Low Carbon Vehicle Public Procurement Programme

2010 - 2013

Final Technical Report

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Cenex

Centre of excellence for low carbon and fuel cell technologies

Executive summary - 1

The Low Carbon Vehicle Public Procurement Programme (LCVPPP) placed 200 hybrid and electric panel vans from four different manufacturers within 21 public sector fleets. This report analyses and evaluates the data collected from the four manufacturers' vehicles.

The trial technical analysis comprised two stages:

- In the first stage (2011) each of the four types of vehicle underwent laboratory testing to assess their performance, and were subject to an initial assessment of their real-world performance in fleet deployment. By the end of this stage, one of the electric van suppliers ceased trading, and a second was being used by too few fleets to provide sufficient data for a thorough study of its performance. Therefore only two vehicles were carried through to the second stage of analysis.
- The second stage (2012-13) therefore focused on a longitudinal performance study of the Ashwoods Hybrid and Smith Electric vehicles that were integrated into 17 public sector fleets.

During the three-year LCVPPP technical assessment period (2011-13) the on-vehicle telemetry collected almost 4.25 million kilometres of driving data making the LCVPPP amongst the most comprehensive vehicle trials yet performed.

The performance of 42 Smiths Edison S002 vans and 113 Ashwoods vans deployed within 17 public sector fleets is analysed in detail from 2011-2013. On average, the Ashwoods vehicles across all fleets covered 1,161km per vehicle per month and the average fuel efficiency was 24.8mpg. The Smith vehicles carried out 350km per vehicle per month with an average energy consumption of 2km/kWh. When only considering the fuelling cost, the Ashwoods and Smith vehicles showed an average cost efficiency of £15.53/100km and £5.05/100km respectively. The real world range of Ashwoods and Smith vehicles was 576km and 101km, respectively.

Between 2011 and 2013, the average energy efficiency (km/kWh) of the Smiths electric vehicles decreased by 10%; which may partly be due to battery degradation. This theory is supported by data from charging events, which also showed a 10% decrease in the battery capacity over time. Both, the Smith and Ashwoods vans showed a higher average energy consumption in the London regions compared to the other areas in the UK; showing the effect that traffic/congestion can have on fuel consumption. During the winter, there was a slight reduction in the energy efficiency of the Smith and Ashwoods vehicles. This effect is normally due to greater rolling and wind resistance in the Ashwoods vehicles and greater use of onboard cabin heating in the Smith electric vehicles.

The real-world emissions from the vehicles on a Well-To-Wheel basis were 369 gCO_2e/km for the Ashwoods and 280 gCO_2e/km for the Smiths. These emissions are difficult to directly compare due to the different operating conditions of the vehicles. However, under consistent and repeatable conditions in the laboratory over the NEDC drive cycle, Tank-To-Wheel emissions for the Ashwoods vehicle were 228gCO_2e/km and for the electric vehicles 210gCO_2e/km, whereas the comparator diesel vehicle had emissions of 266gCO_2/km.

When comparing the NEDC CO_2e emissions test results of the trial vehicles to a standard diesel Ford Transit over the three years, the Ashwoods and Smith vehicles achieved a total carbon saving of approximately 171 tonnes and 20 tonnes of CO_2e, respectively.

Executive summary - 2

A Life Cycle Assessment (LCA) was carried out on the 2nd generation Ashwoods Hybrid System; this assessed the carbon emissions from manufacturing, utilising and disposing the Ashwoods van and was compared to that of a Ford Transit van. The lifetime carbon emissions of the Ashwoods van was found to be 9% lower compared to that of an equivalent Ford Transit. Over 80% of the carbon emissions of both vehicles are released during the use phase.

When considering the hybrid system only, the results showed that 99% of the lifetime carbon emissions are due to the manufacturing, installation and maintenance phases. Moreover, the emissions of the hybrid system only constitute 1.7% of the total lifetime emissions of the Ashwoods van.

Based on the results of a qualitative survey carried out at the end of the first phase of technical analysis during the Programme, 50% of electric van drivers would recommend them to others, but only 26% preferred the electric van to a diesel. Amongst the reasons cited were insufficient payload (30%), finding insufficient charge for their journeys (20%) and the inconvenience of considering how far they could drive on each trip (45%).

Fleet managers' views of the electric vans were similar to those of the drivers, with around 50% feeling more positive about the vehicles after the trial than before. Environmental concerns outweighed vehicle performance issues for the survey group. Purchase price and running costs remain significant factors in vehicle purchase decisions.

The fleet managers surveyed revealed a strong preference for government grants as an incentive to purchase low emission vehicles compared with other possible financial instruments such as low-interest loans.

The majority of hybrid van drivers found their vehicles to be similar to a diesel vehicle, with around two thirds of those returning surveys having no change in their opinion of the vehicles after the trial.

In contrast to the drivers who were broadly neutral about the vehicles, the vast majority (78%) of fleet managers felt more positive about hybrids after the trial.

The majority of drivers returning surveys felt they were able to do their job as flexibly in the hybrid van as in a conventional van. However, hybrids elicited less strong responses than the electric vehicles; 56% of drivers felt the hybrid had environmental benefits, compared to 81% of electric van drivers.

Fleet managers viewed the vans positively, and also perceived that their drivers had a good impression of the vehicles. The vast majority of respondents indicated that hybrid vans should be included in their organisation's vehicle renewal programme.

Contents

Introduction

The Low Carbon Vehicle Public Procurement Programme (LCVPPP) was one of the largest trials of electric and hybrid commercial vehicles carried out in the UK to date. Funded by the Department for Transport's Office for Low Emission Vehicles, and managed by Cenex, this three year programme placed 200 hybrid and electric panel vans from four different manufacturers within 20 public sector fleets.

The objectives of the LCVPPP were to:

- Create demand for low CO_2 vehicles.
- Foster a culture change in public sector fleets.
- Manage the risk of trialling new vehicles for the fleets involved.
- Promote innovation and unit cost reduction.
- Test and validate low CO_2 vehicles in real-world driving conditions.

The vehicle manufacturers and operators that participated in the LCVPPP were chosen through a rigorous process designed to meet a programme specification for range, performance and carbon reduction as described in the report *Low Carbon Vehicle Public Procurement Programme (LCVPPP): Lessons learnt for the practice of Innovation Orientated Procurement (IOP) in a fleet context*.

This report deals with the testing and validation of the vehicles and their operational performance, and includes:

- Two stages of vehicle testing:
    - In the **first stage** (2011) each of the four types of vehicle underwent laboratory testing to assess their performance, and were subject to an initial assessment of their real-world performance in fleet deployment. By the end of this stage, one of the electric van suppliers ceased trading, and a second was being used by too few fleets to provide sufficient data for a thorough study of its performance. Therefore only two vehicles were carried through to the second stage of analysis.
    - The **second stage** (2012-13) therefore focused on a longitudinal performance study of the Ashwoods Hybrid and Smith Electric vehicles that were integrated into 17 public sector fleets.
- Life Cycle Assessment (LCA): a LCA was carried out on the 2nd Generation Ashwoods Hybrid System; this assessed the carbon emissions from manufacturing, utilising and disposing the Ashwoods van and was compared to that of an equivalent Ford Transit van.
- Qualitative data: review of the results of questionnaires sent to 200 drivers, as well as a smaller number of fleet managers and maintenance engineers.

Introduction: vehicles included in the LCVPPP

Ashwoods hybrid transit

Parallel hybrid
1.2kWh $LiFePO_4$ battery
9.1kW / 50Nm electric motor

Smith Edison S002

Electric drive
50kWh $LiFePO_4$ battery
64kW / 170Nm electric motor

Allied Peugeot eBoxer

Electric drive
54kWh $LiFePO_4$ battery
60kW / 130Nm electric motor

Modec LWB panel van

Electric drive
84kWh $NaNiCl_2$ ZEBRA battery
76kW / 300Nm electric motor

Introduction: summary of the vehicle analysis timelines for LCVPPP

cenex

2009-10
- Initial choice of manufacturers to participate in the Programme

2010-11
- **Stage 1 performance assessment, comprising:**
- Laboratory testing of vehicles under controlled conditions
- Initial real-world assessment of deployment of all four manufacturers' vans with public fleets

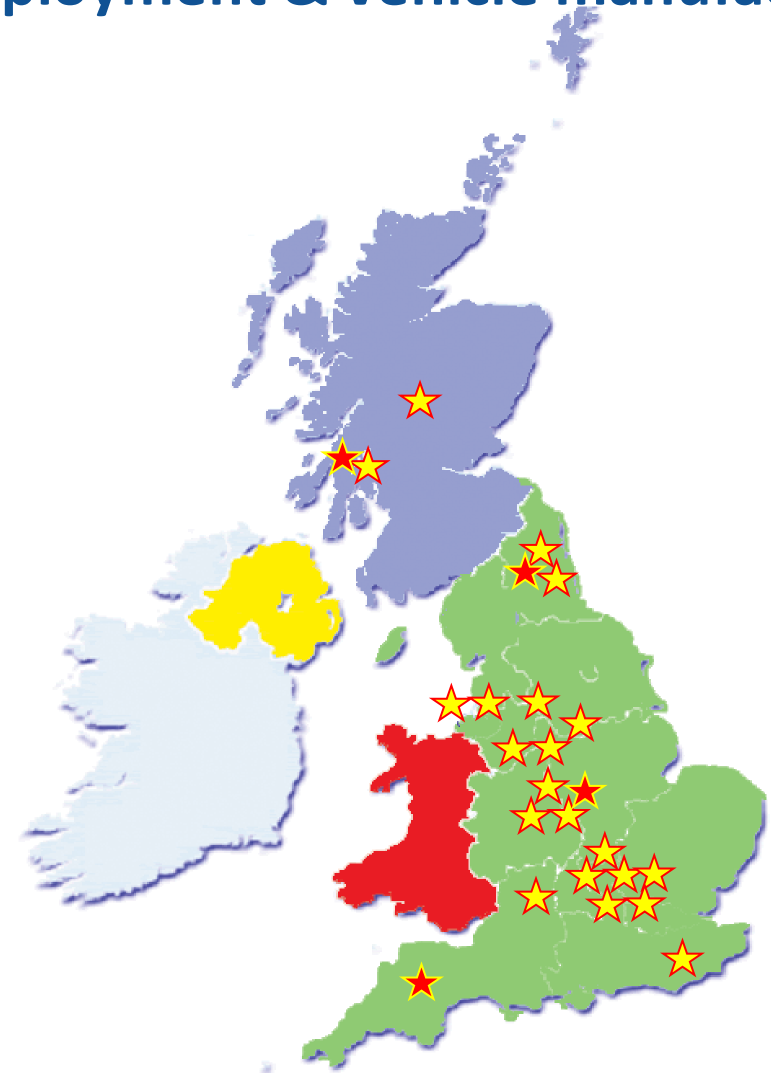
2011-13
- **Stage 2 performance assessment:**
- Longitudinal study of the real-world performance of the Ashwoods hybrid and Smiths electric vans with public fleets

By the end of Stage 1 (2011), one of the electric van suppliers had ceased trading, and a second was being used by too few fleets to provide sufficient data for a thorough study of its performance. Therefore only two vehicles were carried through to the second stage of analysis.

Introduction: Fleet deployment & vehicle manufacturer locations

Vehicle fleets ☆

- Coventry City Council
- Coventry University
- Derbyshire County Council
- Environment Agency
- Gateshead City Council
- Glasgow City Council
- Government Car and Dispatch Agency
- Leeds City Council
- Liverpool City Council
- London Boroughs of Camden, Hackney and Islington
- City of London
- Metropolitan Police Service
- Newcastle City Council
- Perth and Kinross Council
- Royal Mail
- Transport for London
- UK Border Agency
- City of Wakefield Council
- University of Warwick



Manufacturers: ★

- Allied Electric
- Ashwoods
- Modec
- Smith Electric Vehicles

200 vehicles from four manufacturers were deployed in 21 public sector fleets across the UK.

