Go Ultra Low Oxford

Monitoring and Evaluation of Phase One

Final Report

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Executive Summary

On-street charging technologies can help to reduce a key barrier to ultra-low emission vehicle (ULEV) uptake by enabling access to charging infrastructure for those who live in housing without private off-street parking space. A consortium of partners led by Oxford City Council is undertaking Go Ultra Low Oxford (GULO). Funded by the Office of Low Emission Vehicles (OLEV) and running from 2017 to 2021, GULO is developing plans for deploying electric vehicle charging infrastructure across Oxford.

This report is focused on GULO Phase One (2017-2019), which was a trial of five different on-street electric vehicle (EV) charging technologies across 28 locations on public streets in Oxford. These included lampposts converted to include charging capability; three types of bollard chargers; and one type of home charger coupled with a channel dug into the pavement to allow for a cable to be trailed across the footpath.

16 private householders and 5 car club members took part in the trial. The Transport Studies Unit (TSU) was appointed as an independent evaluator, and this report presents findings from monitoring the experiences of trial participants, as well as insights from project partners other stakeholders. The small numbers of trial participants imply that findings need to be interpreted with care.

Performance

The TSU have developed a set of criteria for evaluating the performance of on-street charging technologies, from the user perspective. These are:

- Ease of access;
- Ease of use;
- Installation footprint;
- Robustness;
- Data and billing;
- Maintenance and repair;
- Price;
- Speed of charging.

Other stakeholders such as local authorities, charge point manufacturers and operators may consider additional criteria when evaluating the performance of on-street chargers. We have identified four such criteria:

- Utilisation
- Adoption capacity
- Neighbour complaints
- Commercial sustainability

When evaluating technologies, local context is crucial. Factors such as parking pressure, the location of lampposts, whether storm drains are integrated into pavements, current and predicted uptake of EVs, and low voltage grid capacity each influence which technologies are suitable for different urban environments.

In Oxford, stakeholders were surprised by the number of instances of vandalism and breakdown, which led to lengthy periods in which a few chargers were non-operational. Breakdown impacts battery electric vehicle (BEV) drivers more severely than those with plug-in hybrid electric vehicles (PHEVs).

User Practices and Routines

The evaluation revealed a number of creative practices with respect to gaining access to chargers, and optimising battery range. These included adaptations to parking routines, driving style, route choices and the use of heating and air-conditioning when driving.

Charging habits varied widely between users, with some regularly charging overnight, and others plugging in during the day or more often on weekends. These factors varied according to how people used their cars.

There were considerable differences in the charging and driving practices of BEV and PHEV users. Relying to a greater extent on chargers, BEV drivers suffered most when chargers could not be accessed or had broken down.

Participants' charging practices changed over time, as they became familiar with the equipment and developed techniques. For instance, their bodily movements became more precise, and the time taken to plug-in their EVs reduced over time.

When asked whether they had a preference for any of the charger types, two-thirds of respondents chose the technology that they had been allocated. This can be taken as an indicator of considerable satisfaction with the assigned technology.

Community responses

Traffic Regulation Orders (TROs) associated with the trial attracted 59 responses, including 28 objections. These mostly raised concerns about parking impacts, and access to shops and services.

Signage associated with TROs caused unexpected controversy among users and neighbours. The text on signposts was ambiguous, and either misinterpreted or ignored by trial participants and local residents in several instances. Enforcement of the parking restrictions was inconsistent.

Users reported a range of interactions with neighbours, friends and family relating to charging. Whilst most reported positive and supportive engagements, others expressed feelings of vulnerability when charging their vehicles.

Scaling up

Expansion of on-street charging will require collaboration across the public and private sector. There is an urgent need for interoperability across charger-types, enabling contactless payment and to remove unnecessary barriers to users.

Lampposts performed best in this trial. They are a low-cost solution which proved popular amongst users. Even when sited away from the kerb, the existing electricity supply can be directed through a paired bollard or cable channel. Promotional signage should be deployed to boost usage and promote uptake.

The business case for installing on-street charging bollards in the residential areas considered in the trial is not currently attractive. The requirement for new electricity grid connections, a dedicated parking bay make the cost of installation high when compared with lamppost-conversions or home chargers, and evidence from this trial indicates that the involvement of multiple stakeholders and regulation can lead to lengthy delays.

TROs were perceived negatively by many stakeholders and residents, and were cited as the cause of substantial delays during the trial. Several options are available for local authorities to avoid issuing TROs. These include deploying multiple installations simultaneously; encouraging residents to negotiate parking themselves; and the use of informal arrangements such as advisory signage.

Privately funded home chargers and cable channels should be encouraged with clear guidance for installation.

Plans for infrastructure roll-out should not simply reflect current demand, skewed towards wealthy neighbourhoods, but should recognise the potential benefits for all communities.

There are a range of 'hidden' costs associated with maintaining public charging infrastructure. With the conclusion of Phase One of the GULO project, Oxford City Council and other stakeholders are grappling with the question of how to fund the ongoing maintenance and repair of chargers.

Partners

1. Introduction

Go Ultra Low Oxford Phase One was a pilot project that trialled five different on-street electric vehicle charging technologies across 30 locations on public streets. Funded by the Office of Low Emission Vehicles and supported by the European Regional Development Fund, this trial ran from July 2017 to June 2019. Phase Two will install up to another 100 chargers before March 2021.

Participants in the trial included both private householders, and members of a car club, Co-wheels.

The Transport Studies Unit (TSU) at the University of Oxford was commissioned by Oxford City Council as an independent evaluator of the trial.

This report is structured into five main sections. The introduction provides background information about the trial, including the five charging technologies and the research and methods approaches taken in the evaluation. The remaining four sections are based on each of the objectives listed above.

> ***"We want to use the trial to understand how different charging technologies work in 'real life' - how well they fit into people's daily routine and how quickly people can adapt to use them.***
> ***We are also interested in how well the technology performs technically, and how easy it is for the councils to install."***
>
> ***Go Ultra Low Oxford Website***

Evaluation Objectives

The evaluation by the TSU had four main objectives:

1. Evaluate the performance of the various on-street charging installations;
2. Examine the adaptations to car use routines and the formation of charging habits among pilot participants;
3. Identify local community responses to the charging installations;
4. Develop insights about how the pilot may be scaled up within Oxford and transferred to local authorities elsewhere in the UK.

The Trial

30 locations were originally planned for installations throughout Oxford city. 20 would be located close to the dwelling of private households who had signed up to the trial. The remaining 10 would be provided for car club users.

By the end of the trial, a total of 46 charge points had been installed across 28 locations. These included 29 lamppost chargers, 12 bollard-style chargers and 5 home chargers.

A total of 16 private householders and 5 car club members took part in the full trial. Of the 16 householders, 6 participated using 100% battery electric vehicles (BEVs); 8 used plug-in hybrid vehicles (PHEVs); and 2 had extended range vehicles (EREVs). At the time of writing (July 2019), the car club has 9 EREVs in Oxford. Table 1 illustrates which technologies are used by each of the car types in the trial. The small numbers in the various categories imply that findings need to be interpreted with care.

Table 1: Charging installations and EV types

	BEV[1]	PHEV	CC-EREV
Ubitricity	3	2	4
Chago Station	1	1	2
eVOLVE e-Post	2		1
Zeta Smartscape		2	2
Home charger	2	3	

[1] The private EREVs in this trial are treated as BEVs, reflecting how they were mainly used by participants.

Further details of the sample of participants, including their socio-demographic characteristics, can be found in the 1st and 2nd interim evaluation reports produced for GULO by the TSU.

Research methods

The TSU adopted a longitudinal, mixed-methods approach to the GULO evaluation.

- Qualitative data included in-depth interviews with trial participants. Beginning with a pre-trial interview, private household participants each contributed three further interviews over the course of the trial. During two interview rounds, participants were asked to demonstrate the use of the charging installation assigned to them. Two interviews were conducted with participating car club members, after three and nine months.
- Interviews with stakeholders including council staff, technology manufacturers, operators, funders and the distribution network operator (DNO) were also used.
- Surveys of participants were carried out during each interview to trace how habits, attitudes and community interactions changed over time.
- Further quantitative data was gathered from charging point use, repeated observations of the installations, and responses to City and County Council consultations.

"This is a great project and a great example of using Oxford as a 'living lab' to get new ideas on the ground fast to benefit residents. The pilot element of the project is a learning experience – identifying the best charging solutions for different situations and locations and using our assets in better, smarter ways will help minimise costs. We hope to take what we have learnt from this project and look at how we can support on street charging across the whole of Oxfordshire."

Councillor Ian Hudspeth, Oxfordshire County Council leader

Figure 1 - City Councillors, Officers and a user at a trial installation

Geography

The chargers used by 16 private households in the trial were relatively evenly distributed across Oxford (see Figure 2).

The various installations were located in a range of neighbourhoods and street settings. Some were found in lower socio-economic areas in the east of the city (e.g., Cowley, Littlemore, Headington) and others in more affluent neighbourhoods (e.g., Jericho, Summertown).

