed, although as shown in Table 9-2, this is very much a minority of cases.

If a vehicle can be operationally viable with regular AC charging, this will be beneficial to both the longevity of the battery and the stability of the energy supply within the depot.

The higher output systems require a much greater investment in the electricity supply infrastructure and the technology of DC rapid charging is advancing quickly, so DC chargers are more likely to become obsolete or require upgrading.

The cost of DC infrastructure starts at about £12,000 per unit and increases with DC capacity – some systems cost over £30,000 each. To that can be added significant cabling costs and grid infrastructure upgrades, as high output charging will soon exhaust available grid capacity. The incorporation of battery storage into charging infrastructure can assist in providing a high amount of power at the time it is needed but will further add to costs.

It is very likely that large parts of the charging infrastructure, and in particular the expensive cabling and groundworks, will outlive the first generation of electric vehicles. It is also very unusual to include the cost of the onsite bulk diesel tanks, fuel dispensing systems, fuel monitoring software, and the annual maintenance of the fuel system in the total cost of ownership of a diesel vehicle.

During the summer months, on-site PV generation can be used during the late afternoon and early evening to charge vehicles at a time when the ‘domestic’ site load is falling. Using the PV to displace grid import will have a significant cost saving and GHG emissions reduction. Where there is battery storage, PV power can also feed into this. Any wind power generated could also contribute to charging vehicles.

Meeting the demand for BEV charging

There are several options for charging BEVs. The simplest is to build sufficient site capacity (kW or kVA) to meet the simultaneous maximum demand for charging all the BEVs 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 other option is to alternate when vehicles are charged, so fewer chargers are required.

A potential issue with timed charging, which must be based on predicted need, is that there is a risk of some vehicles not having an adequate charge if charger power is not sufficiently high to enable this in the available time.

It is also possible to link the management of the energy available for charging BEVs 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 may avoid even more expensive capacity upgrades in the local grid and gives the fleet team greater visibility around demand and driver behaviour.

It is important to specify ‘back office’ software that gives clear visibility on the status of chargers and vehicles being charged to the fleet team, whenever required.

11.2 Potential charging capacity at Caenby Corner depot

Figure 11-1 is based on the half hourly (HH) electrical energy consumption data for the connection at the Caenby Corner depot. We have reported on 12 months of WLDC's data from 1 December 2021 to 29 November 2022. The charts show:

- the maximum energy used on-site in any half-hour period (blue)
- the average daily consumption (black line)
- the baseload or minimum daily consumption in any half hour period (red)
- the 'static' (or always available 24/7) charging capacity (dark green)
- the 'dynamic' charging capacity (pale green)

The 'static' charge capacity is the difference between the maximum recorded site use and the site supply maximum adjusted by the site power factor. The 'dynamic' capacity is a measure of the energy available between the recorded peaks of maximum usage.

The 'static' capacity is so called because it can be used to charge vehicles without any sophisticated demand management controls. Provided the total kW demand of the installed charging points cannot exceed the static capacity, the system is self-limiting.

For example, if the static capacity is 25kW, then three 7.4kW (22.2kW) charge points could be installed and used at the same time without exceeding site capacity and with no further management systems. The static capacity is also available 24 hours a day, so the only possible constraint on its use is a desire to avoid higher daytime tariffs and charging during the (national) peak period of electricity demand which occurs between 16:00 and 19:00, Monday to Friday.

The 'dynamic' capacity represents unused capacity that falls between the peaks of daily usage. This capacity could be accessed by using charge points on timers but that would require careful management to ensure a significant margin of error between the demand from the charging points and other site loads. This would only work on more simplistic demand patterns.

The static capacity can be combined with a control system to regulate the current to the charge points such that it never exceeds the site's static capacity and to that could be added, at timed intervals, the site's dynamic capacity. So, in our example of 25 kW capacity, we could have six 7.4 kW charge points but if all six are in use the power to each would be limited to 3.7 kW. As vehicles become fully charged so they stop charging and their share of the site's 25 kW capacity is reallocated over the remaining vehicles. This is a very efficient system and should ensure that all the vehicles are fully charged. It is cost effectively implemented using one primary controller and up to 10 to 20 drone charge points.

The final enhancement is to add a system to continuously monitor the total site load and adjust the power available to the vehicle charge points accordingly. A 'load balancing' system allows all the capacity above the baseload to be utilised. However, the control system must be very responsive and work 100% of the time as a failure to adjust charging capacity in response to an increase in demand elsewhere on the site could result in a site blackout or penalty charges for exceeding the site maximum demand limit.

11.3 Site Summary – Energy capacity and usage at Caenby Corner

Table 11-1 *Caenby Corner connection capacities, power factor, and available kW*

Connection name	Site capacity (kVA)	Power factor	Available (kW)
Caenby Corner	275	0.98 (Est)	270

Figure 11-1 *Caenby Corner connection energy consumption profile 2022*

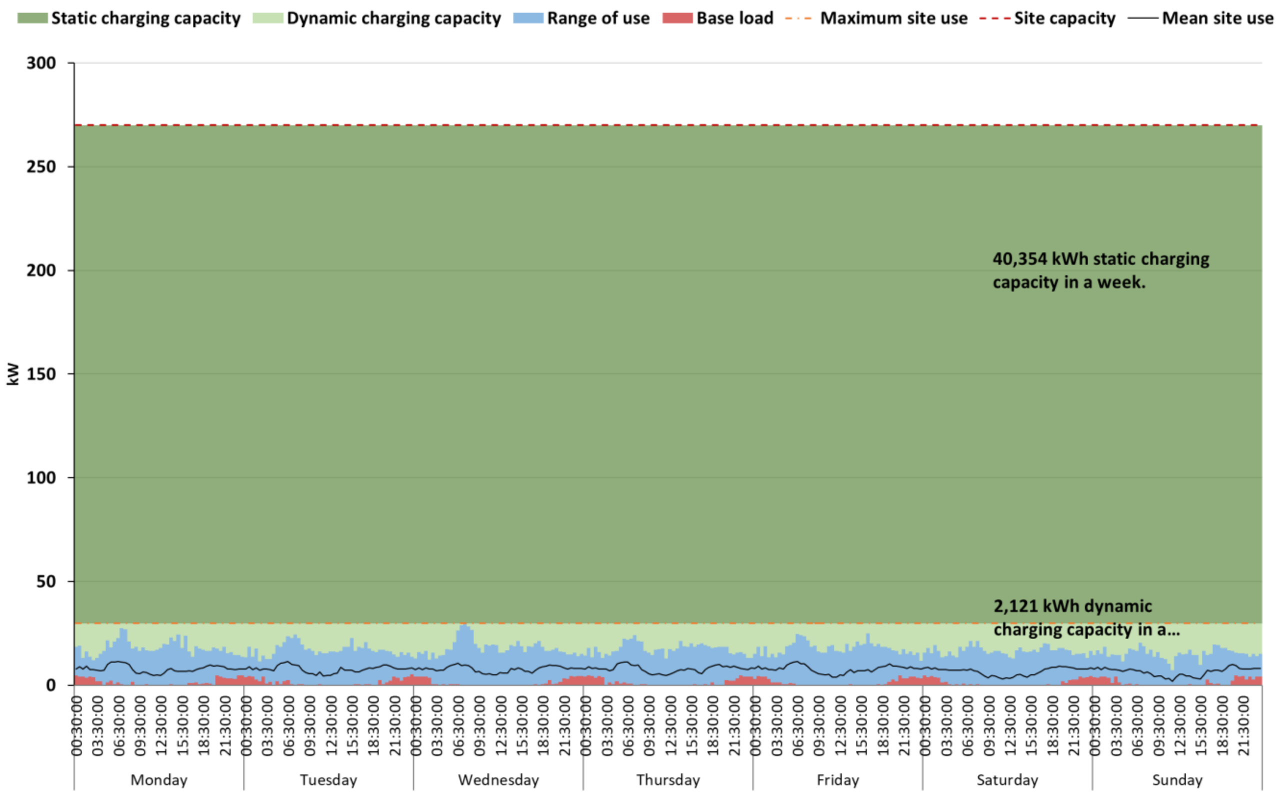


Figure 11-1 shows that the grid connection for the Caenby Corner has a lot of static capacity in relation to current energy consumption levels. Energy consumption in the data provided peaked at just below 30kWh in an hour, which was on a Wednesday morning in December 2021 between 0700 and 0800. This means that for the entirety of the year, there was always 240kVa static capacity available at any one time.

The existing grid connection is capable of charging around eleven electric RCVs, or nine RCVs and all of the LCVs, if they were electrified.

Typical energy usage from this grid connection does not appear to ever exceed 20kVa overnight, giving slightly more capacity (10kVa), for charging, always available at times when vehicles will require it, with the application of a timer.