Data summary: vehicle distance driven

The data collected from on-vehicle telemetry systems during the two analysis Stages of LCVPPP is summarised below.

By the end of Stage 1 (2011), one of the electric van suppliers had ceased trading, and a second was being used by too few fleets to provide sufficient data for a thorough study of its performance. Therefore, only two vehicles were carried through to the second stage of analysis which ran from 2012-13.

The first analysis stage also collected data from 25 diesel vehicles that covered over 278,000 km for comparison purposes.

Vehicle Type	Manufacturer	Number deployed	Number of stakeholder fleets	Distance covered (km)	Time period analysed
Hybrid	Ashwoods	137	14	3,635,000	2011-13
Electric	Smith	43	18	528,000	
	Allied	16	10	64,000	2011
	Modec	4	4	15,000	
Total		**200**	**21***	**4,242,000**	

* A number of the fleets deployed more than one vehicle type.

Data summary: Stage 1 vehicle testing

All the vehicle models in the Programme were tested in controlled test facility conditions before entering the programme, and after six and twelve months of use. There were two principle reasons for this:

- To confirm the achievement of minimum performance requirements for programme inclusion.
- To provide a benchmark for analysis of real-world performance.

The testing undertaken was split into two categories

- Track-based performance testing (e.g. acceleration, maximum speed).
- Laboratory emissions testing for diesel/hybrid vehicles, and range and energy consumption tests for electric vehicles.

The hybrid vehicles achieved a 14-15% CO_2 saving, compared to a comparator diesel vehicle over the NEDC (savings up to 20% were achieved on other drive-cycles).

Based on their lab-tested energy use over the same cycles, and the current carbon intensity of UK grid electricity, the Allied and Smith electric vans (shown in aggregated form) achieved similar levels of emissions to the hybrids. Data is not shown for the Modec van.

Test cycle	Ashwoods SWB	Ashwoods LWB	Electric	Diesel SWB	Diesel LWB
NEDC (gCO_2/km)	228	229	210	266	266
Artemis urban (gCO_2/km)	279	287	293	326	344

Data summary: Ashwood vehicle data

The following table gives a breakdown of the 137 Ashwoods vehicles analysed in this report over the two analysis Stages of LCVPPP (2011-2013).

Vehicle Type	Manufacturer	Fleet	No. of vehicles in fleet	No. of vehicles reporting data	Total distance covered (km)
Hybrid	Ashwoods	Coventry City Council	39	39	928,000
		Doncaster Council	18	18	657,000
		Environment Agency	12	10	425,000
		Gateshead City Council	4	4	151,000
		Leeds City Council	19	18	657,000
		Liverpool Council	5	4	89,000
		London Borough of Hackney	3	3	78,000
		Perth and Kinross Council	4	4	201,000
		Royal Mail	10	10	362,000
		Wakefield Council	3	3	86,000
		London Borough of Islington	2	0	
		Transport for London	3	0	
		London Borough of Camden	1	0	
		UKBA	14	0	
Total		**14**	**137**	**113**	**3,635,000**

Data summary: Smith vehicle data

Data was collected from 42 of the 43 deployed vehicles.

The following table gives a breakdown of the Smith vehicles analysed in this report over the two analysis Stages of LCVPPP (2011-2013).

Vehicle type	Manufacturer	Fleet	No. of Vehicles in Fleet	No. Of Vehicles Reporting Data	Total Distance Covered (km)
Electric	Smith	City of Wakefield MBC	1	1	10,000
		Gateshead City Council	10	10	171,000
		Leeds City Council	5	5	78,000
		Liverpool City Council	1	1	26,000
		London Borough of Camden	1	1	1,000
		London Borough of Islington	10	10	95,000
		Newcastle City Council	4	3	33,000
		Nottingham City Council	2	2	27,000
		Transport for London	4	4	43,000
		University of Warwick	5	5	45,000
Total		**10**	**43**	**42**	**528,000**

Ashwoods analysis

Ashwoods vehicle data summary

The following table summarises the statistics of the 113 Ashwoods vehicles for which a comprehensive dataset was available which are analysed in this report.

Ashwoods fleet summary: January 2011 – December 2013	
Total No. of vehicles	113
Total No. of fleets	10
Total No. of re-fuelling events	7,017
Total gallons refuelled	92,000
Total distance covered	3,635,000km
Average distance between re-fuelling events	518km
Tailpipe CO_2e emissions	304 gCO_2e/km
WTW CO_2e emissions	369 gCO_2e/km

The Ashwoods vehicles travelled a total distance of 3,650,000km, completed 7,000+ refuelling events and fuelled 92,000 gallons of diesel. The average distance between re-fuelling events was 518km. Two-thirds of the refuelling events consisted of drivers refuelling more than 13 gallons (Tank capacity: 17.6 gallons) and the average distance between these events was 576km.

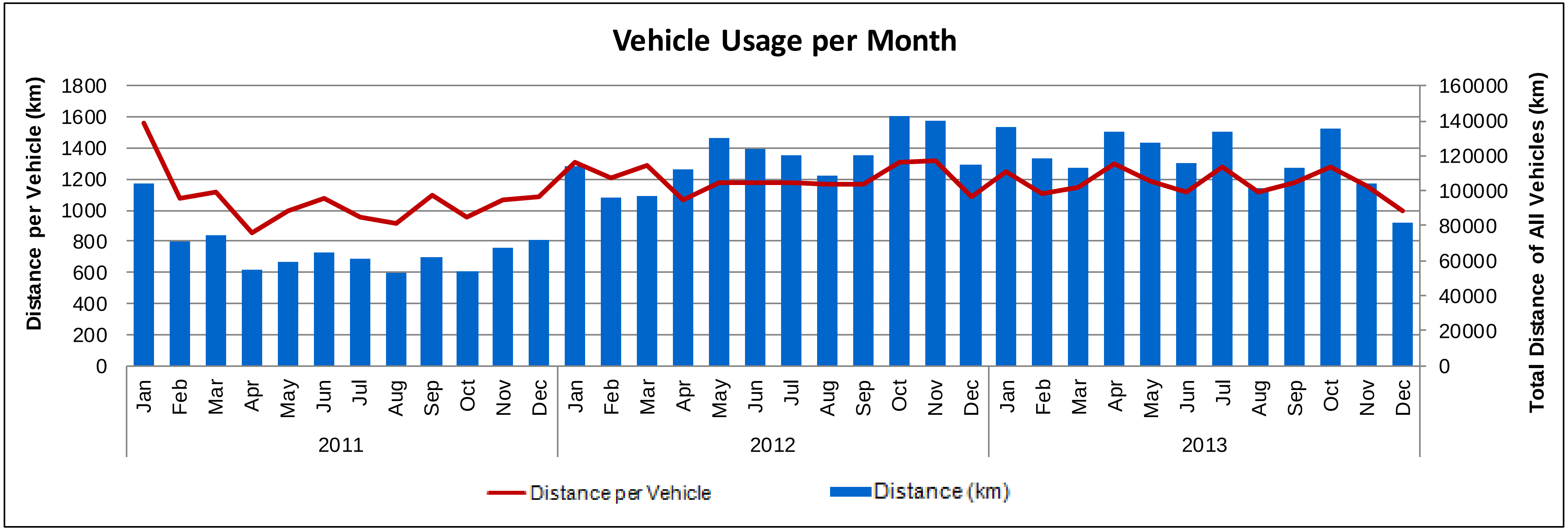
DEFRA 2013 emission factors[1] were applied in order to calculate the tailpipe and WTW emissions. The tailpipe emissions are released directly from the vehicle and are solely based on fuel combustion. The WTW emissions include the carbon emitted from fuel extraction, processing, delivery, dispensing and the tailpipe emissions. It is apparent that the WTW carbon emissions mainly consisted of the tailpipe carbon emissions (82%).

1. Emission factors are taken from the 2013 DEFRA/DECC Guidelines for Company GHG Reporting. All GHG emissions are included and stated on a CO_2 equivalence basis.

Ashwoods Analysis

Vehicle usage

The graph below shows the total distance travelled of all the Ashwoods vehicles and distance travelled per vehicle per month.



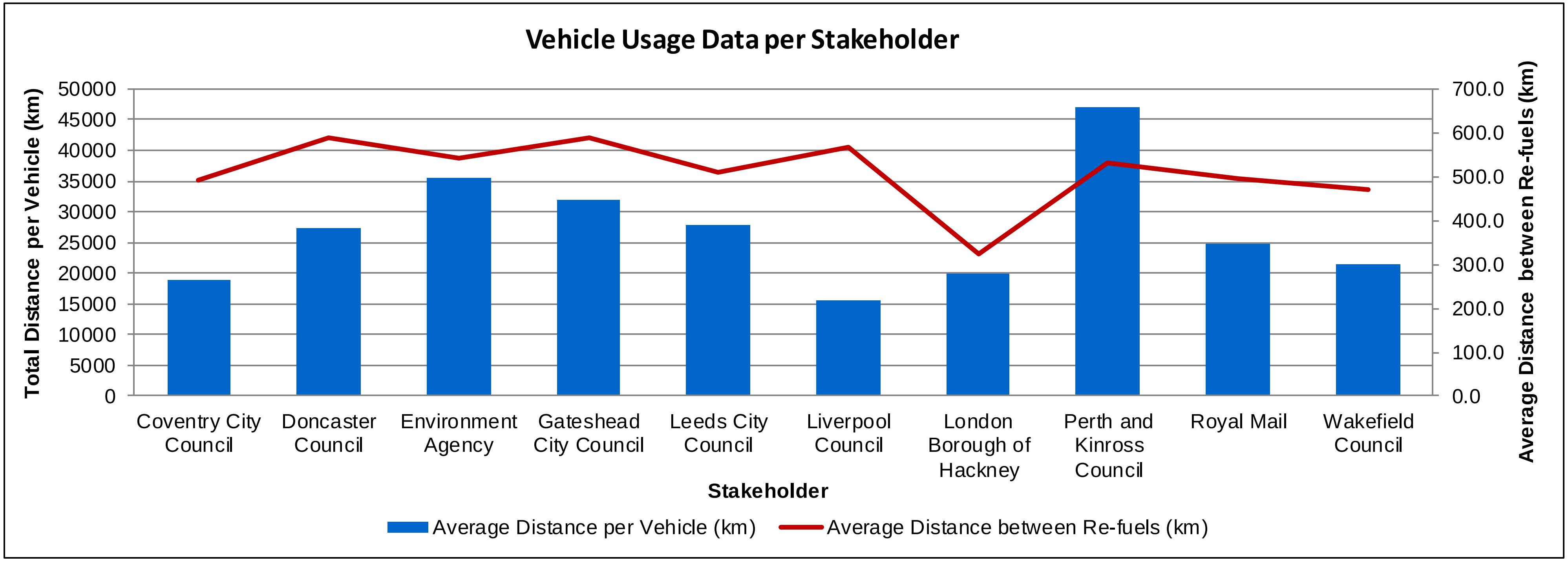
From the graph above, it is clear that the total distance travelled was lower in 2011 than in 2012 and 2013. However, it must be noted that the number of vehicles reporting data was also lower in 2011 than in 2012 and 2013. The distance per vehicle gives a better representation of the distance the Ashwoods vehicles are being driven. The graph illustrates that Ashwoods vehicles were driving approximately 1,190km per month in 2012 and 2013 and 1,060km per month in 2011. The consistent use of the vehicles shows that they were well integrated into the fleets.

The total distance travelled in the August and December months is generally lower than the other months due to holiday periods.

Ashwoods analysis

Vehicle usage per stakeholder fleet

The graph below compares the stakeholder fleets with respect to the average distance travelled per vehicle and the average distance covered between refuels. Only vehicles for which a complete data set (2011-2013) was present were used to produce the graph below.