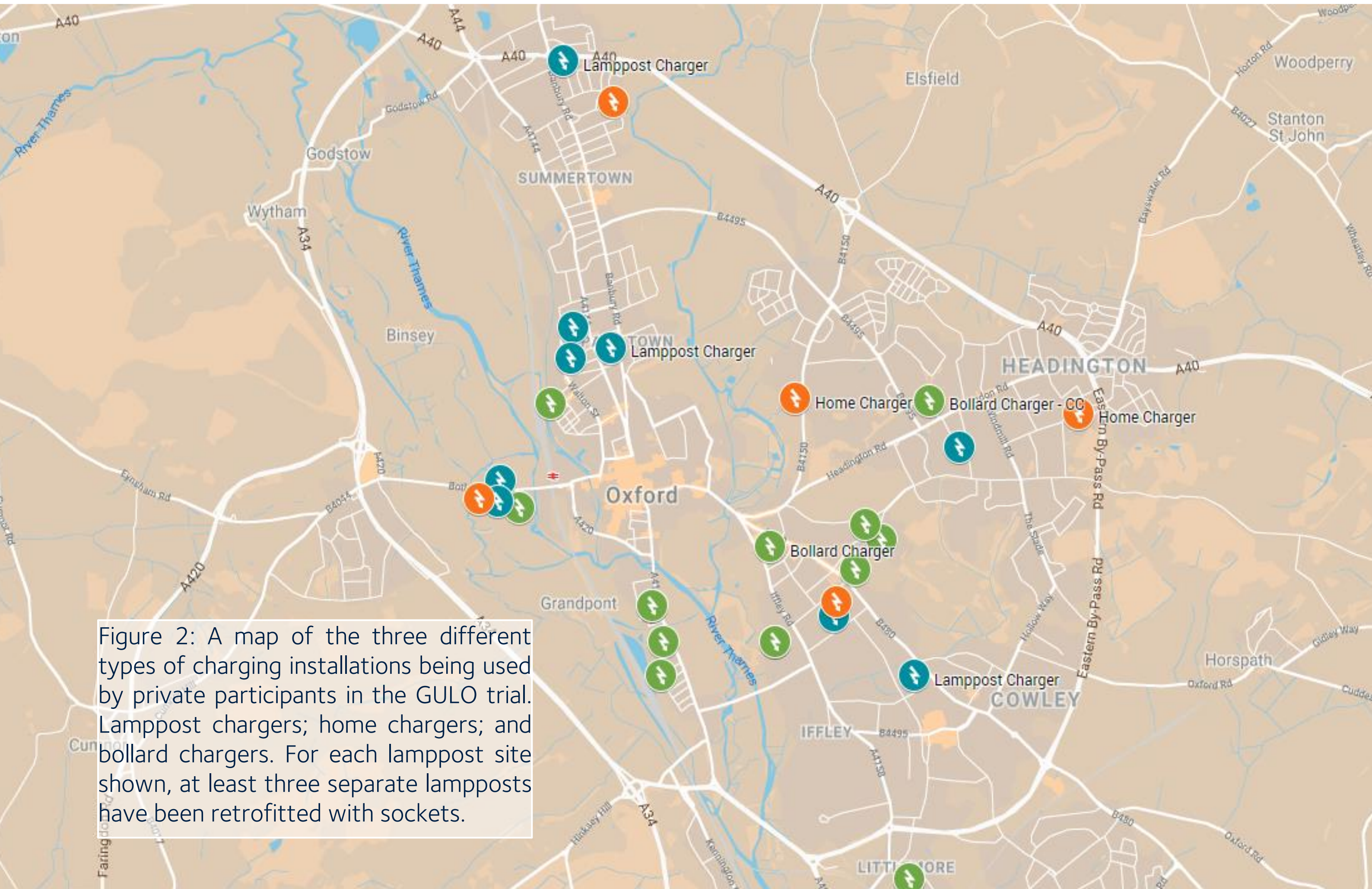


Figure 2: A map of the three different types of charging installations being used by private participants in the GULO trial. Lamppost chargers; home chargers; and bollard chargers. For each lamppost site shown, at least three separate lampposts have been retrofitted with sockets.

Charging Technologies

Five charging technologies have been trialled.

29 lampposts have been retrofitted with EV charging points in 11 streets throughout Oxford. No dedicated parking bays have been allocated. These installations can be accessed only by using an **Ubitricity** SmartCable, with an in-line meter and billing system. The cost (RRP £199) of the SmartCable was met by the trial for all participants. Charging is initiated when plugging in the cable, with no further user interaction required. Ubitricity offers a smart phone app to keep track of usage and payments.

Three types of bollard chargers have been included in the trial. They have been installed in Oxford alongside dedicated parking bays. The Zeta Smartscape is a prototype design, manufactured by an Oxfordshire-based company and developed further since the trial started. Each bollard is operated using an RFID card supplied by **New Motion**, which operates payment and billing for the GULO trial. Users are required to sign up with New Motion, which offers a smartphone app. Any issues such as damage to the bollard are reported via New Motion.

Five households were provided with a home charger, installed on the front of their house with a dedicated meter. Billing occurs via residents' existing electricity provider. For each installation, a gully was dug into the pavement to allow cables to run from the charger to the car without presenting a trip hazard.

Co-wheels car club have deployed 9 electric vehicles across Oxford, each with an allocated parking bay close to a charger. As of July 2019, these vehicles are all EREVs, and use the three bollard technologies as well as lamppost chargers.

Lamppost chargers

Type:	Ubitricity Lamppost Charger
Power output:	3.2 – 5.5kW
Access:	Accessible with smart cable only.
Payment:	Ubitricity payment account
Features:	Can be retrofitted into existing lampposts. 1 socket per installation. 3 per site.

Bollard chargers

Type:	Zeta Smartscape Charging Bollard
Power output:	7.2kW
Access:	RFID card and app access
Payment:	New Motion payment account
Features:	Slim-line design suitable for narrow footways. 1 socket per bollard. This is a prototype, developed by a local Oxfordshire company.

Type:	eVolve e-Post Charging Bollard
Power output:	7.4kW
Access:	RFID card and app access
Payment:	New Motion payment account
Features:	Instructions available on-screen. 2 sockets per bollard.

Type:	Chago Station Charging Bollard
Power output:	7.4kW
Access:	RFID card and app access
Payment:	New Motion payment account
Features:	Load balancing available to manage output. 2 sockets per bollard.

Home chargers

Type:	APT eVolt Home Charger and Cable Channel
Power output:	3.7kW
Access:	Smart energy meter
Payment:	Domestic electricity tariff
Features:	Resident can use own home power supply

Figure 3: On-street charging technologies included in the Go Ultra Low Oxford trial.

2. Evaluating the performance of charging installations

Over the course of the trial, we have developed a set of criteria for evaluating the performance of the various on-street charging installation.

Performance from the user perspective

The following criteria have been developed primarily from the user perspective and were derived from interviews with participants. In two rounds of interviews private participants were asked to demonstrate how they used the installation in the vicinity of their home. Analysis of the recorded demonstrations, alongside participants' narratives during the interviews, resulted in the identification of eight criteria.

Ease of access is based on proximity of the charger to residents' homes, availability of one or more dedicated parking bays, and ease of parking.

Ease of use is based on the user friendliness of cable, installation interface and smartphone app, taking account differences in users' bodily capacities (e.g. ease of moving around, ability to bend over/knees, muscle strength, eyesight, digital literacy).

Installation footprint is a measure of how seamless the technology is integrated into the streetscape, in terms of risks to vehicles and other street users (pedestrian trip hazard, hazard to cyclists and vehicles on the road) as well as aesthetics.

Robustness is a measure of the reliable functioning of equipment and resilience to vandalism and minor collisions with vehicles (e.g. during parking)

Data and billing is assessed from the perspective of interviewees. Is usage data and billing accurate, quick, easy to understand and access?

Maintenance and repair is measured by (1) the ease and speed with which technologies are repaired; (2) how easy it is for users to report faults and (3) the ability to see which (alternative) chargers are operational

Price is based on the cost of charging in absolute terms (£/kWh plus connection fee) and especially relative to other charging options, fossil fuels and electricity in one's home.

Speed of charging is a simple but important criterion. It is assessed by comparing reported power outputs, with actual charging data from the trial.

Table 2 summarises the evaluation scores, which are based on five-point scales, with 1 = very poor/low and 5 = very good/high.

Performance according to other stakeholders

Besides the user-focused criteria, other stakeholders such as local authorities, charge point manufacturers and operators may consider additional criteria when evaluating the performance of on-street chargers. We have identified four such criteria.

Utilisation refers to the extent to which a charging point is used over a period of time (e.g. 24h, week).

Adoption Capacity is the potential for adoption by new or extra users. This is determined by features such as the number of ports available, interoperability (e.g. RFID access and payment systems) and whether the location of the installation restricts access and use (e.g. need for a parking permit, private property).

Neighbour Complaints is based on the frequency with which users and non-users in the vicinity of an installation raise objections with the local council, and the nature of their complaints (e.g. increased parking pressure).

Commercial sustainability is based on the extent to which there is a 'business case' for sufficient profit to be made by manufacturers and operators.

Table 3 evaluates the five technologies in the GULO trial using these criteria, and further information on installation costs can be found in Section 5

It is worth nothing that tensions and conflicts may occur when evaluating performance from the perspective of users and other stakeholders. For instance, commercial operators may wish to maximise the utilisation of chargers by attracting visitors, which may hinder residents' access to chargers.

Table 2	Lamppost charger	Bollard-style chargers			Home charger
	Ubitricity	Chago Station	eVolve e-Post	Zeta Smartscape	APT
Ease of Access	★★★★☆ New users must purchase cable and sign up with Ubitricity. SmartCable cost of £199 may be barrier to wider adoption. Other options have since become available.	★★★★★ Chargers are deployed alongside dedicated parking bays. Some reports of parking difficulties, particularly where vehicles have sockets at the side. Type 2 charging cable required.	★★★★★	★★★★★	★★☆☆☆ Installed on private property; not available to public. Parking close enough, and without cables sticking out into the road, can be a challenge.
Ease of use	★★★★☆ Charging begins on plug-in with no need for further user interaction.	★★★☆☆ Users reported how design and lack of instructions made the bollards initially difficult to use, with the Chago Station marginally less easy. As with all chargers, participants improved their techniques over time.	★★★★☆	★★★★☆	★★★☆☆ Typically requires a long cable (>10m) which can be difficult to handle and manipulate into the pavement channel.
Installation footprint	★★★★★ Seamlessly integrated into existing street furniture.	★★☆☆☆ Both charger and transformer need to be accommodated on the footpath. Compared with the other bollards, the Zeta Smartscape was praised by users for its small footprint and low profile. However, its diminutive height may be one reason why this bollard was subject to more vehicle collisions.	★★☆☆☆	★★☆☆☆	★★★☆☆ Appearance of box and RCD on front of house proved unpopular. Pavement channels integrate into streetscapes where storm drains already exist.
Robustness	★★★★☆ Very few examples of breakdown or vandalism. Reported to be reliable by users.	★★☆☆☆ Numerous examples of socket doors being damaged or removed, with one of	★★★★★ Subjected to vandalism and vehicle strike but have remained functional.	★☆☆☆☆ Numerous reports of break-down, either due to apparent vandalism,	★★★★☆ Largely reliable and robust. In a couple of instances the cables

		two sockets not functioning for long periods.	Some reports of one socket not working for periods.	vehicle strike or unknown faults.	became deformed and stopped working.
Maintenance and repair	★★★★☆ Largely quick and straightforward to maintain and repair. Few examples of delays upon breakdown, although two cases of malfunction led to a lengthy delays for two users.	★★☆☆☆ Several reports of one socket being non-operational for lengthy periods.	★★★★☆ Fewer instances of breakdown than other bollards.	★★☆☆☆ Not modular in design Lack of replacement parts and units Long repair times	★★★☆☆ No information available on fault reporting Cables appear to be vulnerable to deformation Lack of temporary replacement parts
		Users complained of lack of fault reporting information on installations. When reporting via NewMotion app, several complained of no response and no evidence that reporting had led to repair.			
Price	★★★☆☆ Ubitricity is competitive with other public charge points, although the separate connection fee was perceived negatively by some users.	★★★★☆ New Motion's electricity prices are competitive compared with other public chargepoints.	★★★★☆	★★★★☆	★★★★★ Integrated into home electricity supply, prices can be competitive, depending on users' chosen tariff.
Data and billing	★★★★☆ Ubitricity app highly rated by those who used it. Many users preferred to use vehicle app instead, and had little awareness of charges due. Example reported of user not being charged by Ubitricity for >1 year.	★★★★☆ NewMotion smartphone app highly rated by users. Usage data can be downloaded. Data available for analysis in the trial was limited. New Motion explained that the Chago Station and E-Volve E-Post were unable to provide full charge session data.	★★★★☆	★★★★★	★★★★★ Separate sub-meter installed for chargers allows users to separately monitor their usage. Online portal available.
Speed of charging	★★★★☆ Median speed: 3.77kW. During the trial, installations were upgraded to enable speeds of 5.5kW. Users mostly satisfied with speeds.	★★★★☆ No median speed could be calculated as NewMotion were unable to provide data on length of charging episode. Bollard chargers are designed to discharge at 7.4kW for BEVs and 3.7kW for PHEVs, and there were no reports from users of speeds being slower than expected.	★★★★☆	★★★★☆	★★★★★ Median speed: 6.48kW. Faster than a standard 3-pin plug, and very reliable speeds.

