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UK electric vehicle case studies - fleet integration

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Abstract

Cenex, the UK's first Centre of Excellence for Low Carbon and Fuel Cell technologies, has undertaken a trial integrating modern electric vehicles (EVs) into high profile UK fleets. The studies were funded by the UK Government's Department for Business, Innovation and Skills (BIS) and focused on five organisations - Indesit (a household appliance manufacturer), Stagecoach (a bus operator), Commonwheels (a national car club), Groundwork (a national UK regeneration charity) and Asda Walmart (a supermarket). The trial aimed to establish and disseminate user and fleet managers' attitudes towards, and experiences with the EVs together with the technical, economic and emission performance of the vehicles. Through the case studies, Cenex demonstrated the operational factors which contributed to increased EV utilisation and user acceptance as well as examining factors where EVs were not used to their full potential within the fleets. The carbon and economic analysis used modelling software to compare the emissions and fuel use of a diesel vehicle operating over the logged duty cycle of the case study EVs. The comparator energy consumption data was supplemented with a detailed total cost of ownership model that modified annual mileage and fuel prices to determine scenarios where EVs ownership cost was comparable or superior to a best-in-class diesel vehicle. The analysis examined questionnaire returns from EV users and fleet managers. These allowed the users' acceptable range performance, premium cost and perceptions of the EVs to be quantified as well as exploring the users' knowledge and opinions on EV post trial experience. Hence this Smart Move Case Studies paper is a concise, thorough and invaluable evaluation of EV performance and integration aspects.

Keywords: BEV (battery electric vehicle), business models, emission, passenger car, range

1 Introduction

Cenex, the UK's first Centre of Excellence for Low Carbon and Fuel Cell technologies, has undertaken a trial integrating modern electric vehicles (EVs) into high profile UK fleets. The studies were funded by the UK Government's Department for Business, Innovation and Skills (BIS) and focused on five organisations - Indesit (a household appliance manufacturer), Stagecoach (a bus operator), Commonwheels (a national car club), Groundwork (a national UK regeneration charity) and Asda Walmart (a supermarket). The case studies examined in this paper form part of the Cenex Smart Move trial. The Cenex Smart Move trial was a suite of studies which tracked the performance of EVs through laboratory testing, track testing, and real-world usage. The Smart Move studies were conducted between September 2009 and April 2011. Data was collected and analysed throughout the trial in partnership with several UK public and private sector fleets, universities, regional development agencies and EV product suppliers. The approach adopted by Cenex during the Smart Move trial followed technology from the laboratory to the test track through to real-world fleet deployment. This has yielded a comprehensive and unique evidence base for low carbon vehicle performance. A summary of all the Smart Move work streams is presented on the Cenex website www.cenex.co.uk/projects/electric-vehicle-trials/smart-move together with links to further information and reports.

2 Case study vehicles and data capture techniques

The vehicles deployed in the case studies were the smart ed (electric drive) and the Mitsubishi i-MiEV (Mitsubishi Innovative Electric Vehicle). The specifications of both EVs are summarised below in Table 1. The i-MiEV deployed by Cenex is an early Japanese specification model which has since been superseded in the UK by the 2011 European specification model. The 2011 specification i-MiEV which is now commercially available achieves a 150 km range over the EU NEDC regulated range test cycle compared to the 129 km range for the 2010 model described in Table 1 below. Similar performance characteristics may be attributed to the Peugeot iOn and Citroen C-Zero EVs because they are derivatives of the 2011 European specification Mitsubishi i-MiEV.

smart ed	
• Motor:	30 kW DC brushless
• Range:	135 km (NEDC)
• Battery:	16.5 kWh Lithium-ion
• Top speed:	62 mph (limited)
• Seating capacity:	2
• Weight:	965 kg

Mitsubishi i-MiEV	
• Motor:	47 kW AC permanent magnet
• Range:	129 km (NEDC)
• Battery:	16 kWh Lithium-ion
• Top speed:	81 mph (limited)
• Seating capacity:	4
• Weight:	1110 kg

Table 1: Smart Move case studies vehicle specifications

The EVs were fitted with an on-board monitoring system that incorporated a GPS locator and a connection to the EV control area network (CAN) bus. This allowed both journey and charging patterns to be monitored and more detailed technical data to be obtained including energy consumption, battery SoC, ambient temperature and vehicle speed. These data were recorded at a frequency of 1 Hz and the full data set was remotely transferred from the vehicle to a FTP server on a half hourly basis via a GSM link.

3 The case studies

During the Smart Move case studies the EVs were integrated into five private sector fleets, each with a unique application and usage pattern for an EV. The participating organisations and a summary of their usage pattern and the key findings from the case study are detailed below.

Asda (Wal-Mart) used a smart ed to perform pool car functions from its UK head office in Leeds. The electric vehicles undertook mainly visits to local stores and supplier facilities. The vehicle had a dedicated parking bay and recharging post. Asda employees gave positive feedback with staff eager to make EVs a permanent addition to the company despite users reporting some difficulty getting used to the new technology due to insufficient vehicle and charging post training.

Indesit, an electrical appliance manufacture, issued a smart ed to its security team. The vehicle was used for patrols of the Indesit manufacturing and distribution facility in Peterborough on a 24/7 basis. The vehicle was charged from an indoor socket across site from the security team's base. The smart ed was embraced by the Indesit security team who would only charge the EV once it reached 10 – 30% SoC, which occurred every 5 to 7 days.