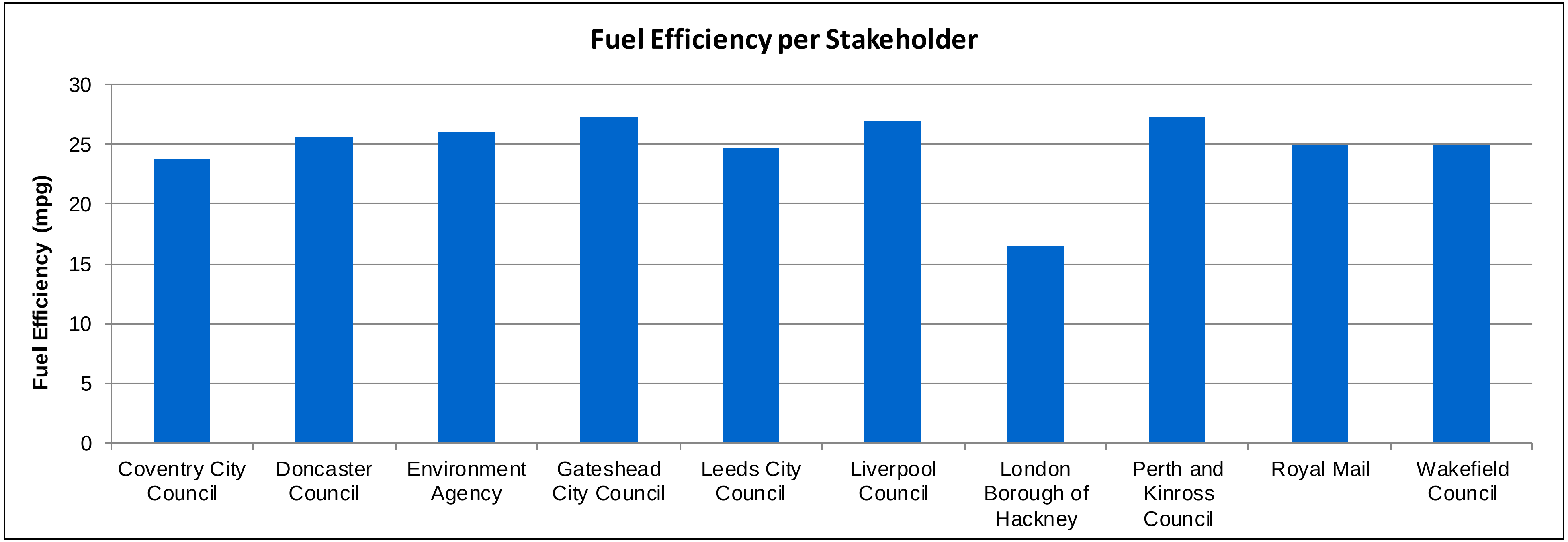
From the graph above, it is noticeable that Perth and Kinross Council utilised the Ashwoods vehicles more than the other stakeholders as each vehicle drove approximately 47,000km. However, the mileage per vehicle is largely dependant on the fleet's operations and can vary from fleet-to-fleet. Coventry City Council, Liverpool Council, London Borough of Hackney and Wakefield Council consisted of vehicles carrying out lower mileages than the other fleets; on average, these vehicles drove 19,000km each.

The average distance covered between refuelling events across all fleets was 511km. This ranges from 324km to 589km between the fleets. London Borough of Hackney (sole fleet based in London) had lower distances between refuelling events than most of the other stakeholders, implying a lower fuel efficiency; this was confirmed by the graph overleaf.

Ashwoods analysis

Fuel efficiency by fleet

The graph below shows the fuel efficiency of the different fleets within the trial.



The average fuel efficiency across all the fleets was 24.8mpg. The London Borough of Hackney was the least efficient with an average fuel efficiency of 16.4mpg. This is likely to be due to the vehicles operating in Central London; the lower fuel efficiency illustrates the effect that traffic/congestion can have on fuel consumption, and confirmed by the fact that these vehicles displayed lower average speeds than those of the other fleets. Gateshead City Council, Liverpool Council and Perth and Kinross Council were the most fuel efficient fleets with an average fuel efficiency of over 27 mpg.

The current cost of diesel is approximately 136.3p/litre[2], hence, the average fuel cost of the Ashwoods vehicles across all of the fleets over the three years is £15.53/100km.

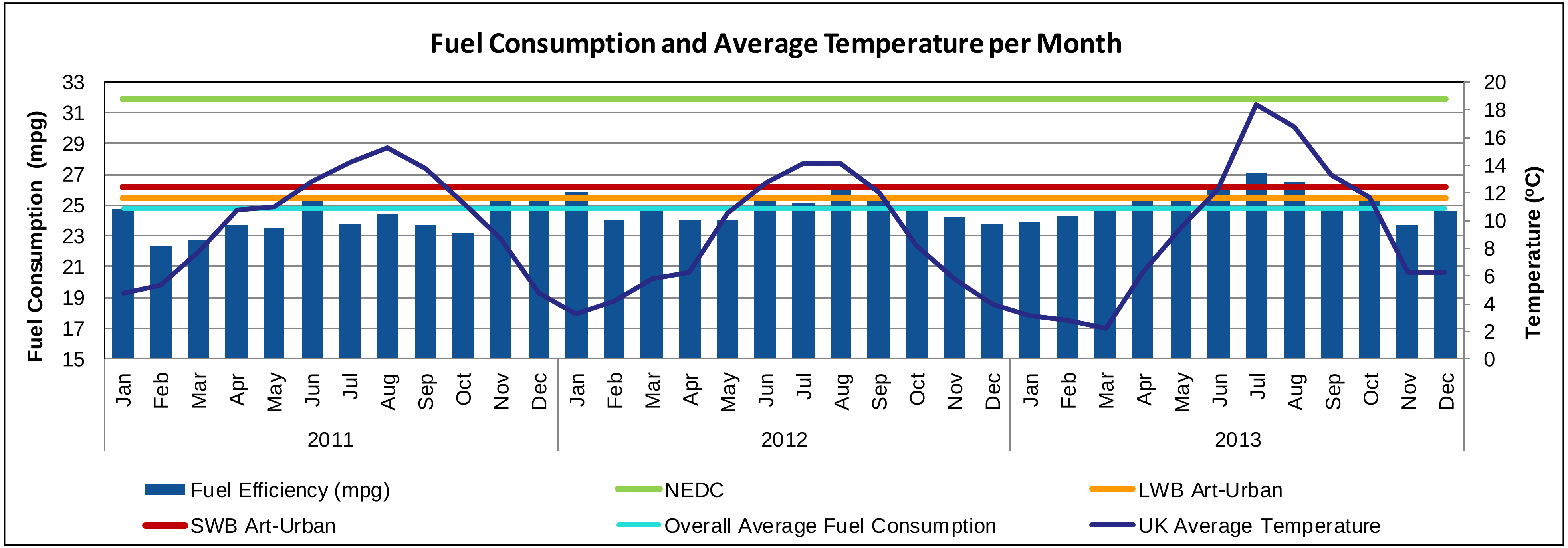
However, it must be noted that the fuel consumption can be affected by many factors such as the payload, driving style, traffic conditions the use of on-board electrical appliances and the weather/temperature. The effect of temperature on the fuel efficiency is illustrated overleaf.

2. Cost of diesel taken from the quarterly energy prices report published by the 'Department of Energy & Climate Change' in March 2014

Ashwoods analysis

Fuel efficiency by month

The graph below shows the fuel efficiency and the UK's average temperature per month and year.



The chart above compares the average monthly energy consumption to that measured over the NEDC (New European Drive Cycle) and Artemis Urban Drive Cycle during laboratory testing. SWB (Short Wheel Base) and LWB (Long Wheel Base) configurations were tested. The NEDC drive cycle is the accepted cycle used across Europe for emissions tests, whereas, the Artemis Urban Drive Cycle is an industry standard cycle considered representative of city driving. The UK's average monthly temperature[3] is also included in the secondary axis.

The real-world fuel consumption was significantly poorer than that measured over the NEDC under test conditions (31.9mpg), but compared closely to that measured for the LWB (Long Wheel Base) over the Artemis Urban Cycles (25.4mpg).

A slight improvement in the fuel consumption can be seen during the summer months (Jun-Aug) compared to the winter months (Dec-Feb); especially during 2012 and 2013. This is likely to be due to reduced rolling and wind resistance in the summer months.

3.Monthly mean national temperature is taken from the Met office website, published February 2014.

Smith analysis

Vehicle data summary

The table summarises the performance of 42 Smith vehicles that operated in 10 different public sector fleets that are analysed in this section.

Smith fleet summary: January 2011 – December 2013	
Total No. of vehicles	42
Total No. of fleets	10
Total days of operation	15,770
Total distance covered	528,000km
Average daily distance per vehicle	33.5km
Tailpipe CO_2e emissions	0 gCO_2e/km
WTW CO_2e emissions	280 gCO_2e/km

The Smith vehicles cumulatively travelled a total distance of 527,979km over 15,770 days. Across the three years the total distance travelled by all the Smith vehicles was approximately 14,700km per month; hence, the total distance travelled per month per vehicle was 350km. When considering the days of operation, the average daily distance per vehicle was 33.5km, which is well within the 150km range of the vehicle. This implies that the fleets' operation consisted mainly of short distance journeys or that the drivers were reluctant to exhaust the range.

It should be noted that a large proportion (45%) of data was collected from by the London Borough of Islington and Gateshead City Council due to the high number of vehicles being operated in these fleets.

The Smith electric vehicles do not produce carbon emissions directly from the vehicle, however production and delivery of electricity in the current UK grid is relatively carbon intensive; and hence, the vehicles produce 280gCO_2e/km (determined using 2012 DEFRA emission factors) on a WTW basis. Emissions from the Smiths will reduce inline with electricity grid decarbonisation.

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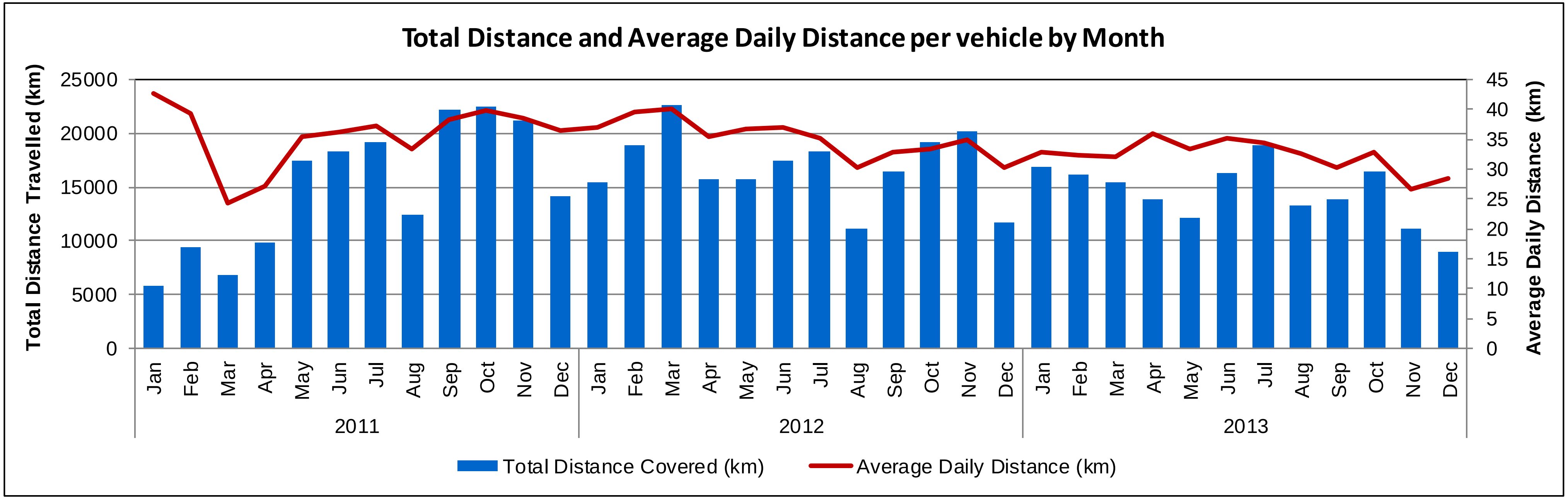
Smith analysis

Vehicle usage

The graph below shows the total distance travelled and the average daily distance per vehicle by month.



