The Ultra Low Carbon Vehicle Demonstrator Programme

FINAL REPORT

Assessing the viability of EVs in daily life

A report to the Technology Strategy Board and the Office for Low Emission Vehicles by Cenex and Oxford Brookes University

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Executive summary

Background
- The Technology Strategy Board (TSB) launched the Ultra Low Carbon Vehicle Demonstrator programme in 2008 as the first major step in a UK wide journey to support the development of technologies and markets for ultra low carbon vehicles (ULCV).
- The programme was jointly funded by the TSB and the Office for Low Emission Vehicles (OLEV).
- Throughout the trial 349 low carbon vehicles were deployed. Over 90% were pure electric vehicles (EVs), with the remaining being plug-in hybrid electric vehicles (PHEVs) and fuel cell electric vehicles (FCEVs). Collectively, the vehicles completed over 276,000 individual trips covering over 1.5 million miles recording over 51,000 charging events.
- This report details the results of a study of the drivers’ perception and attitudes towards the pure EVs, and their real-world performance. The data was collected and analysed by Cenex and Oxford Brookes University on behalf of the Technology Strategy Board.

Motivations and first impressions
- Drivers entered the trial with a variety of motivations (car enthusiasts, interest in assessing EV practicality, desire to advance driving technology, a personal concern for the environment, and a desire for their organisation to reach its carbon targets).
- Drivers showed immediate Primary Adaptation whereby the EV was seen as simple to drive and unfamiliar components such as regenerative braking were adapted to within the first trip. Drivers expected an EV to fit their life immediately and did not wish to alter their lifestyle to accommodate it. The EVs were seen as fun to drive, smooth, and rated very highly on their acceleration performance.

Journey patterns
- EVs were considered as easy to use, with comparable performance to a normal car, although less flexible. This was observed in the vehicle data where the average trip length was 5.1 miles compared to the national average trip length of 7.0 miles. The maximum journey length achieved was 107 miles.
- The EVs were used mainly during the working day with 71.5% of trips being undertaken between 8am and 6pm.
- EVs issued to Individuals (as opposed to multi-user Pool vehicles) showed no significant change in trip or daily mileage throughout the trial which suggested they were mostly used for regular and repeatable journeys. Individuals used the EVs on average 18.1 days per month compared to just 9.5 days for Pool drivers.

Energy consumption and range
- Drivers assumed it would be easy to judge remaining range but learnt that a variety of factors combined to decrease range. Vehicle data showed that on average the range of the EVs reduced by 20% as the temperature dropped to 0°C. Drivers learnt to adapt their driving style and ancillary equipment use depending on the journey length they required. For example, by calculating the theoretical range of the EVs from the energy consumption per mile during each journey, it was shown that short trip lengths achieved a theoretical range of around 60 miles compared to long trip lengths which had a theoretical range of around 90 miles. Hence, drivers stated that EVs needed to provide more accurate and predictive information on remaining range, energy consumption/regeneration (and how these translated into miles). Drivers said that an EV with a 230 mile range would cater for all their trips.
Executive summary

...Energy consumption and range continued

- Few drivers experienced range anxiety because they deliberately did not drive at a state of charge that actually caused concern, instead they drove with a considerable “safety buffer”, relying on a second vehicle for the majority of their longer trips. Only 20% of all trips fell below 50% battery state of charge with just 1.5% of trips falling below 20% battery state of charge.
- Drivers who did challenge the range achieved Secondary Adaptation (learning how to use an EV optimally), drove with a lower safety buffer, and wasted less of the available battery capacity.
- Drivers stated that they did not change driving style unless at a low state of charge.
- Drivers enjoyed taking advantage of the good performance of their EV at higher states of charge. Being able to drive the EV normally meant less adaptation was required than many drivers anticipated.

Charging

- Drivers stated that charging was easy and safe. Private drivers quickly established a routine for themselves and did not charge each day. Pooled Corporate drivers endeavoured to charge after every trip in order to accommodate the next driver and consequently did not learn how many trips/mileage could be achieved from a full battery charge. Private drivers showed a marked preference for charging over refuelling at petrol stations.
- The mileage drivers undertook between charge events increased gradually throughout the loans as drivers became more confident in journey planning and range prediction.
- Drivers with timed infrastructure achieved a higher average mileage between charging showing that timed infrastructure, offering lower cost off-peak electricity, decreased both opportunity charging during the day and charging at times of peak electricity demand.
- Having a public charging infrastructure was strongly endorsed (yet drivers felt they could complete trips without one). The data showed that 10% of charging was conducted at public infrastructure points. Home charging was the most popular charging location. Drivers with infrastructure installed only at their home used this 97% of the time. Even drivers with official infrastructure points installed only at work conducted nearly 1 in 10 recharges at home, using their domestic electricity supply.
- Individual drivers considered a charging time of just over 2 hours to be ideal for personal charging. Corporate managers pointed to much faster charging times as being essential in order to gain maximum use of EVs in a multi-driver fleet.

Environmental opinions

- Low noise came to be seen as an asset of EVs. Drivers paid more attention to pedestrians than they would normally when driving at low speeds.
- All drivers believed EVs lowered carbon emissions. Corporate drivers were often employed by organisations involved in energy or intent on reducing carbon emissions. These drivers endorsed the use of renewable energies more strongly than Private drivers did.

Future expectations and purchasing drivers

- To maximize future uptake, drivers stated that EVs needed to perform and look as good as normal internal combustion engine (ICE) cars, but still be distinguishable as EVs (e.g., through branding, logos, etc) so that the variety and presence of contemporary EVs are visible to the non-EV driving public.
- People expected EVs to be priced at the same level as normal vehicles. Residual value, second-hand market, insurance, battery, maintenance costs, and how quickly the current EV technology will be surpassed influenced drivers' intentions to purchase an EV.
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Introduction

The Technology Strategy Board (TSB) launched the Ultra Low Carbon Vehicle Demonstrator (ULCVD) programme in 2008 as the first major step in a UK-wide journey to support the development of technologies and markets for ultra low carbon vehicles. The programme was jointly funded by the TSB and the Office for Low Emission Vehicles (OLEV) and was designed to deliver:

- Exposure to multiple drivers and drive cycles.
- Real-world testing through in-vehicle logging and analysis.
- An opportunity to understand customer perceptions and concerns.
- An opportunity to understand interface challenges with infrastructure.
- Passenger cars on the road for 12 months each.