Table 3	Lamppost charger	Bollard-style chargers			Home charger
	Ubitricity	**Chago Station**	**eVolve e-Post**	**Zeta Smartscape**	**APT**
Utilisation	★★★★☆ Large number of charging episodes, spread across 29 lampposts.	★★★☆☆ Low levels of utilisation compared with lampposts and home chargers (see Table 4)	★★★☆☆	★★☆☆☆ Very low usage, partly due to lengthy periods of breakdown.	★★★★★ Highly utilised by householders during the trial.
Adoption capacity	★★☆☆☆ SmartCable cost of £199 may be barrier to wider adoption. Existing lamppost placement may constrain roll-out. Those within controlled parking zones limit visitor usage.	★★★★★ Limited locations due to local resistance to dedicated bays. Adoption currently limited by lack of interoperability (contactless payment) and lack of any in-situ instructions for signing up.	★★★★★	★★★★★	★☆☆☆☆ Very limited potential for wider adoption due to private nature of installation. Peer-to-peer platforms such as EVmatch may allow for wider use.
Neighbour Complaints	★★★★☆ Some examples of objections raised by users regarding the specific lampposts chosen for conversion.	★☆☆☆☆ The dedicated parking bays allocated for bollard installations attracted a number of objections, mostly citing parking pressures and access to shops and services. Complaints were also made in relation to the time taken to connect electricity supply, and periods of breakdown.	★☆☆☆☆	★☆☆☆☆	★★★★★ No reported complaints or accidents associated with trailing cable or pavement channel.
Commercial Sustainability	★★★★☆ Low cost of technology and installation means that Ubitricity are actively pursuing on-street charging as a business model.	★☆☆☆☆ Relatively high costs of installation and low utilisation mean that each bollard manufacturer and operator explained when interviewed that they did not consider residential on-street locations to be commercially viable in the near term (5-10 years).	★☆☆☆☆	★☆☆☆☆	★★☆☆☆ Assuming no subsidy for this technology beyond the trial, the business case remains unproven.

Performance overview

In Oxford, the lamppost chargers performed well across all criteria, with a slight edge over the other technologies. Users reported them to be reliable and easy to use. The maximum speed of charging is slightly lower than for bollard-style or home installations, meaning that they may not be optimal for car-club vehicles which require fast charging when bookings are made close to one another.

Home chargers with cable channels were popular amongst users, scoring well across a range of criteria. However, their adoption capacity is comparatively limited.

Collectively, bollard-style chargers seemed to perform adequately on most criteria, although comparatively lower against installation footprint and maintenance and repair.

The performance of different chargers on some criteria such as ease of access and the impact of an installation's footprint depends to some extent on contextual factors such as characteristics of the vehicles (size of the vehicle, position of the flap), characteristics of the street (width) and the parking bay (length of the bay) and others' parking practices.

Caveats and limitations

Whilst our criteria have been developed to give a broad and objective assessment of the five charging technologies, there are factors which make their objective comparison challenging. Caveats and limitations include:

- The sample includes a variety of vehicle types (BEV; EREV; PHEV). These have implications for charging practices: PHEVs can be operated without ever needing to charge, whereas BEVs require regular access to chargers.

A preference for familiarity

In our 4th interview with trial participants, we showed videos of all the charging technologies being used, and explained the features of each.

When asked whether they had a preference for any of the charger types, **2/3rds of respondents chose the technology that they had been allocated.**

This demonstrates that as ULEV drivers became familiar with the technologies and developed charging habits, they grew fond of their installation.

- Our sample does not include an equal distribution of vehicle types across the five technologies trialled (see Table 1). For example, the Chago Station bollard has not been trialled by a user of a BEV.
- Variation in parking pressures. Whilst installations span a range of streetscapes and neighbourhoods in Oxford, important variations include: competition for parking; the proximity of the chargers to participants homes; presence of a dedicated parking; how traffic regulation orders are enforced

These factors mean that criteria for evaluating installations should always be considered against a background of geographical, political and socio-economic context, and cannot be ranked hierarchically, or aggregated into an overall score.

Analysis of charging data

Table 4 provides a summary of charge point usage over the course of the trial. Because different installations went online at different stages, and because some chargers have two sockets, usage data are compared using 'socket-months', which is a measure of how many months the installations were available to use. The data show that home chargers were used most frequently, with each socket used an average of 14.1 times per month. The high figure for

Table 4: Summary of Usage data gathered from the charge point operators

	Ubitricity	*NewMotion (3x bollard types)*	*APT Home Chargers*
Socket-months	250	190	108
Episodes per socket-month	6.7	4.0	14.1
Energy per socket-month	2067.4 kWh	34.1 kWh	147.6 kWh
Energy per episode	8.3kWh	8.49kWh	10.4kWh
Median power output	3.77kW	*Data not available*	6.48kW

average energy discharged in Ubitricity episodes is likely to be influenced by the fact that 2 of the 5 lamppost users owned Tesla vehicles, with batteries capable of storing 95kWh.

Figure 3 indicates that compared with home chargers, which have been used at a relatively constant rate, usage of lampposts has fluctuated significantly over time. This may be due to greater variability in the usage patterns of car club cars, which make up roughly 50% of charging episodes for lamppost installations.

Figure 3 confirms reports of delays to the bollard chargers becoming operational. Since May 2019, when several new car-club EVs were deployed in Oxford, bollard chargers have been used more often. Data from July 2019 (just after the end of the trial), shows 169 charging episodes.

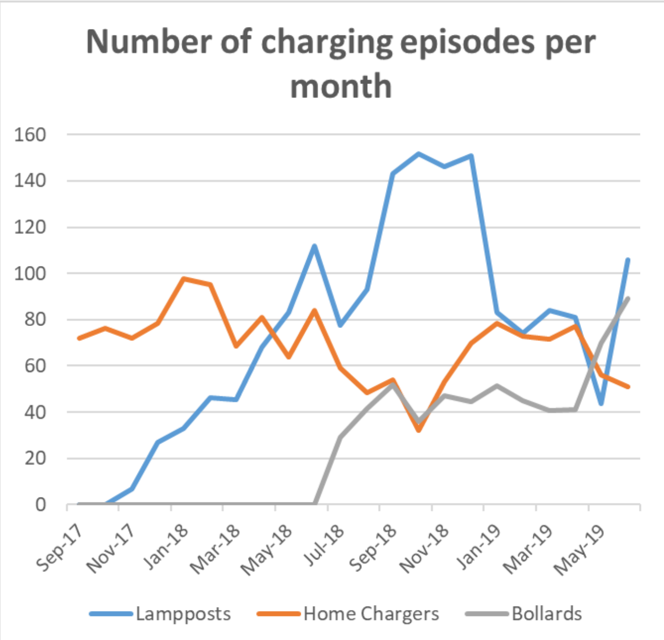


Figure 3 – Usage of chargers over the course of the trial. Month periods have been normalised to 30 days.

Breakdown and issues with chargers

All chargers experienced some malfunctions or breakdowns during the trial. Causes include vehicle collisions, vandalism, user-interface failures and back-end system breakdowns. The 'down time' for breakdowns varied widely, and in some cases lasted for several months. This was influenced by: user-reporting; charger design; institutional capacity and procedures; regulatory requirements; inter-organisational arrangements; and technical challenges.

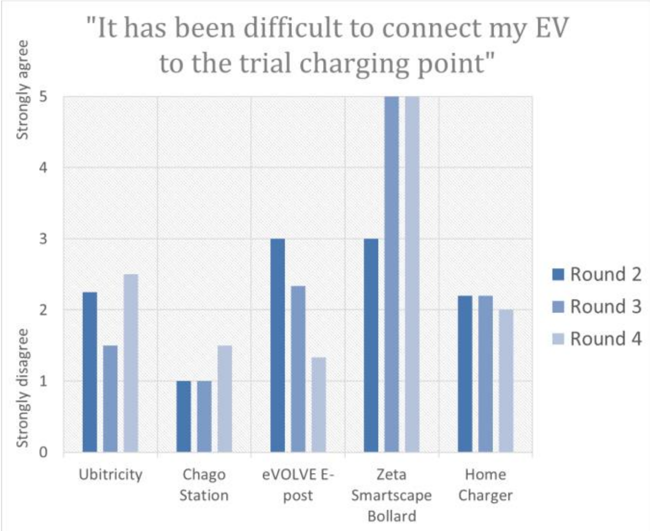


Figure 4 – User survey responses: ease of charging

Figure 4 plots user survey responses regarding the difficulties of connecting EVs to their allocated charging point over the course of the trial. The surveys were administered before the start of interview rounds 1-4, where round 1 was conducted before the trial began, and round 4 was after 11 months or more. Participants were asked to respond to statements using a Likert Scale, where 1 indicates 'strongly disagree', and 5 is 'strongly agree'.

Figure 4 includes responses from rounds 2-4, once users' installations were operational, and shows no clear trend. While users of home chargers and eVOLVE E-posts found it easier to connect their EV over time, Chago Station and Zeta Smartscape users found it more difficult. This is likely to be linked to periods of breakdown experienced by each of these bollards.

Reported issues with lamppost chargers

Users of the Ubitricity lamppost chargers experienced relatively few issues with installations. However, there were two user-reports of the charger not working when plugging in, or stopping before a full charge.

Those who encountered problems observed that it was straightforward to contact Ubitricity through their app and that they were responsive and generally able to resolve issues in a timely manner.

Reported issues with bollard-style chargers

Differences emerged between individual bollard-style chargers in relation to reliability, and maintenance and repair.

One user reported a vehicle collision with their local eVolve e-Post Charging Bollard, after which the charger continued to operate. The user cited its 'robust' and 'solid' design in preventing functional failure. The digital display was valued by users as a way to monitor whether charging was underway.

Chago Station installations include two sockets enclosed by small doors, but at two separate sites one of these failed. Users were less inclined to report these breakdowns as one socket remained functional. At another installation, the door was snapped off, most likely due to vehicle strike.

Of all 5 technologies trialled, the Zeta Smartscape chargers were damaged the most often, and non-operational for the longest time. At five different sites, chargers were damaged by vehicle strikes, and one was badly vandalised. Their design appears to make them more vulnerable to damage than other installations. Repairs required units to be removed and repaired off-site, resulting in comparatively lengthy periods of downtime, and additional costs (e.g. to make the site safe for the public). This bollard is a prototype design, and Zeta are aware of these issues. They reported in our interview that they have substantially redesigned their bollard charger.

Reported issues with home chargers

Users of the APT home charger and cable channel system were generally happy with their installations and found them to be reliable.

Users were however drawn attention to issues with cables becoming deformed and twisted, the cable no longer working and the cable channel filling up with leaves and dirt. In two cases, the cable supplier collected the faulty cable but did not immediately provide a replacement, leaving the users without the ability to charge for a time.

There have been no reports of trips or accidents associated with trailing cables.

Fault reporting

Users were encouraged to report breakdowns via the relevant chargepoint operator (CPO). For bollard installations this was NewMotion, who then worked with technology suppliers and local maintenance contractors to arrange repair.