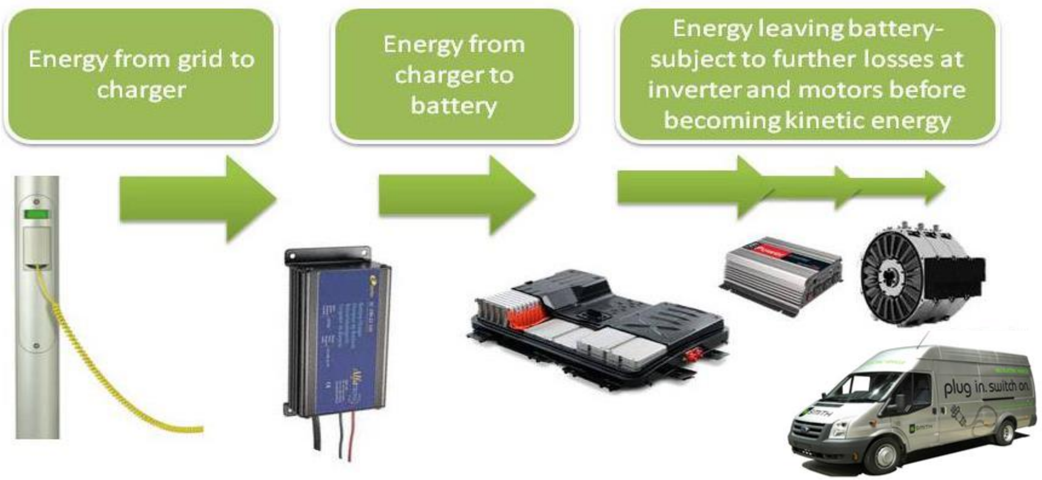
The chart above shows that the total distance travelled per month was much lower in the earlier part of 2011 compared to any other period across the 3 years. The average distance covered per month was 8,000km between January and April 2011, whereas, across the three years it was 14,700km. Also during the earlier months of 2011, the average daily distance per vehicle shows more variations per month. The discrepancies in the data during these months are likely to be due to drivers and fleets acting relatively cautiously, as these new vehicles were being integrated into the fleet's operations. However, following the initial period, the total distance and average daily distance per vehicle becomes more consistent per month.

Similar to Ashwoods vehicles, there was a general reduction in the average daily distance and total distance during the August and December months, coinciding with the holiday periods. The average total distance travelled during the holiday months was 11,900km.

Smith analysis

Energy consumption & losses

The energy consumed was measured by the on-board Smith telemetry loggers. The telemetry logger determines the energy leaving the vehicles' drive batteries by recording the voltage and current at the battery terminals. However, the running costs and emissions from EVs should be based on the amount of energy supplied from an external power source to the vehicle during charging. The power supplied to the vehicle is subject to efficiency losses at various points between the point at which it is supplied to the vehicle's on-board charger, and being finally converted to vehicle movement. The figure below illustrates these losses.



Efficiency	Smith
Charger efficiency	85.3%
Battery efficiency	86.3%
Plug to battery output efficiency	73.6%

As illustrated by the figure above, the amount of energy that enters the charger unit is greater than the amount that leaves it and enters the battery. This is primarily due to transformer losses. Similarly, the amount of energy that enters the battery is greater than the amount that leaves it – due to losses incurred by the conversion of electrical energy to chemical energy, and then back again. Between the battery output and the wheels, there are additional losses in the power electronics and motor. These are not considered in this analysis.

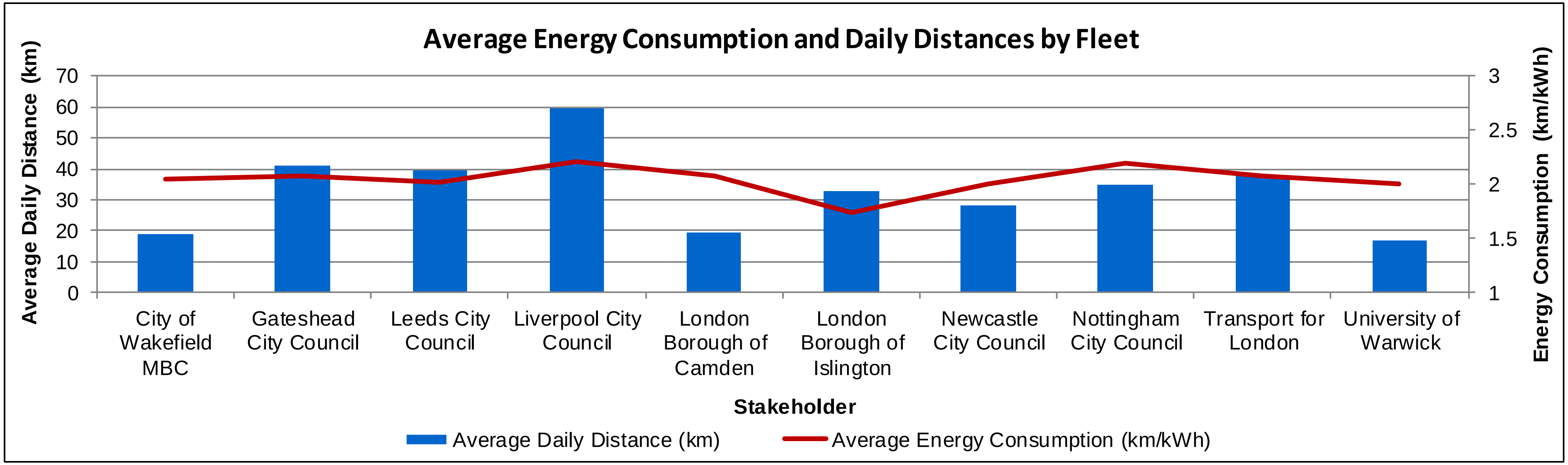
Vehicle telemetry measures the energy leaving the battery when the vehicle is driving. Therefore, measurements and/or estimates of the charger and battery efficiency are required in order to estimate the actual amount of energy consumed by the vehicle.

Cenex carried out tests during the first Stage of LCVPPP in order to calculate the battery efficiencies represented in the table above. The plug to battery output efficiency (73.6%) was implemented to all of the telemetry data in order to calculate the actual energy consumed.

Smith analysis

Vehicle usage and energy consumption by stakeholder fleet

The graph below compares the stakeholder fleets with respect to the average daily distance per vehicle and the average energy consumption.



The average daily distance across all the stakeholders was 33.5km. The average daily distance ranged between 59km and 17km; which were carried out by Liverpool City Council and the University of Warwick, respectively. The average daily distance is mainly dictated by the fleets' day-to-day operations and the fleet managers'/drivers' confidence regarding the reliability and range of the Smith vehicles.

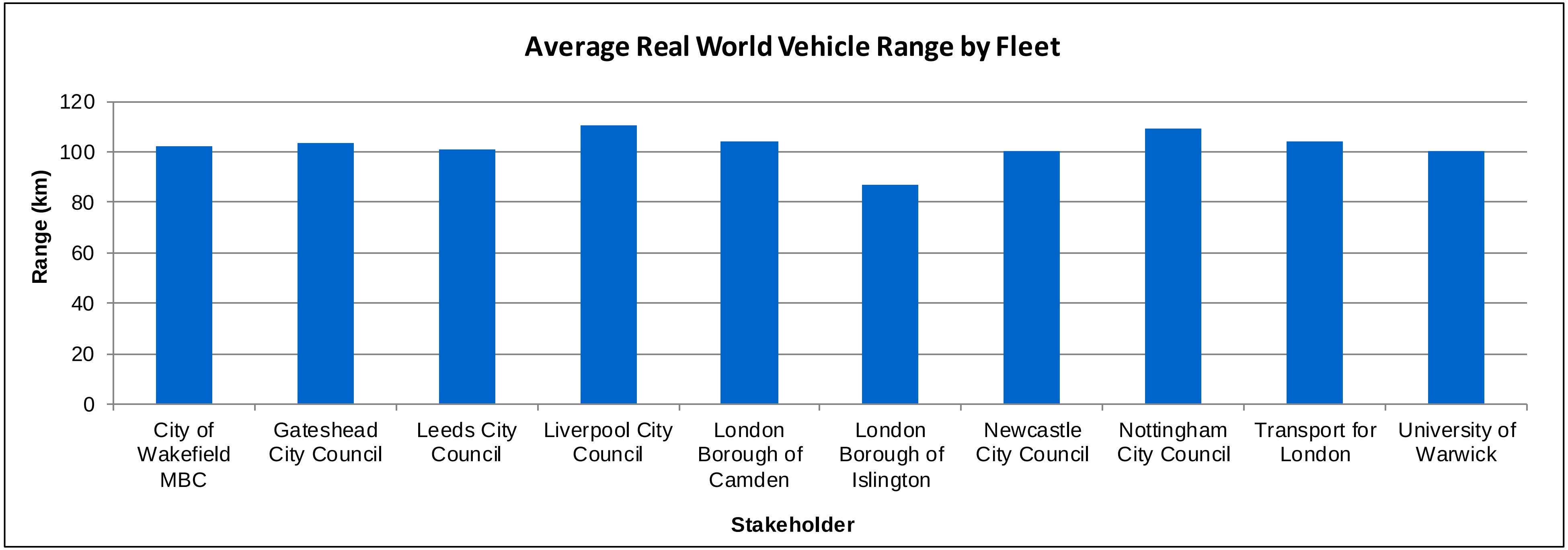
As mentioned in the previous slide, the energy efficiency was corrected for charger and battery efficiency (73.6% efficiency) to account for all of the energy consumed by the vehicle. The average energy consumption across all the fleets was 2.0km/kWh.

Liverpool City Council was the most energy efficient compared to the other stakeholders' fleets with an average energy consumption of 2.2km/kWh. Conversely, London Borough of Islington had the least efficient fleet with an average energy consumption of 1.7km/kWh. The low energy efficiency is likely to be due to the higher levels of traffic in Central London which is strongly supported by the fleet having a lower average speed compared to the other fleets - 15mph compared to a overall fleet average of 19mph.

Smith analysis

Real world vehicle range by stakeholder fleet

The graph below compares the real world range by stakeholder.



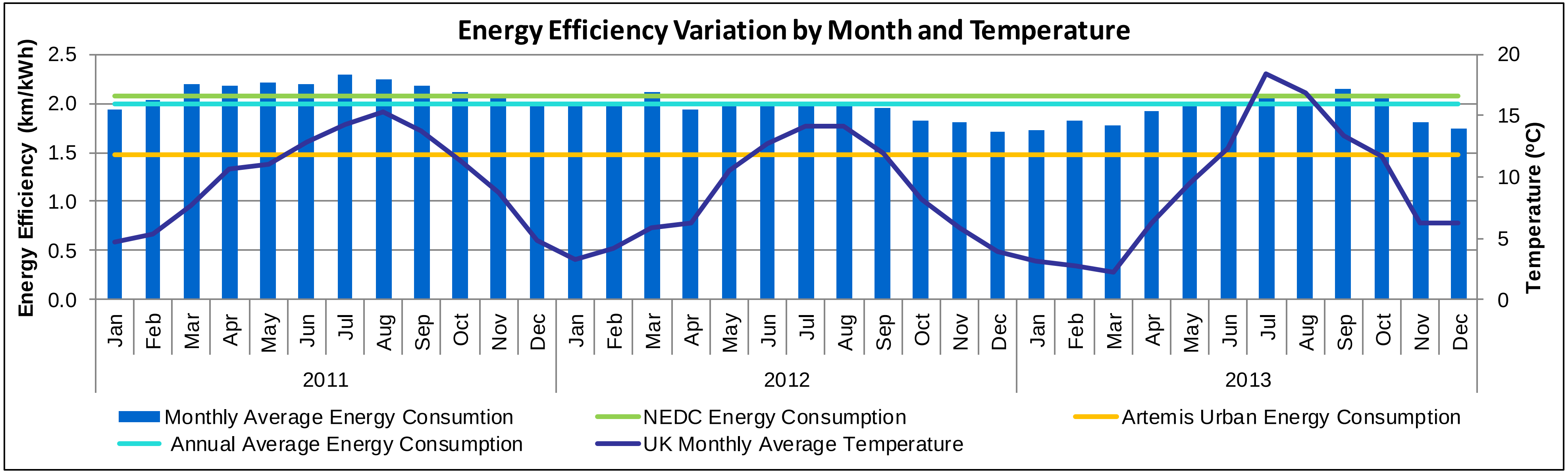
The real world range of the Smith electric vehicles across all fleets was 101km. The range of the electric vehicles varied between 87km and 111km across the different fleets, with Liverpool City Council showing the highest real world range. The London Borough of Islington showed the lowest average range. Again, this is likely to be due to the higher levels of traffic in Central London.