Groundworks is a national environmental regeneration charity. It used a smart ed to perform general pool car functions including local education visits to schools and to attend meetings. The Groundwork maximum daily mileage was 17.7 km which represented just 17.2% of the average available range of the smart ed.

Stagecoach, a UK national bus operator used a Mitsubishi i_MiEV as a operations support vehicle, where its primary function was to transfer bus drivers and ticket inspectors between the bus depot and various route locations. 26% of Stagecoach daily duties achieved a state of charge (SoC) use of over 100% through additional daytime charging with the highest SoC used in a single day being 160%, this demonstrated the effectiveness of implementing an ‘opportunity charging’ policy.

Commonwheels is a UK national car club operator that integrated a Mitsubishi i_MiEV into an existing car club site. The vehicle was hired by club members for general travel purposes and had a dedicated parking bay and charging post. The i-MiEV deployed to Commonwheels car club offered the potential to support 86% of journeys from its location. This suggested that an EV is a suitable addition for sites with multiple vehicles.

4 Case study journey statistics

The case study organisations collectively completed over 1,000 individual journeys covering a distance of over 4,900 km. The average journey length was 4.9 km due mainly to the low speed and low journey length characteristics of the off-highway Indesit security duty. When looking at just on-highway applications, which are generally more representative of fleet vehicle use, the average journey length rose to 9.8 km; this compares to an average UK trip length of 11.3 km[1]. Table 2 below shows journey statistics for each case study. The journey statistics summarised by day throughout this report only consider days when the EV was used.

Case study company	Number of journeys per day	Average Journey length (km)	Average Speed (kph)	Daily distance travelled (km)	Total distance travelled (km)
Asda	3.3	9.3	36.5	30.7	866
Indesit	13	1.4	11.8	18.2	1,012
Groundwork	2.1	7.5	26.9	15.8	173
Stagecoach	8.4	4.7	21.4	39.5	1,484
Commonwheels	3.5	12.8	39.4	44.8	1,374

Table 2: Case study journey statistics

The high frequency, low mileage and low speed journeys of Indesit and Stagecoach are evident from the table above which also shows that the average speed of an Indesit security patrol journey was just 1.4 kph.

5 Emissions

To allow EV emissions in the case studies to be fairly compared to the emissions from a conventional vehicle a same class comparator vehicle must be driven under identical conditions. The EVs replaced vehicles of different classes and fuels, and due to range restrictions, they generally undertook different duties than the organisations’ conventional vehicles. This meant that directly comparable fuel consumption information was not available.

5.1 Smart ed comparator emissions modelling

The Cenex Fleet Carbon Reduction Tool (FCRT) was used to simulate the fuel consumption of a best-in-class diesel comparator vehicle. The FCRT is a sophisticated software package which simulates the performance of different vehicle technologies, fuels and drive trains over user defined drive cycles. The vehicle models in this simulation were calibrated using the fuel consumption results from regulated and real-world drive cycles measured in a vehicle testing laboratory. The comparator vehicle is the smart Cdi which has a declared emission figure of just 86 gCO_2/km. Modelling the performance of the smart Cdi allows the energy consumption and emissions of a smart ed and a smart diesel vehicle to be compared over a drive cycle representative of each organisations’ driving duty. The vehicle speed and time data from each case study was input to the FCRTs drive cycle creation module to produce a drive cycle statistically representative of the real-world data. Figure 1 below shows an example of the Asda drive cycle.

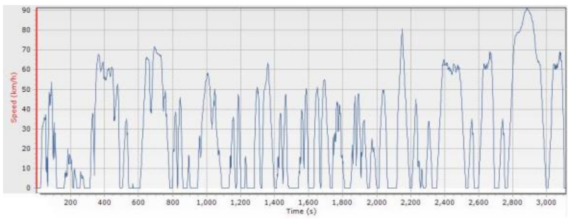

Figure 1: ASDA drive cycle developed by the FCRT

Table 3 below shows the drive cycle statistics generated by the modelling exercise for each case study. The variation is a measure of the speed variation over the drive cycle. It should be noted that although the drive cycle data from Stagecoach and Commonwheels was gathered from i-MiEV driving data, the simulation was run using a smart ed and smart Cdi.

Case study company	Mean speed (kph)	Max speed (kph)	Variation	Road classification duration (%)		
				Town	Motor-way	Road
Asda	28.3	91.3	22.4	58.3	16.8	24.9
Indesit	10.0	64.3	20.8	94.0	0	6.0
Groundwork	19.3	85.8	22.0	81.9	4.4	13.7
Stagecoach	19.1	67.6	32.0	88.5	0	11.5
Commonwheels	33.2	127.1	15.9	48.4	22.3	29.3

Table 3: Case study drive cycle statistics

5.2 Emission savings

Well-to-wheel (WTW) methodology was used to accurately compare the emissions performance of conventional and alternatively fuelled vehicles. This takes into account both the well-to-tank (WTT) and tank-to-wheel (TTW) emissions of transport fuels. WTT emissions are derived from the energy required to extract, process, deliver and dispense the fuel whereas the TTW emissions are those emitted directly from the vehicle. As EVs have no tailpipe emissions their emissions are due to the generation and distribution of electricity (predominantly gas, coal and nuclear in the UK). Figure 2 below shows that the smart ed reduced the WTW CO_2 emissions by between 5.4% and 15.1% relative to the diesel comparator over the modelled drive cycles. The Stagecoach and Indesit drive cycles provided the largest potential for CO_2 reduction. This is due to both vehicles being operated in low speed stop-start environments where the diesel engine operates at low efficiency.