Ubitricity performed both of these roles for the lamppost chargers.

Home chargers users were billed by their household electricity supplier, and would have contacted APT if the outside meter were to break down.

Some users reported confusion over who to contact in the occurrence of a fault, leading in some cases to reluctance to report issues at all. In most cases of breakdown, participants contacted the Oxford City Council's GULO project officer.

Examples of issues and challenges in GULO

> ***"It's not just about getting the infrastructure in. That's the easy bit actually"***

A detailed example of the issues and challenges encountered by one household participating in the GULO trial is offered below. It has been selected because it encapsulates a variety of the obstacles and setbacks reported across the sample of users.

Case Study

Participant #05 experienced delays of 10 months from the start of the trial to their first usage of the charger.

The participants, a couple with a PHEV, were allocated a bollard-style charging installation. Before the trial started, they had already been using a storm drain to lead a cable from their home, and thus felt a private charger with pavement channel would have been preferable.

Initially, the City Council had planned to allocate a dedicated parking bay next to the bollard charger. Through three rounds of consultation, objections were raised by neighbours, who objected to the installation of a large sign in the small street. The participants suggested a number of compromises such as reducing the size of the sign, and making it advisory rather than enforceable. They reported, however, that there was little scope for discussion with the local authority, nor willingness to experiment. They compromised, and chose the softer option of having no dedicated bay, but would instead 'rely on the understanding of neighbours'.

The householders then found that their second-hand hybrid vehicle had not been supplied with a rapid charging cable, meaning that they would have to purchase one costing more than £150. They were unhappy about having to spend this money, which equates to a large amount of electricity and many full-charges. This, combined with their hectic lives, meant another delay in starting the trial.

Unfortunately, before their cable arrived, the bollard was hit by a delivery vehicle, reversing around the tight street corner and putting the bollard out of service. The bollard – a Zeta Smartscape charger – could not be repaired on site. Further delays were incurred as it was removed to be repaired. It was said that its non-modular design may have contributed to delays.

Once the EV owners had the correct cable and the bollard was functioning, they still remained faced with the need to negotiate with other car users to gain access to the charger. The participants described one car in particular being parked in a way that prevented them charging for weeks on end, and they had been forced to contact its owner to politely request it be moved. Positive community spirit was highly valued by the participants, who felt reluctant to 'make a fuss'. They did not relish the need to leave notes on windscreens and knock on neighbours' doors, which they felt made them into 'aggressors'.

This case study example illustrates how social, technological and financial factors can combine to inhibit and delay the adoption of on-street charging in practice.

Figure 5 - A Zeta Smartscape bollard that has been vandalised and put out of service

3. Examining the adaptations to car-use routines and the formation of charging habits among pilot participants

Driving and charging electric vehicles involves practices which are, in some cases, markedly different from driving conventional vehicles. Throughout the trial we monitored how participants' practices changed as they became familiar with their car and charging installation.

Car use routines

For most participants there were no significant changes in how often, where or when they drive their cars. Most changes in habits and routines related to how participants negotiate parking and when, where and how they charge.

Several participants discussed how they had altered their driving style, the use of the car stereo, air-conditioning and even route planning to increase the range of their ULEV.

Describing their changed driving style, one driver, explained how he avoided 'putting [his] foot to the floor so often' or 'doing 80mph constantly along a motorway'. Instead, he now 'locks it in cruise [control] on about 65mph/70mph'.

One participant learned during winter that when his range was low, the 'heated seats' used 'significantly less power' than the 'cabin heater':

> ***"****The heated seats reduce your range by three or four miles whereas heating the whole cabin reduces [it] by twenty to thirty miles. So it's like going along and 'oh my bum's quite warm but my hands are about to drop off, this is crazy.****"***
>
> ***Trial Participant***

Another BEV driver explained how he once ran the battery flat on his commute to work. He planned a route using Google Maps, which was just within the car's estimated mileage on a full charge. However, as soon as he hit the Chiltern Hills the estimated range suddenly plummeted and he realised he wouldn't make it. He explained how he adapted his plans:

> ***"****The week after, I used a calculator to know which route should I take to not have to recharge and… [the GULO Council Officer] advised me to go to Aylesbury to avoid the hill, so I made it to work.****"***
>
> ***Car Club Participant***

One participant household purchased a new petrol car to use on longer journeys, because they felt the range of their EV would be insufficient for their needs.

PHEV or Tesla Model 3 drivers tended to make fewer changes to their driving style. For PHEV drivers this was because of their small battery capacity and ability to drive on petrol. With a battery capacity of at least 220 miles, Tesla Model 3 drivers were less concerned about range compared to other BEV drivers. Figure 6, based on longitudinal survey data, illustrates this difference. It also shows a gradual reduction in the need to plan by BEV drivers over time, with participants anticipating a greater need to plan journeys before the start of the trial than when later surveyed. PHEV drivers appeared to plan more over time, possibly as they increasingly wanted to maximise the use of their battery over relying on petrol.

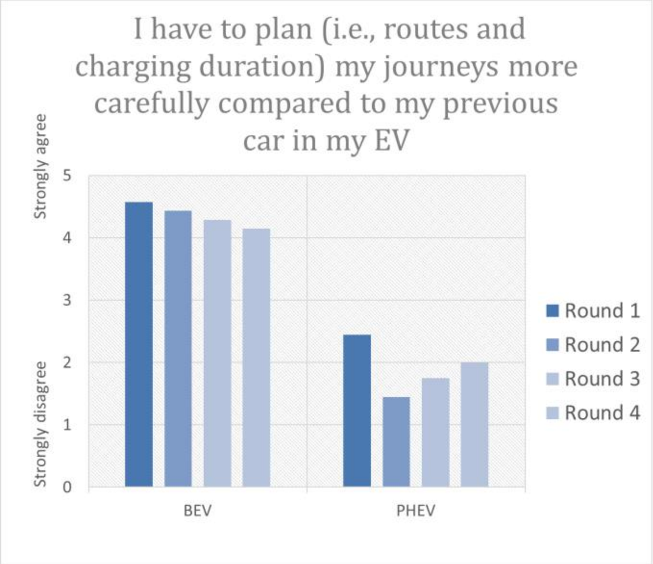


Figure 6 - User survey responses: need for planning

Charging Habits

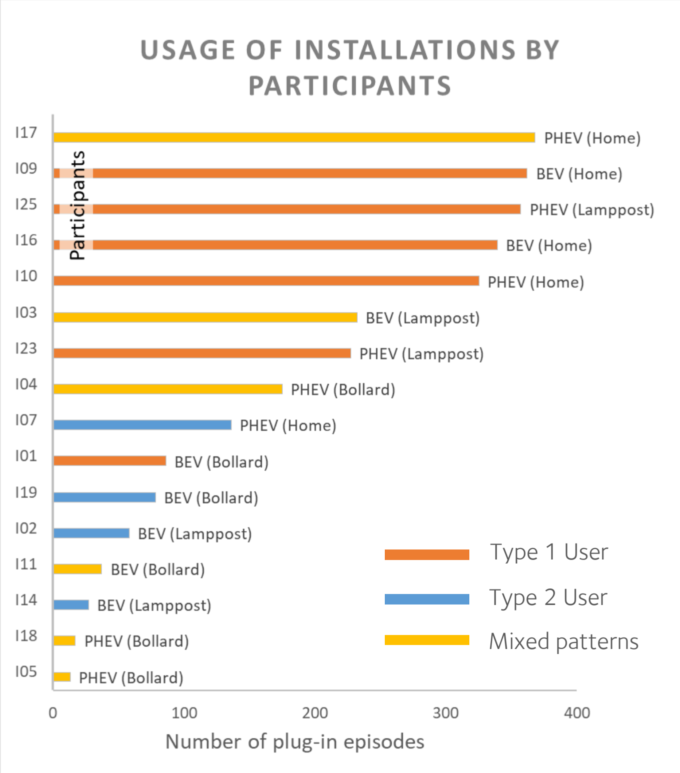


Figure 7 – Charging habits for private participants

Figure 7 displays the number of plug-in episodes for all private users and classifies them into user 'types'. For this analysis, we assumed that participants charged using the installations closest to their home address.

The charging habits of participants were determined by a variety of factors. These include the proximity and accessibility of a charging space, their personal and/or household routines, how far they had recently driven and the capacity of their battery.

Analysis of charging habits from the 16 private participants revealed two main patterns of usage:

- Type 1 users primarily plugged their ULEVs into chargers on weekday evenings (between 5pm and 1am). They occasionally also plugged-in before 10am on weekdays. Weekend charging was more evenly spread out over the day.
- Type 2 users usually charged their ULEVs between 9am and 5pm during weekdays. Their weekend charging habits were more dispersed across the day.

As illustrated in Figure 7, 11 of the 16 private participants could be characterised as either Type 1 or Type 2 users. Type 1 users tended to charge their ULEVs more frequently, and these 7 participants used 68.6% of all the energy used by private participants in the GULO trial. Type 2 users tended to use the chargers less frequently, and correspondingly used less energy. Different charging habits (Type 1, Type 2, or mixed patterns) were observed amongst users allocated to all three types of chargers, and with both BEVs and PHEVs.

Figure 7 illustrates strong variation in the number of plug-in episodes across the 16 private participants. Two patterns can be seen:

- 4 of the 5 most frequent users of chargers were those allocated with home chargers and cable channels.
- Bollard users tended to plug-in less frequently.

There could be several reasons for these patterns, including the reliability of installations (there were no reports of breakdown from users of home chargers, while bollards took longer to be installed initially, and were often reported as non-operational); the price of electricity; or factors related to ease of access.

Figure 8 displays energy used by lamppost and home charger users by time of day. Corresponding with the observation that 4 of the 5 home charger users primarily plugged their ULEVs during the evening (Type 1), it shows that peak usage by PHEVs was between 6pm and 7pm, while BEVs – with larger batteries - continued to charge until the early hours, with a peak between 9pm and 10pm. The trend for early morning charging can also be seen, particularly by BEV-home charger users.

Usage of lampposts was highest between 1pm and 8pm, reflecting the mix of Type 1 and Type 2 users using this technology. Energy consumption by car-club BEVs was notably more spread out over the course of the day.

Reliance on GULO trial chargers:

All BEV drivers in the trial suggested they charge at non-trial public chargers, especially on longer journeys. Meanwhile, only half of PHEV drivers reported that they had attempted to charge away from their trial installation. This is supported by the survey responses summarised in Figure 9, showing slightly higher agreement with the statement from PHEV drivers.