Trial key stats

- £25.5m public sector funding (£52m project value).
- 8 consortia running projects.
- 18 vehicle manufacturers.
- 349 vehicles deployed (electric, plug-in hybrid electric, hydrogen fuel cell).
- 276,989 individual trips.
- 1,559,144 miles travelled (2,508,663 km).
- 51,657 charging events.
- 319 MWh electricity consumed.

This report details the results of a study of the drivers’ perception and attitudes towards the EVs and their real-world performance. The data was collected, analysed and presented on behalf of the Technology Strategy Board by Oxford Brookes University and Cenex.
Introduction: Consortium Groups

The 8 consortia were made up of OEMs, energy suppliers, university partners and local authorities in regions across the UK, operating 349 vehicles from 18 manufacturers.
Data Collection Methods and Driver Demographics
Vehicle data collection

- The trial consortia monitored and reported journey and charging event data for the first 12 months of vehicle operation. The data was collected between Dec 2009 and March 2012, which coincided with individual consortium vehicle deployment plans.
- Typical data points received from the consortia included journey and charging event start and end times, energy consumption, distance travelled, charging locations and journey temperature.
- Some consortia were also able to provide additional data on individual vehicle loan dates, vehicle duties and whether users had access to charging infrastructure at work or at home.
- 98.1% of the data recovered was automatically recorded by on-vehicle data loggers, with the remainder being recorded on manual driver log sheets.
- Data submissions between consortia were not fully compatible therefore, where appropriate, the data analysed in this report used different data populations dependent on subject of the analysis.
- The vehicle drivers and their usage types were selected by the consortia for the purpose of their individual projects. It is not proposed that the usage experienced in this trial is representative of expected UK average vehicle performance or demographics.

Vehicle ownership lengths

- Vehicle data covered drivers that were issued with vehicles for between one and twelve months. 5 to 12 month deployments were the most popular, covering 82% of the data.
- Where this report conducts trend analysis (behaviour change with time), the first 6 months of usage data were analysed for vehicle loans of over 6 months duration. This ensured the population of vehicle drivers remained constant throughout the behavioural analysis.

Key point

The trial consortia monitored and reported journey and charging event data for the first 12 months of vehicle operation. 98.1% of the data recovered was automatically recorded by on-vehicle data loggers. The vehicle drivers and their usage types were selected by the consortia. It is not proposed that the usage experienced in this trial is representative of expected UK average vehicle performance or demographics.
To allow a deeper understanding of usage patterns the majority of consortia provided the following additional data that was cross referenced with vehicle performance data.

- **Driver type**
  - Drivers were split into two categories. Corporate drivers (70%) did not contribute financially towards the vehicles whereas Private drivers (30%) paid for the lease of their vehicles.

- **Vehicle usage**
  - Vehicle usage was split into two categories. Vehicles were either issued to, and mainly used by an Individual (65%), or vehicles were available to a Pool of drivers (35%).

- **Infrastructure access**
  - Drivers either had infrastructure installed or made available at home (44%) or work (44%) locations, or both (12%).

- **Smart meter**
  - Many infrastructure locations had smart meters installed (45%) where charging timers could be set to allow users to take advantage of lower cost night rate electricity.

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**Key point**

To allow a deeper understanding of usage patterns the majority of consortia provided additional usage data (vehicle duties, infrastructure access, infrastructure type) that were cross referenced with vehicle performance data. The majority of the drivers (70%) were Corporate drivers who did not contribute financially to operating the vehicles.
Driver data collection

- Drivers completed questionnaires and interviews throughout the trial.
- Questionnaires were completed at pre-trial and 3 months after picking up their car.
- Questionnaire items required drivers to use a 5-point scale (where 1 = Strongly Disagree and 5 = Strongly Agree) to indicate the degree to which they agreed with specific statements. Pie charts indicate the % of drivers agreeing to each questionnaire item.
- Drivers were also interviewed at pre-trial and at 1 week into the trial (to assess immediate adaptation) and 3 months into the trial (to assess longer-term adaptation).
- Interviews involved drivers responding to open-ended questions and elaborating upon their expectations and experiences with their EV.
- Together, the questionnaires and interviews give a comprehensive insight into the drivers’ expectations and experiences throughout the trial.
- 3 months was picked as a data collection point for two reasons. First, this gave a consistent point for data collection across consortium trials of different lengths. Second, previous experience shows that all major issues pertinent to adaptation have been confronted by that point.

Key point

Questionnaires and interviews were conducted with drivers at pre-trial and also after using an EV. The data presented in this report is a comprehensive overview of drivers’ expectations and experiences. Pie charts indicate the % of drivers agreeing to each questionnaire item.
Drivers’ demographics

<table>
<thead>
<tr>
<th></th>
<th>Drivers (n = 352)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age</strong></td>
<td>Mean: 46 years (Range: 23 – 71 years)</td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td>Male: 76%</td>
</tr>
<tr>
<td></td>
<td>Female: 24%</td>
</tr>
<tr>
<td><strong>Household Income</strong></td>
<td>82% &gt; £41,000</td>
</tr>
<tr>
<td></td>
<td>45% &gt; £71,000</td>
</tr>
<tr>
<td></td>
<td>25% &gt; £101,000</td>
</tr>
<tr>
<td><strong>Status</strong></td>
<td>85% Married or living with partner</td>
</tr>
<tr>
<td><strong>Ethnicity</strong></td>
<td>91% White</td>
</tr>
</tbody>
</table>

- Private drivers (n = 212) and Corporate drivers (n = 140) did not differ in any of the tabulated demographics.
- Private drivers paid a monthly lease fee (average price: £267) for their participation, whereas Corporate drivers paid no such fee.
- The only additional demographic difference between the two groups of drivers relates to level of education. 67% of Private drivers were graduates as compared to 44% of Corporate drivers.
- Drivers’ reactions to their vehicles were remarkably consistent across both Private and Corporate groups, especially in terms of adapting to driving an EV.
- The rest of this report presents data for all drivers together apart from in those instances where it is more informative to talk of the differences between Private and Corporate drivers.

Key point

Men outnumbered women by a ratio of 3:1. Drivers tended to be in their mid-40s, White, living with a spouse or partner, and to have a higher than average income. Drivers’ experiences with their EV were largely similar across driver type regardless of cost of participation.
Drivers’ Motivations and Judgments of Performance
Drivers’ motivations for participation

- Drivers were interested in cars (with more of the Private drivers than Corporate drivers identifying themselves as car enthusiasts).
- Drivers were interested in assessing the current practicality of EVs and in contributing to the advance of driving technology in addition to having an environmental concern.
- Drivers were future-focused and often indicated that they were also interested in being at the vanguard of innovative technology.
- Corporate drivers were often in companies that were seeking to reduce carbon emissions and this had a knock-on effect on their own motivation for participation: “This is important for us as an organisation. We are very focused on the importance of sustainable economic development. It’s important for us not just to be talking about it. It’s important that we are actually showing action”.
- At the 3 month stage, drivers felt that their participation had contributed to new driving technology and that driving EVs did help to do something for the environment.

