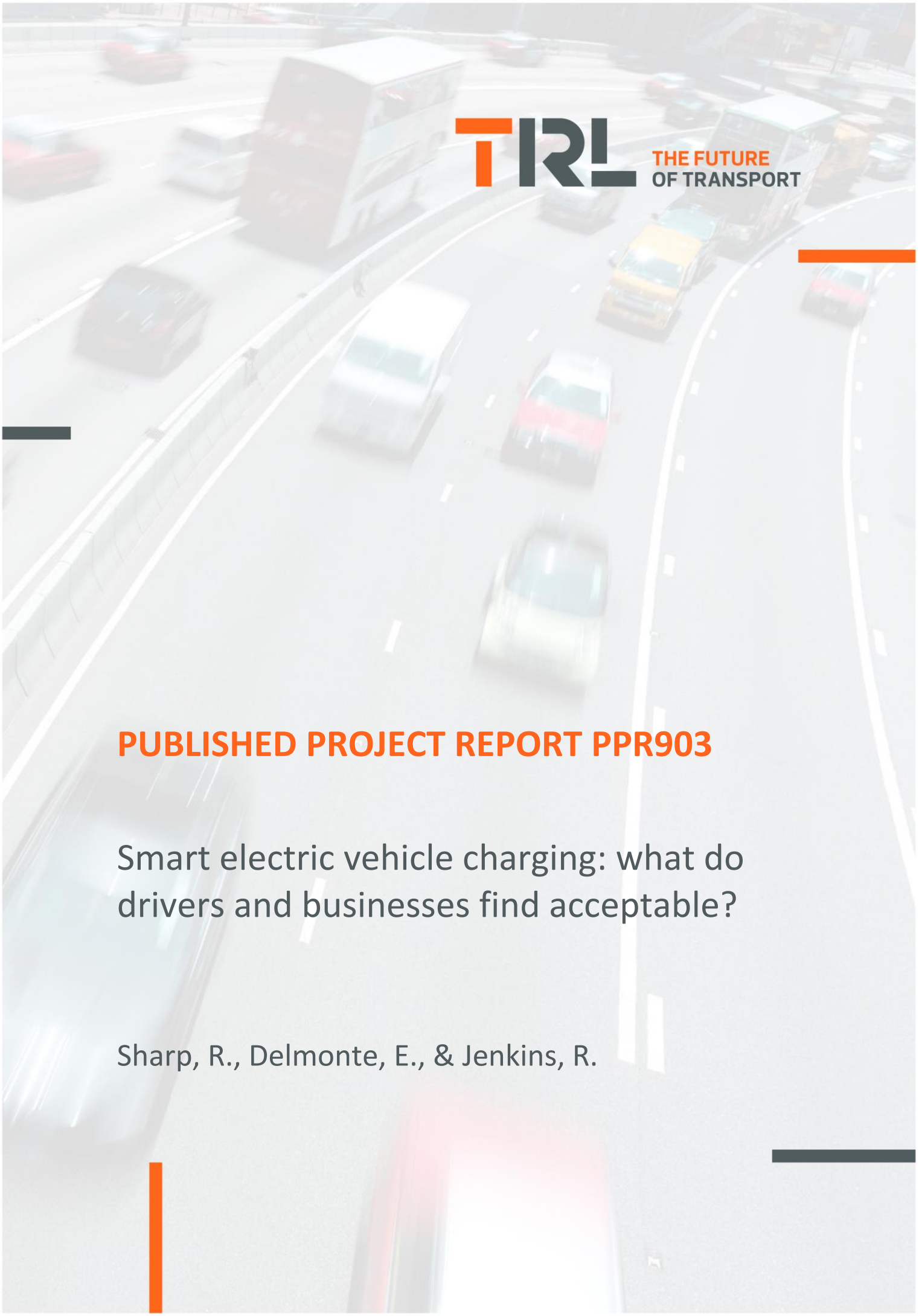

THE FUTURE OF TRANSPORT

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Smart electric vehicle charging: what do drivers and businesses find acceptable?

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Summary

Introduction

The increasing prevalence of electric vehicles (EVs) in the UK is bringing both challenges and opportunities for the energy system. Energy networks need to find ways to integrate EVs into the electricity system, which is constrained by how much electricity can be generated, transmitted and distributed. Successful integration of EVs into the electricity system will require a balance between managing the individual needs of current and future EV drivers to enable convenient, reliable charging, and mitigating against excessive peaks in energy demand. This must be done in the most efficient way, for the benefit of all electricity bill payers, who collectively pay for electricity networks. A key enabler in achieving such balance will be smart charging solutions that move charging away from times when electricity is already in high demand and which enable the potential benefits of EV batteries to be realised by the electricity network (e.g. their ability to feed energy back into the grid). To make these smart charging solutions appealing to drivers, it is crucial that government, regulators, and industry ensure current and future EV drivers' needs and perceptions are fully understood and considered.

TRL conducted this research on behalf of Citizens Advice, the statutory watchdog for energy consumers. We explored the attitudes and perceptions of current and prospective EV drivers, conventional vehicle drivers, and business representatives in relation to being flexible in their energy use, various options for facilitating smart EV charging, and what provisions (if any) would make those options more (or less) acceptable and compatible with their needs.

The research addressed five questions, specifically:

1. To what extent do households and businesses understand the need for them to become 'flexible' in their energy use, and how acceptable do they find this?
2. To what extent do households and businesses find various smart charging options acceptable?
3. What are households' and businesses' concerns or perceived barriers to uptake regarding these options?
4. What are households' and businesses' information needs before signing up to these options and who would they prefer to provide that information to them?
5. What provisions would households and businesses like to be put in place to increase acceptability of these options?

We discussed six smart charging options with participants:

1. Static time-of-use energy tariffs

Different price bands for electricity throughout the day, with higher rates applied at peak times, when demand for electricity is greater.

2. Dynamic time-of-use energy tariffs

Real-time or predictive prices for electricity throughout the day, which may change as often as half-hourly. Higher rates are applied when demand for electricity is greater.

3. Third-party charge management schemes

Allowing a third party to control EV charging, such as when and how quickly charging happens.

4. Vehicle-to-grid (V2G) services

Enabling EV users to return energy stored in their EV batteries to the grid when electricity is in high demand.

5. Smart charging technologies

6. Mandatory managed charging

For example, smart-enabled charge points and charging functions built into EVs which enable remote control and scheduling of charging, and which facilitate engagement with options 1-4.

Temporary slowing or pausing of EV charging by a third party, implemented as a 'last resort' if other options fail to reduce peaks in energy demands.

Method and sample

TRL conducted eight immersive, deliberative workshops with EV and Internal Combustion Engine (ICE) vehicle drivers, as well as two shorter 'mini' workshops with ICE vehicle drivers; one with parents of young children and one with individuals with mobility difficulties. Additionally, we interviewed representatives of small businesses (with up to 50 employees), of which some used EVs for business purposes and some used ICE vehicles. Samples for the workshops and interviews included individuals from England, Scotland and Wales, and from both urban and rural areas. Figure 1 details the sample characteristics for the workshops and interviews, including the numbers of participants in each sample.