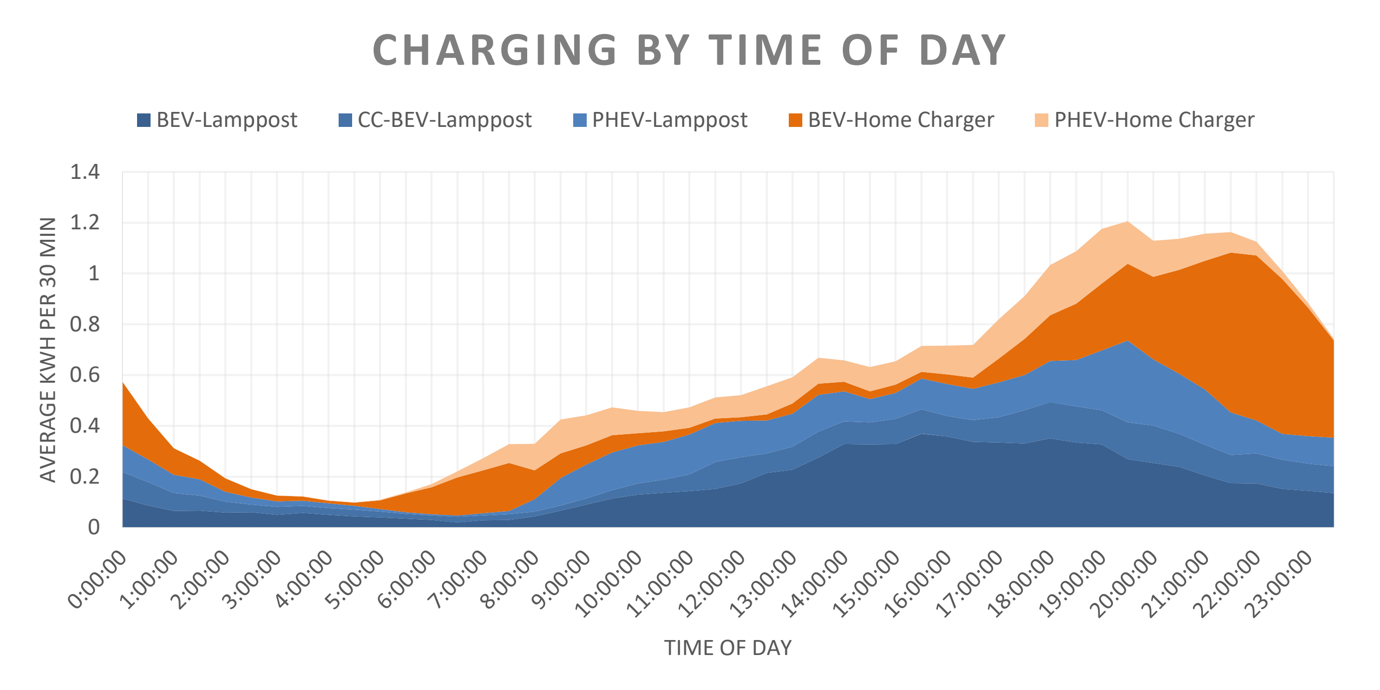


Figure 8 – Diurnal charging habits for different users (data for bollard users unavailable)

Charging Technique

The process of connecting vehicles to charging installations involves a range of physical movements including the handling of cables, pushing and/or pulling of charging flaps and covers and inserting cable ends into the car and installation. The filming of participants charging their vehicle at two different moments showed that, over time, the process became more precise and effortless. This was most noticeable for users of the home chargers, who typically had lengthy cables which needed carefully uncoiling and placing in pavement channels. Whereas at the start of the trial users typically started by placing the cable and finished the plugging in procedure at the car, over time they realised that first plugging in sockets at both ends, and then placing the cable in the channel was more efficient.

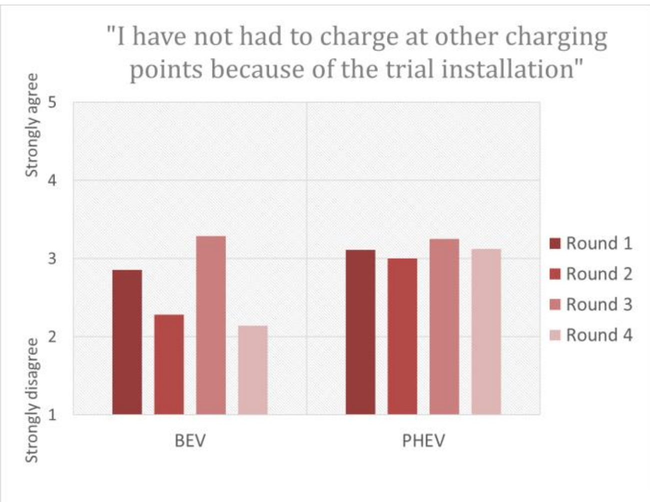


Figure 9 - User survey responses: need for charging elsewhere

Parking dynamics and strategies

The ability of different private participants to access the chargers varied considerably, and depended on a variety of factors:

- **Competition for street parking**: some roads in the trial had dense housing, with high parking demand;
- **Parking fluidity:** the degree to which parking dynamics changed through the day (e.g. around school and working hours);
- **Controlled Parking Zones**: there tended to be less competition for spaces in permitted areas;
- **Dedicated Bays**: most participants with these had no trouble with access; although where more EVs were present, competition increased.
- **Enforcement**: gaining access tended to be more challenging during nights and weekends when parking restrictions and rules (residents parking, EV-only bays, yellow lines) were more commonly disregarded and less likely to be enforced.

Our first Interim Report includes further detail about the strategies used by participants for gaining access to spaces where they can charge their EVs.

Car club users

Summary

- We interviewed 6 car club members who regularly use Co-wheels BEVs.
- Car club BEVs were used mostly for short and local journeys due to range anxiety and uncertainties about charging on-the-go.
- Most users overcame initial charging issues quickly.
- Hassle of using cables; range anxiety and lack of information available were the main negative experiences reported by Co-wheels users.

Driving EVs

Participants agreed that car club BEVs are best suited to shorter and local journeys. Most users were unsure about how and where to charge away from the trial installation and expressed concerns about their inability to monitor and control the battery state of charge prior to their hire period.

Charging

Due to delays in deploying all 10 car club BEVs, our sample focused on 4 cars, all using Ubitricity installations.

At first, most users experienced some difficulties trying to work out how to unplug the cable from the car and charging installation. This was mainly because most users were unable to locate the release button that unlocks the cable from the vehicle's charging socket and allows it to be removed from the installation. Others struggled to start the vehicle and the battery ran out of charge for one participant during their first use.

Most managed to overcome these initial difficulties through trial and error and, if present, reading the laminated step-by-step instructions provided.

Information received and wanted

Having booked an EV for the first time, none of the users reported receiving any special information from Co-wheels via email. One member was 'furious' about this as they had not realised the new car was electric.

Several users found the step-by-step instruction sheet in the car helpful and one mentioned he had subsequently realised that further information was available on the Co-wheels website about their EVs.

Several users expressed concern about how the procedure for booking EVs was no different from conventional vehicles. Although Co-wheels ask members to leave the EV always plugged in, the risk is that back-to-back bookings may not leave sufficient charge for the subsequent user's needs. Several users expressed a wish to see a vehicle's state of charge on the booking portal before arriving to pick it up, but explained that this still would not fully alleviate the risk of insufficient charge if their booking came immediately after the car had been used by another user.

One user chose to mitigate this danger by booking two hours extra before they needed the car. When preparing for longer journeys, they would walk over to the car to check it was charging, and come out again for the start of their journey. This user suggested that a faster charger would help to alleviate their concerns, but that the Ubitricity installation was under-powered for the needs of a car club BEV. Other users simply chose petrol vehicles when concerned about range.

Co-wheels' future plans

Co-wheels explained when interviewed that they were aware of the user concerns cited above, and are developing an improved booking system which will give users data on state of charge.

As of August 2019 there are 9 EREVs in Oxford. All are BMW i3s with a relatively large battery capacity; and several are now connected to faster bollard-style chargers.

Figure 10 - A car club car charging from a lamppost

4. Identifying local community responses to the charging installation

Throughout the trial we asked participants about their interactions with the local community. Most examples provided were of neighbours initiating conversations about plugging in and unplugging vehicles; the trial itself; and the possibilities and challenges associated with driving a plug-in hybrid or full battery electric vehicle. Much of the focus was on range, the types of journeys you can make, the convenience of charging and to a lesser extent the car itself and the running costs.

Some of the trial participants appeared to fulfil a community leadership role in reference to EV diffusion by helping to increase the visibility and awareness of, and familiarity with, EVs and EV charging in local communities. Nevertheless, despite reporting many engagements with the local community, some participants questioned the extent to which these would lead to increased uptake of EVs. One user, for example, said that people are 'usually interested for about a minute', but 'that's it' as at 'the end of the day it is just a charging point [and] you're just plugging something in'. Some users indicated that the various delays and periods of breakdown may have *discouraged* their neighbours from buying EVs.

Vulnerability

Some users reported a general sense of vulnerability they felt when their car was on-charge.

Drivers of EVs with sockets at the side of the vehicle, for example, cited their reluctance to have the plug on the road side, and when parking, always ensure the socket was on the kerb-side, even when this meant reverse parking in difficult circumstances, for instance, blocking oncoming traffic.

Several participants avoided charging their ULEVs overnight. These specific individuals feared that the protruding charger and trailing cable may attract attention from vandals, or lead to collisions with pedestrians and vehicles taking less care overnight. Others still preferred to charge their vehicles within line of sight from their homes.

One participant expressed concerns about people, especially drunk students, trying to pull the cable out of the car:

> ***"Jericho … is as good a place as any to get drunk in Oxford [and] we are on the way to St Hugh's [College]. … [M]y concern was that we get a drunk student trying to pull [the cable] out. That hasn't happened yet [but] it doesn't mean it won't happen. [I]t's a shiny thing that flashes light and I think it will be like the moon to a moth for a drunk student."***

In general, however, participants were positive about the responses of the local community to the chargers. This is clear from survey responses in Figure 11, which especially show the ease felt by Ubitricity users:

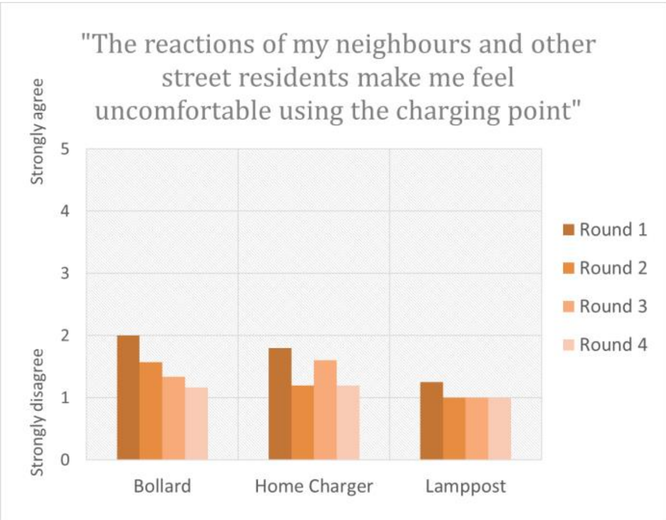


Figure 11 – User survey responses: reactions of neighbours

One concern raised by participants and the local community related to the trip hazard associated with trailing cables. Fortunately, there have been no reports of any accidents relating to cables throughout the trial.

Deference

Given the sense of vulnerability associated with charging in public streets, participants adopted a degree of deference with respect to their neighbours. In contrast to those unwilling to charge overnight, several lamppost and home charger users left their vehicles plugged in even when they were fully charged, including overnight. Without a dedicated parking bay, they felt that this tactic might increase neighbourhood awareness that the space was used for charging.