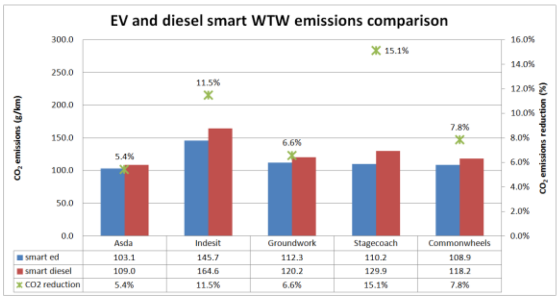

Figure 2: EV and comparator vehicle emissions

The modelling above demonstrates the variation and magnitude of CO_2 emissions over real-world drive cycles. The smart Cdi achieves an emissions figure of just 86 gCO_2/km over the regulated drive cycle, whereas the real-world driving cycles show emission variations from 109 to 164 gCO2/km representing an increase of between 26.7% and 90.7%.

5.2.1 National grid intensity

Emissions associated with EVs here are directly related to the carbon intensity of the UK national grid; the most recent (2009) emissions figure for the UK grid is 594 gCO_2/kWh[2]. Importantly, the emissions from EVs will reduce as renewable and low carbon energy generation sources are installed in the UK. As the UK works towards its 2050 target of an 80% CO_2 reduction, the light duty vehicle market will increasingly be able to exploit the potential of electricity as a low carbon fuel. Table 4 below looks at countries that already have lower carbon electricity grids[3]. The fuels used to generate electricity in these countries are predominantly nuclear and renewables. The table compares the relative emissions of each EV case study based on the energy consumption modelled by the Cenex FCRT.

Case study company	Drive cycle emissions by different electricity grid emission factors (gCO_2/km)			
	Denmark (375 gCO_2/kWh)	Spain (343 gCO_2/kWh)	France (72 gCO_2/kWh)	Sweden (23 gCO_2/kWh)
Asda	65.1	59.5	12.3	4.0
Indesit	92.0	84.1	17.4	5.6
Groundwork	70.9	64.8	13.4	4.3
Stagecoach	69.6	63.7	13.2	4.3
Commonwheels	68.8	62.9	13.0	4.2

Table 4: Case study emissions factored by other countries' electricity grid carbon intensity

6 Economics

This section provides a cost of ownership analysis for operating the smart ed and diesel comparator vehicle over each organisations' drive cycle for ownership periods of 3, 5 and 7 years.

6.1 Model inputs

The following items were included in the cost of ownership modelling.

6.1.1 Energy consumption and costs

The energy used by the vehicles per km was calculated by the FCRT model based on simulating the fuel consumption of the vehicles over each organisations bespoke drive cycle. The energy costs were modelled using both current UK energy prices and extrapolated fuel prices from historical UK energy price trends[4]. The energy cost input to the model is given below.

6.1.2 Electricity tariff and charging patterns

Commonly, users paid a two rate tariff with a low cost night rate typically running from midnight to 7 am and a higher rate for electricity used at all other times. Interestingly, when averaged over the five organisations the EVs spent only 11.6% of their charging time on cheap night rate electricity tariffs and 88.4% charging at other times. The charging distribution graph is shown in Figure 3 below. Smart charging units were not used by the Smart Move case study companies.

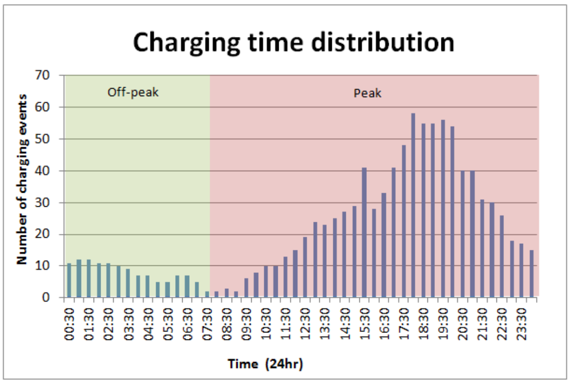

Figure 3: Charge time frequency for case study companies

The economic analysis in this paper includes both 90% peak and 90% off-peak charging scenarios to analyse the effect of charging time management on EV economics. The energy cost used in the analysis is detailed below. Note: ppl is UK pence per litre and p/kWh is UK pence per kWh.

- Fixed energy cost model (current energy costs**)**
  - 111.4 ppl diesel
  - 9.4 p/kWh peak electricity
  - 5.7 p/kWh off-peak electricity

- Linear rising energy cost scenarios
  - 111.4 rising to 200.4 ppl diesel in year 7
  - 9.4 rising to 15.1 p/kWh peak in year 7
  - 5.7 rising to 11.4 p/kWh off-peak in year 7

6.1.3 Maintenance cost

Scheduled maintenance costs were supplied by Mercedes for both the diesel and smart ed. Unscheduled maintenance was excluded for both vehicle types. It is likely that the unscheduled maintenance cost for a diesel smart is higher due to the increased number of wear components in a diesel combustion and exhaust system when compared with an electric power train. It is also likely that EV braking components undergo less wear due to the regenerative systems.

6.1.4 Vehicle purchase cost and depreciation

Annualised ownership costs in the analysis included the vehicle purchase cost minus the residual value (RV) factored over the analysis period. Purchase costs were set to £8,392 for the diesel smart and £15,833 for the EV. The smart ed was not commercially available and Mercedes had not announced a price for the vehicle. Therefore this purchase price is based on the insurance value of the vehicle minus the UK Government's £5,000 Plug-in Car Grant.