<table>
<thead>
<tr>
<th>Motivation</th>
<th>Private Drivers</th>
<th>Corporate Drivers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car Enthusiast</td>
<td>51%</td>
<td>90%</td>
</tr>
<tr>
<td>Judge the Practicality of EVs for Myself</td>
<td>91%</td>
<td>91%</td>
</tr>
<tr>
<td>Interested in Doing Something for the Environment</td>
<td>90%</td>
<td></td>
</tr>
<tr>
<td>Would Like to Contribute to New Driving Technology</td>
<td>91%</td>
<td></td>
</tr>
</tbody>
</table>

**Key point**

Drivers entered the trial with a variety of motivations (car enthusiasts, interest in assessing EV practicality, desire to advance driving technology, and a concern for the environment). The widely-held view that EVs are strictly the domain of those who are solely environmentally motivated is shown to be outdated. For corporate drivers, working for a company that seeks to match action to environmental policy is an important motivation for driving an EV.
Ease, and type of adaption to EVs

- The car was seen as simple to drive. Novel aspects such as regenerative braking were picked up right away.
- All drivers adapted almost immediately to the basic mechanics of their EV. We term this form of adaptation, *Primary Adaptation*.
- People often assumed that an EV will bring an additional “cognitive load” to the driving experience. This load was largely due to having to consider the limitations of range.
- By the 3 month period, drivers had recognized that the degree to which they would need to plan their journeys had dropped and the effect that would have on them had also dropped.
- Drivers were asked whether they had received enough training to use the car effectively. While 80% of Private drivers agreed that they had received sufficient training, only 57% of Corporate drivers felt they had. Corporate pooled car drivers particularly felt that they were not sufficiently equipped to understand how to use the EV optimally (and some report not having had any training).
- There was no difficulty in adjusting back to driving an ICE.

Key point

Drivers showed immediate *Primary Adaptation* whereby the EV was seen as simple to drive and unfamiliar components such as regenerative braking were adapted to within the first trip. Drivers’ sense of having to plan their journeys more carefully dropped with experience of the vehicle. Corporate drivers needed more training than was offered to feel equipped to use their EV optimally.
Drivers’ judgments of EV performance

My EV has been fun to drive
- 92% agreed

“My EV has been fun to drive

“The acceleration is amazing. If you’ve got a scale of 1-10, I’d give the acceleration a 10”

My EV had a good pick up from a standing start
- 89% agreed

“My EV had a good pick up from a standing start

“It’s lovely to drive. It’s smooth, it’s modern, the performance is excellent and it drives so well. Most people wouldn’t notice much of a difference in performance. It is really lively and you have absolutely no problem at all in traffic. If you need to pull out sharpish you are safe; it is easy and there is no lag, no delay. Just put your foot down and go for a ride. I’m not just pleased, I’m very impressed. One of my colleagues who didn’t like “Eco” went ‘look how fast it is’. It goes like a rocket.”

My EV’s acceleration when was very good when the car was already moving
- 78% agreed

Performance was rated highly across consortium groups. Strength of response was associated with the power of the vehicle and the speed restrictions placed on individual vehicles.

Key point

Old performance stereotypes associated with previous generation EVs were successfully countered. The current EVs were seen as fun to drive, smooth, and rated very highly on acceleration from both standing and when the car was already moving.
Drivers’ comparison of EVs with their normal car

- Although perceived flexibility of EVs increased at 3 months, EVs were still not seen as flexible as drivers’ regular vehicles.

- Judgements regarding both the ease of use, and the performance of the EV increased significantly at the 3 month period.

- Note the high standard set for the item regarding performance. Over a third of drivers stated their EV had *superior* performance to their normal car, which is a particularly notable finding given the quality of cars owned was commensurate with the relatively high salary of the participant group.

“It has felt like just driving a normal car. If say I’d driven it and nobody had told me it was electric, you wouldn’t have thought any different, which is good. So it just felt like a normal automatic.”

Key point

EVs were as easy to use as a normal car. Performance comparisons were favourable, but EVs were considered less flexible than the drivers’ normal cars.
Journey Patterns
Distance travelled statistics

<table>
<thead>
<tr>
<th></th>
<th>Average mileage (miles)</th>
<th>75% of mileages were less than.. (miles)</th>
<th>Maximum mileage (miles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trip</td>
<td>5.1</td>
<td>6.2</td>
<td>107.0</td>
</tr>
<tr>
<td>Daily</td>
<td>21.4</td>
<td>29.8</td>
<td>241.5</td>
</tr>
<tr>
<td>Weekly</td>
<td>94.8</td>
<td>134.3</td>
<td>622.9</td>
</tr>
<tr>
<td>Monthly</td>
<td>326.2</td>
<td>459.2</td>
<td>1852.0</td>
</tr>
<tr>
<td>Annual*</td>
<td>3914.4</td>
<td>5510.4</td>
<td>-</td>
</tr>
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</table>

- A trip was defined as ignition-on to ignition-off. The average EV trip length was 5.1 miles which compares to the national average trip length of 7.0 miles [1]. This represents both the limited range in an EV and that the data captured included numerous short duration trips which may not constitute a purposeful journey and therefore would not be included in national travel statistics.

- The average daily mileage was 21.4 miles, with the EVs being used an average of 4.4 times per week.

- The journey data was skewed towards low distance trips, this is demonstrated in the table opposite which shows 75% of the distances travelled were close to the average distance.

- Whilst the vast majority of drivers kept comfortably within the capable range of the EVs, a small subset demonstrated the potential performance of the vehicles. The maximum trip mileage was 107 miles and the maximum daily mileage was 241 miles. Just 12% of users were responsible for all trips greater than 60 miles.

- *Since the majority of drivers had vehicles for durations of less than 12 months, the average monthly distances were used to extrapolate annual mileages. This resulted in annual average distances of 3914 miles with 75% of the vehicles achieving mileages < 5510 miles. Clearly this is lower than the average annual private vehicle covering circa 12,000 miles per annum and reflects the fact that the majority of vehicles were either used as Pool cars or by Individual drivers who had access to a second vehicle.