From April to October, there are many times during the day where this grid connection draws nothing from the grid. This is when the sun is shining, and the current solar array generates more power than is required for operation of the site. In summer this can be the case for several successive hours. This suggests there is even more energy freely available, which if stored, could also be used to re charge electric vehicles overnight.

If significantly more solar PV was to be installed within this grid connection, then most of the power generated would be excess to depot requirements and would also be generated at a time when most vehicles are off site. Therefore, the viability of any infrastructure would depend on making suitable arrangements to store, sell or export any additional generation capacity.

It is also apparent that because there is always 240kVa unused during the day, that over 10 hours, each night, a further 2,400kWh of energy (enough for eight or nine more eRCVs) could, in theory, be obtained and stored from this grid connection, should WLDC find the grid connection insufficient and difficult to extend to meet the needs of a fully electric fleet. However, this would require a very large and (potentially) expensive battery storage facility.

11.4 Potential energy demand for an electrified WLDC fleet

Taking a simplistic approach, it would be tempting to plan for future energy capacity based on each vehicle or machine having a suitably sized charger available (discounting those not based at Caenby Corner) that could be used concurrently, at full power with all others. Adding up all charger capacities would give a total maximum demand by which connection size could be procured. This gives a total of around 530 kVA, when allowing 22kW for RCVs and large HGVs (16 was the maximum RCVs recorded as used in one day), 11kW for cage tippers and sweepers and 7.2kW for other vehicles.

This is not the typical recommended approach because it is likely to build in much unnecessary cost associated with the extra capacity and is not an efficient use of grid capacity that will also need to serve electrification of other local businesses.

A more efficient approach would be to understand the peak demands for charging and use smart charging to moderate charge levels over the available charging period. Table 11-2 summarises potential maximum energy demand from the vehicles based at Caenby Corner, based on 14 hours availability to charge.

However, prior to using these totals, opportunities to reduce peak demand are afforded by organising day-time charging for vehicles that are not on duty all day. Three 22kWh chargers at this site that were installed to coincide with the arrival of two Nissan small vans. Whilst these vehicles have 22kWh charging capability, they should only be charged at this rate in the day, so it does not affect the spare capacity available for RCVs and heavier vehicles at night. Charging these vehicles during the working day, when available, will maximise the benefits from cheaper, greener solar on-site generation and will happen in a short time frame. If these vehicles do need overnight charging, then the use of a 3.5kWh charger would be much better for the distribution of grid capacity around the rest of the fleet.

Calculations have been carried out using different estimates based on the quality of data available. The best data was for RCVs that refuelled every day. Good data was also available for vehicles with daily mileage records (cage tippers and two sweepers). Data for other vehicles is based more on estimates. The assumption that a BEV will use 30% of the energy of the diesel applies in all cases, based on the best combination of fuel data, and existing efficiency of individual vehicles. Any vehicles that do not appear in fuel records, may not be adequately reflected in this table, as it is not possible to forecast their daily energy consumption.

Table 11-2 *Expected daily energy use from an electrified WLDC fleet by vehicle category.*

Activity level	Vehicle category	Max vehicles in use a day	Daily EV kWh at 30% of diesel	Total daily kWh needed per vehicle on charge	Total kVA for all vehicles to be charged fully (Over 14 hours)
Peak	RCV	16	4,212	263	301
Average	RCV	12.5	3,014	242	216
Peak*	5t Tipper	5	504	101	36
Average	5t Tipper	5	383	77	27
Peak*	Sweeper & 7.5t^	4	685	171	49
Average	Sweeper & 7.5t	4	452	113	32
Peak*	LCV	5	240**	48	17
Average	LCV	5	99	20	7
Average	Other	Unknown	154	n/a	11
Peak	**Total**	**30**	**5,795**	**n/a**	**414**
Average	**Total**	**26.5**	**4,102**	**n/a**	**293**

* *Day of highest combined energy consumption across all vehicles in category **based on max battery capacity*
^ based on peak use for all vehicles happening on same day

The hypothetical maximum daily energy demand using this method at Caenby Corner is 5,795 kWh. It is based on all vehicle categories having peak energy consumption on the same day and as such is far higher than any possible worst-case scenario. In these circumstances an electric vehicle fleet would demand 414 kVA of energy capacity to charge over 14 hours, providing charger output is connected and controlled by a smart facility. This also assumes all vehicles would need to be fully charged following a ‘worst-case’ day.

Average figures are 4,102kWh in a day, which would equate to an additional energy demand of 293kVA, which is only marginally more than the 240kVa availability.

The 414kVa peak figure is based on all vehicles having their peak activity on the same day and would far exceed a worst-case scenario for a fully electric fleet; this would include vehicles for which there are not yet suitable BEV replacements. The actual maximum demand may be closer to the average than the peak due to peak activity not occurring in all vehicles at the same time. In the short term the current grid connection will suffice for most of the demand that will arise over the next few years, providing charging is managed and the right kind of chargers are specified. Actions such as charging small vans overnight on 22kW chargers must be avoided, with these higher capacities, instead reserved for eRCVs. Charging vehicles in the day (when free) would assist in this process and battery storage could be installed to enable greater overnight charging capacity, utilising solar PV in the summer and (primarily) grid power in the winter.

11.5 Charging a fully electric fleet at Caenby Corner

The lack of sufficient spare capacity within a grid connection can sometimes provide a significant obstacle to fleet electrification and could require careful storage and redistribution of every potential kWh to minimise grid re-enforcement implications. However, the risk for WLDC is low as there is currently a lot of spare capacity within the grid connection, that will provide for a significant proportion of the future needs of an electric fleet.

The substation that is local to the depot is operated by Northern Powergrid. This is classified as amber, so appears to have some spare capacity. WLDC could consider a small increase in grid connection size (circa 100kVa) to ensure sufficient future supply for a fully electric fleet. This may be a relatively cheap option, and as such worth implementing as soon as possible to minimise the risk of it not being available later. However, this may not be necessary if enough self-generation is put in place to deliver all the additional energy required beyond the capacity of the existing grid connection.

If upgrading the grid connection, consideration should also be given to future non-fleet demands for power (such as that created by a transition to heat pumps), and allowances made for any likely fleet expansion. It is generally more cost effective to avoid multiple upgrades, and rather make provision for all likely future development at an early stage in the transition.

If approaching Northern Powergrid, the local distribution network operator (DNO) for the upgrade, then there would be a monthly cost for each additional kVA capacity that is obtained, in line with what is paid for existing capacity, and there may be a one-off infrastructure upgrade cost, depending on what is physically needed to achieve a larger connection.

It is possible to secure capacity and avoid monthly charges by arranging grid upgrades through an independent distribution network operator (iDNO). In this case, capacity can be secured in advance without the monthly charge, due to a differing legislative framework. These factors should be considered in costing any upgrade. Quite often, suppliers will offer a package of grid upgrade, charging infrastructure installation and finance, if desired.

11.6 Meeting extra capacity needs through other sources

As an alternative to a larger grid connection, it may be possible to meet the additional needs through different methods of generation, storage or procurement of energy. This can also off-set the need to use grid electricity that is already available, providing a lower emission, cheaper alternative.

On-site Solar Photovoltaic (PV) generation at Caenby Corner

There are currently onsite solar PV panels covering the depot roof as shown in Figure 11-2. Whilst no details were provided on peak generation capacity, it would appear to be sufficient for all current site daytime needs, when the sun is shining from May to September. It appears that this could be at least 20-25kW in summer, when compared with peaks within the half hourly data. Generation is highly concentrated in the months with more daylight and brighter conditions. This is already taken account of within the energy consumption profile in figure 11-1. There is also power generated that is not used, as indicated by 944 half hourly day time segments where no electricity was needed from the grid to power the depot. Unfortunately, this is not at the same time as when most electric vehicles would typically be available to charge, so the only way to harness this low-cost power, would be through battery storage, which would bring its own capital costs. We did not have access to sufficient data to quantify the excess generation taking place.

Figure 11-2 *Caenby Corner Depot, showing roof mounted solar PV array*

Expansion of solar PV at Caenby Corner

Within the depot compound there is an area of grassed land that should be suitable for solar PV infrastructure (figure 11-3). A more detailed assessment of its potential was undertaken as part of this review (shown in Appendix E:).

The generation potential was assessed at around 111kW for this area. Over the course of the year, this would be expected to produce around 107,000 kWh of energy, based on estimated and modelled sunshine hours and intensity.