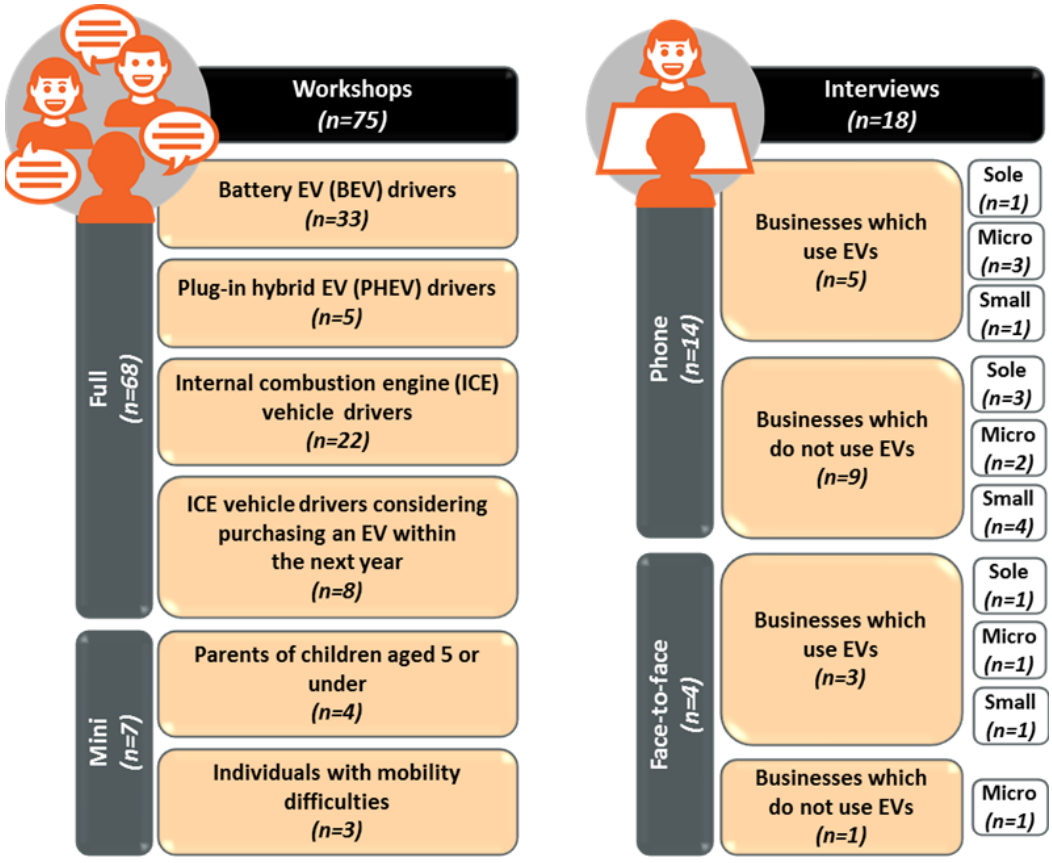


Figure 1: Sample sizes and characteristics

During the workshops, we gradually introduced the smart EV charging options to participants in an immersive way to ensure participants gained a clear understanding of the options. We provided participants with the opportunity to interact with the concepts and carry out practical exercises to help them to envisage how the options might impact their households. We captured participants' views on each option via workbooks and audio recordings of discussions.

For the business interviews, we provided participants with information about the six smart charging options to read in advance, before discussing the options in the context of their business needs during the interviews. Interviewers took notes to capture business interviewees' opinions.

Key findings

Generally, participants understood and accepted the need to be flexible in their energy use, so as to accommodate the increased demands on the electricity network that are likely to result from increased EV adoption. Some participants believed that EV drivers should be responsible for helping to balance electricity supply and demand, while others felt that this responsibility lies with National Grid, energy suppliers, or the government.

Attitudes towards smart charging options

When deciding which smart charging options were most suitable for them, participants were most likely to consider factors relating to saving money and the environment, with EV drivers placing greater emphasis on being environmentally friendly than ICE vehicle drivers. Convenience of use and the assurance of a minimum level of charge for upcoming journeys were also key considerations. Participants from rural locations were concerned that a lack of Internet and mobile signal where they lived meant that they would find it difficult to use some of the options, such as smart charging technologies. Additionally, participants who had mobility difficulties or young children expressed concerns that their irregular routines would make it difficult to plan their electricity usage.

Overall, views on each smart charging option were mixed, with some participants accepting them and others rejecting them. Nonetheless, all household participants felt that at least one of the options could fit in with their household. Generally, static time-of-use tariffs were preferred by most households. V2G services were also seen as a promising approach, and smart charging technologies were seen as a valuable tool to support implementation and engagement with other options. Third-party charge management schemes and dynamic time-of-use tariffs were the least favoured options amongst households.

The overarching theme from business participants was that time-of-use tariffs were the least suitable offers for their business needs, irrespective of business size or whether they used EVs or not. Most business participants suggested that if they needed to use EVs to meet their operational needs, they would simply ensure they were sufficiently charged, whether this meant charging at peak times (and at higher prices) or not. Because of the cost savings associated with running vehicles on electric power rather than fossil fuel, business participants did not tend to place much weight on any potential additional savings associated with smart charging. However, business participants saw the potential of V2G services and third-party charge management schemes to benefit their organisations financially.

Table 1 provides further detail on participants' views on each of the smart charging options.

Table 1: Summary of participants' views on each smart charging option

	Perceived advantages or benefits	Concerns or perceived barriers to uptake	Provisions that could increase acceptability
 Static time-of-use energy tariffs	Easy to understand. Most household participants thought that it would be easy to shift their energy use and EV charging to fit in with off-peak tariff bands, and that they could save money by doing so. Allow energy consumers to control their energy usage and predict the costs of electricity bills.	Business participants generally thought that synchronising energy use with off-peak tariff bands would be difficult. Could financially discriminate against those who may be unable to use electricity at off-peak times (e.g. businesses and families with young children).	A significant and proven cost saving. A guarantee that users would not be financially 'penalised' for charging when needed. No long-term contracts.
 Dynamic time-of-use energy tariffs	Could save energy consumers money on electricity bills, particularly compared with other types of tariff (e.g. static time-of-use tariffs).	Concerns were largely the same as those surrounding static time-of-use tariffs. Additionally, participants thought coinciding energy use with times at which electricity would be cheaper on these tariffs would be too complex and time-consuming.	Provisions to increase acceptability were largely the same as those for static time-of-use tariffs. Additionally, participants said suppliers should cap peak electricity prices or the cost of monthly electricity bills.
 Third-party charge management schemes	Business participants viewed a third party managing their energy supply as delegating some of their workload. Could save energy consumers money when combined with a time-of-use tariff.	Household participants disliked the idea of handing control of charging to a third party, especially if the third party or their services were not established or well-known. Potential financial costs associated with using these schemes (e.g. paying a third party).	A significant and proven cost saving. Ability to set EV charging preferences which third parties would be required to adhere to. Ability to override charges scheduled by the third party.
 V2G services	Compensation for allowing the grid to access energy stored in EVs' batteries.	Could leave customers (especially businesses and families with young children) without enough charge for unexpected or urgent journeys. Potential adverse effects on EV battery health. Potential financial costs associated with using these services (e.g. purchasing a V2G-enabled EV and charge point).	Significant and proven financial compensation. Discounts on V2G-enabled charge points and EVs. Ability to set charging preferences so an EV has sufficient charge for the next journey (e.g. to specify how much power the grid would be able to retrieve from an EV battery). Guarantees about impact on EV battery health.

	Perceived advantages or benefits	Concerns or perceived barriers to uptake	Provisions that could increase acceptability
 Smart charging technologies	Easy to understand. Helpful for managing EV charging. Could save energy consumers money when combined with a time-of-use tariff. Trusted because they are typically already established and widely used. Available in various forms (e.g. apps, websites, and systems built into EVs).	Would require a fixed routine and good Internet or mobile signal, so would not be suitable for all energy consumers (e.g. families with young children or those living in rural areas). Potential technical faults and data privacy or security violations.	Functions that allow users to schedule charging and override scheduled charges so they can start a charge immediately for an unexpected journey. Should be easy to use and not too time-consuming.
 Mandatory managed charging	Necessary to avoid blackouts and brownouts as the popularity of EVs increases. EV drivers are unlikely to notice its effects, as curtailment of charging would be temporary.	Could impact emergency services' and other EV drivers' ability to travel somewhere urgently if their EVs did not have the expected amount of charge when needed. Potential impacts on business operations if curtailment of EV charging became frequent. Unfairly discriminates against EV drivers.	Curtailment of EV charging should be time-limited. EV drivers should be given advanced warning of charging curtailment. Certain people and services should be exempt (e.g. those with mobility difficulties or emergency services).