Depreciation for the smart ed and diesel comparator vehicle was modelled at 40%, 32% and 22% of the vehicles' original value in years 3, 5 and 7 respectively. These figures broadly agreed with publically available residual values (RV) for electric and hybrid vehicles and the smart diesel. The RV of the smart vehicles was modified to take into account the annual mileage of the modelled scenario.

6.1.5 Annual mileage

To understand and demonstrate the effect of annual milage the model considered three scenarios as described below.

Base mileage case - the average daily mileage of each case study
Increased mileage case - the average daily mileage of each case study increased by 50%
Stretched mileage case - the average daily mileage of each case study increased to 62 km, representative of 12,000 miles per annum (MPA), which represents just 46% of the manufacturer's declared range capability

Both vehicles qualify for a £0 rate UK road tax. No soft incentives, such as exemption from parking charges and road pricing fees, were included in the analysis and no allowance was included for the installation and maintenance of recharging infrastructure.

6.2 Model outputs

Table 5 below shows the differential between the diesel and EV annual ownership costs for each of the case studies based on an ownership length of 3, 5 and 7 years. This incorporates the energy price, mileage utilisation and charge time scenarios discussed above. For ease of viewing the ownership costs have been colour coded as shown below.

	Red – More expensive to own an EV
	Amber – Marginally more expensive
	Green – Marginally cheaper
	Dark Green – Cheaper to own an EV

		Annual ownership cost differential (£) at current energy prices						Annual ownership cost differential (£) with linear rising energy prices					
		90% peak			90% off-peak			90% peak			90% off-peak		
	Case Study	Yr 3	Yr 5	Yr 7	Yr 3	Yr 5	Yr 7	Yr 3	Yr 5	Yr 7	Yr 3	Yr 5	Yr 7
Base mileage	Groundwork	705	585	563	677	557	535	668	523	477	641	496	449
	Asda	619	482	452	570	433	403	537	345	261	488	296	211
	Indesit	599	479	457	558	438	416	523	353	280	482	311	239
	Commonwheels	528	371	332	452	295	256	396	152	25	320	76	-51
	Stagecoach	483	346	316	416	278	249	351	126	7	283	58	-60
Increased mileage	Groundwork	693	555	525	651	514	484	637	463	397	596	422	355
	Asda	552	395	357	478	322	283	429	191	70	355	117	-4
	Indesit	534	397	367	472	335	305	420	207	101	358	145	39
	Commonwheels	359	203	164	245	89	50	162	-127	-297	48	-241	-411
	Stagecoach	349	192	153	247	90	52	150	-139	-310	48	-241	-412
Stretched mileage	Groundwork	512	355	316	403	247	208	367	504	-21	259	396	-129
	Asda	444	287	248	344	188	149	278	11	-138	179	-88	-238
	Indesit	198	42	3	58	-99	-138	-60	-389	-601	-201	-530	-741
	Commonwheels	398	242	203	293	137	98	216	-62	-223	111	-167	-328
	Stagecoach	325	168	129	218	62	23	117	-178	-356	10	-285	-462

Increased annual mileage

Rising energy prices and utilisation of off-peak tariffs

Table 5: Annualised cost of ownership under various mileage and energy price scenarios

Modelling current energy prices and trial daily mileages showed that the average cost saving for utilising mainly off-peak electricity was £81 per annum. The average annual ownership cost reduced from a premium of £462 to £202 per vehicle when the daily mileage was stretched to 62 km (representing 12,000 MPA).

Incorporation of linear rising energy costs into the scenario lead to a marginal and in some cases significant ownership cost reduction when using EVs, especially when amalgamating high annual mileage with off-peak electricity prices.

The cost reductions were greatest from Indesit and Stagecoach where the EVs were operating in lower speed stop-start environments (conditions where diesel vehicles are least efficient). However, in such duty cycles it is challenging to increase the daily mileage sufficiently to permit a beneficial economic scenario. Further to this, the case studies showed that users were able to increase EV utilisation through daytime opportunity charging; clearly this was to the detriment of their ability to use a high proportion of low rate off-peak electricity at night.

Additionally, the annual EV ownership cost premium rose, on average, from £224 to £1163 per annum when the PiCG incentive was removed from the economic scenarios.

The economic analysis showed that whilst the right operational conditions must exist for marginal or cost beneficial operation, the increase in annual cost appears to be at a sufficiently low level to be considered by companies wishing to reduce carbon, air quality and noise emissions.

6.2.1 Breakdown of ownership costs

Figure 4 below shows the contribution of vehicle fuel cost, scheduled maintenance and capital cost toward the total cost of ownership for 3 year and 5 year periods over the Commonwheels drive cycle. The figure demonstrates that significant savings are available from current fuel cost differentials, but these are insufficient to amortise the additional capital cost of the EV. However, when looking at a linear rise in fuel prices, a lower annual EV ownership cost is observed during a five year ownership period.

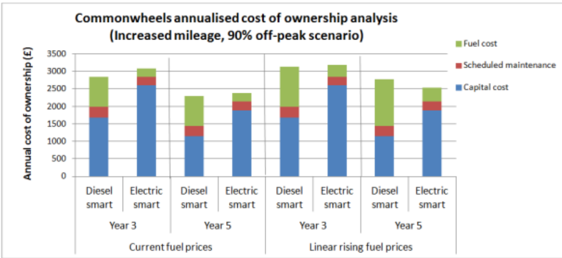

Figure 4: Annualised total cost of ownership analysis

7 User perceptions - buying and driving EVs

Perceptions and attitudes towards EVs were assessed by issuing questionnaires to users of the vehicles. Although the vehicles were deployed to fleets, the individual vehicle users were responding to these questions in their capacity as private consumers. 147 complete questionnaire returns were received from EV users.