Whilst this is more than the current 63,300kWh used on this grid connection, it is only likely to be around 11% of that which is required by a future fully electric fleet and except for late spring and summer evenings, it will be delivered at a time when the fleet cannot benefit directly. Because of the size of the existing grid connection, exporting surplus energy will be possible from this without major delay. Current rates may be between 5p and 15p per kWh, so it would represent much better value to use as much of this power as possible for charging the fleet. This could be achieved by installing battery storage, but this is capital intensive, with approximate costs expected at around £150 per kWh of battery storage. To assess financial viability, the expenditure on electricity that this approach saves would need to exceed the cost of a battery over the whole life of that battery. In the case of WLDC, savings from minimising grid connection size are not likely to be a significant consideration.

A project of this size is likely to be of insufficient scale to be worth selling power to neighbouring businesses.

Figure 11-3 *Location and layout of potential solar PV expansion*

Development of solar PV adjacent to Caenby Corner Depot

While evaluating the Caenby Corner site for solar capacity, it became apparent that adjacent land (formerly the Caenby Corner Raceway) is for sale for around £100,000. This land has substantial potential for generating electricity, should it be developed using solar PV.

At the request of WLDC we have also assessed this site for its potential solar generation capacity (area shown in figure 11-4). Details are shown in Appendix F:.

This is a much larger area and so could have a generation capacity of 2.47MW, which would generate an estimated 2.362GWh of electricity during a year. This would be nearly two and a half times the requirement of a fully electric fleet.

For this development to be viable, it would be essential to export the majority of the energy – therefore we recommend that a grid connection request is submitted as soon as possible to establish what is possible and in what time scale. WLDC do not need to own the land to make this enquiry but do need to enquire to ensure it is a possibility.

Financial viability of a project of this size would be significantly enhanced if agreements to sell energy to businesses in the immediate vicinity can be achieved. It would also appear necessary to store some of this energy in batteries to assist with fleet recharging. This would be a substantial investment, but one that with the right agreements to sell the energy, would deliver a significant financial return in the mid to long term.

Figure 11-4 *Potential layout of adjacent solar PV generation*

The potential for wind power

The Central Lincolnshire Local Plan (adopted April 2023) states that "proposals for a small to medium single wind turbine…are in principle supported throughout Central Lincolnshire…" (page 45). This is subject to suitable scale, siting and design, no impact on aviation, navigation and acceptable impacts on the amenity of sensitive neighbouring uses.

The exposed nature of the depot suggests that this may be a productive location for a wind turbine, although we recommend that this is measured by a wind speed monitor for a year before installation, to check and ensure benefits are worthwhile and quantifiable. It is possible to find companies that offer free of charge feasibility studies to research local wind speeds.

One of the key benefits of a wind turbine is that it will generate electricity at times when the solar PV is unable to, such as after dark and in the winter months. Any power generated when the fleet is back in the compound and charging would offset grid electricity, at a lower cost and at zero emissions. This would also contribute to reducing the need for a larger grid connection.

Taking the example of a 50kW wind turbine that is 25m tall to the hub, and using a pessimistic capacity factor of 20%, we could expect an annual generation of 87,000kWh a year. If, as quoted by some manufacturers, a turbine has a 20-year life, return on investment will be delivered in the first half of the projects life. This will depend on (1) how much the cost of the turbine and project is, and (2) how much WLDC grid energy consumption can be offset and (3) the price achievable by exporting excess energy. WLDC should thoroughly investigate and consider a project of this nature.

Energy from biogas generated from food waste

There is a significant biogas facility in Hemswell, which uses food waste and anaerobic digestion processes to produce an effectively zero emission source of energy.

Whilst gas-powered vehicles have already been discussed in Section 5.2 and do not seem viable for use in this fleet, the most likely potential application for biogas within this fleet is through power generation to charge electric vehicles.

Where biogas is burned to generate electricity, it is an efficient process. If this electricity is used to charge BEVs, not only is it being used in another efficient process, it also means these vehicles can be operated at zero GHG emissions.

The main issue faced in using this source of electricity is how to transport it from where it is generated to the depot (or the fleet). A private wire arrangement would be likely to require overhead cables to reach the depot. This is a distance of 2.5km ‘as the crow flies’ but would need to be further depending on how much extra distance would be needed to achieve an acceptable route (assuming this was achievable, and permission could be achieved). Based on a hypothetical cost of £150 a metre, derived from similar projects, this could cost over £400,000 to install. (Burying cables would cost several times more than this). This would require a very low base cost of electricity, guaranteed for a significant amount of time, to achieve any kind of financial return.

As such, it appears that unless there is an option to cost effectively rapid charge vehicles on the AD site, this option may prove costly. If regular rapid charging on this site is an option that can be worked to fit in with some vehicles operating patterns or, if a small number of vehicles could charge overnight in this location under an operationally suitable arrangement, savings could be achievable and the need for any additional grid capacity at the Caenby Corner depot would be prevented or at least diminished.

It may still be possible to buy this electricity directly from the supplier through a process called a ‘sleeved power purchase agreement’ (or PPA), but transmission would be through the grid, which would attract its own cost and this would not make any contribution to increasing the size of the depot grid connection. Prices can be agreed and fixed for long periods with this arrangement, which has both potential advantages and disadvantages for the purchaser. Zero emission electricity is effectively being purchased by this method, so greater carbon emissions savings can be reported.

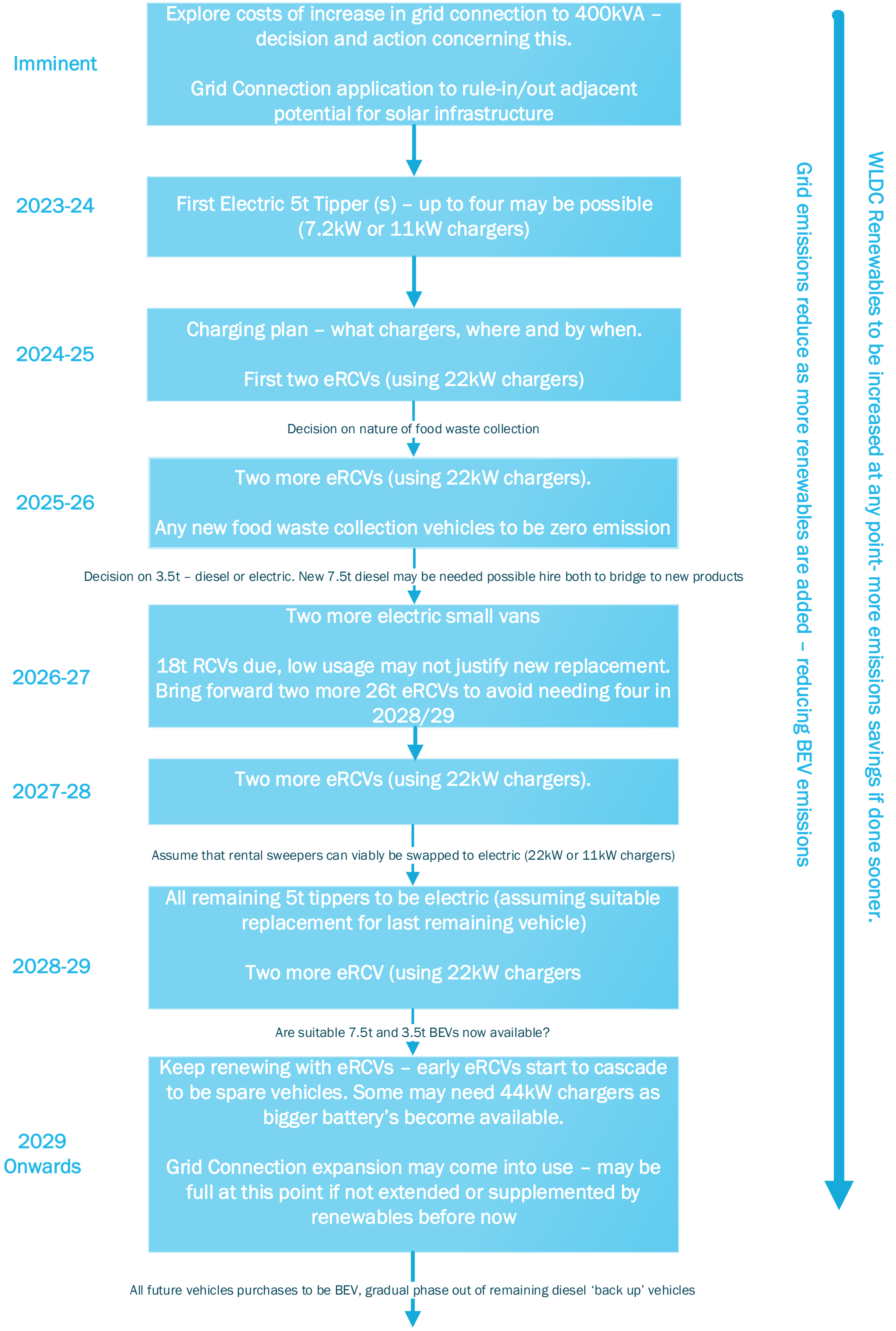
11.7 EVCI Summary

WLDC have substantial headroom within the current grid connection, that with linked smart charging and specification of 22kW AC chargers for RCVs and smaller 11kW, 7.2kW or 3.5kW AC chargers for smaller vehicles, could enable the successful transition of much of the current fleet to BEV. If higher output DC chargers are specified, the connection will be insufficient and only limited benefits realised. It is therefore important that all infrastructure is purchased with due consideration of a vehicle (or fleet sector’s) availability to charge over a long period, and adjusted to the lowest output that could achieve a full recharge.