[1] DfT National Travel Survey 2010

Key point

The average trip distance was 5.1 miles, with the average daily and weekly mileages being 21.4 and 94.8 miles respectively. Whilst the vast majority of drivers kept comfortably within the capable range of today's EVs, a small sub set demonstrated the potential performance of the vehicles. The maximum trip mileage was 107 miles and the maximum daily mileage was 241 miles. Just 12% of users were responsible for all trips greater than 60 miles.
Trip distance trends

The data suggested Private drivers gradually explored the capabilities of the EVs throughout the loan with the spread of trip lengths and maximum trip lengths per day increasing. Whereas Corporate drivers spread in trip lengths and maximum trip distances reduced.

14% of users were responsible for achieving the daily maximum trip lengths throughout the trial.

The average trip distance for EVs issued to Individuals remained constant throughout the loan, suggesting that the users adapted quickly to the vehicles and, in the majority of cases, the vehicles were mainly used for regular and repeatable journeys.

The average trip mileage and deviation in mileage for EVs used as Pool vehicles reduced over the duration of the vehicle loan showing that the impersonal nature of Pool vehicle use did not encourage drivers to continue exploring and expanding the capabilities of the vehicles.

Key point

Individual drivers average daily trip distance remained constant throughout the loan suggesting that the EVs were used for regular and repeatable journeys whereas EVs used as Pool vehicles saw a reduction in trip distance over the same period. Private drivers gradually explored the capabilities of the EVs throughout the loan with their spread of trip lengths and maximum trip lengths per day increasing.
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Distance travelled by usage type

- Private and Corporate drivers achieved similar average trip and daily mileages but Private drivers used the vehicles on more days per week which enabled them to achieve 37% greater mileage per month than Corporate drivers. On average Private drivers used their EVs 19.2 days per month compared to 12.9 days for Corporate drivers.

- When split by Individual and Pool drivers, again the daily mileages were very similar however Individuals who had ownership of the vehicles used them on average 18.1 days per month compared to 9.5 days for Pool drivers. Here Individual drivers achieved 92% greater monthly mileage than Pool drivers.

- EVs issued to Individuals rather than Pools of drivers were utilised most. Clearly this was due to the majority of Individuals also being able to use their vehicles for commuting and pleasure.

Key point

The average trip and daily mileages were similar between the different user groups however the EVs were used on more days per week when under the control of Individual drivers, who achieved 92% greater monthly mileage than Pool car drivers. Private drivers also achieved 37% more mileage than Corporate users of EVs.
Journey times

- Journey start and end time distributions were similar. This shows that short duration trips dominated the data set.

- The EVs were used mainly during the working day with 71.5% of trips commencing between 8am and 6pm. Corporate users were responsible for 75% of daytime trips and Private users were responsible for 66%.

Key point

The EVs were used mainly during the working day with 71.5% of trips commencing between 8am and 6pm.
EV Range and Energy Consumption
# State of charge use statistics

A batteries state of charge (SoC) represents the amount of energy remaining or used from the battery (i.e. 0% SoC is a fully discharged battery and 100% SoC is a battery which is fully charged).

The average trip consumed 7.1% of battery charge and drivers on average consumed 27.2% battery SoC per day. 75% of daily use consumed less that 42% battery SoC.

<table>
<thead>
<tr>
<th>Average values</th>
<th>Mean average (SoC use)</th>
<th>75% of SoC use was less than...</th>
<th>Maximum SoC use</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Trip</strong></td>
<td>7.1%</td>
<td>8.85%</td>
<td>98.0%</td>
</tr>
<tr>
<td><strong>Daily</strong></td>
<td>27.2%</td>
<td>42.0%</td>
<td>189.8%</td>
</tr>
<tr>
<td><strong>Weekly</strong></td>
<td>120.7%</td>
<td>170.9%</td>
<td>628.1%</td>
</tr>
</tbody>
</table>

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**Key point**

The average trip consumed 7.1% of battery SoC and drivers on average consumed 27.2% battery SoC per day. 75% of daily use consumed less that 42% battery SoC.
Drivers’ perception of range

- **The range is sufficient for my daily needs**
  - Pre: 77%
  - 3mth: 72%
- **I will know how much range I have left when driving**
  - Pre: 83%
  - 3mth: 68%

- Drivers had already assessed their individual mobility needs and anticipated the car would be adequate for their own lives.
- Drivers did not want to compromise their daily routine.
- Drivers commonly stated that the car needed to fit their lives rather than vice-versa.
- Drivers were confident that they would be able to judge the remaining range at the pre-trial data collection point, but then learnt that it was more difficult than they had anticipated to determine decreasing range accurately.
- Drivers learnt to use their own experience to judge the remaining range. But expressed a desire for more accurate, predictive information to be fed back while driving.

“It’s difficult [to gauge the range]. It shows a percentage of charge, but the range depends on how many people are in the car, how many hills, how fast we’re going, how slow, stopping and starting. So, we don’t know what the range is. We know how much battery is left, but not how many miles we’ll be getting.”

**Key point**

Drivers judged EVs to suit their daily range requirements prior to participation. They expected a new vehicle to fit their life immediately and did not want to alter their lifestyle to accommodate it. Drivers assumed it would be easy to judge remaining range but learned that a variety of factors combined to decrease range. Displays need to provide accurate and predictive information on remaining range.
Drivers’ perception of range

- Few drivers deliberately set out to see how far they could actually go on one charge.

- Therefore, drivers’ judgements of how far they could go on one charge tended to be estimates rather than reports of actual distance.

- Driving with a sizeable safety buffer reduced the risk of running out of range on daily journeys and consequently resulted in negligible range anxiety.

- Only drivers who actually did challenge the range (or accidentally found themselves in circumstances where they may run out of charge) achieved Secondary Adaptation.

- Secondary adaptation involved being aware of the inter-connected nature of driving style, regenerative braking, route selection, state of charge, and the information fed back from the displays. Drivers who achieved this could drive with a significantly lower safety buffer.

**Key point**

Few drivers experienced range anxiety because they deliberately did not drive at a state of charge that would actually cause concern. Therefore, the EV had more battery power than was used, with most drivers driving with a sizeable “safety buffer”. Drivers who did challenge the range achieved Secondary Adaptation, drove with a lower safety buffer, and wasted less battery capacity.
Vehicles’ range and energy consumption

The theoretical range of the EVs were estimated by comparing the trip mileage with the battery SoC used. This gave the range of the vehicle assuming the energy consumption over a single trip (expressed in SoC/mile) would be used for the entire capacity (100% SoC) of the battery.