7.1 Purchasing assessment

EV users were presented with a series of considerations and asked to quantify what aspects would be important in influencing them to purchase an EV. The questions also sought to find out the price premium and range the users would be willing to accept and to identify barriers and opportunities to EV purchase.

7.1.1 Purchasing considerations

Vehicle users were asked to rate how important they considered certain factors to be when purchasing an EV. The average ratings are shown below in Figure 5. The scale denotes the user's perception of importance for each item from Not important (1), A consideration (2), Important (3) to Very important (4). No technical or economic data was presented to users in advance of completing the questionnaire.

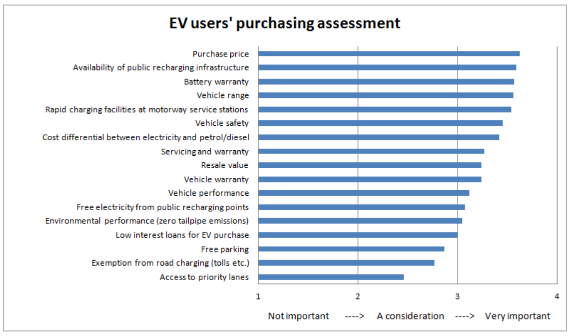

Figure 5: EV users' purchasing assessment

EV hardware related items such as purchase price, recharging infrastructure and battery warranty were rated as the most important purchasing considerations. This supports the UK Government main EV incentive schemes (the PiCG and PiP) which offer fiscal support for EV and infrastructure purchasing respectively, and these schemes include minimum safety and warranty standards a vehicle must meet before being eligible for grant support. Usage related incentives such as free parking, access to priority lanes and exemption from road charging were rated as least important. Generally users who undertook longer journeys rated the importance of rapid charging facilities higher than those who performed shorter journeys, and users who undertook a high number of journeys also rated charging infrastructure as more important than those who had only undertaken a few journeys. This supports research carried out by the Tokyo Electric Power Company (TEPCO) which has shown that regular EV users expand their journey boundaries given appropriate recharging facilities[5].

7.1.2 EV purchase premium cost

Users were asked what cost premium they would pay for an EV and were allowed to select one of the following answers: None, 0-5%, 5-10%, 10-20%, 20-50%, 50-100%. Figure 6 below shows the split of the premiums users were willing to pay for an EV along with the current price premium a user is expected to pay for a Nissan Leaf and a Mitsubishi i-MiEV in April 2011. The conventionally fuelled comparator vehicles for the Nissan Leaf and Mitsubishi i-MiEV pricing assessment were the Peugeot 1.6 HDI and Ford Fiesta 1.4 TDCi respectively.

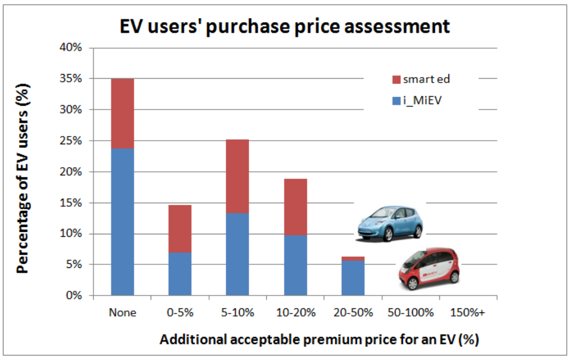

Figure 6: EV users' purchase price assessment

The graph above shows that although 65% of users were willing to pay a premium for EVs, they were not willing to pay more than 50%, with only 6.3% willing to pay a premium of 20 – 50%. Analysis of the data set by gender showed 75% of females were willing to pay a premium compared to 60% of males. There was no clear trend when the data were analysed by age or EV experience. Users were not asked if they would only pay less for an EV in this survey.

Here we can conclude that although there is a willing early adopter market for today's EVs, a significant price reduction is required before EVs can penetrate the mainstream passenger car market.

7.2 Range acceptance

Users were asked what minimum range they would require from an EV before they would consider a purchase. Figure 7 below shows the distribution of the users range requirements. This is overlaid with the real-world case study range distributions that are discussed further in section 9.

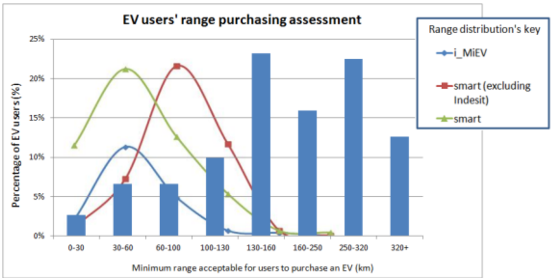

Figure 7: EV users' range purchasing assessment

The chart above shows that 26% of EV users were willing to accept a range of below 130 km when making a purchase. This meets the manufacturers' declared range performance of the case study EVs. However, it was found that the average real-world range (<100 km) experienced during this trial would only be suitable for 16% of users. This finding suggests that a considerable improvement in range performance is required before mass acceptance of EVs is possible. In fact, 74% of users required a range of between 130 to 320+ km before they would consider purchasing an EV.