Views on provisions that could increase acceptability of smart charging options

Household participants offered a variety of suggestions for ways in which acceptability of smart charging options could be improved, which differed between participants.

- EV drivers placed more importance on electricity coming from renewable sources and automated charging, whereas ICE vehicle drivers placed more importance on the certainty of charging costs.
- In relation to the **provision of information**, many participants said that they would like to receive notifications or information about costs of electricity and EV charging, compensation for services (e.g. allowing the grid access to energy stored in their EV battery), and their vehicle's current state-of-charge.
- **Adequate design of smart charging offers** was also important to household participants.
    - Participants suggested that smart charging options should be convenient to set up and use. Being able to use options without a smartphone or Internet access was more important to participants living in rural areas, due to having poor Internet or mobile signal.
    - Having control over charging (e.g. via the ability to set charging preferences and to override scheduled charges) was also important to the majority of household participants. Those with mobility difficulties and young children particularly emphasised the importance of being able to override scheduled charges to allow them to charge immediately for an emergency car journey.

- Receiving adequate financial incentives was also essential to participants, such as the service or scheme being offered at a low cost or free-of-charge.

- Participants said that the **provision of guarantees** would be an important factor when making decisions about smart charging options, such as guarantees about the cost of electricity bills and the effects of using a service or scheme on the health of EV batteries.

Information needs

Participants stated that they would value information that is clear in terms of how a smart charging option would operate, the costs, and the finer details of the contract and associated fees. Being able to visualise the option was felt to be important, including elements such as an easy-to-understand app interface and how cost savings would be presented. Where claims are made about a smart charging option (for example relating to its environmental benefits), participants required evidence to substantiate the claim. In terms of sources of further information about the options, the vast majority of participants said that they would use the supplier's website or a search engine, or the app associated with the option.

Conclusions

This research with households and small businesses, current and future EV drivers, illustrated the diversity of participants' energy consumption needs and perceptions of the advantages and disadvantages of various smart charging options; where one option may be accepted by one household or business, it may be rejected by another.

However, each participant felt able to adopt at least one of the smart charging options. Participants suggested provisions such as receiving further information, adequate design of smart charging offers, and receiving guarantees that could further encourage them to charge their vehicles flexibly. These findings are promising, given that smart charging will be vital to the integration of EVs into the UK's energy system.

Findings from this research indicate that there will be no 'one-size-fits-all' smart charging option – EV drivers will require a number of offers to choose from, depending on their needs and behaviours, and additional guarantees and information to encourage them to adopt smart charging. However, findings also suggest that EV drivers can understand the need for smart charging when impacts on the electricity network and environment are explained to them.

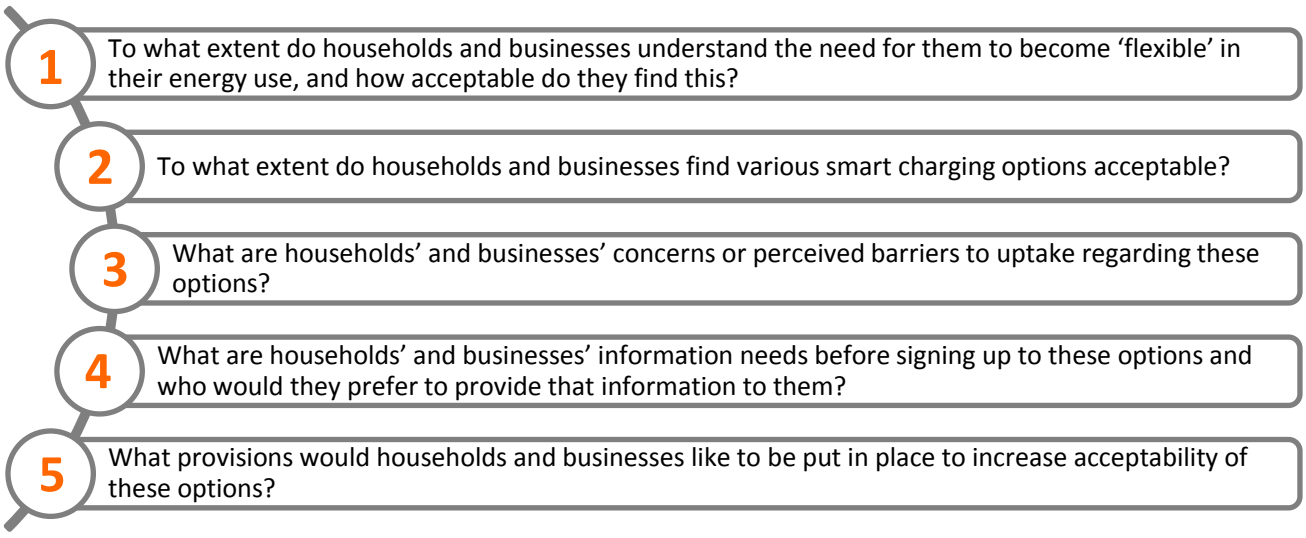
It is important to conduct further research to explore energy consumers' attitudes towards and use of various smart charging options, especially as the details of these options are further developed in the market. This research could include further qualitative studies, quantitative surveys or stated preference techniques to explore consumer choice in greater depth; specifically how consumers trade-off between various attributes of smart charging options when choosing their preferred option. Robust real-world evaluations should also be conducted (preferably using Randomised Controlled Trial designs) to collect quantitative data on consumer engagement with smart charging options. In particular, the role of smart charging options for consumers without off-street parking needs to be explored in detail, to understand how systems should be designed to fit the needs of these types of consumers where access to charging infrastructure may be shared across a number of households. Further research should also explore the potential (positive and negative) impacts of smart charging options on the energy system, and the steps which can be taken to maximise their effectiveness for balancing EV charging demand.

1 Introduction

The electric vehicle (EV) market in the UK is in an early stage of development, but expanding rapidly. Despite recent increases in sales, the share of battery EVs (BEVs) and plug-in hybrid EVs (PHEVs) in the UK is falling behind some of our European neighbours. There is a need for EVs to be adopted more widely in the UK, in part driven by stringent requirements to reduce greenhouse gas emissions in 2050 by 80% compared to 1990 levels[1]. The UK government's announcement to end all sales of vehicles powered solely by petrol or diesel by 2040 (2032 in Scotland) is part of the Road to Zero strategy[2] to meet these requirements.

Increased adoption of EVs will bring about new and significant challenges for energy consumers and the UK's energy system, which will face additional demands associated with charging EVs. It is therefore crucial that a good understanding is developed of how best to integrate EVs with the energy system to manage this charging demand. The design and implementation of appropriate 'smart' charging options will likely be essential to this integration. Various smart charging options are already available or under trial, and all assume that the EV driver will adopt a degree of personal flexibility in terms of when and how they charge their vehicle. To achieve sufficient uptake of smart charging options by current (and future) EV drivers, smart charging must be compatible with drivers' needs and perceptions.