However, in the longer term there may be the need for an additional 100kVa grid connection size to achieve reliable power for a fully electric fleet. A simple, low risk way to secure this would be to extend the size of the grid connection now while there is still opportunity and capacity available at the local substation. However, if WLDC are planning to invest in more renewables or energy storage, this could ultimately prove to be unnecessary. The issue will be that if the decision to make a grid connection increase is made at a significantly later date, the substation might not have any spare capacity and the upgrade could become a significant obstacle to the final stages of fleet electrification.

WLDC should form a strategy for achieving the future energy supply and make an early decision on increasing grid connection size. Assessing and understanding the cost of increasing the connection to around 400kVa (or more) could be a key driving factor in the decision, which, whilst removing risk would not prevent other developments described in Section 11.6.

12. Decarbonisation road map



Imminent

Explore costs of increase in grid connection to 400kVA – decision and action concerning this.

Grid Connection application to rule-in/out adjacent potential for solar infrastructure

2023-24

First Electric 5t Tipper (s) – up to four may be possible (7.2kW or 11kW chargers)

2024-25

Charging plan – what chargers, where and by when.

First two eRCVs (using 22kW chargers)

Decision on nature of food waste collection

2025-26

Two more eRCVs (using 22kW chargers).

Any new food waste collection vehicles to be zero emission

Decision on 3.5t – diesel or electric. New 7.5t diesel may be needed possible hire both to bridge to new products

2026-27

Two more electric small vans

18t RCVs due, low usage may not justify new replacement. Bring forward two more 26t eRCVs to avoid needing four in 2028/29

2027-28

Two more eRCVs (using 22kW chargers).

Assume that rental sweepers can viably be swapped to electric (22kW or 11kW chargers)

2028-29

All remaining 5t tippers to be electric (assuming suitable replacement for last remaining vehicle)

Two more eRCV (using 22kW chargers

Are suitable 7.5t and 3.5t BEVs now available?

2029 Onwards

Keep renewing with eRCVs – early eRCVs start to cascade to be spare vehicles. Some may need 44kW chargers as bigger battery's become available.

Grid Connection expansion may come into use – may be full at this point if not extended or supplemented by renewables before now

All future vehicles purchases to be BEV, gradual phase out of remaining diesel 'back up' vehicles

Grid emissions reduce as more renewables are added – reducing BEV emissions

WLDC Renewables to be increased at any point- more emissions savings if done sooner.

Appendix A: 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
Defra	Department for Environment Food and Rural Affairs
DVLA	Driver and Vehicle Licencing Agency
DVSA	Driver and Vehicle Standards Agency
EV	Electric Vehicle - usually battery-powered (BEV)
GHG	Greenhouse Gas - in transport usually CO_2, CH_4 and N_2O
GVW	Gross Vehicle Weight – Replace by MAM
GWP	Global Warming Potential
H2FC	Hydrogen (H_2) Fuel Cell
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
LNG	Liquid Natural Gas – methane (CH_4)
MAM	Maximum Authorised Mass – replaces GVW Gross Vehicle Weight.
NAEI	National Atmospheric Emissions Inventory – Transport Factors
NCAP	New Car Assessment Programme - Safety
NEDC	New European Driving Cycle (now replaced by WLTP)
NG	Natural Gas – methane (CH_4)
OEM	Original Equipment Manufacturer, e.g. Ford, Nissan, Toyota etc.
OZEV	Office of Zero Emission Vehicles
PHEV	Plug-in Hybrid Electric Vehicle
PM	Particulate Matter – associated with wide range of human illness
RDE	Real Driving Emissions (RDE1 and RDE2)
t	Tonnes
TTW	Tank to Wheel
ULEV	Ultra-Low Emission Vehicle
ULEZ	Ultra-Low Emission Zone (London only)
V2G	Vehicle to Grid – Technical Guidance (UK Power Networks)
VCA	Vehicle Certification Agency
VED	Vehicle Excise Duty – also called Vehicle Tax.
VRM	Vehicle Registration Mark
WLC	Whole Life Cost
WLTP	Worldwide Harmonised Light Vehicle Test Procedure
WRI	World Resources Institute – GHG Protocol
WTT	Well to Tank
WTW	Well to Wheel
ZEZ	Zero Emission Zone (TfL and Mayor of London Guidance)

Appendix B: Introduction to electric vehicle charging infrastructure

Charging an electric vehicle fleet

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

AC or DC charging and Smart Management

There are two basic types of charging infrastructure: AC (Alternating Current) and DC (Direct Current). An AC charger relies on the vehicle's "on-board" charge management system to convert the AC to DC and ensure that the battery is not damaged during charging. This is the simplest type of charger. The output of AC charging systems ranges from 3.7kW (240 Volt, 16 Amp, single phase) up to 44 kW (400 Volt, 60 Amp, three phase) but are usually 7.4 kW (240 Volt, 32 Amp, single phase) or 22 kW (400 Volt, 32 Amp, three phase).

Limited information is exchanged between the vehicle and the AC charger, as the "on-board" hardware and software is managing the charging process. As a result, the AC charger does not know the State of Charge (SoC) of the battery or the battery capacity. That will change when the Open Smart Charging Protocol is widely adopted by both vehicle manufacturers and charge point suppliers but until then, AC systems cannot use information about the vehicle's State of Charge (SoC) and battery size (kWh) to develop an optimal strategy.

DC charging systems deliver the power directly to the batteries and bypass the vehicle's AC/DC on-board charge management system. To do this safely and without damaging the expensive batteries, the DC charge point must communicate with the vehicle's battery management system and understand the size of the battery as well as its SoC. DC chargers are, therefore, a lot "smarter" and management of DC charging can be more sophisticated as the charge management software knows the SoC and battery size of connected vehicles.

ABB has announced a 350 kW "Terra" rapid charger which, in theory, could provide a compatible electric car with about 100 miles of range in five minutes and it is unlikely that DC charging technology will stop at 350 kW. Tesla are known to have ambitions for much higher charging rates, their fastest V3 "Superchargers" are 250 kW and are connected to a 1MW power cabinet, they reduce Tesla charge times by 50% - so fast that some Tesla owners have complained they do not get a long enough break after three or four hours driving. A Tesla V4 Supercharger is under development and the company is understood to be considering 1MW for their Tesla Semi truck.

One way of making both the AC and DC system 'smarter' is to require the driver to enter all the information needed by the charging system, either through a smart phone app or on the charger itself. The BEV charging infrastructure at CalTech, California, is an experimental system that requires the driver to enter the vehicle's details (this includes battery size) the current SoC of the battery and the time when the vehicle is required to be 100% charged. This information is then processed through an optimisation algorithm to minimise the electricity demand and carbon impact, while still meeting the user's requirements – the system is known as an Adaptive Charging Network (ACN). It is not commercially available yet and the optimisation algorithms are still subject to refinement but have been published as open source code.

In the short term, the closest we can get to the perfect charging system may require the integration of on-board vehicle telematics with a vehicle identification system in the charge point. The telematics can report the SoC and battery capacity to the charge management system and the charging post can report which vehicle is plugged in, either by using a contactless RFID Card or automatic number plate recognition (ANPR) camera.

A charging strategy must also consider the non-linear nature of the process. If a vehicle returns to a 7.4kW charger needing 74 kWh of energy to replenish its battery, it will take longer than 10 hours to fully recharge it. When a battery is fully depleted, there is little internal resistance to the flow of current (Amps) and so energy can be quickly transferred to the battery but as it reaches 80%-90% SoC, the internal resistance increases, and the charging system has to increase the voltage to maintain the current. However, there is a maximum voltage above which damage to the battery will occur. When that voltage is reached, the flow of energy to the battery (Amps) falls and the battery charge rate diminishes. Because of this, the vehicle that returns to a 7.4kW charger requiring 74 kWh of energy may take 12 hours to fully recharge.

Number of charge points

Our expectation is that every vehicle requiring overnight charging will have its own parking bay and charge point as this allows the charging load to be spread throughout the evening making maximum use of the site import capacity. The alternative is to have some sort of charging rota for drivers or to have someone on site, overnight, whose job it is to move the vehicles from parking bays to charge point bays. Rota systems are prone to user error and a failure to plug in on the allotted evening would mean the vehicle may not be available for use the following day.