It should be noted that examining overall theoretical range only gives an indication of range performance as drivers tended to modify their driving behaviour to allow an increase in range when longer trip lengths were required. The relationship between trip length and energy consumption is examined further elsewhere in this report.

The graph above shows the frequency distribution of energy consumption per mile. The average energy consumption was 1.5% SoC/mile which extrapolated to a theoretical range of 66.7 miles. 79% of trips had a range of over 58.9 miles and 90% of trips achieved a range greater than 45.4 miles. The energy consumption and range statistics are from a mix of EVs with different specifications and performance characteristics.

The variation observed in energy consumption was due to both the technical specification of the different vehicles on trial and factors such as vehicle duty cycle, driving style and ancillary equipment use.

Key point

The average energy consumption was 1.5% SoC/mile which extrapolated to a theoretical range of 66.7 miles.
State of charge use

- Examining journey end SoC gives an indication of how often users frequented low battery state of charges. The graph below shows the percentage of trips that went below a certain battery SoC.

State of charge use

- Very low battery SoC was used infrequently by the drivers with just 1.5% of trips going below 20% battery SoC.
- 30% battery SoC, which drivers considered as a low SoC, was reached in 5.3% of journeys.
- Private drivers utilised lower SoC areas slightly more than Corporate drivers, with Private drivers achieving 21.4% of journeys which ended at less than 50% SoC compared with 18.7% of journeys from Corporate users.

Key point

Very low battery SoC was used infrequently by the drivers with just 1.5% of trips going below 20% battery SoC. Private drivers utilised lower battery SoC areas marginally more than Corporate drivers, with Private drivers achieving 21.4% of journeys which ended at less than 50% SoC compared with 18.7% from Corporate users.
Drivers’ responses regarding reliability illustrated their confidence in the car. They consistently stated their confidence in the EV manufacturers in their interviews.

Drivers’ responses regarding their concern about reaching their destination were more focused on their own confidence as drivers. For Private drivers this concern dropped over time, but for Corporate drivers it remained high.

Corporate drivers tended to have a larger number of shorter trips and fewer opportunities to challenge the range. As they did not stretch the range, these drivers did not learn how to drive at lower states of charge and therefore concerns about range remained stable for this group.

**Key point**

All drivers were confident in the reliability of the EV. Personal concern about being able to reach a destination dropped for Private drivers, but not for Corporate drivers (many of whom charged after every trip and did not drive at a state of charge that would enable them to see the variety of journey lengths that were possible in their EV).
Few drivers went on long enough journeys to worry about the different factors that affect range (and this was especially true of many Corporate pooled drivers).

Some pooled Corporate drivers were not allowed to take their EV beyond a specified journey length.

There needs to be some way of communicating energy consumption more accurately to the driver (and those factors that affect energy consumption).

On a related note, all drivers adapted quickly to the regenerative braking (and preferred it to simply having a normal brake pedal). However, they also could not tell precisely how much energy was regained through regenerative braking, and how this translated to extending range in terms of distance travelled.

The regenerative braking currently simply increases drivers’ confidence in completing journeys that they were already going to undertake and that were within the range of the vehicle.

**Key point**

Drivers did not drive far enough for the influences of different factors on range to be an issue. Energy consumption and regeneration (and how that energy translates to range in miles) need to be communicated accurately to the driver.
Range

- Drivers quickly recognised that they could drive the EV “normally” provided it was not on a low SoC.
- Drivers did not drive more efficiently unless they were forced to do so.
- Being able to drive normally meant less adaptation was required than people originally anticipated.
- Few drivers allowed the SoC to drop to a level that they consider to be “low”.

“This reflects very much on your driving technique. If you drive carefully you’ll probably do a lot more miles. If you drive badly you’ll do a lot less, so it’s a very rapid indication, whereas with a petrol car, you don’t notice that so much. It’s a very important moderator of driving behaviour I think.”

Key point

Drivers did not change driving style until they reached a low state of charge. Drivers enjoyed taking advantage of the good performance of their EV at higher states of charge. Being able to drive the EV normally meant less adaptation was required than many drivers anticipated.
The energy consumption of a trip was related to the trip’s distance. There was a higher rate of energy consumption per mile and a larger variation in energy consumption for shorter duration trips where users can confidently adopt any driving style in the knowledge that the vehicle has the range to complete its journey. The data suggested that drivers adopted their driving style dependent on the journey length. With longer trips having a lower rate of energy consumption. This was observed across all EVs independent of the vehicles battery capacity.

There was no link between journey end SoC and trip energy consumption, meaning that if trip was of a short length and range was not considered to be an issue then drivers did not automatically adopt a more efficient driving style just because the vehicle was at a low battery charge.

The graph below shows the relationship between energy consumption and trip length. There was a clear relationship between average trip length and trip efficiency.

The table below shows that when users required a trip length of between 40 and 80 miles the average theoretical range was 88.7 miles, compared to a theoretical range of just 59.8 miles for trips less than 20 miles.

<table>
<thead>
<tr>
<th>Trip length (miles)</th>
<th>Energy consumption (SoC/mile)</th>
<th>Theoretical range (miles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 20</td>
<td>1.7</td>
<td>59.8</td>
</tr>
<tr>
<td>20 – 40</td>
<td>1.3</td>
<td>79.8</td>
</tr>
<tr>
<td>40 – 60</td>
<td>1.1</td>
<td>87.7</td>
</tr>
<tr>
<td>60 – 80</td>
<td>1.1</td>
<td>89.7</td>
</tr>
<tr>
<td>80 - 100</td>
<td>1.0</td>
<td>96.4</td>
</tr>
</tbody>
</table>

The data showed drivers adopted a more efficient driving style when undertaking longer trip length. When drivers required a trip length of between 40 and 80 miles the average theoretical range was 88.7 miles, which compares to a theoretical range of 59.8 miles for trips of under 20 miles.
Energy consumption by temperature

- Whilst vehicle usage reduced during the summer months, presumably due to holidays, this had no significant effect on the overall average trip and daily mileages.

- The theoretical range of the vehicles reduced in the winter months. A slight reduction in range was also observed during summer months.

- The average monthly temperatures over the trial ranged from 5.2 °C to 18.0 °C, the individual trip temperatures ranged from -13 °C to 38 °C.