The purpose of this research was to understand current and prospective electric vehicle drivers' attitudes towards being flexible in their energy use and various smart charging options, and what provisions (if any) would make the options more acceptable. Citizens Advice, in their role as the statutory consumer body for energy consumers, commissioned TRL to undertake this research to address a number of key gaps in evidence. Firstly, most previous EV research has involved current EV drivers (i.e. the 'Innovators'), whereas in the future, EV drivers will be more demographically diverse and may be less willing to accept smart charging. Secondly, the views of small businesses in relation to these issues have largely been overlooked. Finally, no previous research has explored the attitudes of drivers who have vulnerable household members and therefore may rely more on their vehicle. We aimed to address these gaps to inform ongoing industry and policy work undertaken by Citizens Advice, by answering five research questions:



[1] The UK Government (2008). *Climate Change Act 2008: Chapter 27*. London, UK: The Stationary Office Ltd.

[2] Office for Low Emission Vehicles (2018). *The Road to Zero: Next steps towards cleaner road transport and delivering our Industrial Strategy.* London, UK: Department for Transport.

2 Method

2.1 Overview

To address the research questions, this research focused on six options related to 'smart' charging (see Figure 2). TRL conducted workshops and interviews in England, Wales and Scotland to explore participants' attitudes towards these options:

- Eight full-length deliberative, immersive workshops explored EV drivers' (n=38) and ICE vehicle drivers' (n=30) attitudes. Recruitment activities included online adverts, forums, social media, organisations local to the venues, and snowballing. A sampling matrix was used to ensure a mix of those who currently drive EVs and those who drive ICE vehicles, age, and urban/rural locations.
- Two mini workshops were less immersive but explored attitudes of two distinct groups: parents of young children aged 5 or under (n=4) and individuals with mobility difficulties (n=3). These groups were of interest as they may have had additional or different vehicle usage needs, and therefore different attitudes in relation to the acceptability of the smart charging options to their household. We recruited these participants via local online forums.
- 14 telephone interviews and four face-to-face interviews were conducted with representatives of sole (n=5), micro (n=7), and small (n=6) businesses to explore their attitudes towards the six options in relation to their business operations. We recruited interviewees using a variety of channels including social media, business associations, and existing contacts.

Details of the workshop participant demographics can be found in Appendix A and Appendix B, and details of the business interviewee demographics can be found in Appendix C.

Static time-of-use energy tariffs

- Different price bands for electricity throughout the day
  - Dependent on the time of day, day of the week, or season
  - Higher rates are applied when demand for electricity is greater (i.e. when less electricity is available)
- In some cases, installation of a smart electricity meter is required
- Aim: To encourage you to use electricity at times when more electricity is available cheaply

Dynamic time-of-use energy tariffs

- Real-time or predictive prices for electricity throughout the day
  - Dependent on the time of day, day of the week, or season
  - Higher rates are applied when demand for electricity is greater
  - Prices may change as often as half-hourly
  - You can be notified of price changes in advance
- Cannot be used in conjunction with prepayment meters
- Aim: To encourage you to use electricity at times when more electricity is available cheaply

Third-party managed charging

- Allows a third party to directly control charging of your electric vehicle (e.g. when and how quickly charging happens)
- Generally requires a smart-enabled charge point
- Aim: To give a third party responsibility for meeting your charging requirements whilst avoiding delivering charge when demand for electricity is high

Vehicle-to-grid (V2G) services

- Electric vehicles can return energy stored in their batteries to the grid when electricity is in high demand
- You can be compensated for making your electric vehicle battery power available
- Requires:
  - A V2G-enabled vehicle
  - A 'two-way' charge point
- Aim: To encourage you to provide energy to the grid so that overall demand for electricity can be met

Smart charging technologies

- An 'enabler' of mechanisms 1-4
- Includes technologies such as smart-enabled charge points or charging functions built into electric vehicles
- Could be used with time-of-use tariffs
- Needed for other charging management schemes
- Aim: To enable remote control and scheduling of charging

Mandatory managed charging

- Third parties may need to intervene if other methods of managing electricity use fail to reduce peaks in energy demands
- They may slow down or pause charging of electric vehicles
- Would be used as a last resort, and only in extreme situations
- No option to override
- Aim: To avoid localised blackouts or brownouts

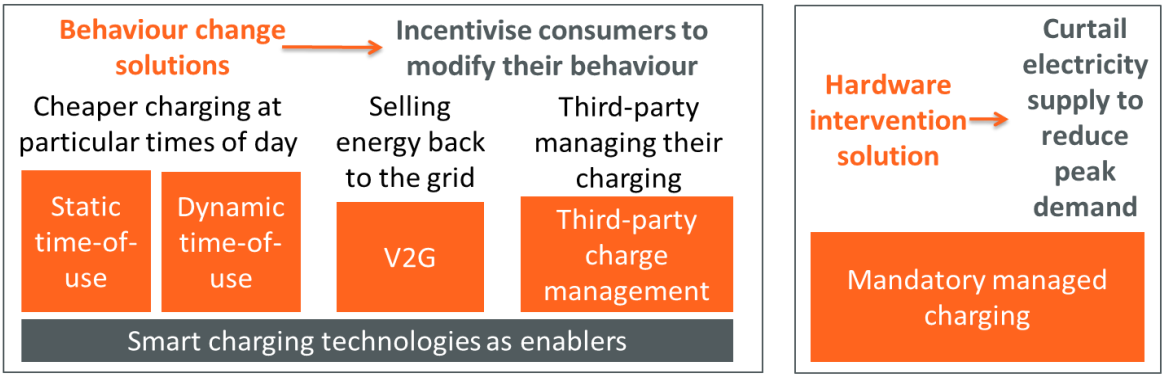


Figure 2: Overview of the six smart charging options

2.2 Full-length workshops

TRL conducted eight full-length workshops during January and February 2019 in England (three workshops; 35 participants), Scotland (three workshops; 19 participants), and Wales (two workshops; 14 participants). A pilot workshop in England was conducted prior to these workshops to ensure the approach and the data collected would effectively address the research questions.

Participant characteristics comprised a variety of ages, genders, and locations (rural and urban[3]). We conducted two types of full-length workshop; one with current EV drivers and another with current ICE vehicle drivers, including individuals who indicated they would be likely or very likely to purchase a BEV or PHEV in the next year (denoted as 'soon-to-be' (STB) EV drivers). The split of participants across these groups is shown in Table 2.

Table 2: Full-length workshop participant groups

Workshop type	Group name	Definition	No. of participants
 EV drivers	BEV drivers	Current BEV drivers	33
	PHEV drivers	Current PHEV drivers	5
 Current ICE vehicle drivers	ICE vehicle drivers	Current ICE vehicle drivers who were not considering buying or leasing an EV within the next year	22
	STB EV drivers	Current ICE vehicle drivers who were considering buying or leasing an EV within the next year	8

The full-length workshops were deliberative and immersive in nature. Individuals who are psychologically distant from a concept tend to construe it in high-level, abstract terms, rather than low-level terms which directly relate to their own needs and lifestyle. Deliberative workshops which provide an immersive environment for participants are an effective way of reducing psychological distance from novel concepts – something which is particularly pertinent for EV consumer research since the EV market is still in its early stages, meaning the majority of the mass-market have had little direct experience or knowledge of smart EV charging options (or indeed of EVs in general for ICE vehicle drivers). The workshops aimed to bring the smart charging options 'to life' for the participants in order to improve their understanding (and therefore the validity of their appraisals of the options, and their anticipated adoption).

With these considerations in mind, we designed the workshops to be deliberative in nature; this method does not seek to simply explore participants' current viewpoints, but gives participants the opportunity to fully consider the information and issues surrounding the topic of smart charging options for charging EVs. We also designed the workshops to be as immersive as possible, helping bring the concepts to life for participants to aid their understanding, and encouraging participants to envisage the impacts of each option on their own household and daily travel needs. Each workshop lasted approximately four hours and employed a number of immersive techniques. Figure 3 summarises the workshop structure.