Another example of deference was reported by one user of a bollard installation and dedicated bay. Knowing that theirs was the only ULEV on the road, they chose to leave the car parked in the dedicated bay, *despite* the traffic regulation stipulating a 3-hour daytime limit:

> ***"If I'm not parking my electric vehicle in that space, I'm taking up another space….there's no point leaving it empty."***

One couple involved in the trial mentioned on a number of occasions how their area was quite 'rough', and reported instances of car windows being smashed. Despite this, they said that their experience of using the charger had been positive, and they had noticed:

> ***"Quite a few times cars will be parked up here and they'll leave a gap by the charge point."***

In return, this couple, who were retired, said:

> ***"There's only so many parking places so you've got to think of your neighbours. Charge it during the day so they can park there at night."***

As well as being reliant on the good favour of their local community, participants were also aware of their own role as neighbours.

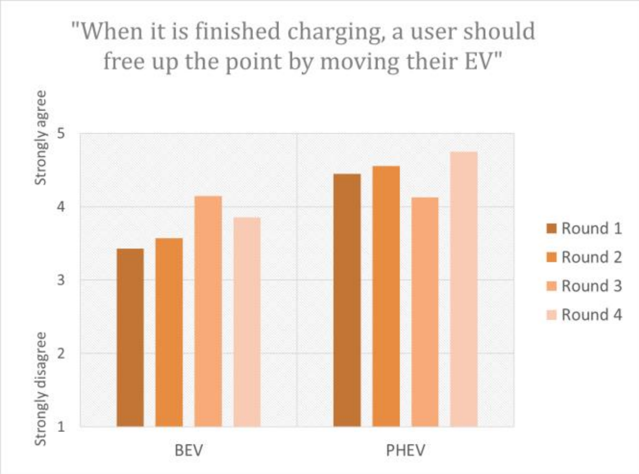


Figure 12 – User survey responses: freeing up charge points

Figure 12 shows that ULEV drivers generally agreed that they should free up a public charging space, but there is a marked difference in responses from BEV drivers and PHEV drivers. The lower scores reported by BEV drivers may reflect their greater dependence on chargers, and their *inflexibility* relative to PHEV drivers.

Signage – and its interpretation

Where dedicated parking bays for ULEV charging have been put in place in Oxford, a sign has been installed

Vandalism

Over the course of the trial the free-standing bollard chargers were subject to a level of vandalism that surprised those involved in running the trial. The operator of the bollard chargers told us that "at least half have been vandalised at some point". Examples range from simple graffiti, to damage inflicted leading to breakdown, as doors were ripped off the Chago Station, and the top of the Zeta Smartscape was removed. The eVolve e-Post was spared from this level of vandalism.



Figure 13 – Official signage installed alongside all dedicated parking bays with bollard-style chargers.

nearby, explaining the rules associated with its use (Figure 13).

The sign stipulates that the use of the space from 08:00 to 18:30, Monday to Saturday should be limited to 3 hours. It can be used by any ULEV owner, but only for charging. Outside of these hours, it should be used only for charging, *and* only by permit holders.

This rather complex set of rules was misinterpreted or ignored by both trial participants and local residents in several instances. Most commonly, the assumption was made that on evenings and Sundays, the space may be used for parking by non-ULEV permit holders. There were no reports of parking tickets being issued to deter this practice.

Enforcement of these rules was variable. Several users reported leaving their car plugged in during the day for longer than 3 hours with no consequences. They speculated that when ULEV ownership remained low, parking attendants may be using their discretion. On one occasion, however, a participant *unplugged* his car but left it in the bay, and was given a ticket.

In one conservation area, trial participants declined the option of a dedicated bay, citing concern expressed by neighbours for the size and appearance of the sign. They requested a non-enforceable, 'advisory' sign to be installed, and enquired about painting their own lines, but were told by the Highways Authority (Oxfordshire County Council) that this would not be possible, and that any paint or informal signage would be removed:

> ***"We wanted just a small sign to say this is a charging bay ... so that people would know and think twice about parking there. ... but there was no compromise between having nothing which is what we've got, and having this huge sign."***

By contrast, one couple using the home charger and cable channel designed and installed their own advisory sign on their front garden wall (Figure 14). This couple also emailed their neighbours to explain their involvement in the trial, and politely asked them when possible to leave the space outside their house free.

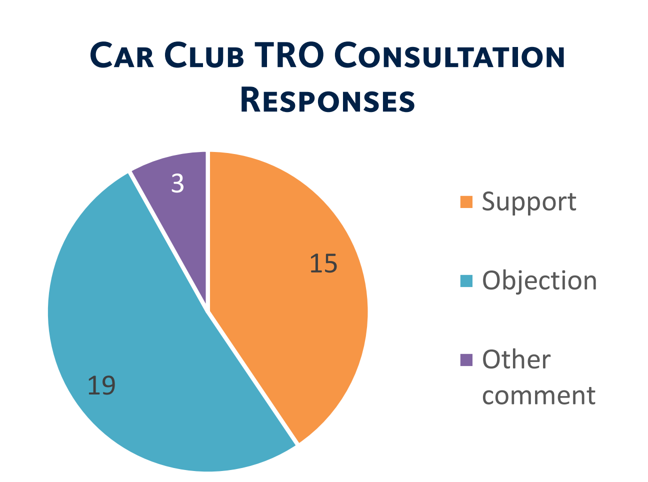
Figure 14 – an unofficial, advisory sign made by a user of a home charger and cable channel.

Consultation Responses

The process for allocating a parking bay for exclusive use by ULEVs or car clubs is called a Traffic Regulation Order (TRO) and involves publishing proposals and inviting public responses. This process is in place since:

> ***"People need to be able to have a say about the places where they live and parking is a very emotive issue."***
>
> ***Oxford City Council Officer***

There was a total of 59 responses to the proposals for dedicating parking bays associated with the GULO trial. The Car Club bays attracted 37 responses, and there were 22 for the general ULEV dedicated bays (see Figure 15).



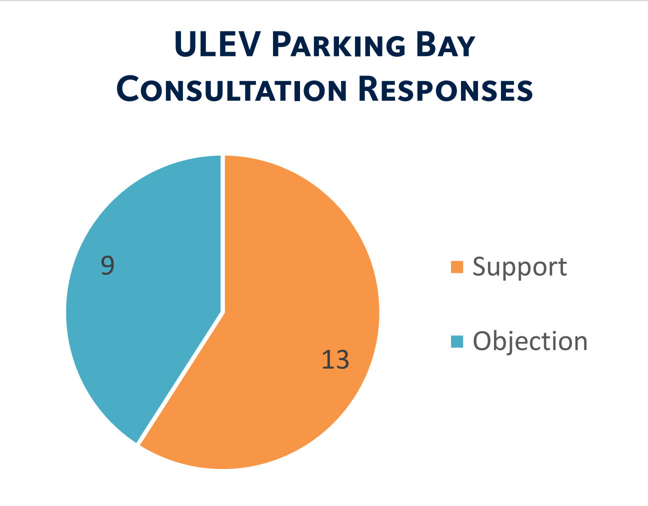


Figure 15 – Summary of consultation responses

The geographical distribution of responses across Oxford was uneven. Table 6 shows the 6 locations attracting most responses. While the parking bays associated with the trial were distributed across almost all of Oxford, the sites in West and North Oxford attracted most responses. This may be due to these neighbourhoods having higher parking pressures, or having politically active citizens.

Table 6: Summary of consultation responses

	For	Against	Other
East Street (OX2): *Car Club*	3	5	0
Alexandra Road (OX2): *Car Club*	4	2	0
Bainton Road (OX2): *Car Club*	0	6	0
Observatory Street (OX2)	0	4	1
St John Street (OX1)	2	2	1
Vicarage Close (OX4 4PL)	2	3	0

Figure 16 summarises the objections raised across Oxford in relation to the GULO TROs. Of the 28 raised, 18 (64%) cited local parking pressures as the main reason for their objection.

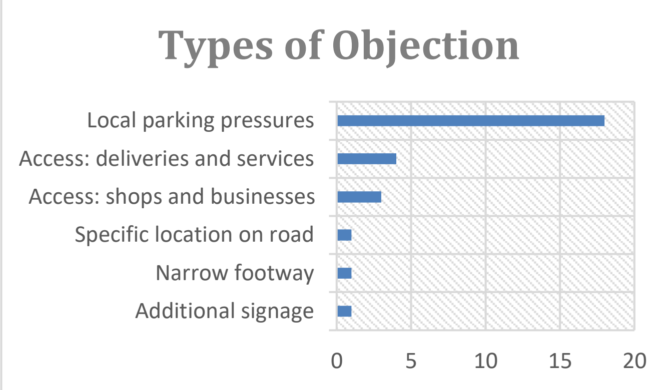


Figure 16 – Most common types of objections raised (n=28)

Summary

The response of the local community to the installation of new on-street ULEV chargers has been mixed. On the one hand, the number of instances of vandalism surprised and disappointed those involved in running the trial. On the other, participants provided numerous examples of neighbourly good will. They also reported having numerous conversations with neighbours, friends and family about charging and electric vehicles, especially in the early stages of the trial, and some assumed community leadership roles in relation to EV adoption.

The signage associated with dedicated parking bays was a source of some confusion for both participants, other car drivers, and even parking attendants.

5. Developing insights about how the pilot may be scaled up within and beyond Oxford

This chapter is divided into two parts. The first half examines the challenges and opportunities associated with scaling up on-street EV charging within Oxford, and the second identifies factors to consider when deploying similar technologies in other cities in the UK and beyond.

Scaling-up within Oxford

Charging technologies

Lamppost charging

There is significant opportunity for expanding lamppost charging infrastructure in Oxford. This is most straightforward where columns are located on the kerb side of the footway. However, current County Council policy is to relocate lampposts to the rear of the footpath when feasible, or as part of other works. Whilst a number of stakeholders called for a reversal of this policy, the trial successfully overcame this problem in some locations, by installing small charging bollards nearby which draw on the lighting electricity supply (see Figure 17). Another option not yet explored would be to pair cable channels with lampposts.

Figure 17 – Example of Ubitricity bollard installed close to, and drawing power from lampposts in some locations.

Ubitricity are now developing installations which negate the need for their Smart Cable (and its £199 price tag), and will allow contactless payment. This has been enabled by the decision taken by Elexon (the organisation responsible for administering electricity trading in the UK) to allow measuring devices to be installed in unmetered supply points, which will also open up lamppost charging to competition from suppliers such as APT.

Promotional signage required

While some users and the local community saw the seamless integration of charging into the urban landscape as a benefit of on-street installations, other users and stakeholders were frustrated by the lack of publicity associated with the trial. A highways engineer interviewed for this evaluation explained that signs had not yet been included in the traffic regulations in the County Council's 'direction manual', and that this would be required before any official signs could be installed. Although chargers are visible online through platforms such as Zap Map, many of the 40% of Europeans who intend for their next car to be an ULEV may not use or be aware of those platforms. There is a clear need for Oxford City Council to promote publicly available chargers with signage in the physical streetscape.

Besides the need for promotional signage, many users and stakeholders mentioned that the chargers themselves included neither information about the operator, nor instructions for signing up. There is therefore no obvious indication that the installation was available for public use.