To have someone moving the vehicles to charging bays throughout the evening would require the charging system to know the SoC of the fleet and calculate the order in which vehicles should be presented for charging. There would also need to be spare capacity to cope with vehicles returning with a lower SoC than expected.

There is the option of using rapid DC chargers like a conventional fuel pump, but this could result in queuing and long delays without careful time management as a full charge could still take over 20 minutes. In the future, it may be possible to charge new battery technologies more quickly and fully recharge a vehicle in 5-10 minutes from a powerful DC charger; that technology is not available on the current generation of vehicles but will have a role if a rapid top-up is required during the working day.

A further benefit of have one charger per vehicle is the ability to use “pre-conditioning”. This is the term given to either heating/defrosting (winter) or cooling (summer) the vehicle while it is still attached to the power supply and just prior to it entering service. Typically, pre-conditioning can be configured to turn on 30 minutes before the vehicle is normally required and it can also be initiated from a phone application. Using this feature means the vehicle starts the day at the right temperature and with a 100% SoC and battery capacity is not used defrosting the windows or cooling down the driver’s compartment.

Charging cars and commercials up to 3.5 tonnes

For vehicles with battery sizes up to 75 kWh, a 12-hour charging window usually provides enough time in which to recharge the battery from a fully depleted SoC (only 10% residual charge in the battery) using a basic 7.4 kW charger. Almost all the vans up to 3.1 tonnes GVW have battery options under 75 kWh, as do cars with a single charge range of less than 240 miles. Only cars and vans specified with a greater range or load carrying capability and therefore larger 100 kWh batteries, may need longer than 12 hours to fully recharge at 7.4 kW from 10% SoC.

On many sites, 7.4 kW charging can use the site’s unused capacity to charge a small fleet of cars and vans, without the need for complex charger management. As long as the combined demand of all the chargers operating simultaneously does not exceed the available capacity, there is no requirement for smart charger management.

A simple domestic 7.4 kW AC charger can be purchased from hardware stores for under £400 and installed by a competent electrician. The most sophisticated 7.4 kW charge points with card scanner, GPRS network connection, management software and full barrier protection cost about £1,700 for a two-port pillar. A further £1,000 for specialist installation, management software, billing systems, commissioning, and on-site support should be added to this, with about £250 of that cost being an annual expense. These costs can escalate if a lot of groundwork is required, or if the system requires local grid infrastructure to be upgraded.

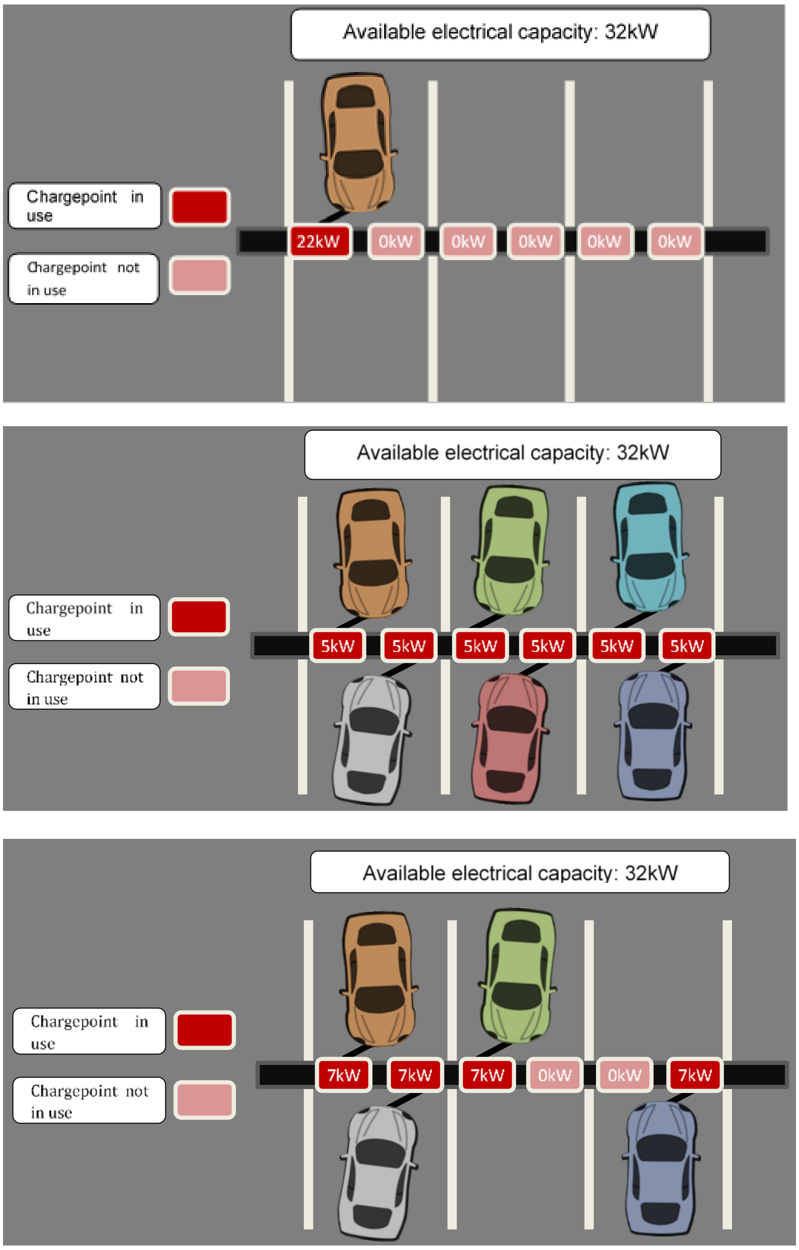
Load Management

Load management offers a potential solution for multiple charge points to be operated without exceeding the maximum power capacity of a site. It can be achieved through dynamic power management to charge points, reducing the speed of charge as necessary to moderate total electrical demand, striking a balance between the number and the speed of charge points.

Load management systems can also be configured to limit the proportion of a site’s total energy supply that BEV charge points can use, again to prevent exceeding the total site capacity. Moreover, load management technology can avoid or minimise costly upgrades to the electrical supply.

The principle of load management is that when a charge point is being used, the vehicle is charged at the fastest speed permitted by the charge point and vehicle in question. When several charge points are being used, the speed being delivered to each can be reduced. The following diagrams illustrate the principle.

Figure C-1: Load management charging infrastructure



Charge point systems with features such as remote access, back office integration and load management also help to manage the BEV fleet. This may include the ability to remotely control the charge points (to end a charging session, for example) and to monitor the usage of the infrastructure on site.

The end-user can be identified through an RFID card or user app which allows the amount of electricity used by each vehicle to be measured, individual vehicle and driver efficiencies to be determined and allocated to cost centres

Charging heavy commercial vehicles (from over 3.5 tonnes to over 30 tonnes)

Heavy commercial vehicles, with very large batteries need a more powerful charging infrastructure if they are to recharge in time for work the following day. This can be 22/44 kW three-phase AC (400V, 32/60A) units which can be doubled up (two per vehicle), or more sophisticated 50-150 kW DC chargers. Some large buses with 385 kWh battery packs use 2 x 44kW AC chargers. These high-power AC and DC systems require a much greater investment in the electricity supply infrastructure and the technology of DC rapid charging is advancing quickly, so DC chargers are much more likely to become obsolete or require upgrading in the future.

The cost of DC infrastructure starts at about £12,000 per unit and increases with DC capacity – some systems cost over £30,000 each. To that can be added significant cabling costs and sometimes grid infrastructure upgrades, if the site does not already have a very good electricity supply.

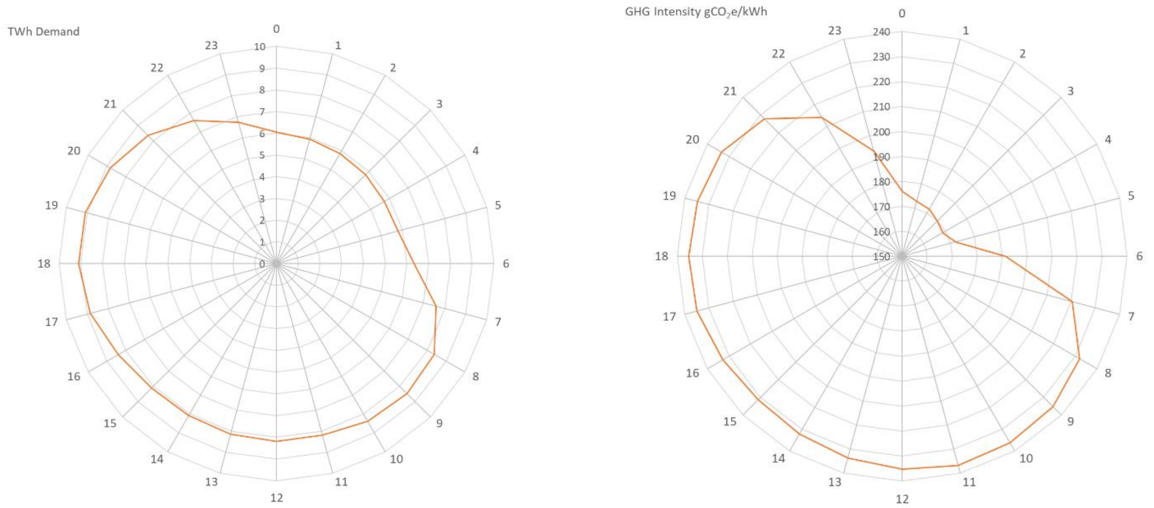
It is very likely that large parts of the charging infrastructure, and in particular the expensive cabling and groundworks, will outlive the first generation of electric vehicles. It is also very unusual to include the cost of the onsite bulk diesel tanks, fuel dispensing system, fuel monitoring software, and the annual maintenance of the fuel system in the whole life cost model of a diesel vehicle.