Users who rated rapid charging as an important purchasing consideration also stated that they would require a high range from an EV. This indicates that rapid charging availability is a factor that influences consumer choice as well as alleviating range anxiety.

7.3 Driving assessment

Users were asked to rate the performance of the EVs compared to that of similarly sized conventional vehicles. The users rated each performance aspect from 1 to 5 which denoted Much worse (1), Worse (2), About the same (3), Better (4), Much better (5). The performance aspects rated were Noise, Range, Driver display, Eco friendliness, Top speed, Acceleration, Braking performance, Comfort and Driver display. Figure 8 below shows the users' ratings of the smart ed and i-MiEV vehicles.

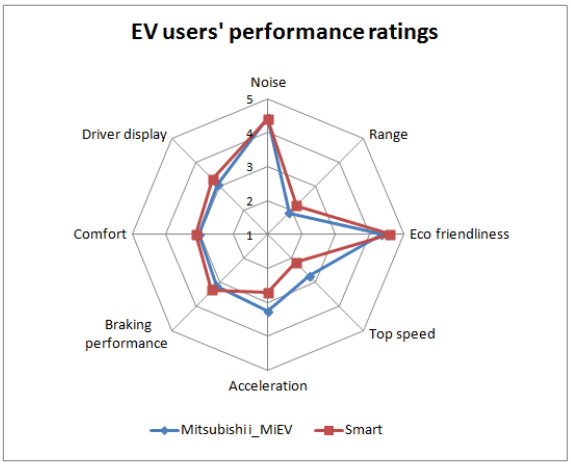

Figure 8: EV users' ratings for the performance of the smart ed and i-MiEV vehicles

On the majority of performance aspects users agreed that the EVs were comparable to their fossil fuelled counterparts. Clearly, range scored lowest, with the i-MiEV scoring slightly worse than the smart. The top speed of the i-MiEV (81 mph) was perceived as comparable to a conventionally fuelled vehicle. This demonstrated that 81 mph is an acceptable maximum speed for a small EV in the primarily urban duty roles seen in this trial.

7.4 Integration perception

The integration questionnaire was designed to identify procedural and technology management aspects that could present barriers to the successful integration of the EVs into the company fleets. Users were asked if they agreed with a number of integration evaluation statements with predefined answers ranging from Strongly disagree (1), Disagree (2), Neutral (3), Agree (4), to Strongly agree (5).

This questionnaire section provided two similar statements from both a positive and negative perspective. The purpose of which was to judge the validity of answers. The positive answers given by the users reverse when the negative questions are asked as shown in Figure 9 below. This indicates that the answers in the questionnaire are generally considered and valid.

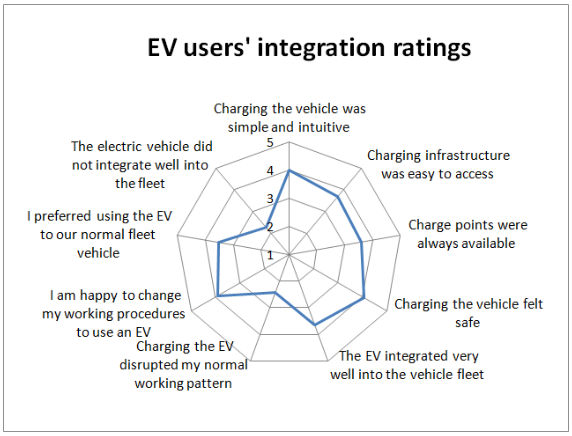

Figure 9: EV users' integration ratings

Users found the charging process simple and intuitive and were happy with the method by which the EVs were integrated into the fleets. 75% of users stated they would be happy to change working procedures to incorporate EVs. Only 16% of users preferred using their conventional vehicle and just 19% of users considered that charging the EV disrupted their normal working patterns.

7.5 User knowledge and behaviour assessment

EV users were presented with a number of statements designed to assess both their own driving behaviour and their knowledge of EV aspects that have an effect on journey efficiency.

Key points of interest from the user knowledge and behaviour assessment include:
72% of users were aware that ancillary equipment use reduces the range of an EV, but only 33% were willing to reduce cab heating to preserve battery power and 37% of users were willing to modify their driving style to preserve range. Here we can conclude that most of the EV users valued creature comforts and acceptable levels of performance above any power and comfort restrictions designed to extend range. However, 63% of EV users were willing to use the visual eco-driving display to improve journey efficiency.

The questionnaire identified that 28% of users were not aware that use of cab heating and cooling would reduce the vehicle's range and 16% of users were not aware the eco-driving indicator was there to help them extend the range of the vehicle. It is clear from these statistics that there are still opportunities to improve EV performance through education.

When the user knowledge and assessment data were analysed by vehicle type only 30% of users were aware the i-MiEV was speed limited which again demonstrates that 81 mph is a reasonable speed limit to place on an EV. Users of the i-MiEV were generally more aware that the vehicle had regenerative braking and that the eco-driving display was there to help users to drive more efficiently. It is suggested here that the eco-driving colour display in the i-MiEV is more user friendly than the smart ed. The smart ed displays power as either positive or negative kWs, depending on whether power is being delivered by or to the battery. This notation may not be intuitive to a non-technical vehicle user.
When the data were analysed by the number of drives a user had undertaken, trends showed that users knowledge and awareness increased with experience. For example 94% of users with over 20 drive experiences realised that cab heating effected range compared to 55% for users with only a few drives. Similar statistics were found for regenerative braking where 77% of users with over 20 drive experiences were aware the vehicle had regenerative capabilities compared to 46% of users with only a few drives.