Bollard charging

The free-standing bollards in the trial were associated with the greatest cost of installation, the longest delays to going live, and the lengthiest periods of breakdown. They were accompanied in the trial by dedicated bays, and a number of stakeholders regretted the length and bureaucratic nature of the TRO process. Their comparatively large footprint is suboptimal when footpaths are narrow. These reasons suggest that these are the least attractive option for Oxford city as it expands its on-street charging infrastructure.

However, bollards are capable of faster charging speeds than lampposts, and a number of private sector manufacturers are developing robust units which will be interoperable, enabling contactless payment. It is worth noting, however, that each supplier of bollard chargers revealed that their primary focus was on 'destination charging', for instance in public car parks and retail parks. They considered on-street locations to be substantially less appealing, both commercially, and in terms of risk of damage.

Rising bollards mitigate the problematic footprint, and the City Council is currently trialling one design as part of OxPops, a sister project to GULO in which chargers are deployed for a whole street at once.

Home charging

Home chargers and cable channels proved popular in the trial. When considering their suitability for scaling up within Oxford, two issues must be considered.

Firstly, residents in many parts of Oxford struggle to consistently park their car close enough to their property to enable reliable charging. In streets with high parking pressures, home chargers may work effectively alongside other nearby charging installations, but are unlikely to be sufficient alone. Where competition for parking is lower, including in some controlled parking zones (CPZs), they are likely to be more suitable.

Secondly, both the home charger and the cable channel were fully funded in the trial. However, it is unclear whether private householders can expect public subsidy for installations in future. Currently, the County Council (Highways Authority) has no guidelines to allow residents to pay for a channel to be dug into the footpath. They are aware of the urgent need to provide this, but one civil servant raised concerns about accounting for hidden costs. Once factors such as design, kerbstone cutting, maintenance and the need to budget for potential removal are considered, the cost of installation is likely to exceed £1,500, which householders may find off-putting.

Procurement and contracting

City Council staff emphasised the importance of carefully planning the structure of contracts and legal agreements. A key decision taken at an early stage was to separate the contracts awarded to charger manufacturers and the CPO. One Council employee said:

> ***"We wanted to have the simplest possible system for residents in the long-term right across all of the charging infrastructure in and around the city that we would accept some complexity in the short-term."***
>
> **Oxford City Council Officer**

This decision allowed the project to trial three separate bollard technologies which would be *interoperable* for ULEV drivers. However, interviews with the charge point manufacturers and the operator revealed that this separation had not worked smoothly, particularly in relation to maintenance and repair procedures.

Bollard operator NewMotion reported frustration with the procedure for repairing broken-down chargers. Relying on 3rd party contractors without having legal contracts in place, they described themselves as being the 'piggy-in-the-middle' between firms and the City Council. They felt that that repair contractors seemed to be looking for reasons *not* to send an engineer out. They said:

> ***"From a public perspective that's really damaging because they just see it going down it's not working and then if two weeks later it's still not working that's massively damaging because that feeds the Daily Mail hysteria of 'there's not enough charge points and none of them work'."***
>
> **NewMotion**

While the council's concern for interoperability should be lauded, there are signs that manufacturers and operators are moving away from proprietary systems. Users may soon benefit from the opportunity to 'roam' across a variety of charger types, paying for their charging episodes using contactless technology. However, this may lead to increased costs. There is an urgent need for further synchronisation across the industry, requiring central government to corral, coordinate and regulate.

Planning and Regulation

The bollard installations and car club locations included in the trial were accompanied by TROs. Whereas the public consultation process received a mixture of positive and negative responses, most stakeholders expressed a strong desire to avoid the TRO process entirely in future. There are three main drawbacks of issuing TROs alongside on-street chargers:

1) Time. TROs were handled by an under-resourced team in the County Council. County Council officers accepted that this had led to delays in administering the TROs, with knock-on impact on when chargers were installed. Changes resulting from the public consultation led to requirements for new grid connection designs, and further delays.

2) Inflexibility. The TRO process requires planners to be flexible, re-siting parking bays in response to objections, for example. Similarly, plans for charger locations may need to be moved from one side of the road to another to minimise grid connection costs. Running these two processes in parallel can lead to trade-offs, including increased costs and time delays.

3) Morale. Two stakeholders expressed feelings of regret and disappointment relating to negative TRO responses. Working hard to deliver charging infrastructure and motivated by environmental and community causes, they found public engagement one of the most challenging aspects of their roles.

Frustrated with the challenges of securing dedicated parking bays, Co-wheels have plans to use GPS and smart-phone technology to allow their cars to be parked within a zone, as opposed to a specific bay. They hoped that the City Council would support them to obtain residential permits to meet this goal. For their EV fleet, they hope to have a local employee who can use nearby rapid chargers to ensure the vehicles maintain ample charge.

> *"We learned from the TROs process that when people just respond to a yes or no question sometimes they can be quite obstructive, or have strong opinions which can affect your ability to put chargers where you feel that they would be best suited."*
>
> ***City Council Officer***

The City Council are also pursuing strategies to avoid the need for TROs. This is being done most deliberately in the OxPops project.

Table 7 details responsibilities and stakeholders associated with on-street charging

Responsibilities	Current responsibility holder(s)	Comment
Investment in installing new on-street chargers	Central Government via City and County Councils	Potential for private sector to lead investment, but indications from stakeholder interviews are that on-street chargers are unlikely to present a commercially attractive proposition in the next 5 years
Gauging demand, both from existing and potential EV drivers	Local Authorities (both City and County Councils)	Currently unsystematic. Some data available on ULEV registrations at the city level. Knowledge of suppressed demand for EV uptake due to lack of charging infrastructure is very limited. Potential role for universities and consultants.
Maintenance and repair of charge points, including fault reporting, liaison, public safety	Electrical and highways engineering contractors	Contractors are engaged by Oxford City Council and are required to liaise with operators.
Optimising the usage of the **electricity grid**, in such a way as to avoid costly upgrades.	Distribution network operator (SSEN)	Other stakeholders are playing an increasing role in developing knowledge about Oxford's grid capacity. These include independent connection providers and others.
Strategic planning for a suite of chargers, meeting the needs of different charging practices (e.g. overnight, daytime, destination charging)	Local Authorities (both City and County Councils)	While Local Authorities have strategic oversight, they aim to leverage private sector investment where possible. Evidence suggests this is most attractive for destination charging locations (e.g. Park & Ride), meaning that Local Authorities must drive the supply of on-street charging infrastructure.
Payment and billing services	Chargepoint operators: NewMotion; Ubitricity	Other operators active in Oxford include Chargemaster, Centrica, Pod Point and Swarco.
Ensuring **interoperability** for consumers, across socket-type and payment method	Local Authorities, Central Government, the Energy Systems and Connected Places Catapults; industry associations, British Standards Institute and private sector providers each have a role to play in delivering interoperability.	

Responsibilities of stakeholders

There are several questions which remain open regarding the precise responsibilities for extending and maintaining an EV charging infrastructure that meets the growing needs of EV drivers in Oxford. Table 7 summarises where responsibilities currently lie.

Capacities of stakeholders

Oxford City Council and Oxfordshire County Council are well-resourced with regards to electro-mobility, compared with the majority of local authorities in the UK. A series of successful bids for central government funding have embedded skills and capacities within these organisations. However, while some departments have ample resources, others are stretched, as the delays seen in the TRO process illustrate. Furthermore, being a small city, expertise in is held by a handful of individuals, and staff turnover within LAs presents a risk to Oxford's continued leadership in provision for electric mobility.

Many stakeholders complained of insufficient capacity within the Distribution Network Operator (DNO), primarily relating to the time taken to provide connections designs and quotations. Scottish and Southern Electricity Networks (SSEN) are the DNO responsible for the network in Oxford, and are working hard to become a more open, responsive and customer-focused organisation. They expressed a wish to be involved in future projects from an earlier stage, playing a more strategic – as opposed to responsive – role. Competition from independent connection providers makes this transition even more urgent.

With the exception of Ubitricity, charge point manufacturers and operators appear to be investing greater resources into charging infrastructure in public car parks, business locations and private households than in on-street charging.

Factors unique to Oxford

It is important to identify factors which are unique to Oxford, in order that policy makers might consider how their local environments differ.

Governance:

- Two-tier Local Authority system
- High degree of capacity within sustainability and innovation teams at both Local Authorities
- Advanced plans for a Zero Emissions Zone

Geography:

- Dense urban neighbourhoods and narrow streets
- Affluent neighbourhoods without off-street parking
- Comparatively environmentally conscious and motivated population
- Existing storm drains built into pavements
- Constrained distribution grid

Innovation ecosystem:

- Two leading universities
- Advanced automobility and electro-mobility industries
- A thriving, well-established car club

Scaling Beyond Oxford

Charging technologies

There can be no 'one size fits all' solution for on-street charging, and this report has highlighted how myriad factors influence how and when chargers are used, how they become integrated into local streetscapes and residential communities, and require the cooperation of several organisations.

Lamppost charging

Ubitricity claim to be working with several local authorities around the UK to convert lampposts into EV chargers. Oxford's experience has been that this technology is low cost (see Table 8), quick to install and reliable for users. However, capable of only one socket per column, lampposts may not be sufficient to supply residential roads filled with ULEVs.

Whereas lampposts sited at the kerbside are most suitable for retrofit, those at the rear of the footpath can be coupled with a small plastic bollard, although the need for trenching increases the cost of installation (see Table 8).

Bollards

For urban environments with wide pavements, bollards may be more suitable than in the often cluttered footpaths of Oxford.

Site selection should be considered carefully. Costs of installation can be drastically reduced when located close to the mains electricity cable, while the Oxford TRO consultation process suggested that siting

Costs of installation

The costs associated with installing the different technologies vary significantly. Table 8 summarises the approximate costs of installing the different chargers in the GULO trial, and shows that bollards were most costly to install. This is largely due to the need for new grid connections, the cost of which varies significantly depending on the need for trenching and road closures. Table 8 excludes indirect costs such as staff time and other Local Authority resources required to manage the TRO process. If included, these would increase the costs of bollard installations further still.

Table 8: Cost estimates of hardware, installation and grid connection

Charger type	Hardware Cost	Installation Cost	Electricity Grid Connection Cost
Lamppost	Approx £1050	Approx £400 (without trenching)	N/A
Bollard	Approx £2000	Approx £2100	£2500 - £7500
Home charger and cable channel	Approx £800	Approx £600	N/A

dedicated bays directly in front of homes or shops should be avoided.

Home chargers

Home chargers coupled with cable channels are well-suited to Oxford's residential streetscapes because storm drains are already integrated into footpaths. Oxford City Council was able to extend their storm-drain maintenance contract to include cable channels. In cities without pavement storm drains, maintenance contracts may need to be put in place, and channel installations may attract objections from local residents.

Most stakeholders agreed that public subsidy for private chargers should be minimised, although residents might wish to self-fund channel installations. There is an urgent need for local authorities to produce policies and develop strategies to address questions of ongoing maintenance, managing trip hazard risk, and the eventual costs of removal.