Please note that the range of the vehicle was calculated based on a 50kWh battery, if the battery management system did not allow the driver to fully utilise the 50kWh capacity of the battery, the range would be proportionally reduced.

Smith analysis

Energy efficiency by month

The graph below shows the energy efficiency and the UK's average temperature per month per year.



The chart above compares the real-world average monthly energy consumption to that measured over the NEDC and Artemis Urban Drive Cycles during laboratory testing. As mentioned earlier, the NEDC drive cycle is the accepted cycle used across Europe for emissions tests, whereas, the Artemis Urban Drive Cycle is an industry-standard cycle considered representative of city driving.

The 12 month real-world energy consumption across all fleets (corrected for charging efficiency) was 2.0km/kWh. The real-world energy efficiency was marginally lower than that measured over the NEDC under test conditions (2.07km/kWh), but significantly greater than that measured over the Artemis Urban Drive Cycle (1.48km/kWh).

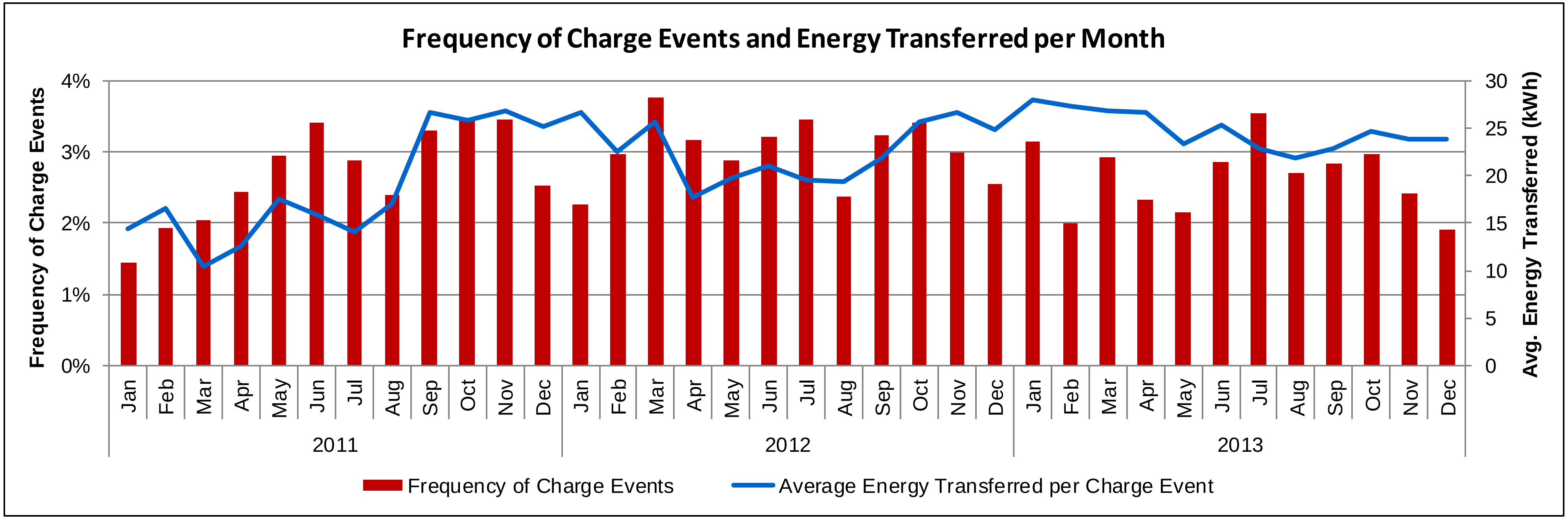
The real-world efficiency showed a clear seasonal variation. The efficiency energy decreased broadly inline with falling mean national temperature during winter months. Generally, temperature had a negative correlation with energy consumption mainly due to the increased rolling & wind resistance and greater use of onboard cabin heating during the winter. Other temperature related reductions in battery and regeneration efficiency also have an effect.

Between 2011 and 2013, the average energy efficiency (km/kWh) decreased by 10%; which may partly be due to battery degradation. This theory is supported by data from charging events, which also showed a 10% decrease in the battery capacity over time.

Smith analysis

Smith vehicle charging patterns

The chart below shows the frequency of charge events per month and the average energy transferred per charge event per month.



This graph agrees with the journeys per month data, as the frequency of charge events and the energy transferred (corrected for efficiency losses) is significantly lower in 2011 compared to 2013. The average energy transferred per charge event is 30% lower in 2011 compared to 2013, which could be due to the drivers' improved confidence in the range of the vehicle. Coinciding with the Ashwoods and the drive data, the frequency of charge events during the holiday periods (August and December months) is generally lower than the other months.

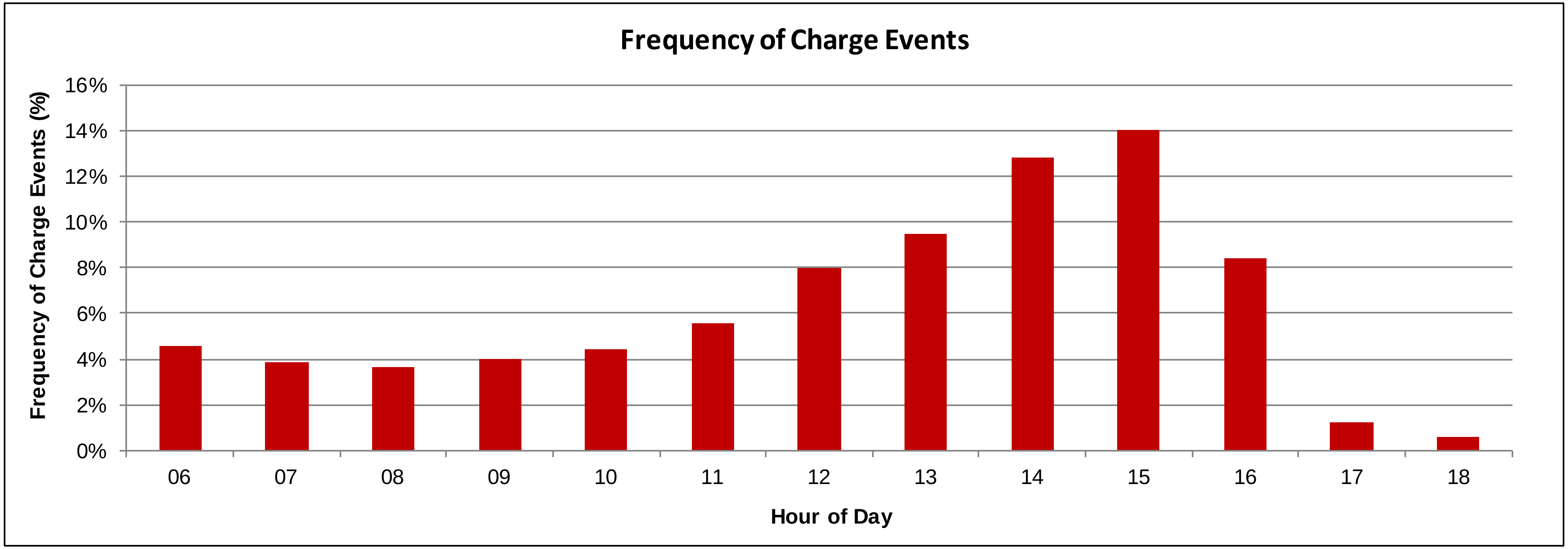
The average energy transferred per charge event across the three years was 22kWh, which is less than 50% of the rated battery capacity (50kWh); emphasising that the vehicles range was generally not exhausted. The total energy transferred was approximately 285,000kwh which achieved a total distance of 527,979km. The average cost of electricity in the UK at present is 10.1p per kWh[4]; giving an average energy cost of £5.05 per 100km. Furthermore, the average cost per charge event is £2.22.

4.Cost of Electricity taken from the 'Business Electricity Prices' website, published 2014.

Smith analysis

Smith vehicles – start time of charge events

The chart below shows the frequency of charge events per hour during working hours.



The graph above shows that a large proportion (27%) of the charge events commenced between 2pm and 4pm; this is likely to be due to the fleets' day-to-day operational schedule whereby the vans are put on charge at the end of their daily operational duties.

The average SoC at charge commencement was 51.5%. This further emphasises the fact that drivers were either reluctant to exhaust the range of the vehicles or the fleets' operations mainly consisted of short distance journeys.

Ashwoods and Smith operational data comparison

	Ashwoods Vehicle (Hybrid)	Smith Vehicle (Electric)
Average Monthly Distance per Vehicle	1,161 km	350 km
Average Energy Consumption	24.8 mpg	2.0 km/kWh
Cost Efficiency	£15.53/100km	£5.05/100km
Average Real World Range	576km	101km
Real World Tailpipe CO_2e Emissions	304 gCO_2e/km	0 gCO_2e/km
Real World WTW CO_2e Emissions	369 gCO_2e/km	280 gCO_2e/km
Test (NEDC) WTW CO_2 Emissions	280gCO_2e/km	289gCO_2e/km

Please note that the cost efficiency does <u>not</u> incorporate the maintenance and capital cost of the vehicle.

The real world CO_2e emission calculations are based on the drive cycles and payloads incorporated within the fleet's operation.

The table above shows the usage, performance and carbon emissions of the Ashwoods and Smith vehicles trialled by all fleets between 2011 and 2013.

On average, the Smith vehicles covered a significantly lower mileage (70% lower) than the Ashwoods vehicles. This is likely to be due to different duty cycles assigned to the hybrid and electric vans by each stakeholder. The Smith vehicles were generally charged on a daily basis, whereas, the Ashwoods vehicles were refuelled approximately every 13 days.

The emissions are shown on a tailpipe and WTW (Well-To-Wheel) basis. The tailpipe emissions are released directly from the vehicle and are solely based on fuel combustion. The WTW emissions include the carbon emitted from fuel extraction, processing, delivery, dispensing and the tailpipe emissions.