[3] The rural/urban split was defined using data on the population density of the electoral ward (Office of National Statistics); a population density <1,000/km^2 was defined as rural, and a population density >=1,000/km^2 was defined as urban.

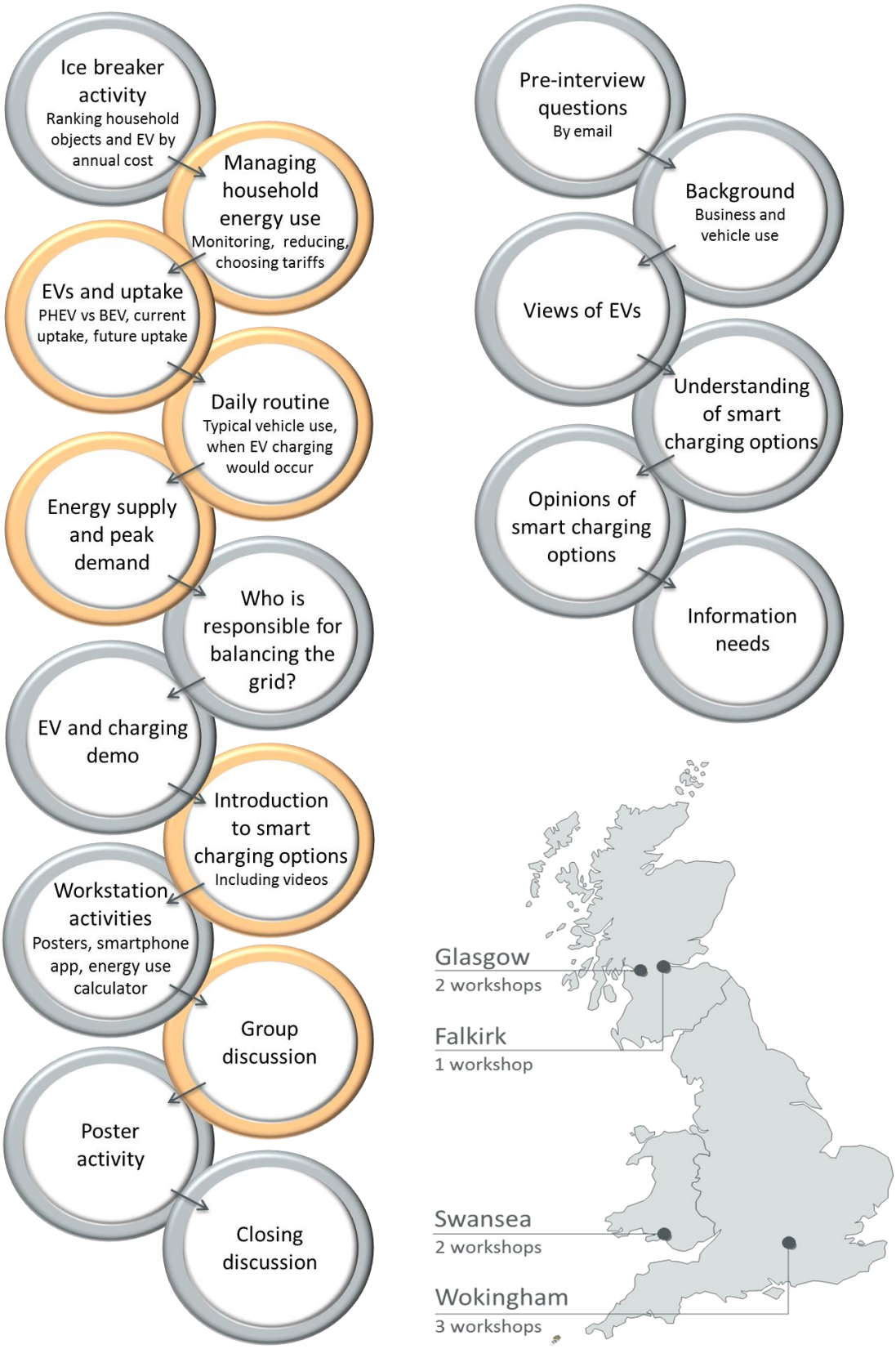


Figure 3: Workshop structure and locations of full-length workshops[4]

[4] Elements of the workshop structure highlighted in orange are those that formed parts of both the full and mini workshops.

Facilitators gradually introduced the key concepts to participants throughout the workshop. The workshops included paired discussions, group discussions, and interactive activities (see Figure 4) including:

- A 'daily routine' exercise in which all participants indicated on a large timeline the times of day at which they would typically leave home, arrive home, and charge their EV. This exercise provided a visual summary of the peak demand issue.
- A demonstration of an EV and how to charge it.
- Posters from fictional energy providers providing information on smart charging offers.
- An interactive calculator demonstrating the cost of charging at certain times of day on static and dynamic time-of-use energy tariffs (see Figure 5).
- Visualisations of mock smartphone apps that could be used alongside the offers.

The complete slide deck used in the workshops is shown in Appendix D. We provided each participant with a workbook (see Appendix E) to enable them to record their initial responses to the options, thoughts that they did not verbalise in the discussions, and responses to some quantitative questions.

Figure 4: Photos taken during the workshops, including example of the 'timeline' exercise

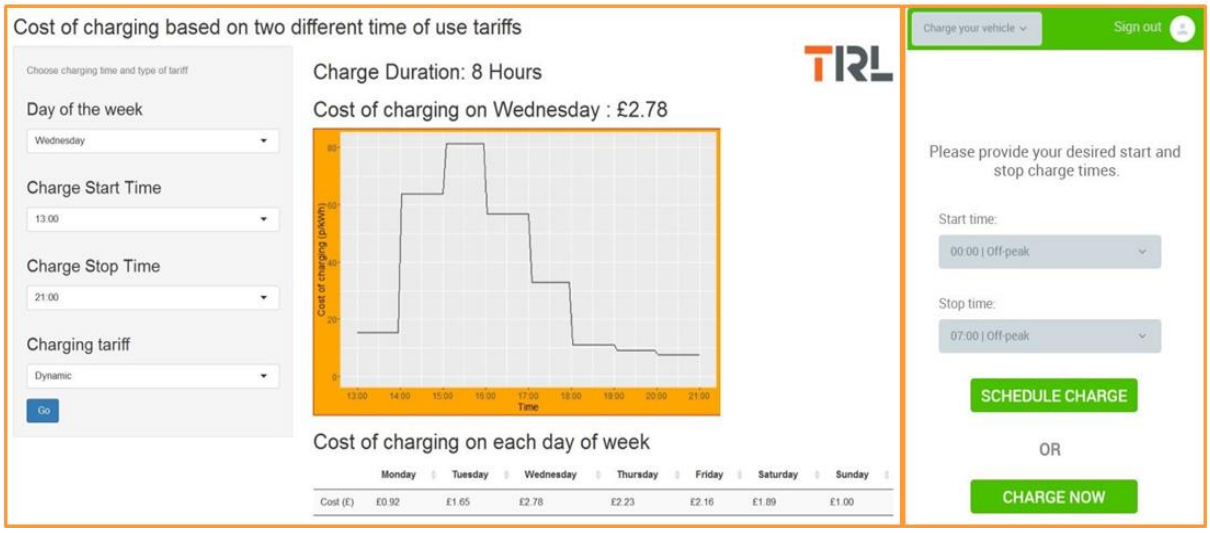


Figure 5: Example time-of-use energy tariff calculator (left) and example smart charging app screenshot (right) used to demonstrate smart charging options during the workshops

2.3 Mini workshops with drivers with vulnerable household members

We conducted two mini workshops in England with a total of seven participants (four were parents of children aged five or under, and three were individuals with mobility difficulties). All participants were current ICE vehicle drivers. Each workshop lasted approximately 90 minutes, and so a reduced level of immersion was provided to participants compared to the full-length workshops, but they covered the same core topics and research questions.