Grid capacity and management

There are six separate distribution networks operators active in Great Britain, all undergoing organisational transitions and changes to their functions, as the electricity system is transformed by distributed generation and demand for new connections. The low voltage electricity network in Oxford is managed by SSEN. Interviews with stakeholders working nationwide suggest that SSEN lags behind some other operators in their transition to becoming a Distribution *System* Operator. Whereas previously responsible for managing one-way flows of electricity from central sources of generation to consumers, operators will need to get used to managing dynamic electricity flows so that they can accommodate intermittent sources of distributed generation. This can only be achieved with far better knowledge about local demand and network constraints, and significant investment, including central government subsidy, is being channelled into Smart Grid technologies in Oxford, which will allow SSEN to be more proactive when it comes to new connections.

> ***"We're reaching out to more and more organisations to see how best we can use the data that we've currently got and what else could be done with the art of the possible using datasets that we haven't yet got."***
>
> ***SSEN Manager***

Accessing data

Gaining access to quantitative charging data proved difficult in this evaluation, despite Oxford City Council including a detailed specification in their contracts with suppliers.

Charging data is critical for ongoing monitoring and strategic planning. Local authorities may need to insist on regular data outputs or direct access via online portals.

When interviewed for this project, SSEN expressed a desire to be consulted by local authorities earlier in the process of planning for on-street charging. Rather than simply responding to requests for grid connection designs, this would allow them to plan more strategically, potentially aligning other works such as grid reinforcements or the installation of new smart monitoring devices in parallel with EV charger installations.

It is clear that some teams and individuals within operators are prepared and able to engage with external stakeholders; while the legacy of managing a simpler, centralised energy system persists in some of the procedures and practices of others.

Key messages for central government

Standards and policies Ubitricity explained that most local authorities have a standard which specifies a maximum of 25 working days for repairing faulty streetlights. They suggested that where chargers have been incorporated into lampposts, this standard should be significantly shorter, given their additional value to the public.

Interoperability The need for interoperability across charging types is urgent. Currently ULEV drivers are required to hold accounts with multiple operators, and in some cases carry multiple cables in order to charge their vehicles across the UK. For the sake of existing drivers, and to remove any unnecessary barriers to further EV adoption, Government must work with industry stakeholders to establish a system of contactless payment for on-street charging.

Learning and legacy Having funded multiple local authorities as part of the Go Ultra Low City (GULC) scheme in early 2016, there now exists a cohort of forerunners who have developed valuable knowledge and capabilities in relation to ULEV charging. Not all initiatives have included an independent evaluation such as GULO, and there is a risk that the experience and expertise across the GULC scheme dissipates as funded projects come to an end. One charging manufacturer claimed to have noticed a north-south divide with regards on-street charging infrastructure:

"*[the challenge is] raising awareness to local authorities up north. They don't compare. They don't really have the knowledge and insight into what's going on in central government so perhaps there's a communication barrier there.*"

Charge point manufacturer

There is an opportunity for the cohort of frontrunners to continue sharing experiences and best practices, and to engage with other local authorities beginning to develop their charging infrastructure strategies.

"*Take the examples of Go Ultra Low cities that have done great work. Promote that and keep driving it at other local authorities. Because… there're some local authorities that've not reached out to us on the EV front, they've not responded to our queries.*"

SSEN Manager

Funding Interviews with stakeholders made clear that the business case for investing in on-street charging by the private sector remains unclear. There are doubts over the potential for on-street bollard installations to be commercially sustainable over the next 5 to 10 years. Even for the comparatively inexpensive lamppost installations, there may well be a

Options for avoiding TROs

1. Plan for multiple, simultaneous installations. Installing multiple chargers in a streetscape can mitigate the challenge of gaining access to chargers by ULEV drivers. The relatively low cost of installing lamppost chargers has allowed Oxford City Council to convert 3 lampposts per trial location, meaning that TROs have been avoided.

2. Encourage residents to negotiate parking themselves. Trial participants gave examples of communicating with their neighbours to negotiate access to chargers without dedicated bays. Technologies such as smart-phone apps may help to facilitate this, and can be encouraged by LAs.

3. Consider informal arrangements such as advisory signage. Some trial participants installed their own informal signage, while others requested that bays be painted on the road surface, but not enforced. Local authorities should consider allowing these options.

"*If there was support in one particular road, it would be quite nice to put that stuff in and possibly to have a wider conversation not just about signage for electric vehicles but including cyclists and street users in general. That's the kind of thing that you take and say 'right, let's make this happen, because this is common-sense'.*"

Oxford City Council Officer

need for continued public subsidy to help accelerate the adoption of ULEVs by residents of urban environments with limited off-street parking.

Charging infrastructure is unevenly distributed across urban environments around the UK, with some local authorities in cities such as Oxford, Brighton, Dundee and London leading the way. Central government may also wish to consider how to provide funding and support to areas where skills and capacities are low.

Strategic considerations for local authorities

Local authorities have a crucial role to play in planning, coordinating and perhaps even operating on-street chargers. They also have a responsibility for considering the longer-term development of the urban environment and the welfare of citizens. This section sets out some strategic questions that policy makers may wish to consider when developing EV charging plans.

Legacy and hidden costs There are a range of 'hidden' costs associated with maintaining public charging infrastructure. Resources are required to manage contracts with operators of charge points, to ensure that installations are well-maintained and repaired quickly when they break down. Enforcement of contract terms is costly in terms of time, resources and good will. Local authorities should consider how they might integrate ongoing maintenance into existing infrastructure systems.

Enforcement vs neighbourly negotiation. Where dedicated bays have been allocated in Oxford, TROs are accompanied by signs indicating rules for parking. To prevent confusion over signage, not only should wording should be carefully considered, but policy makers may explore alternative, less-formal arrangements. These can include facilitating neighbourly negotiation via online platforms.

The design of the urban landscape. In many urban environments, pavements are narrow and can be difficult to navigate. On refuse collection days footpaths can be unnavigable for wheelchair or pram users. Adding street furniture such as bollards or gullies to dense roadways can exacerbate access issues.

Local Authorities should set realistic expectations as to the operational life of charging installations. Given the frequency of vandalism and breakdown, and with increased utilisation forecast, this may be as little as 2-3 years for some technologies.

Consultation and democracy. The TRO consultation process not only demanded staff time and resources from Oxford City Council staff, but required patience, agility and effective communication skills when engaging with communities. Policy makers might consider whether the model of open consultation is the right one for on-street charging infrastructure, or whether alternative approaches may be suitable.

Equity and justice. What steps can be taken to ensure that on-street charging does not unfairly benefit wealthy communities and exclude disadvantaged groups such as low-income households and ethnic minorities? Such tensions are likely to be at play between the private sector, driven by the need to maximise utilisation of charging stations, and the public sector, who have a statutory responsibility for social welfare and equality of opportunity. How can the benefits of ULEVs for clean air and lower fuel bills be fairly distributed?

The wider electric vehicle ecosystem. How does on-street charging infrastructure complement other charging solutions, such as rapid 'destination' chargers? Policy makers wishing to reduce vehicle congestion should pay particular attention to the involvement of the car club in the GULO trial, as well as ongoing work by both City and County Councils to install chargers at Park & Ride locations on Oxford's perimeter.

Indirect impacts on mobility. Investment in on-street charging infrastructure has the implicit effect of 'backing' the car as the dominant mode of transport in cities. Does on-street charging infrastructure make it more difficult to bring about substantial increases in walking, cycling, the use of e-scooters and bike sharing, which also require infrastructural investment? Does this infrastructure detract from investment in better public transport?

Visions of future mobility. What role does on-street charging play in future visions of mobility in a city? Some techno-optimists predict that car ownership will soon become a thing of the past, as 'mobility as a service' becomes more widespread; or when connected autonomous vehicles remove the need for driving oneself. Might these disruptive innovations render on-street charging points redundant? Several stakeholders thought that on-street charging was necessary for the short and medium term, but that alternative forms of mobility may render them unnecessary in the longer term. Policy makers need to consider what explicit and implicit visions for the future of mobility underpin their strategic planning.

6. Conclusions

The Go Ultra Low Oxford trial has generated a series of insights which can inform all stakeholders involved in the rolling out of on-street charging infrastructure. We conclude with a summary of key lessons learned.

User perspective

Our evaluation has focused on the usage patterns and practices associated with charging installations. We have observed heterogeneous practices, including how drivers negotiate parking and access to chargers; when, where and for how long cars are plugged in; and for what reasons trips in private cars and car club cars are actually made.

We have developed a set of criteria for evaluating the performance of charging installations from the perspective of users (Table 2), and other stakeholders (Table 3) which may be adopted for use in similar trials elsewhere in the UK and beyond. Yet, scoring the criteria requires the consideration of the context of use and should be adapted to local settings. We therefore do not recommend reducing scores to simple numbers.

One key finding was that when interviewed after a year of charging their vehicles, users grew fond of the installation they had been allocated, with 2/3rds expressing a preference for this technology over the other four that were trialled.

Community responses

The GULO trial revealed that local residents often feel strongly about issues such as parking and street design. The public consultation relating to traffic regulation orders attracted 59 responses, of which 18 raised concerns about parking pressures. On the other hand, 31 responses gave positive support for the expansion of EV charging and car club spaces.

Users generally reported positive interactions with their neighbours regarding the installations, and gave examples of cooperation. Nonetheless, the number of instances of vandalism and vehicle strike surprised many users and other stakeholders.

Where parking bays were allocated, signage caused unexpected confusion and some controversy among users and neighbours, in part because text was ambiguous, and rules were inconsistently enforced. Examples were given of informal, advisory signage being used.

Scaling up

Responsibilities for expanding charging infrastructure are distributed across multiple stakeholders who must work together to deliver reliable, robust, interoperable charging infrastructure. Collaboration will require changes to existing practices and the development of new skills and capacities.

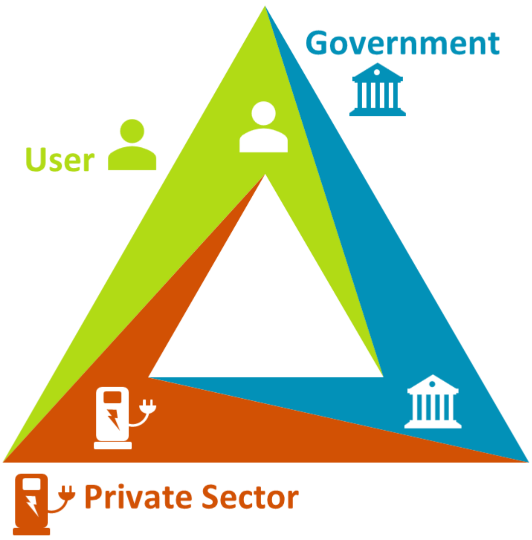


Figure 18 - Users, government and the private sector are the 3 main sets of actors regarding on-street charging.

Lampposts performed best in this trial. They are a low-cost option for scaling up, allowing TROs and new grid connections to be avoided. Promotional signage should be deployed to boost usage and promote uptake.

Privately funded home chargers and cable channels should be encouraged with clear guidance for installation.

Plans for infrastructure roll-out should not simply reflect current demand, skewed towards wealthy neighbourhoods, but should recognise the potential benefits for all communities.

Plans for infrastructure roll-out should not simply reflect current demand, skewed towards wealthy neighbourhoods, but should recognise the potential benefits for all communities.

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