Getting the timing right

Ideally, vehicles should be charged overnight to avoid the demand from large-scale BEV charging negatively impacting the grid. During the working week, from 06:00 to 23:00 hrs, demand on the UK Grid is at its maximum and grid GHG emission intensity (kgCO_2e/kWh) may be high due to the use of fossil-fuel based generation to meet demand.

However, avoiding the peak entirely leaves a very narrow window of seven hours in which to charge vehicles. The reduction in GHG emissions from avoiding the higher "daytime" intensity is only 10%-15% over the entire charging period and in terms of tonnes of GHG rather than percentage this will diminish in importance as the grid decarbonises.

Figure C-2: Variation in energy demand (TW) and GHG intensity (gCO_2e/kWh) during the working day (2019).



Note the above chart of GHG intensity has an axis from 150 to 240 gCO_2e/kWh

During the summer months, on-site PV generation can be used during the late afternoon and early evening to charge vehicles at a time when the "domestic" site load is falling. Using the PV to displace grid import will have a significant cost saving and GHG emission reduction.

Some organisations have addressed site capacity by installing battery storage that can store any unused capacity during the day and then charge the vehicles at night.

Getting the tariff right

When implementing an electric vehicle fleet, it is essential to negotiate low off-peak tariffs for electricity at all sites where the electric vehicles are based. This may mean a new tariff structure as the highest demand may have shifted from daytime to off-peak use.

There is an increasing range of innovative tariffs in the domestic sector aimed at owners of electric cars as well as households with "power walls" and at least one of these – Agile Octopus – includes negative tariffs. During the first nine months of 2020 there were 80 hours of negative electricity pricing in the UK. The domestic Octopus Go tariff charges £0.05/kWh from 00:30 to 04:30 hours because it makes use of surplus generation. With many more large battery electric vehicle fleets on the grid the need for "curtailment" of wind generation could be significantly reduced or eliminated.

It is anticipated that innovative tariffs will become available in the commercial sector as the BEV charging market grows. The National Grid Electricity System Operator (ESO), working with partners, has already developed and published an open system called the "Carbon Intensity API" which makes available the predicted carbon intensity of the grid up to two days in advance in half hour periods.

In the future this forecast could be used to adjust the price paid for electricity by lowering the cost (£/kWh) when renewable generation is high (carbon intensity low) or curtailment of wind generation may occur and increasing the cost when fossil fuel generation is high (carbon intensity high). This has the aim of modifying customer behaviour as well as being used to directly manage the activity of "smart" appliances which could include electric vehicle charging systems. The objective would be to eliminate curtailment of wind generation and match demand to supply throughout the day.

Overcoming capacity issues

An issue at some depots is the lack of local grid capacity and, as indicated earlier, the upgrade of the local grid to provide the significant additional capacity required can be very expensive. On sites with inadequate capacity there may be another local substation with spare capacity that can be accessed. In the first instant the local Distribution Network Operator (DNO) should be contacted but they may not be able to offer an affordable solution.

Alternatives to DNO capacity upgrades include the use of on-site renewable generation coupled with battery storage or just the use of battery storage to absorb any spare capacity during the day and then feed it back into the vehicles overnight combining stored energy with site capacity. This is the solution that has been implemented at the bus company Stagecoach’s Guildford Depot by Zenobe Energy.

Figure C-3: Tesla Powerpack (78 units) installed at Stagecoach's Guildford Dept

The Tesla Powerpacks charge during the day when the depot is empty and then discharge at night into the bus fleet. According to Zenobe, owner and supplier of the pack as well as the charging infrastructure, the system was installed more quickly than the grid upgrade required at the site and at a lower cost. It also has the advantage that it can be moved to another site if Stagecoach no longer have access to the depot.

There are Independent DNOs (IDNOs) in the market such as Vattenfall and Octopus/Eclipse Power and these may also offer innovative and affordable grid reinforcement or upgrade options including integration of PV canopies and battery storage with the grid upgrade and charging systems.

Some of the heavy goods vehicle manufacturers (for example Volvo) are entering into partnership with energy providers to offer a “turn-key” solution which includes installing the charging infrastructure, refurbishing, or recycling of the vehicles at their end of life and refurbishing, repurposing, or recycling of the batteries.

Appendix C: UK Grid 2014 to 2030

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

Error! Reference source not found. shows:

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

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

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

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

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

Appendix D: Whole Life Cost (WLC) in practice

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

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

Purchase price (L): Most large organisations will be able to obtain a discount, especially if committing to the purchase of several vehicles, or purchasing from one manufacturer for a period.

OZEV grant (L): OZEV offers grants to encourage the take-up of ZEVs. This is accessed by the manufacturer or dealer and will have been deducted from the final price at the point of sale.

Residual value (L): This represents the value of the vehicle at the end of its operational life. The difference between the initial purchase cost and the residual value is known as depreciation. It will vary significantly depending on vehicle type, age, and final condition. Some vehicle types are fully amortised over their operational life and any residual value is treated as a disposal surplus.

With BEVs, the batteries will have a value at the end of the vehicle's life and can be refurbished and reused in energy storage arrays; you might want to consider valuing the batteries separately.

Servicing, Maintenance, Repair (SMR) and Tyre Costs (L): Several organisations can provide a forecast of SMR and tyre costs. However, these are usually limited to four or five-year budgets. If you are planning to keep a vehicle for eight or ten years, you will need to base this cost on your experience, or past fleet records.

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

Fleet Management Charge: Many fleet operations include an internal management fee to cover day-to-day management of the vehicle including organising servicing, breakdown cover, fuel cards, driver training and other support services. For some this is a flat rate, but others vary the rate depending on the category of vehicle. This may also include the cost of any additional telemetry installed on the vehicle and the data connection charges.

Insurance: Corporate insurance rarely takes account of the risk of individual vehicles or drivers; instead, it applies a fixed charge for the whole fleet, and will usually reflect previous claims history. How this is apportioned varies but there is merit in linking the charge to the past claims record of the department using the vehicle, so good driving is rewarded and managers are incentivised to act on bad driving.

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

Appendix E: Assessment of solar PV potential within depot

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Annual Production Report produced by Jim Cardy

Design 1 (copy) Caenby Business Park, LN8 2AW

Report

Project Name	Caenby Business Park
Project Address	LN8 2AW
Prepared By	Jim Cardy jim.cardy@est.org.uk

System Metrics

Design	Design 1 (copy)
Module DC Nameplate	111.7 kW
Inverter AC Nameplate	100.0 kW Load Ratio: 1.12
Annual Production	107.1 MWh
Performance Ratio	86.4%
kWh/kWp	958.8
Weather Dataset	TMY, 10km Grid, meteonorm (meteonorm)
Simulator Version	5a828301ef-c9982c5683-28f505e3d1-4bb5a64251