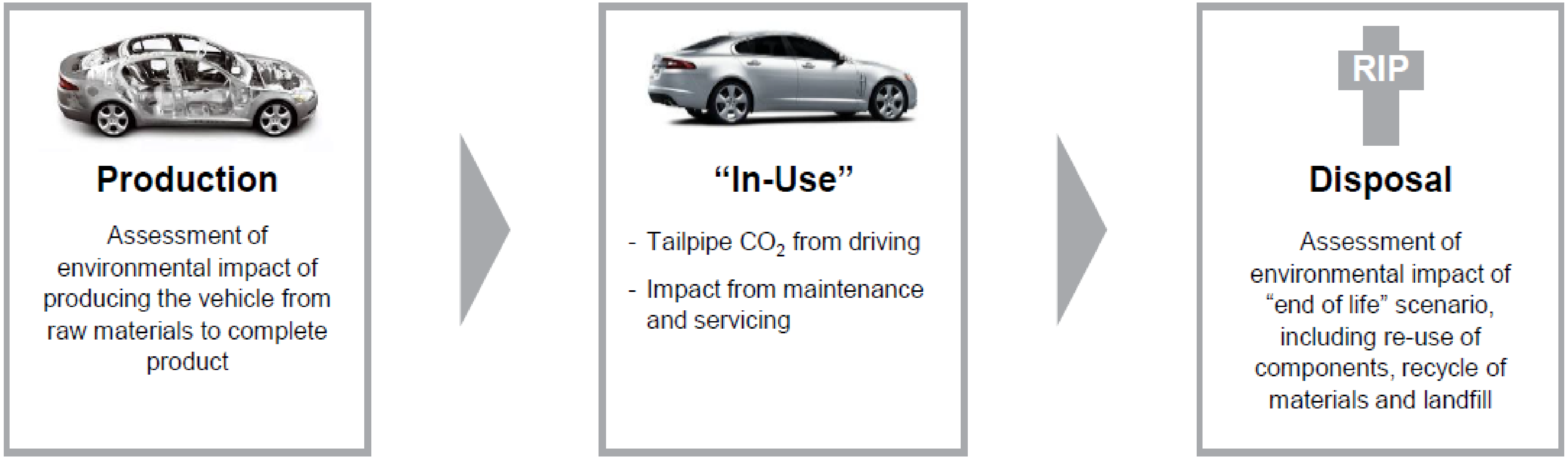
It should be noted that the average emissions between the vehicles are difficult to directly compare due to different operating conditions such as driving duties, payloads and driving style. However, under consistent and repeatable conditions in the laboratory over the NEDC drive cycle, the WTW emissions for the Ashwoods vehicle were 280gCO_2e/km, whereas the WTW emissions for the Smith vehicles were 289gCO_2e/km. Clearly, emissions from the Smiths will reduce inline with electricity grid decarbonisation. When comparing the NEDC CO_2 emissions test results of the trial vehicles to a standard diesel Ford Transit over the three years, the Ashwoods and Smith vehicles achieved a total carbon saving of approximately 171 tonnes and 20 tonnes of CO_2, respectively.

As the Smith vehicles do not employ an Internal Combustion Engine (ICE), no local air quality emissions are generated, the noise pollution will also be significantly reduced.

Life cycle assessment

Introduction to LCA

A Life Cycle Assessment (LCA) of a vehicle refers to the total carbon emissions of manufacturing, utilising and disposing a vehicle. The illustration below[5] outlines a typical LCA for a vehicle.



LCA - Ashwoods 2nd Generation Hybrid Vehicle

Due to the success of the 1st Generation Ashwoods Hybrid System, Ashwoods introduced a2nd Generation of its Hybrid System. As a result, Cenex were asked to carry out an LCA on the 2nd Generation system.

The LCA Calculator, designed and developed by Industrial Design Consultancy (IDC) was utilised to determine the total carbon emissions over the lifetime of the Ashwoods hybrid system. The EcoInvent database containing the emissions of numerous materials is incorporated into the calculator. Other sources were used for materials that were not included in this database. In the case of the Ashwoods Hybrid System, there was only one component not included in the LCA Calculator (the neodymium magnets).

To gain a better understanding of the LCA regarding the outcomes, the lifetime carbon emissions of the Ashwoods hybrid van was compared to that of an equivalent Ford Transit. The verification process, the total emissions of the hybrid system and its individual components are described overleaf.

5.Ricardo, Preparing for a Life Cycle CO_2 Measure, published 2011.

Life cycle assessment

LCA – verification process

Ashwoods provided Cenex with the different component details of the Hybrid System and their corresponding mass. In order to ensure the credibility of the components, Cenex carried out a verification process at MCT ReMan Ltd, Ashwoods' sole contractor for manufacturing the hybrid system. 10 of the high emission components were indentified and assessed by Cenex to ensure that they corresponded with the information provided. Cenex confirmed that there were no omitted components, by ensuring that the mass of the entire hybrid system corresponded to the total mass of all the components.

LCA – lifetime carbon emissions

The following table* shows the results of the lifetime carbon emissions of the Hybrid System

	Emissions			
Assembly	**Manufacturing, Installation & Maintenance CO_2e (Kg)**	**Disposal CO_2e (kg)**	**Transport CO_2e (kg)**	**Total CO_2e (kg)**
Lithium Battery	184.0	0.1	1.5	**186**
Motor Controller	240.9	0.2	3.3	**244**
Battery Management System	165.8	0.4	0.4	**167**
Motor	50.1	4.4	0.0	**54**
Intelligent Power Pack Module Case	56.9	0.1	0.1	**57**
Phase Loom	10.2	0.3	0.0	**10**
Light Foot Hub	34.1	0.1	0.0	**34**
Light Foot Display	22.7	0.0	0.0	**23**
Motor Coupling	3.4	0.0	0.0	**3**
Neodymium Magnets (Within Motor)[6]	14.6	0.0	0.0	**15**
Total	**782.6**	**5.5**	**5.2**	**793**

It is apparent from the table above that the manufacturing, installation and maintenance process of the hybrid system emits the majority (99%) of the carbon emissions over the lifetime of the Hybrid System. The main components within the assemblies contributing to these process emissions were:

- Manufacturing the different integrated circuitry, which is a part of various assemblies.
- Manufacturing the cells and PCB board in the lithium battery.

These two components account for 61% of the total carbon emissions during the lifetime of the Hybrid System.

The recycling processes for the components that are recycled at the end of their lives have been incorporated in the disposal phase, resulting in lower carbon emissions during this phase. The transport process comprises of the carbon emissions from transporting the assemblies/components to the hybrid system manufacturing site. Components that were manufactured on-site therefore mitted no carbon dioxide during transportation.

6.PE International, Life cycle CO_2e Assessment of Low Carbon Cars Final Report, published 2013.
* All figures are rounded to 1d.p

Life cycle assessment

LCA - Ashwoods and Ford Transit van comparison

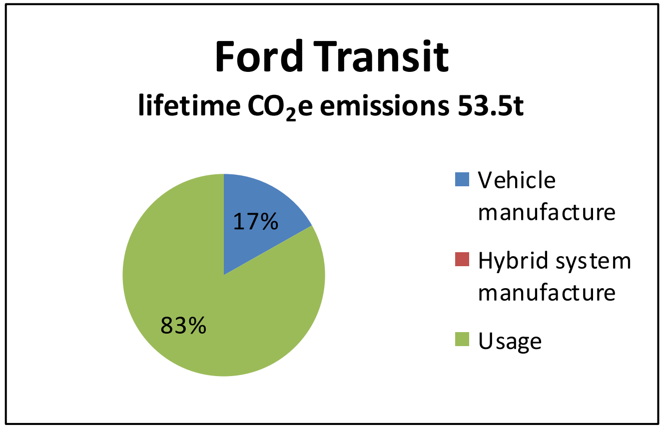
In order to understand the lifetime carbon emissions of the hybrid system, the entire lifetime emissions of the Ashwoods van was compared to that of a Ford Transit. The following two assumptions were made when carrying out the comparison:

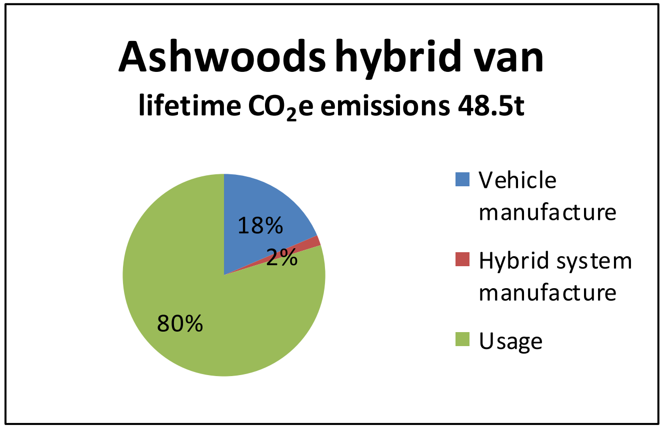
- The lifetime carbon emissions of producing and disposing the Ashwoods van (excluding the hybrid system) was equivalent to that of producing a Ford Transit van, i.e. 9,000kg[7]
- Both vans will carry out 200,000km over the lifetime of the vehicle.

The University of Bath conducted emissions tests (NEDC) on the 2nd generation Ashwoods van and a Ford Transit[8]. Using the results of tests and the assumed lifetime mileage, the total usage emissions were calculated. The following table shows the lifetime carbon emissions of the Ashwoods and Ford Transit vans.

	Lifetime CO_2e Emissions (Tonnes)			
	Vehicle	Hybrid System	Usage	Total
Ashwoods Van	9.0	0.8	38.7	**48.5**
Ford Transit	9.0	0.0	44.5	**53.5**

The total lifetime carbon emissions of the Ashwoods van were 9% lower compared to a Ford Transit. However, as the lifetime emissions of the hybrid system only constitutes *ca.* 2% of the total lifetime emissions of the Ashwoods van, the fuel savings from the system have a significant effect in reducing the total lifetime carbon emissions. The following charts show the lifetime carbon emissions of Ashwoods vehicle and the Ford Transit.





7. The Life Time Carbon Emissions of the Ford Transit was taken from the Life Cycle Assessment of Vehicle Fuels and Technologies Final Report published by Clear Zones in 2006.

8. Emission tests carried out at the University of Bath, Department of Mechanical Engineering

Qualitative analysis: Driver responses to electric vans

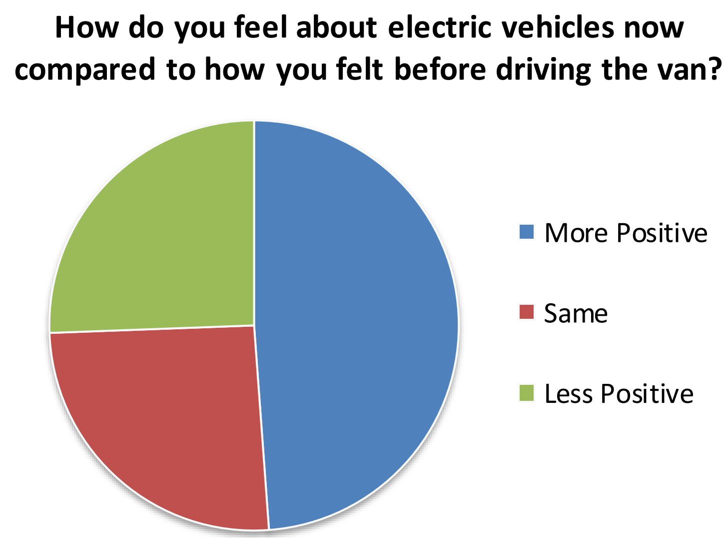
44 drivers of electric vans returned questionnaires.

Around 50% of drivers felt more positive about the electric vans after the trial than they had before, compared with 25% feeling less positive.