- The graph opposite shows the relationship between journey temperature and theoretical range. Highlighted in orange, the chart also shows the percentage reduction in range from the average maximum range (which occurred at 15-20 °C).

- At extreme low temperatures (below 0 °C), the range reduced by 21% and at extreme high temperatures (above 30 °C) the range reduced by 15%.

Key point

The theoretical range of the vehicles reduced in the winter months, and a slight reduction in range was also observed during summer months. The maximum average vehicle range occurred at 15-20 °C. At extreme low temperatures (below 0 °C) the range reduced by 21% and at extreme high temperatures (above 30 °C) the range reduced by 15%.
The chart opposite shows energy consumption (SoC / mile) by journey temperature.

- An increase in both average energy consumption and deviation in energy consumption as temperatures dropped below 18 °C and rose above 20 °C was observed. This is most likely to represent the drivers’ use of cabin heating and air conditioning, as well as factors not under the drivers control such as the vehicles’ battery management systems provided heating, cooling and restricting energy regeneration at very low temperatures as a battery protection measure.

- It was also apparent that the energy consumption in some very low and high temperature trips was similar to the ‘normal’ minimum energy consumption of a trip. This suggests that for longer journeys drivers reduced auxiliary power use to conserve energy.

**Key point**

The energy consumption and variation in energy consumption per mile increase at extreme high and low temperatures. Mainly due to human factors, such as an increase in climate control use, as well as other factors due to the characteristics of EVs. A significant amount of ‘normal’ energy consumption at extreme temperatures was also observed suggesting that for longer journeys drivers reduced auxiliary power use to conserve energy.
Range: Judgments of adequate and ideal EV Range

- At 3 months, Private drivers estimated that they could confidently drive 67 miles on a fully charged battery and Corporate drivers estimated they could confidently drive 76 miles on a fully charged battery.

- While Private drivers required less “day-to-day” range than Corporate drivers, they required a greater “Ideal” range in order to accommodate the relatively infrequent long-distance journeys that assumed a disproportionate importance in a driver’s mind.

- Private drivers were more likely than Corporate drivers to judge EVs to be practical (84% vs. 71%). This may be due to a greater variety of roles being required for corporate vehicles compared to private vehicles. Corporate drivers commonly stated that a vehicle needed to be “fit for purpose” and pointed to the fact that those purposes varied according to the job being undertaken.

**Key point**

Private drivers said they required less range for day-to-day driving than did Corporate drivers, but required more range to accommodate all trips. A 230 mile range would cater for the drivers of each group.
Charging
Charge start times

- The graph opposite shows the frequency of charging events by their start time. This frequency is split between events which occur on a weekday and a weekend. 83% of charge events occurred during weekdays where morning, afternoon and evening peaks occurred at circa 8am, 2pm and 9pm. On weekends drivers tended to charge vehicles more towards late afternoon, with no morning peak in charge activity.

- The 9pm charge peak shows that smart infrastructure is an effective method of transferring the charging load of EVs to outside peak electricity use hours. 27% of charges commenced between the hours of 9pm to 1am, this compared to 5.9% of journeys that ended within the same time period.

- The majority of day time charging (8am to 6pm) were due to Corporate vehicle drivers, with Private drivers dominating charging events out with these times. 68% of Corporate drivers charged during the day compared with 35% of Private drivers.

**Key point**

83% of charge events occurred during weekdays where morning, afternoon and evening peaks occurred at circa 8am, 2pm and 9pm. The 9pm charge peak showed that smart infrastructure was an effective method of transferring the charging load of EVs outside peak electricity use hours where 27% of charges commenced between the hours of 9pm to 1am, this compared to 5.9% of journeys that ended within the same time period.
Adapting to charging

Drivers did not anticipate any problems with charging their EV, or any safety issues involving charging.

The actual experience was even more straightforward than they had initially imagined.

Charging was handled differently according to whether drivers were Private (with personal wallbox) or Corporate (with work-based charging facilities).

Work-based charging was typically managed by a Fleet Manager who encouraged drivers to plug their vehicle in upon their return from each trip.

“We’ve drummed it into them. It must go on charge as soon as they’ve finished with it and not be left with anything less than 100% charge for the next user. Anybody that fails to comply, we will knock them off the scheme.” Fleet Manager

“IT’S VERY EASY. IT’S AS EASY AS PLUGGING IN ANY APPLIANCE, SO IT’S VERY STRAIGHTFORWARD.” Private Driver

Key point

Charging was easy and safe. Private drivers quickly established a routine for themselves and did not charge each day. Pooled Corporate drivers charged after every trip in order to accommodate the next driver.
Charging: Private vs Corporate drivers

Private drivers quickly learnt that they did not need to charge their EV at every available opportunity.

In contrast, pooled Corporate drivers were often required to charge upon completion of each trip. Such a charging regime made sense in ensuring that cars were always ready to be used by the next driver. However, there was an unintended consequence inasmuch as Corporate drivers did not learn how many trips and how many days could be accommodated on a single charge.

Consequently, it is not surprising that Corporate drivers showed elevated levels of concern about reaching destinations and had little concern of the factors that reduced range (as they rarely reached the lower SoC that would make the effect of such factors clear).

“I just think that being able to charge up at home is an added advantage than having to go to a filling station” Private Driver

“I prefer charging to going to petrol stations

Private Only 3mth Corporate Only

Private drivers valued the freedom of not being tied to expensive fuel prices.

Corporate drivers did not show the very high levels of preference for charging compared to refuelling at petrol stations. This may be a function of having to charge following each trip (whereas refuelling was done far less frequently) and not being able to receive personal financial compensation for driving an EV as they would an ICE.

Key point

Private drivers did not charge at each available opportunity. Corporate drivers charged each trip and consequently did not learn how many trips/mileage could be achieved on one charge. Private drivers showed a marked preference for charging over refuelling at petrol stations. Corporate drivers did not and some also lamented that they did not benefit financially from driving an EV as they did an ICE.
**Distance travelled between charges**

- The average distance travelled between charging was 25.4 miles.

- Pool drivers adopted good practice in frequently charging the EVs leaving a full charge for the next user. Whereas Individual drivers had the freedom to plan charging with their anticipated vehicle use. This feature was also observed in the average distance drivers travelled between charging, with Pool drivers travelling 22.3 miles compared to Individual drivers whom achieved an average of 28.7 miles.

- Drivers with timed infrastructure achieved a higher average mileage between charging of 30.3 miles compared with those without timed infrastructure who achieved 21.6 miles. This suggested that timed infrastructure, offering lower cost off-peak electricity, both decreased opportunity charging during the day and charging at times of peak electricity demand.