Project Location

Monthly Production

Sources of System Loss

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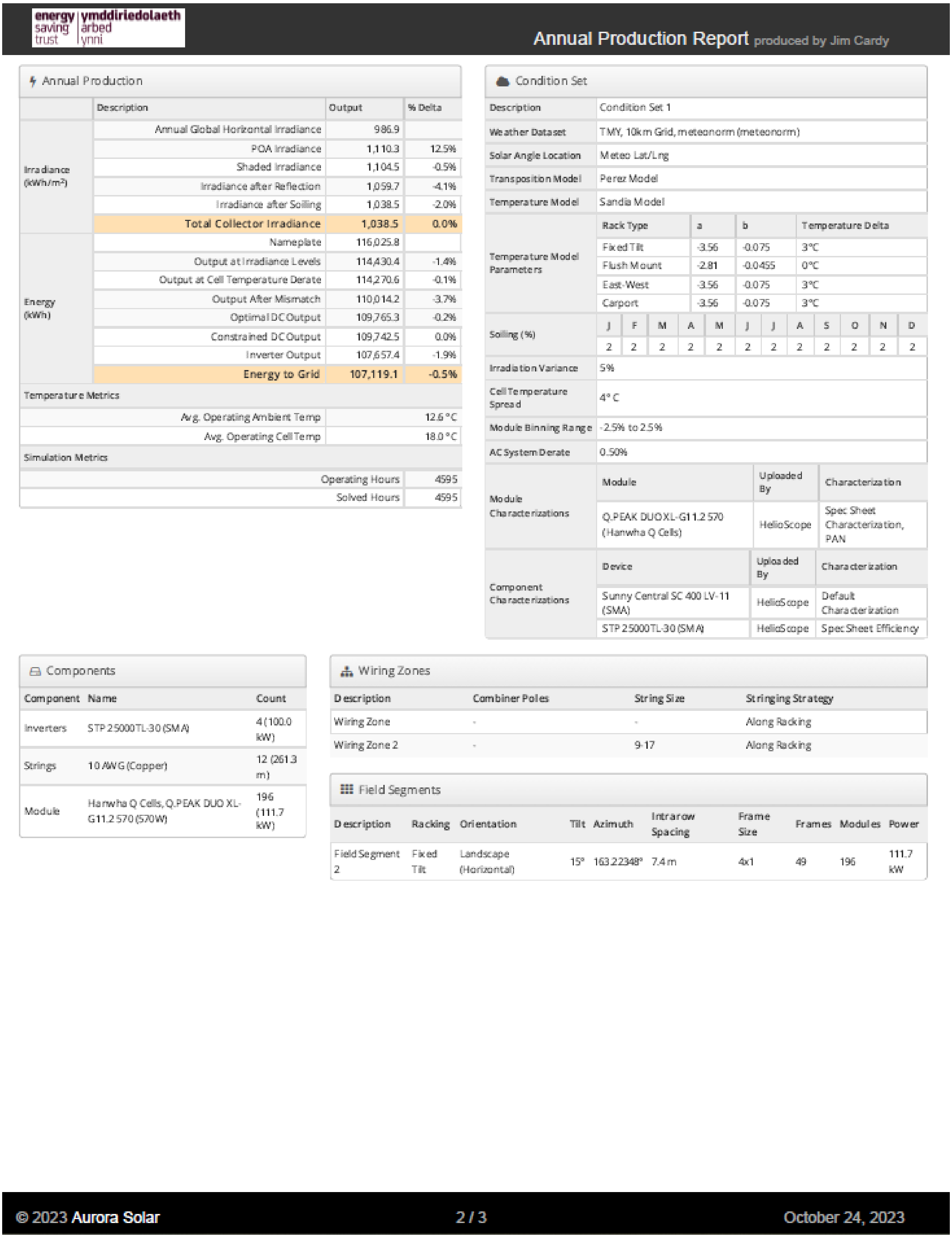

Annual Production Report produced by Jim Cardy

Annual Production

	Description	Output	% Delta
Irradiance (kWh/m²)	Annual Global Horizontal Irradiance	986.9	
	POA Irradiance	1,110.3	12.5%
	Shaded Irradiance	1,104.5	-0.5%
	Irradiance after Reflection	1,059.7	-4.1%
	Irradiance after Soiling	1,038.5	-2.0%
	Total Collector Irradiance	**1,038.5**	**0.0%**
Energy (kWh)	Nameplate	116,025.8	
	Output at Irradiance Levels	114,430.4	-1.4%
	Output at Cell Temperature Derate	114,270.6	-0.1%
	Output After Mismatch	110,014.2	-3.7%
	Optimal DC Output	109,765.3	-0.2%
	Constrained DC Output	109,742.5	0.0%
	Inverter Output	107,657.4	-1.9%
	Energy to Grid	**107,119.1**	**-0.5%**
Temperature Metrics			
	Avg. Operating Ambient Temp		12.6 °C
	Avg. Operating Cell Temp		18.0 °C
Simulation Metrics			
		Operating Hours	4595
		Solved Hours	4595

Condition Set

Description	Condition Set 1
Weather Dataset	TMY, 10km Grid, meteonorm (meteonorm)
Solar Angle Location	Meteo Lat/Lng
Transposition Model	Perez Model
Temperature Model	Sandia Model

Temperature Model Parameters

Rack Type	a	b	Temperature Delta
Fixed Tilt	-3.56	-0.075	3°C
Flush Mount	-2.81	-0.0455	0°C
East-West	-3.56	-0.075	3°C
Carport	-3.56	-0.075	3°C

Soiling (%)

J	F	M	A	M	J	J	A	S	O	N	D
2	2	2	2	2	2	2	2	2	2	2	2

Irradiation Variance	5%
Cell Temperature Spread	4° C
Module Binning Range	-2.5% to 2.5%
AC System Derate	0.50%

Module Characterizations

Module	Uploaded By	Characterization
Q.PEAK DUO XL-G11.2 570 (Hanwha Q Cells)	HelioScope	Spec Sheet Characterization, PAN

Component Characterizations

Device	Uploaded By	Characterization
Sunny Central SC 400 LV-11 (SMA)	HelioScope	Default Characterization
STP 25000TL-30 (SMA)	HelioScope	Spec Sheet Efficiency

Components

Component	Name	Count
Inverters	STP 25000TL-30 (SMA)	4 (100.0 kW)
Strings	10 AWG (Copper)	12 (261.3 m)
Module	Hanwha Q Cells, Q.PEAK DUO XL-G11.2 570 (570W)	196 (111.7 kW)

Wiring Zones

Description	Combiner Poles	String Size	Stringing Strategy
Wiring Zone	-	-	Along Racking
Wiring Zone 2	-	9-17	Along Racking

Field Segments

Description	Racking	Orientation	Tilt	Azimuth	Intrarow Spacing	Frame Size	Frames	Modules	Power
Field Segment 2	Fixed Tilt	Landscape (Horizontal)	15°	163.22348°	7.4 m	4x1	49	196	111.7 kW

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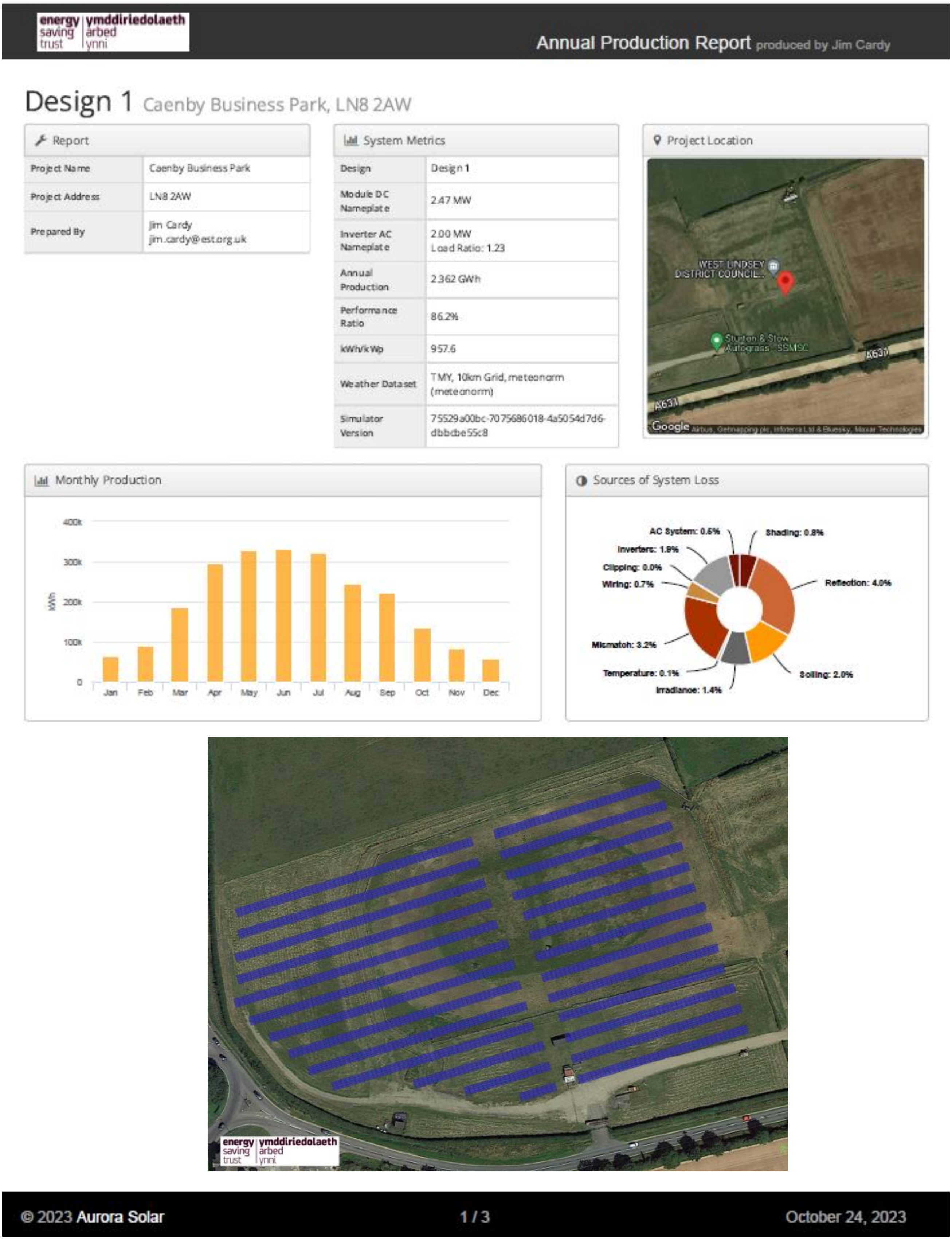
Appendix F:Assessment of solar PV potential of adjacent land