2.4 Interview with small business representatives

We interviewed 18 representatives from a range of business types (for example taxi operator, IT support, training) and sizes ('sole' - sole trader, 'micro' - up to ten employees, or 'small' - 11 to 50 employees). All participants were responsible for vehicle procurement within their business and eight of the businesses used EVs for their operations. We conducted face-to-face and telephone interviews, lasting up to one hour. Before the interview, we asked participants to complete a short survey (see Appendix F) to gather background information. We developed a semi-structured interview topic guide (see Appendix G) to ensure a consistent approach was followed during the interviews. The interviews focused on current vehicle usage and opinions of the smart charging options in relation to the business' needs.

2.5 Data collection and analysis

All workshop participants and interviewees completed a registration survey which gathered background and demographic information. We audio-recorded all workshops and interviews, and workshops were then transcribed.

Four researchers conducted all research activities, and three of those researchers thematically analysed the transcripts, workbook contents, and business interview notes. As per Braun, Clarke, and Terry (2014)[5], a recursive process was used: involving familiarisation with the data; generation of initial codes relevant to the

[5] Braun, V., Clarke, V., & Terry, G. (2014). Thematic analysis. In P. Rohleder & A. Lyons (Eds.), *Qualitative research in clinical and health psychology*. Basingstoke, UK: Palgrave MacMillan.

research questions; searches for themes and broader patterns of meaning; review and refinement of themes; and detailed analysis of each theme, before the final reporting of findings and conclusions.

We have included quotes from the transcripts and free-text workbook responses throughout this report to help illustrate the themes. Where possible, we have assigned the quote to an individual participant. On occasion, the transcripts did not identify the specific participant who was speaking; in which case we attributed the quote to the participant's vehicle type (i.e. EV or ICE vehicle driver) and country where the workshop was held (England, Scotland or Wales).

The majority of this work is qualitative but we collected some quantitative data from the workshop participants' registration surveys and workbooks, which have been used to supplement the findings. Findings based on these data should be interpreted with caution due to small group sizes.

We discuss differences between participants who currently drive an EV and those who currently drive an ICE vehicle throughout the report. Where relevant, we also discuss differences between those from different countries, from rural or urban areas, and between those with or without vulnerable household members (i.e. those with mobility difficulties, or households with children aged five or under).

2.6 Limitations

We collected the majority of data qualitatively, with the workbooks and registration survey providing a quantitative element. A number of limitations should be considered alongside the conclusions from this research.

2.6.1 Self-selection bias

We selected participants using an opportunistic sampling technique. Individuals decided for themselves whether to respond to the registration survey. Their motivations for participating are unknown, but may have related to particular attitudes, interests or opinions about the research subject, wanting to find out more information about the research subject, wanting to contribute to research (in general), or the financial incentive on offer. Due to endeavouring to meet a sampling frame (for vehicle type, country and urban/rural locations), we did not invite all individuals interested in the research to participate. The sampling frame was not designed to represent the general population, rather to ensure a mix of participant types and views. Therefore the sample was prone to self-selection bias, meaning that it is unlikely to be truly representative of the general population.

2.6.2 Sample size and stratification

Despite using various recruitment methods, achieving the target sample was difficult, particularly when recruiting small business representatives in Scotland and Wales. Recruitment of business participants is typically difficult, as there is a risk that participation could impact on operations, and so business representatives can be reluctant to give up their time to take part in research activities. In addition, the difficulty recruiting representatives of businesses which use one or more EVs could be indicative of the current vehicle market.

We did not strategically sample household participants with and without off-street parking, and discussions and activities in the workshops were focussed on using the smart charging options at home. Compared with charge points installed at homes with off-street parking, there is likely to be added complexity associated with applying smart charging options to on-street charging infrastructure which may be shared across multiple households. As such, the household workshop findings cannot be readily applied to these use cases.

2.6.3 Gender bias

There also appeared to be an androcentric bias, with 89% of EV drivers in the workshops being male (and 71% of all participants). However, this may be somewhat representative of EV drivers in the UK; limited comprehensive or recent data are available, but a 2013 study with a small sample of early EV adopters found that 89% were male[6]. About 50% of ICE vehicle drivers in the workshops were male, which reflects the general population of driving licence holders (in 2017, 53% of all driving licence holders in the UK were male). Therefore, while there was an over-representation of males amongst the participants, it can be considered that this is reflective of the current vehicle market.

2.6.4 Dominance bias

The group dynamics within the workshops may also have biased responses, with the presence of dominant or reserved personalities observed in some of the sessions. Dominance bias is associated with the risk of other group members assuming that a dominant person is also competent[7], and that their views are correct, thus influencing group opinion.

2.6.5 Researcher bias

Given that we introduced participants to concepts that they may have been unfamiliar with, participants' attitudes towards the smart charging options are likely to have been influenced by the way in which we presented the options and the information we provided to participants. However, we made every effort to inform participants about the options in an impartial manner.

2.6.6 Moderator bias

Moderator bias may also have been introduced. Two out of a pool of four moderators, who differed in style and personality, facilitated each workshop. However, the method was consistent for each workshop, with moderators using a standardised guide to ensure the same topics were explored, and so these potential biases should not have introduced substantial confounding effects.

2.6.7 Hypothetical bias

Despite using immersive techniques to help participants envisage how the smart charging options might impact their households, the questions we asked of participants were hypothetical (e.g. 'Do you see 'smart charging' as something that *could* fit in with your household?'). Participants may have responded differently if they had been asked to make decisions that would actually impact their households in the real-world.

[6] Hutchins, R., Delmonte, E., Stannard, J., Evans, L., & Bussell, S. (2014). *Assessing the role of the Plug-in Car Grant and Plugged-in Places scheme in electric vehicle take-up.* Crowthorne, UK: Transport Research Laboratory.

[7] Anderson, C., & Kilduff, G. J. (2009). Why do dominant personalities attain influence in face-to-face groups? The competence-signaling effects of trait dominance. *Journal of Personality and Social Psychology, 96*(2), 491.

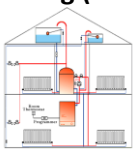
3 Results

3.1 Baseline knowledge of EVs and charging

3.1.1 What do households know about electricity demand management, EVs, and charging?

For the initial exercise in each full-length workshop, facilitators asked participants, in groups, to rank five household objects in terms of their average annual household energy costs in Great Britain. The results are shown in Table 3; here it is clearly shown that ICE vehicle drivers generally had a lower level of knowledge than EV drivers of the cost of charging an EV, with widely varying responses across the groups. One group ranked the EV as most expensive, and another as least expensive. On the other hand, the EV driver groups consistently ranked the EV correctly in terms of relative average annual energy cost.

Table 3: Participant rankings of average annual costs of electricity used for household appliances and EVs (each row represents the rankings of one group within a workshop)

	Most expensive →				**Least expensive**
	Gas central heating (GCH) 	**Electric vehicle (EV)**[8] 	**Fridge-freezer** 	**TV** 	**Electric oven** 
Correct ranking					
ICE vehicle drivers' rankings	EV	GCH	Fridge-freezer	Electric oven	TV
	GCH	EV	Electric oven	Fridge-freezer	TV
	GCH	Electric oven	EV	TV	Fridge-freezer
	GCH	Electric oven	EV	Fridge-freezer	TV
	GCH	Electric oven	EV	Fridge-freezer	TV
	GCH	Fridge-freezer	Electric oven	EV	TV
	GCH	Electric oven	Fridge-freezer	TV	EV
EV drivers' rankings	GCH	EV	Fridge-freezer	Electric oven	TV
	GCH	EV	Electric oven	Fridge-freezer	TV
	GCH	EV	Electric oven	Fridge-freezer	TV
	GCH	EV	Electric oven	TV	Fridge-freezer
	GCH	EV	Electric oven	Fridge-freezer	TV
	GCH	EV	Electric oven	Fridge-freezer	TV
	GCH	EV	Electric oven	Fridge-freezer	TV
	GCH	EV	Electric oven	TV	Fridge-freezer

We asked participants to indicate their level of knowledge in relation to five statements about energy use and charging EVs. As shown in Figure 6, EV drivers on average had a greater level of self-declared baseline knowledge compared to ICE vehicle drivers.