- Distances travelled between charging steadily rose by an average of 14.9% over the first 6 months of vehicle ownership. Since average trip length did not increase over the same period this showed that drivers were gradually becoming more confident undertaking more journeys between charge events.

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**Key point**

The average distance driven between charging was 25.4 miles. Pool drivers adopted good practice in frequently charging the vehicle leaving a full charge for the next user. Whereas Individual drivers had the freedom to plan charging with their anticipated vehicle use. Over the first 6 months the distances travelled between charging steadily rose by an average of 14.9% showing that drivers were gradually becoming more confident undertaking more journeys between charge events.
Charging: battery SoC transferred

On average the EVs were placed on charge 3.5 times per week. Corporate drivers charged more frequently at 3.7 times per week compared to 3.3 times for Private drivers.

The graph opposite shows the SoC at charge commencement was broadly distributed between 25% and 90%. The EVs were mostly charged until full with the majority of charging (>70%) ending at over 95% SoC.

The average SoC at the start of a charging event was 58%.

Throughout the loans the drivers gradually increased the average SoC being transferred during a single charge from 29.0%, 33.2% to 34.3% during months 1, 3 and 6 respectively.

This supports the observation made earlier where drivers also increased their journey distance travelled (and hence energy consumption) between charging.

Key point

On average the EVs were placed on charge 3.5 times per week. Corporate drivers charged more frequently at 3.7 times per week compared to 3.3 times for Private drivers. The average SoC at the start of a charging event was 58%. Throughout the loans the drivers gradually increased the average SoC being transferred from 29.0%, 33.2% to 34.3% during months 1, 3 and 6 respectively.
Views on public infrastructure

Both sets of drivers strongly believed they could complete their trips without a public charging infrastructure. On average, Private drivers had used public charging 6 times during their trial, with only 21% of them reporting public charging as easy to find and only 42% of them reporting public charging as easy to use.

Corporate drivers had a strong pre-trial desire to have a public charging infrastructure and this was maintained at a high level by the 3 month mark. Relatively speaking, Private drivers reduced their desire to have a public charging infrastructure by the 3 month mark. The differences were likely due to the relatively routinized nature of the Private drivers’ journeys (where home charging was largely sufficient for trips) as compared to the wider potential of trips that could need to be taken by Corporate drivers.

Private drivers’ sense of a public charging infrastructure dropped (but still remained high) after having driven their EV. Corporate drivers remained convinced that public charging sites were essential for the integration of EVs into their fleet.
Charging locations

- The majority of consortia used the GPS devices in the vehicles to create geo boundaries where locations of known charge points could be identified. Charge locations were classified as ‘Work’, ‘Home’ and ‘Other’. The pie chart opposite shows that most charging occurred at Home. ‘Other’ locations include any location not recognised as a home or work location (for example, public infrastructure, charging at external meetings, social occasions, charge points not recorded on the consortia locations database etc).

- Two Consortia gave more detailed information about charge location, and in this instance public charging could be separated from the ‘Other’ category. Here 10% of charging occurred at Public charge points.

- Interestingly home charging dominated the data set even considering that 58% of users had access to work place charging. This is because drivers with infrastructure installed only at their home used it 97% of the time. Even drivers with official infrastructure points installed only at work conducted 9% of recharges at home, using their domestic electricity supply.

Key point

The data showed that 10% of charging was conducted at public infrastructure points. Home charging was the most popular charging location. Drivers with infrastructure installed only at their home used this 97% of the time. Even drivers with official infrastructure points installed only at work conducted nearly 1 in 10 recharges at home, using their domestic electricity supply.
Drivers’ responses showed that for general charging, times of just over 2 hours would be seen as ideal.

Corporate Managers indicated that when an EV was being charged the “asset” was out of operation. In order to maximize or “sweat the asset”, managers told us in interviews the recharge time would need to be as quick as possible.

“One of the big issues at the moment with a fleet vehicle is ‘sweating the asset’. It’s utilising the vehicle to its fullest potential, which is double shifting. So if you’ve got it out on days and then another crew come in and it can go out on nights as well, so you’re getting more usage out of that vehicle obviously. You’re not easily able to do that with electric vehicles, because you have a limited range before you need 6 – 8 hours of charge.” Manager

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th>3mth</th>
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<tbody>
<tr>
<td><strong>Private Sufficient</strong></td>
<td>325 Mins</td>
<td>278 Mins</td>
</tr>
<tr>
<td><strong>Corporate Sufficient</strong></td>
<td>411 Mins</td>
<td>239 Mins</td>
</tr>
<tr>
<td><strong>Private Ideal</strong></td>
<td>152 Mins</td>
<td>137 Mins</td>
</tr>
<tr>
<td><strong>Corporate Ideal</strong></td>
<td>180 Mins</td>
<td>125 Mins</td>
</tr>
</tbody>
</table>

Drivers considered a charging time of just over 2 hours to be ideal for personal charging. Corporate managers pointed to much faster charging times as being essential in order to gain maximum use of EVs in a multi-driver fleet.
Drivers’ Opinions on Environmental Aspects and EV Purchasing Requirements
Energy

Private and Corporate drivers strongly believed that widespread use of EVs would lower carbon emissions in the UK at both pre (90%) and 3 month (87%) points of data collection. However, Corporate drivers showed a clear preference for using renewable energy either as a source, or the only source of power for EVs. This may, in part, be due to the number of Corporate drivers who were employees of organisations involved in energy or in organisations intent on reducing carbon emissions:

“We need to be seen to be actively engaged in trying to lower our environmental impact and of being an example, leading by example.”

All drivers believed EVs lower carbon emissions. Corporate drivers were often employed by organisations involved in energy or intent on reducing carbon emissions. These drivers endorsed the use of renewable energies more strongly than did Private drivers.
Safety and low noise

- EVs were positively compared to normal cars in terms of safety.
- The lack of engine noise was often a pre-trial concern for drivers, but this was quickly seen as an asset of EVs in providing a more relaxing driving experience.
- Over time, drivers’ sense of the low noise being a danger to people outside the car dropped.
- Corporate drivers showed stronger agreement with the statement that pedestrians had failed to notice them (Private: 34% vs 54% Corporate). These results may reflect the greater amount of time spent driving in built-up urban areas and car parks.
- Drivers rarely indicated they had not being noticed by other drivers, cyclists, or animals as a result of the low levels of noise.
- Drivers paid more attention to their surroundings and other road users, especially when driving in low-speed areas.