8 Fleet managers' perceptions

Perceptions and attitudes towards EVs were assessed by questionnaires issued to the managers responsible for the EVs during the loan. The fleet managers answered purchasing related questions on behalf of their organisations. A total of eight questionnaires were received from fleet managers who took part in the trial activity.

8.1 Purchase price assessment

Similar to the EV users' questionnaire, the fleet managers were asked how much of a cost premium they would pay for an EV and were allowed to select one of the following answers: None, 0-5%, 5-10%, 10-20%, 20-50%, 50-100%, 150%+. Figure 10 below shows the split of the premiums users were willing to spend on EVs along with the current price premium a user is expected to pay for a Nissan Leaf and a Mitsubishi i-MiEV in April 2011. The conventionally fuelled comparator vehicles for the Nissan Leaf and Mitsubishi i-MiEV pricing assessment were the Peugeot 1.6 HDI and Ford Fiesta 1.4 TDCi respectively.

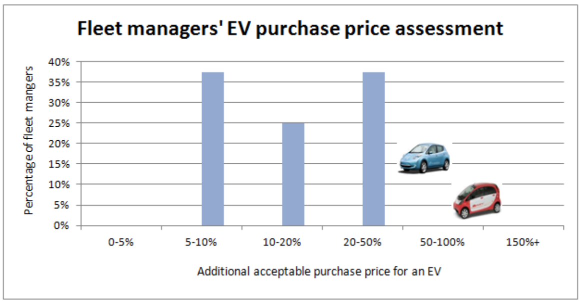

Figure 10: Fleet managers' EV purchase price assessment

The fleet managers surveyed in this questionnaire were prepared to spend up to a maximum of a 50% premium for an EV. However, unlike the EV users' questionnaire 100% of fleet managers in this survey recognised that an EV was sold at a premium and were willing pay an additional amount.

8.2 EV purchasing priorities

Fleet managers were asked to prioritise a list of EV purchasing drivers. Reliability, purchase price, running costs and tailpipe emissions were seen as most important. Range was considered a high priority, but only ranked 10th out of the 20 items considered. This may be due to the fact that the fleet managers were comfortable with the range characteristics of EVs given their experience in the trial. Reliability was ranked as the highest priority above environmental and cost aspects.

8.3 Perceptions and attitude

Overall fleet managers were very positive about the prospects of EV integration and stated that positive feedback had been given from staff and management. They were also willing to modify fleet behaviour to incorporate EVs. 88% of fleet managers considered that EVs were positively received by staff and 75% of fleet managers thought EVs were positively received by management. 68% of fleet managers said that involvement in the Smart Move trial had accelerated their company's interest in EVs and 75% of fleet managers said their opinion of EVs increased over the trial. Only 25% of fleet managers reported that they were not willing to modify their fleet operations to incorporate EVs. Importantly, when asked if the trial accelerated their interest in EVs, 63% of fleet managers could see EVs being integrated in their fleets before 2013 compared to just 25% before the trial.

8.4 Reasons for trial participation

Fleet managers were asked to rate the influence that a list of predefined drivers had on their desire to participate in the trial. The most influential reason was to take the opportunity to learn about EVs and how they could be integrated into fleets to meet company environmental aspirations. Support from Cenex was also noted as an influence. Reassuringly, the publicity opportunity from the trial was a minor influence for companies and no one cited that they were told to participate in the trial. 88% of fleet managers stated this was their first opportunity to trial a modern EV.

9 Range and auxiliary power use

The efficiency (km/%SoC) of each journey was used to calculate the theoretical range of the EVs. The average extrapolated range was 75.7 km from the smart ed and 67 km from the i-MiEV. The unique and non-representative Indesit usage pattern had a significant effect on the overall smart ed range. Removal of the Indesit data from the smart ed population increased the average range to 103 km. Figure 11 below shows the range distribution over the trial. The Indesit range has been shown separately to highlight its effect on the smart ed data set.

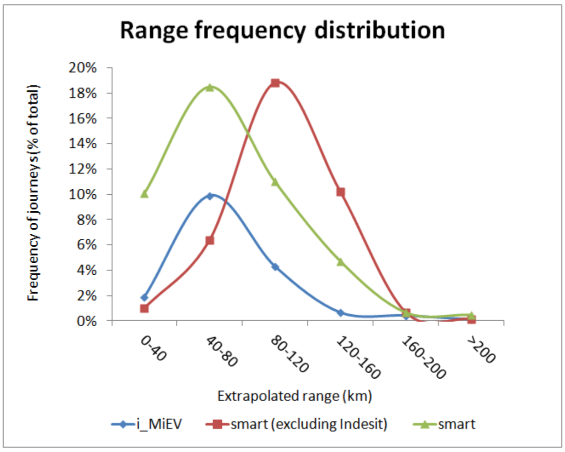

Figure 11: Range frequency distribution

The extremes in high and low ranges shown above are a product of extrapolating very short journeys which often presents an unrealistic scenario as the journey may have been dominated by one particular characteristic - i.e. entirely uphill, downhill, high heating load etc.

Data for the Smart Move case studies was captured during the autumn and winter of 2010/2011 when many parts of the UK road network were severely impacted by relatively extreme cold temperatures and significant snowfall. This had a clear effect on the range of the vehicles over the trial. Figure 12 below shows the percentage of power supplied to the vehicle for drive and auxiliary power demands (heating, cooling and 12v DC loads). The most power hungry of these is the vehicle cab heater which is rated at 4 kW. The auxiliary devices consumed 52% of the power used by Indesit. This compared to 24% from Asda and 15% from Groundwork where journey average speeds and ambient temperatures were higher. Clearly the Indesit duty cycle represented an extreme case where little drive power was required when the average journey speed was just 11.8 kph.