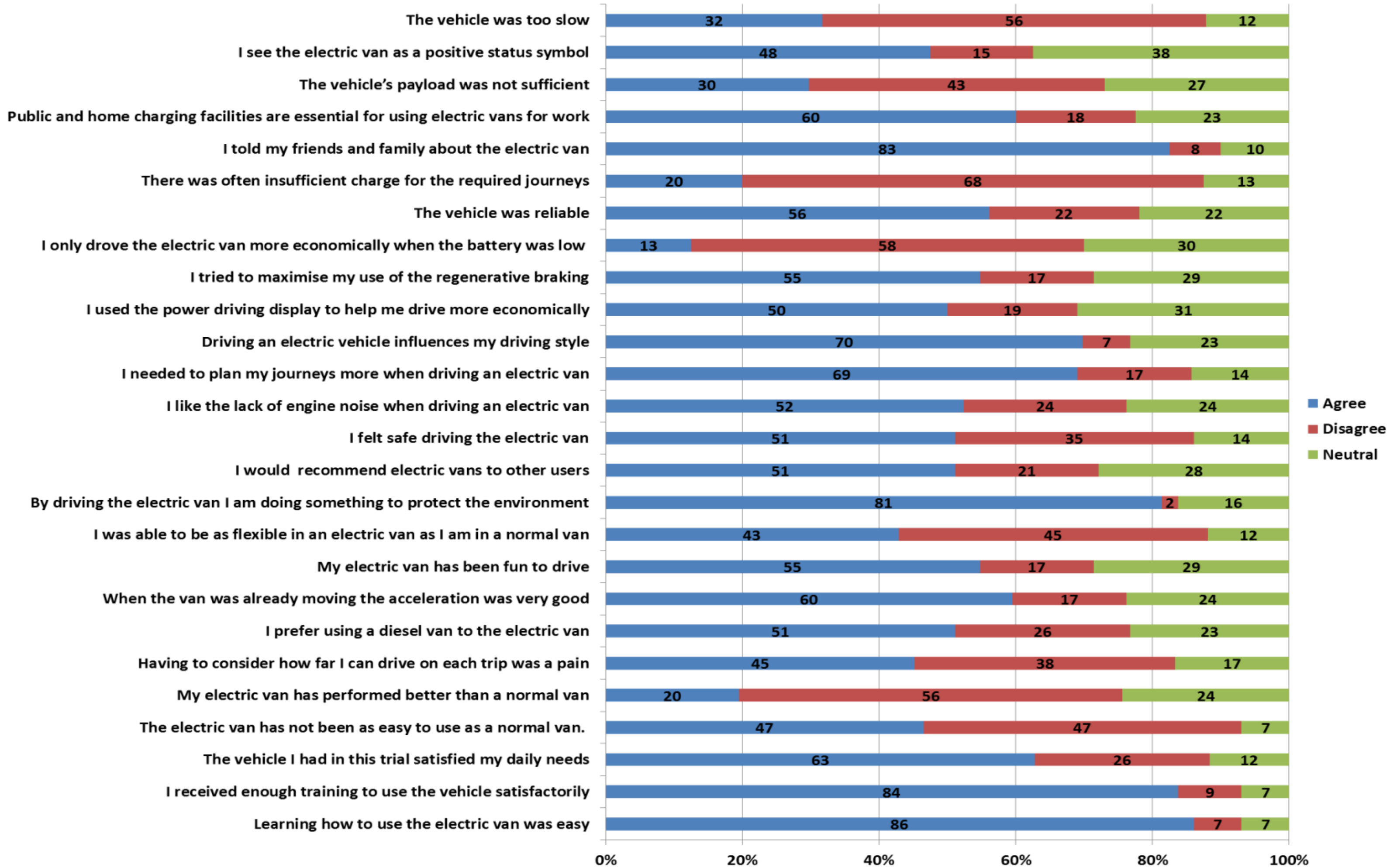
EVs elicited stronger opinions and more noteworthy results than the hybrids, reflecting the relative novelty of the technology.

Full range of responses are shown overleaf reveals a more varied picture. Drivers believe the vehicles have environmental benefits; many saw it as a positive status symbol; and 81% told their family and friends about it. Over half found the vehicles fun to drive, and 51% would recommend them compared to just 21% who wouldn’t.

Only 20% felt the vehicle performed better than a ‘normal’ van, and only 26% preferred it to a diesel. The reasons for this are not clear cut – 30% found the payload insufficient, 20% found they often had insufficient charge for their journeys and 45% found it inconvenient to have to consider how far they could drive on each trip.



Qualitative analysis: Driver responses to electric vans (continued)



50% of electric van drivers would recommend them to others, but only 26% preferred the electric van to a diesel. Amongst the reasons cited were insufficient payload (30%), finding insufficient charge for their journeys (20%) and the inconvenience of considering how far they could drive on each trip (45%).

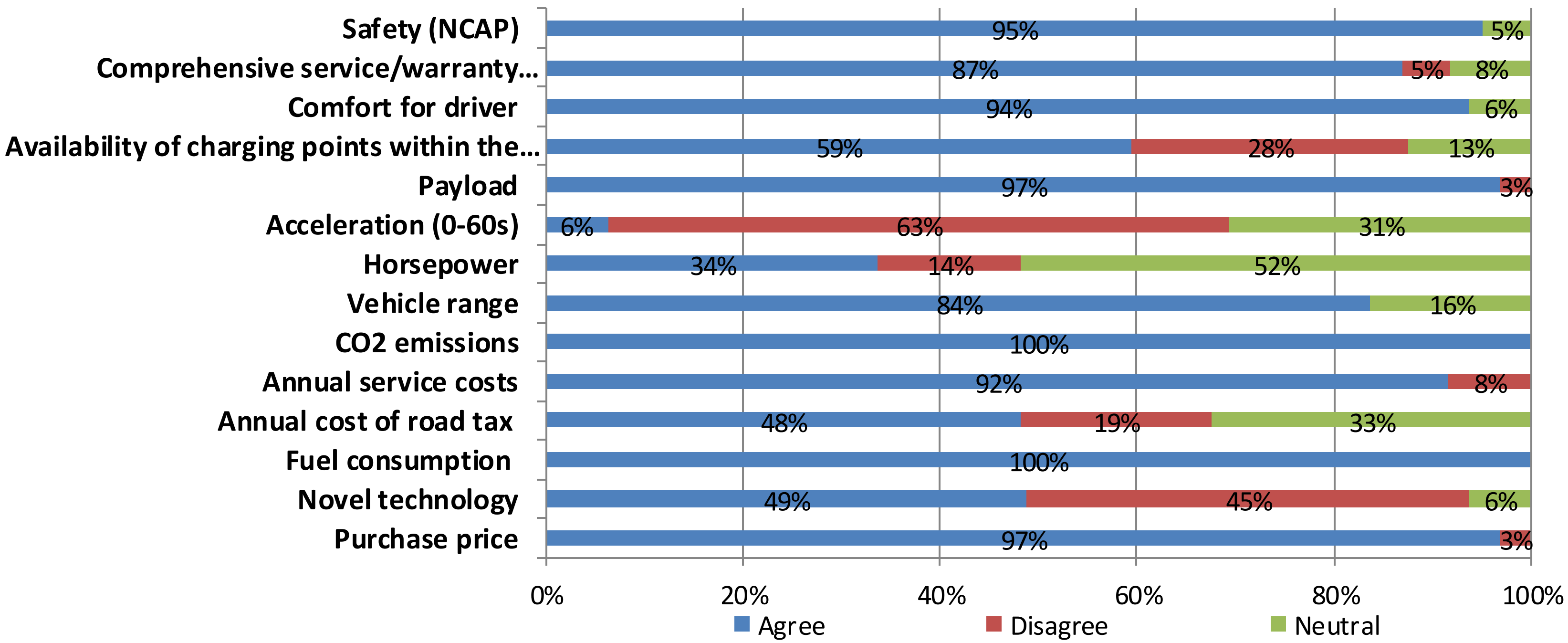
Qualitative analysis: Fleet manager responses to electric vans

Fleet managers' view of the electric vans were similar to those of the drivers, with around 50% feeling more positive about the vehicles after the trial than before, with only a quarter feeling less positive.

More detailed responses to the question of the importance of various factors in purchasing a van are presented below. Environmental considerations are clearly significant to fleet managers taking part in LCVPPP, with 100% citing CO_2 emissions as a significant factor.

Factors related to vehicle performance (acceleration, etc.) were rated as much less important.

Purchase price and running costs are clearly very important considerations for this group.

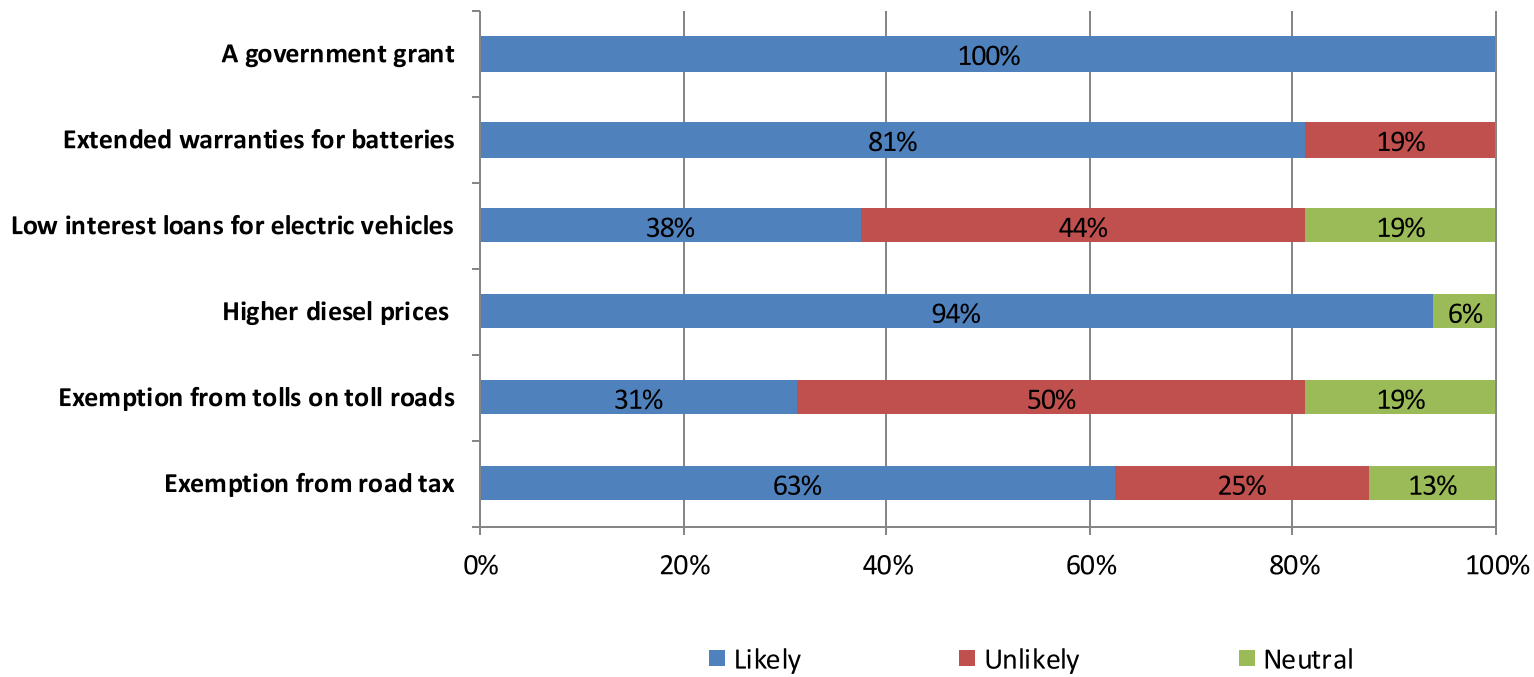


Qualitative analysis: Fleet manager responses to electric vans (continued)

Fleet managers were asked to indicate whether a range of incentives were likely to influence their decision to buy a van.

As discussed previously, running costs (diesel price) are a key consideration, while road tax is less important.