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Annual Production Report produced by Jim Cardy

Design 1 Caenby Business Park, LN8 2AW

Report

Project Name	Caenby Business Park
Project Address	LN8 2AW
Prepared By	Jim Cardy jim.cardy@est.org.uk

System Metrics

Design	Design 1
Module DC Nameplate	2.47 MW
Inverter AC Nameplate	2.00 MW Load Ratio: 1.23
Annual Production	2.362 GWh
Performance Ratio	86.2%
kWh/kWp	957.6
Weather Dataset	TMY, 10km Grid, meteonorm (meteonorm)
Simulator Version	75529a00bc-7075686018-4a5054d7d6-dbbdbe55c8

Project Location

Monthly Production

Sources of System Loss

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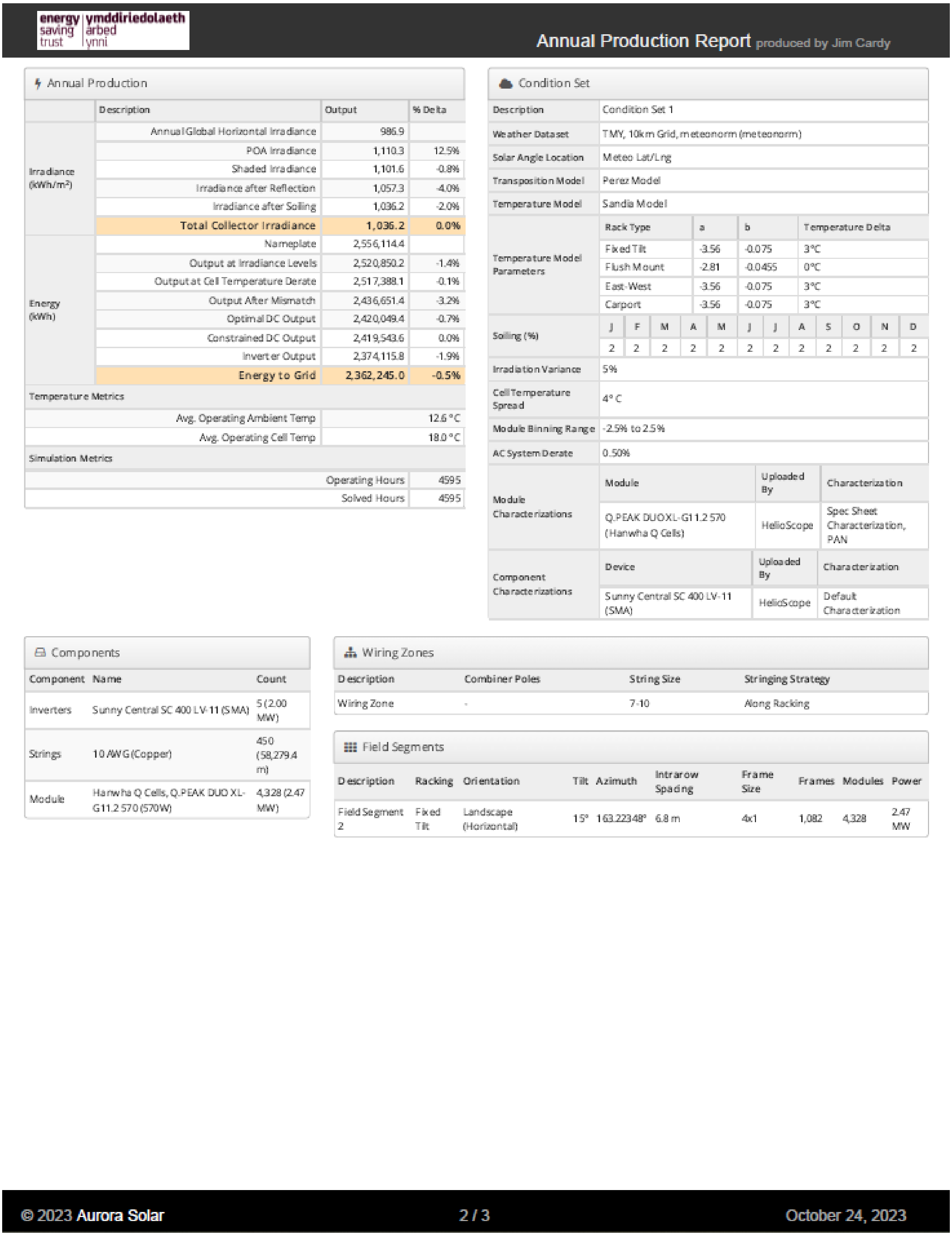

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Annual Production Report produced by Jim Cardy

Annual Production

	Description	Output	% Delta
Irradiance (kWh/m²)	Annual Global Horizontal Irradiance	986.9	
	POA Irradiance	1,110.3	12.5%
	Shaded Irradiance	1,101.6	-0.8%
	Irradiance after Reflection	1,057.3	-4.0%
	Irradiance after Soiling	1,036.2	-2.0%
	Total Collector Irradiance	**1,036.2**	**0.0%**
Energy (kWh)	Nameplate	2,556,114.4	
	Output at Irradiance Levels	2,520,850.2	-1.4%
	Output at Cell Temperature Derate	2,517,388.1	-0.1%
	Output After Mismatch	2,436,651.4	-3.2%
	Optimal DC Output	2,420,049.4	-0.7%
	Constrained DC Output	2,419,543.6	0.0%
	Inverter Output	2,374,115.8	-1.9%
	Energy to Grid	**2,362,245.0**	**-0.5%**
Temperature Metrics			
	Avg. Operating Ambient Temp	12.6 °C	
	Avg. Operating Cell Temp	18.0 °C	
Simulation Metrics			
	Operating Hours		4595
	Solved Hours		4595

Condition Set

Description	Condition Set 1
Weather Dataset	TMY, 10km Grid, meteonorm (meteonorm)
Solar Angle Location	Meteo Lat/Lng
Transposition Model	Perez Model
Temperature Model	Sandia Model

Temperature Model Parameters	Rack Type	a	b	Temperature Delta
	Fixed Tilt	-3.56	-0.075	3°C
	Flush Mount	-2.81	-0.0455	0°C
	East-West	-3.56	-0.075	3°C
	Carport	-3.56	-0.075	3°C

Soiling (%)	J	F	M	A	M	J	J	A	S	O	N	D
	2	2	2	2	2	2	2	2	2	2	2	2

Irradiation Variance	5%
Cell Temperature Spread	4° C
Module Binning Range	-2.5% to 2.5%
AC System Derate	0.50%

Module Characterizations	Module	Uploaded By	Characterization
	Q.PEAK DUO XL-G11.2 570 (Hanwha Q Cells)	HelioScope	Spec Sheet Characterization, PAN

Component Characterizations	Device	Uploaded By	Characterization
	Sunny Central SC 400 LV-11 (SMA)	HelioScope	Default Characterization

Components

Component	Name	Count
Inverters	Sunny Central SC 400 LV-11 (SMA)	5 (2.00 MW)
Strings	10 AWG (Copper)	450 (58,279.4 m)
Module	Hanwha Q Cells, Q.PEAK DUO XL-G11.2 570 (570W)	4,328 (2.47 MW)

Wiring Zones

Description	Combiner Poles	String Size	Stringing Strategy
Wiring Zone	-	7-10	Along Racking

Field Segments

Description	Racking	Orientation	Tilt	Azimuth	Intrarow Spacing	Frame Size	Frames	Modules	Power
Field Segment 2	Fixed Tilt	Landscape (Horizontal)	15°	163.22348°	6.8 m	4x1	1,082	4,328	2.47 MW

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