Key point

EVs were compared positively to ICE vehicles in terms of safety. Low noise became seen as an asset of EVs. Drivers paid more attention to pedestrians than they would normally when driving at low speeds.
The data above indicated that people expected EVs to be marketed at the same price as their ICE counterparts. 85% of Private drivers saw EVs as the cars of the future, 80% could imagine replacing one of their existing vehicles with an EV and 50% intended to purchase an EV after the trial. 60% indicated that they would still own an ICE as a backup, with a smaller proportion of drivers (50%) claiming they would only need occasional access to an ICE for journeys that required greater range than is currently offered by EVs. Only a minority of drivers (33%) imagined that they would only have an EV.

**Key point**

People expected EVs to be priced at the same level as normal vehicles. They wanted their financial benefit, through lower running costs, to be immediate. 80% of drivers could imagine replacing one of their vehicles with an EV, and 50% intended to do so upon completion of the trial. The majority of drivers would still own an ICE in partnership with an EV.
Purchase Intentions: Battery Aspects

- Drivers felt that batteries should cost £1,957 to replace and thought that they should last 65 months before needing to be changed.
- As there are fewer moving parts to an EV, drivers assumed they will be easier to maintain.
- On the other hand, drivers stated that they could not take an EV to a normal garage for a service and wondered what support would be available to them.
- The residual value, second-hand market, and insurance are currently important unknowns that would influence whether a person bought an EV.
- Additionally, the state of technological development is currently unknown, meaning that some drivers pondered whether they could potentially be left with a vehicle that would quickly become technologically obsolete.

**Key point**

Residual value, second-hand market, insurance, battery, maintenance costs, and how quickly the current EV technology will be surpassed influenced drivers’ intentions to purchase an EV.
Drivers’ interactions with non-EV drivers

91% of drivers would recommend EVs to others. Drivers were interviewed about their encounters with members of the non-EV driving public. We found that 3 major categories of views (Traditional, Ambivalent, Positive) were held by the public about EVs.

1. **Traditional**: Affective-based negative stereotype existed with those individuals holding such views lacking knowledge or experience of EVs. Yet, these people frequently made confident assertions about their deficiencies and were resistant to contrary or disconfirming information. These supposed deficiencies were seen as justification for not finding out more about EVs.

2. **Ambivalent**: Cognitively-based, ambivalence showed people to hold some negative views about past EVs but also to be willing to assess the capabilities of current EVs. These people were more receptive to learning than those who embraced the *Traditional* stereotype, and were prepared to go beyond immediate impressions by ‘looking at the finer points’. Their approach was primarily based on rational judgements and weighing up the advantages and disadvantages of EVs and they entertained the notion of owning an EV in the future.

3. **Positive**: Based on a combination of affect, cognition and behaviour, the Positive view was held by non-EV drivers who were engaged with the new technology and saw EVs as well developed now and also as cars of the future. These people converted to the EV drivers’ point of view. This largely occurred following an encounter with the EV itself, which shattered preconceptions about poor performance and instantly exceeded expectations, leaving people surprised and impressed. As a result of this personal contact, members of the public came to see EVs as (a) real; (b) normal in appearance and performance; and (c) viable as a functional means of transportation.

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**Key point**

The traditional view of EVs is becoming challenged by groups of people who would be useful targets for future marketing. EVs need to perform and look as good as normal ICE cars, but still be distinguishable as EVs (e.g., through branding, logos, etc) in order that the variety and presence of contemporary EVs are visible to the non-EV driving public.
Concluding statements

- EVs were positively received by drivers in the trial and were showed to be viable for everyday life. Typical stereotypes of EVs (e.g. owners being purely environmentally focused and EVs having lower drive performance than conventional vehicles) were shown to be outdated. The drivers in this trial drivers were mainly car enthusiasts, interested in assessing EV practicality, and had a desire to advance driving technology.

- The majority of drivers whom took part in the trial clearly had access to another vehicle and tended to use the EVs for regular and repeatable journeys. In fact, drivers entered the trial with the intention of using the EV in conjunction with their normal vehicle, and not as the sole vehicle available for use.

- The drivers were quick to adapt and there was little range anxiety experienced as most drivers got nowhere near the potential range capability of the EVs.

- Over the first 6 months the distances travelled between charging steadily rose by an average of 14.9% showing that drivers were gradually becoming more confident undertaking more journeys between charge events.

- There were different levels of adaptation (primary and secondary), with primary adaptors quickly gaining a satisfying level of comfort, performance and routine from the EV. Secondary adaptors attempted a more thorough integration of the EV within their lives and continued to investigate range and performance boundaries. There was limited secondary adaption within the trial. Training, and encouraging users to break down comfort zones, can be used to enhance secondary adaptation, especially with Corporate vehicles users.

- Drivers expressed a need for better range prediction from the vehicle and better feedback from the effect of factors linked to range e.g. regenerative braking, driving style, ambient temperate and on-board features. Improvement in this area would also increase the range potential of the vehicles.

- When looking at EV purchasing intentions drivers required EVs to be comparable to ICE vehicles on many dimensions: Performance, Cost, Range, Convenience and to be superior in terms of environmental efficiency – these are the things that the consumer wants.
### Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
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<tr>
<td>DfT</td>
<td>Department for Transport</td>
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<tr>
<td>EV</td>
<td>Electric vehicle</td>
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<tr>
<td>FCEV</td>
<td>Fuel cell electric vehicle</td>
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<tr>
<td>ICE</td>
<td>Internal combustion engine</td>
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<tr>
<td>mth</td>
<td>Month</td>
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<tr>
<td>OEM</td>
<td>Original equipment manufactures</td>
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<tr>
<td>PHEV</td>
<td>Plug-in hybrid electric vehicle</td>
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<tr>
<td>SoC</td>
<td>Start of Charge</td>
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<tr>
<td>TSB</td>
<td>Technology Strategy Board</td>
</tr>
<tr>
<td>ULCV</td>
<td>Ultra low carbon vehicle</td>
</tr>
<tr>
<td>ULCVD</td>
<td>Ultra low carbon vehicle demonstrator</td>
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### Disclaimer

This work was carried out by Cenex and Oxford Brookes University for the Technology Strategy Board. The information presented is based on a data supplied by the trial consortia. Whilst all analysis of this information is provided in good faith, the ideas and conclusions presented in this report must be subject to further investigation, and take into account other factors not presented here, before being taken forward. Therefore the authors disclaim liability for any investment decisions made on the basis of this report.