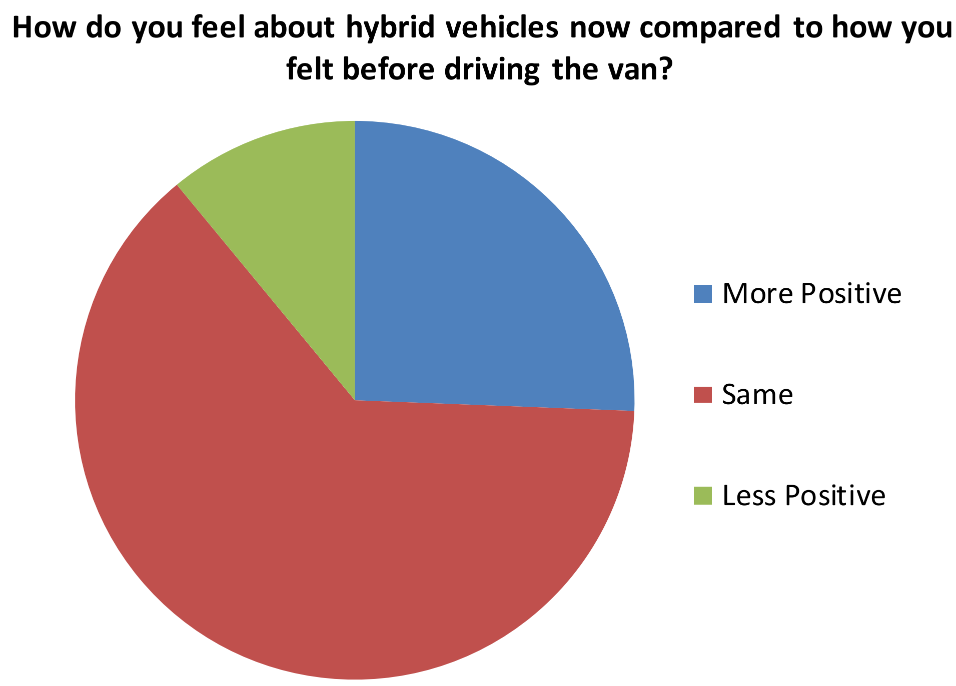
The survey group showed an overwhelming preference for government grants over low interest loans, which warrants further investigation to understand whether it is down to the way that local government finance operates, or a lack of information to support longer term cost benefit calculations, or both.



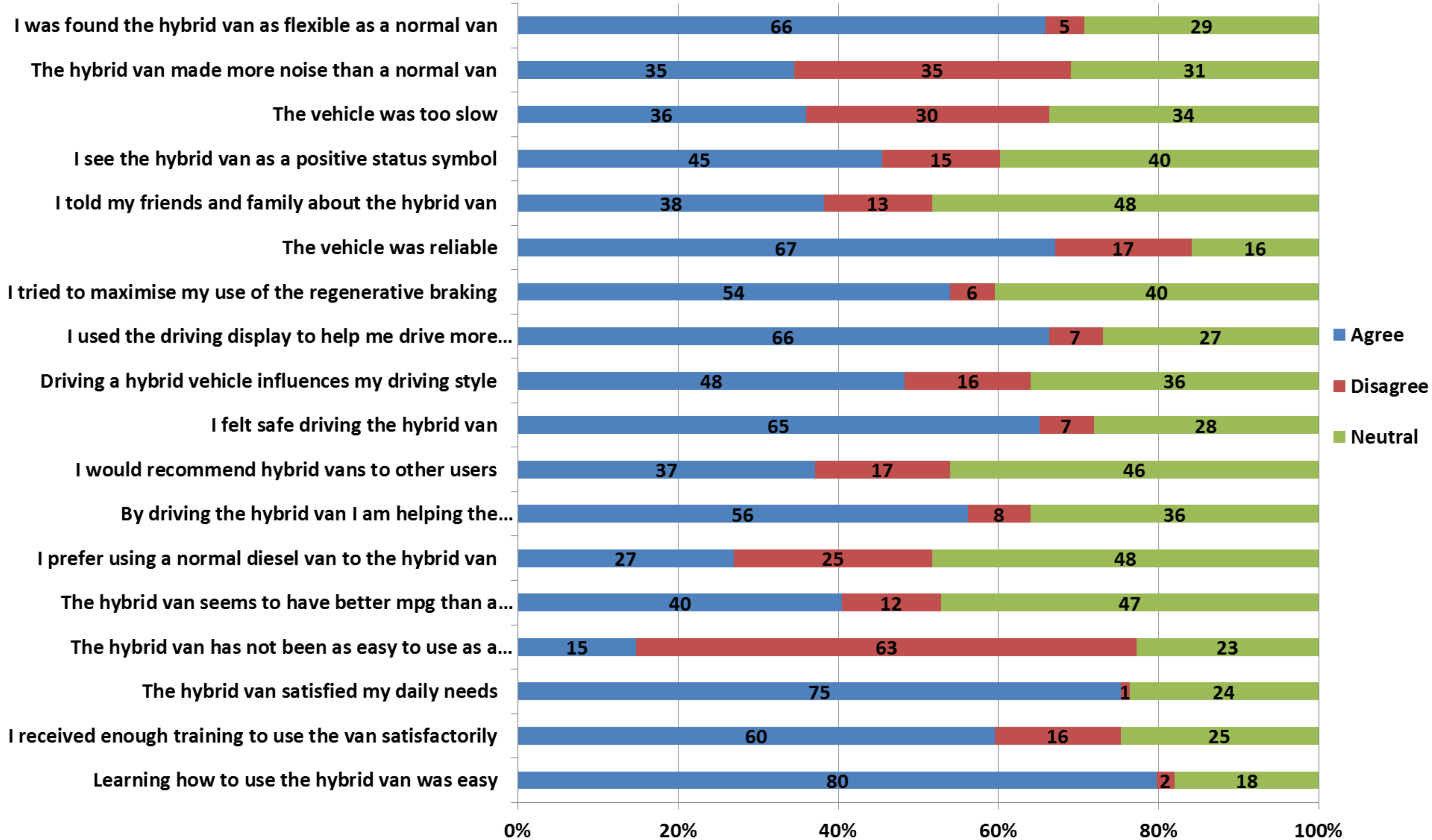
Qualitative analysis: Driver responses to hybrid vans

76 drivers of hybrid vans returned questionnaires.

The responses suggest that they generally found the vehicles to be very similar to a diesel van. 63% of drivers showed no change in their opinion of the vehicles after the trial.



Qualitative analysis: Driver responses to hybrid vans continued

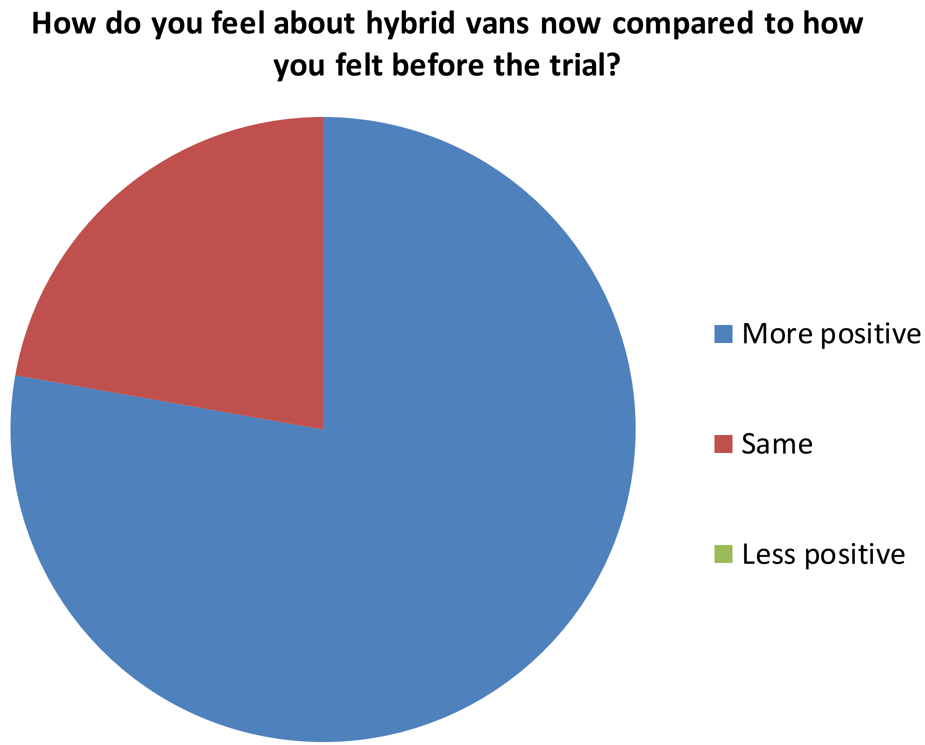


The majority of drivers returning surveys felt they were able to do their job as flexibly in the hybrid van as in a conventional van.

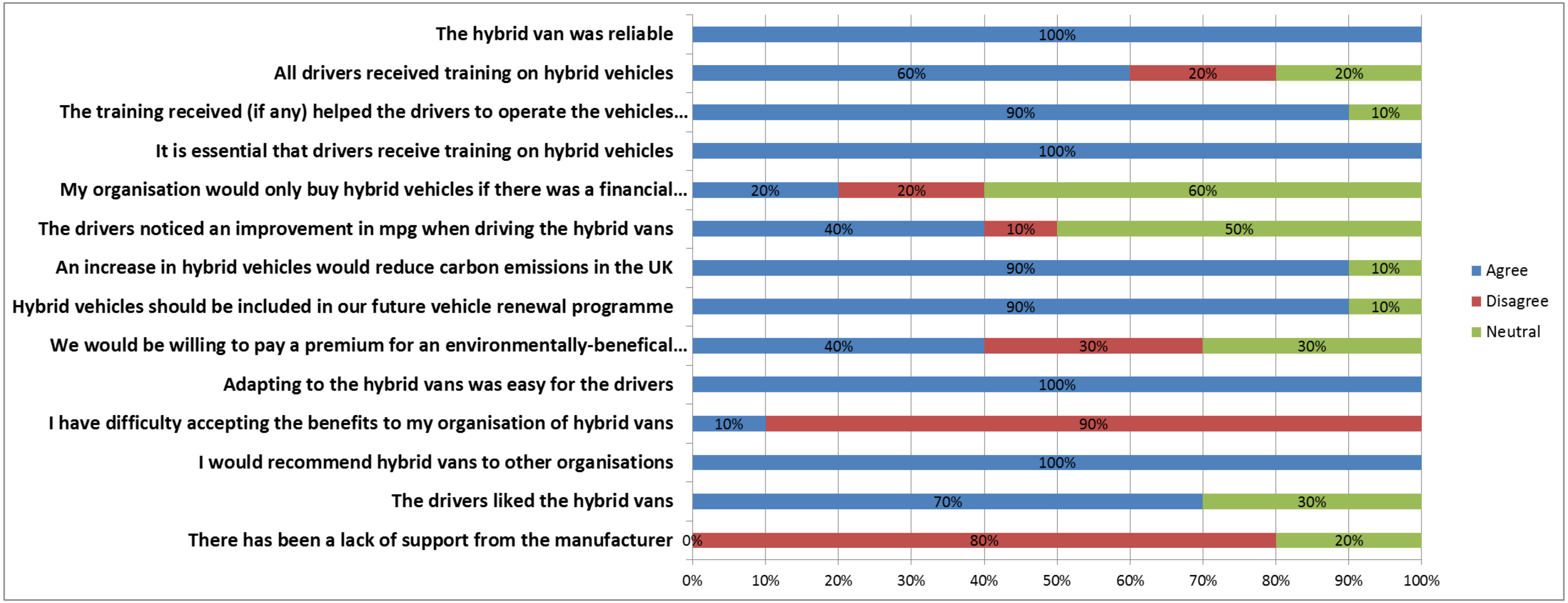
However, hybrids elicited less strong responses than the electric vehicles. 56% of drivers felt the hybrid had environmental benefits, compared to 81% of electric van drivers.

Qualitative analysis: Fleet manager responses to hybrid vans

In contrast to the drivers who were broadly neutral about the vehicles, the vast majority (78%) of fleet managers felt more positively about hybrids after the trial.



Qualitative analysis: Fleet manager responses to hybrid vans continued



Fleet managers viewed the vans positively, and also perceived that their drivers had a good impression of the vehicles. The vast majority of respondents indicated that vans should be included in their organisation's vehicle renewal programme.

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