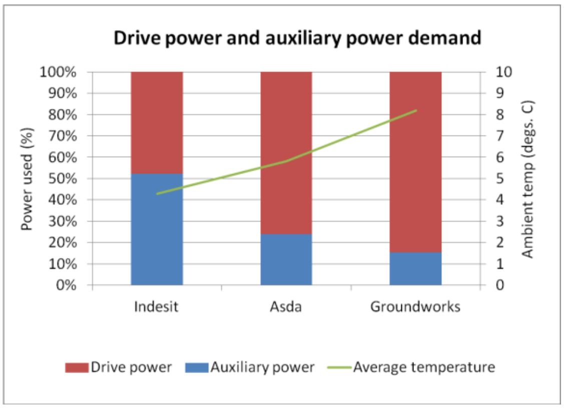

Figure 12: Drive and auxiliary power demand

10 EV utilisation

Throughout the case studies, the average time the EVs spent driving, charging and parked was 6%, 10% and 84% respectively. This highlighted an opportunity to improve the economics of running these EVs by increasing the amount of time the vehicles spend driving. Figure 13 below shows the vehicle utilisation split for each organisations.

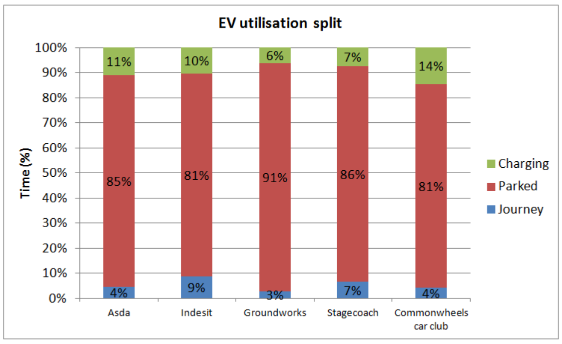

Figure 13: EV utilisation split

The journey time utilisation of an EV is limited by the vehicle's duty cycle and recharging time. Utilisation can also be expressed in terms of SoC use per day. Figure 14 shows the average SoC used per day for each organisation. Unlike the time base utilisation in Figure 13 above, only days where the vehicles were driven are included in the SoC utilisation.

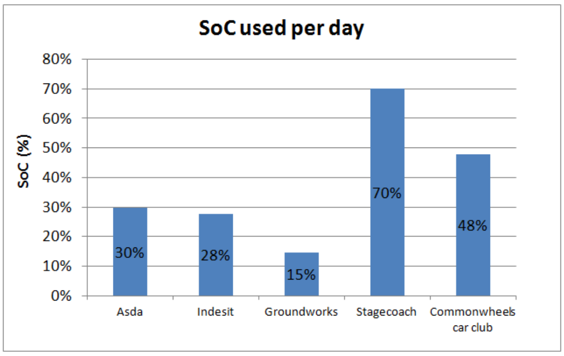

Figure 14: SoC used per day

The high SoC utilisation by Stagecoach supports the feedback from operational personnel that the vehicles were always charged between shifts, this allowed them to obtain maximum use from the vehicle. Commonwheels, who also employed an intensive recharging and EV redeployment policy, also regularly achieved a SoC use of over 100%. Clearly, the higher range available from the smart ed is also reflected by the lower daily SoC use from Asda, Indesit and Groundworks.

11 Conclusion and final discussion

The case studies highlighted the ability of fleets to modify usage patterns and behaviour to accommodate the range restrictions of EVs whilst maintaining generally positive feedback from both users and fleet managers. This is an encouraging example of maximising the benefits of an EV, but does also highlight that the name-plate range of an EV is not an ideal indication of its practical range given the variation in energy demand that duty cycle and ancillary electrical loads cause. Emission savings were shown to be between 5.4% and 15.1% across the case study organisations (using the carbon intensity of the UK's national electricity grid) when compared to a best-in-class diesel comparator. The economic analysis presented in this report is encouraging and showed that the smart ed can be operated at a lower cost of ownership than a smart Cdi diesel when extrapolated energy prices are considered over the analysis period, or at a marginal cost increase when current energy prices are considered. Most importantly this report presented a range of boundary conditions and associated economic performance allowing the fleets to look for sweet spots of operability if economic performance is the key consideration. Clearly this analysis is only relevant to the vehicles considered because the purchase cost premium of the EV has a significant influence on ownership costs. This study, in agreement with previous studies, shows that modern OEM produced EVs are usually enthusiastically and quickly accepted by both fleet users and fleet managers who are willing to modify their fleet operations to incorporate EVs even with their range and recharging limitations. Where the report also explores the acceptable EV range and price users that fleet managers would be willing to accept and pay for an EV, the limitations of this enthusiasm are shown in that a clear step change in both cost and range performance is required before EVs can be accepted as a mainstream transport option.

The Smart Move EV trials conducted by Cenex since 2010 have repeatedly shown that interest and permanent integration of EVs into fleets is accelerated by allowing a no-cost opportunity to trial and experience market ready environmentally friendly transportation technologies.

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4. The participating organisations: Stagecoach, Indesit, Asda, Commonwheels, Groundwork, Durham University, Durham County Council, Lincoln Council, Newcastle City Council, Gateshead Council and Pinewood Studios.

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