[8] Based on a 30kWh battery, a real-world range of 115 miles, annual mileage of 8,000 miles

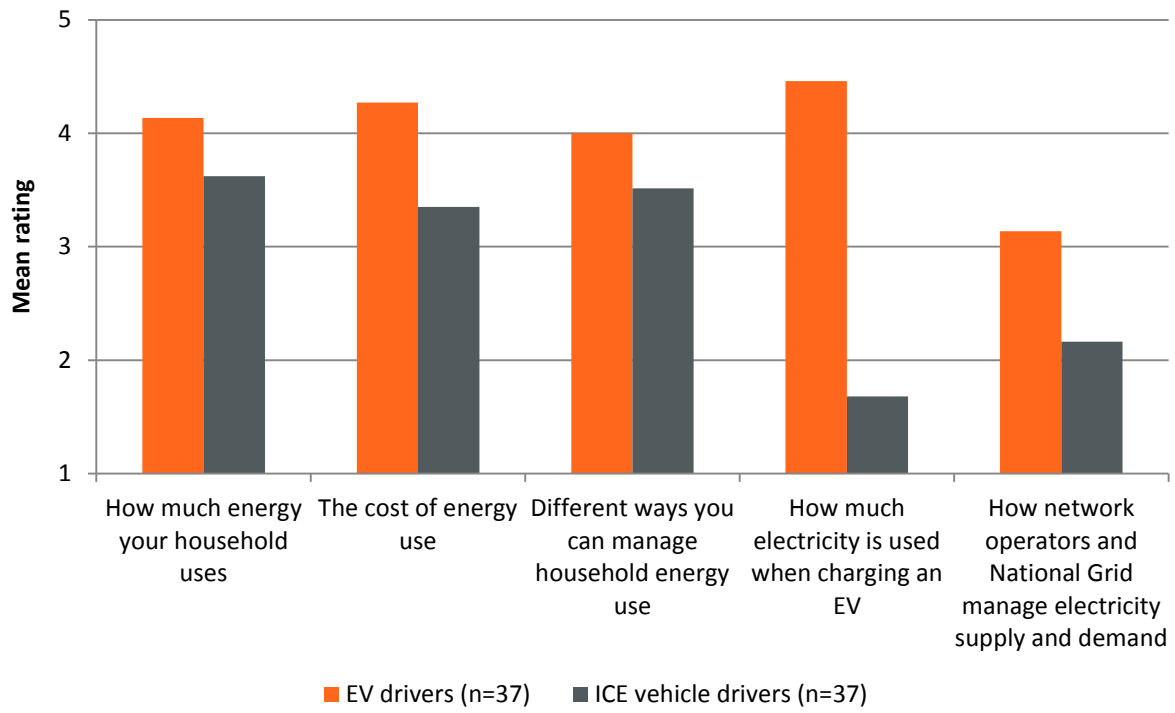


Figure 6: Participants' average self-reported levels of knowledge about several aspects of energy use before the workshop, from 1 ('I know nothing about this') to 5 ('I know a great deal about this')

In a free-text question, we asked participants what percentage of registered vehicles in the UK was made up of plug-in EVs in 2018 (with the correct answer being 0.5%[9]). Generally, participants thought the percentage of plug-in EVs was greater than 1% (as shown in Figure 7).

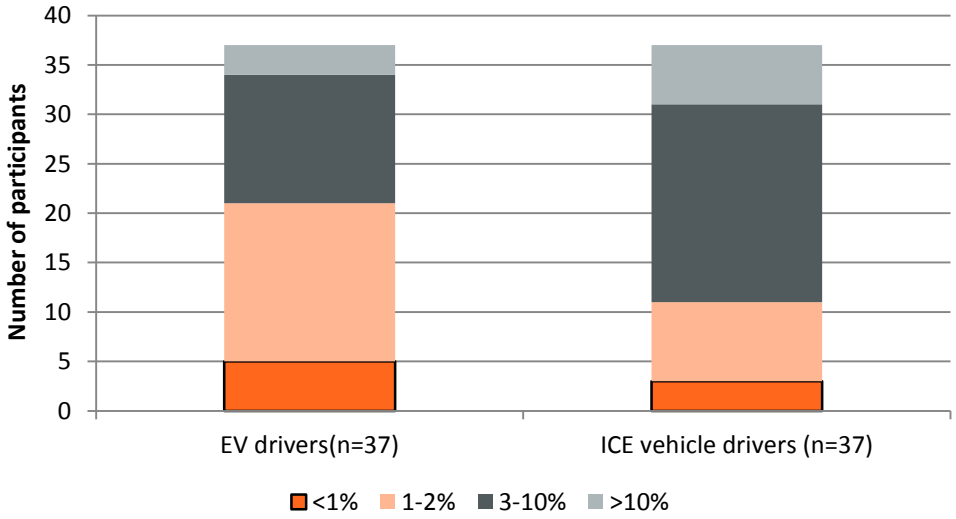


Figure 7: Participants' estimates of the percentage of plug-in EVs in the UK in 2018 (correct responses are outlined)

Another free text question asked participants the year by which the government aims to stop sales of new conventional petrol and diesel cars and vans, with the correct year being 2040 for England and Wales, and

[9] Department for Transport (2019). *Vehicle Licensing Statistics: Annual 2018.* London, UK: Department for Transport.

2032 for Scotland. Figure 8 shows that more EV drivers than ICE vehicle drivers in England, Wales, and Scotland knew the correct year.

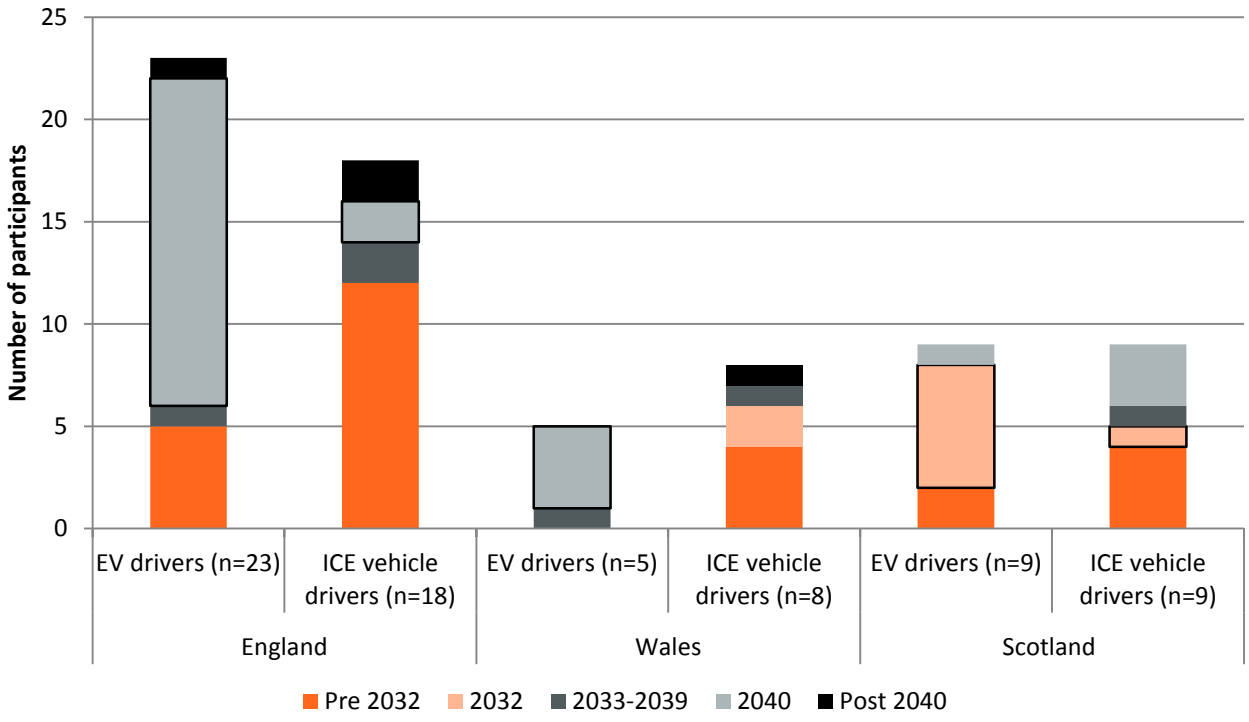


Figure 8: Participants' estimates of the year by which sales of conventional diesel and petrol vehicles will end (correct responses are outlined)

Inter-group differences regarding self-declared levels of knowledge of EVs and charging

There were no discernible differences in self-declared levels of knowledge by country or urban/rural location.

3.1.2 To what extent do households understand the need for them to become 'flexible' in their energy use and how acceptable do they find this?

The workshops explored whether participants believed that EV drivers should have responsibility for balancing the grid at times of peak demand, and if not, who should have responsibility. We encouraged participants to propose any ideas for managing increases in peak demand.

Should EV drivers be responsible for helping to balance the grid?

Participants held a range of views about where the responsibility for balancing the grid should sit. Some EV drivers thought that they had a degree of responsibility and said that they would be willing to adjust their charging routine to help balance the grid.

> *"I think it is essential because if the number of electric vehicles on the road grows, which we expect it to, to not have to need more generating capacity; we have got to make use of all this technology and tariff incentives to smooth the demand out. So, I think it is going to happen."* (EV driver, England)

Some participants felt that their contribution should be incentivised.

> *"It would have to be a joint effort i.e. incentives to charge at times when excess in the network is available. The onus is on the supplier/government to educate and incentivise."* (B21, BEV driver, England, urban)

A number of EV drivers believed that an increase in the number of EVs would not impact the demand on the grid, proposing instead that EVs (and their batteries) were actually the "*the way forward*" in managing supply and demand.

> *"EVs and the grid should cooperate to automatically control consumption and smooth peaks using communication to the EVs."* (B43, BEV driver, Wales, rural)
>
> *"Cars will help balance the grid… you're driving round a power pack… most vehicles are sitting idle 80% of the time, if you plug it into the grid when you're not using it, that energy can be harnessed by the grid to help balance the peaks and troughs."* (B18, BEV driver, England, urban)

A few ICE vehicle drivers suggested that EV drivers had a responsibility to help balance the grid.

> *"Be responsible and only charge your vehicle if and when required. Do not use unnecessary electricity."* (I35, ICE vehicle driver, Scotland, urban)

Both EV and non-EV drivers typically felt that some responsibility for balancing the grid should also sit with National Grid. Some EV drivers felt that they had already made their contribution to the environment by buying their EV and that making EV drivers responsible would have a potentially negative impact on EV uptake.

> *"You know, your average Joe on the street shouldn't have to be responsible for that, and if that's a consequence of buying an electric vehicle, the average Joe on the street won't want to."* (BEV driver, England)

In addition to National Grid, participants suggested that energy suppliers and the government had a responsibility for balancing the grid. Views on the ways in which energy suppliers could support balancing the grid were centred on incentives that they could or should offer to influence people to charge EVs at times where demand on the grid is lower.

> *"Energy companies need to offer pricing structures to influence/encourage."* (B38, BEV driver, England, urban)

Participants felt that the government could do a number of things in order to support balancing the grid, including imposing building regulations on newly built homes to insist on the provision of sustainable charging points or energy storage facilities.

> *"Government could make house builders install solar panels plus electric storage batteries in all new houses."* (B39, BEV driver, Wales, rural)

It was also felt that the government should provide more public charging points or charging points at business premises, which would result in additional charging options for EV drivers, increasing opportunity to charge outside of peak periods.

One of the elements of the workshop was a role play exercise, where we asked participants to imagine that they worked for an organisation that was responsible for balancing the grid, and to discuss how they would manage an increase in energy demand resulting from an increased uptake of EVs. In pairs, participants discussed their ideas, which included:

- Financial incentives for EV drivers to charge at times of the day where energy demand is lower

> *"Make overnight costs less than daytime or even have an 'electric car' tariff."* (B11, BEV driver, mobility difficulties, Scotland, rural)

- Make use of alternative energy sources to increase the amount of energy available to consumers

> *"By increasingly looking at other resources i.e. wind power, nuclear power stations etc."* (S04, STB EV driver, parent of young child, England, rural)

- Energy storage solutions (such as V2G or vehicle-to-home services)

> *"If the car identifies itself to the grid, then the grid can modulate use."* (P02, PHEV driver, England, rural)

Current energy supply

Some participants indicated that they were already adopting a 'smart' approach to charging, by choosing energy supply tariffs that provided cheaper electricity at off-peak times (e.g. an Economy 7 tariff). EV drivers were more likely to use an Economy 7 (or similar) tariff than ICE vehicle drivers, whereas fixed tariffs were more common amongst ICE vehicle drivers than EV drivers.

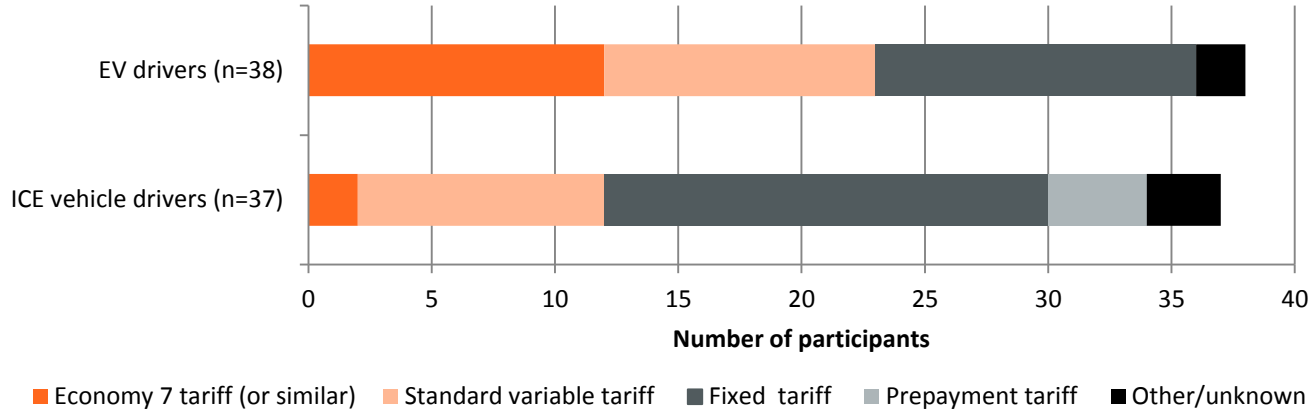


Figure 9: Participants' self-reported current energy tariffs

Two thirds of business participants indicated they had sole responsibility for making decisions about energy supply for their business. Sole traders and small businesses tended to be home-based (almost two thirds), and seemed to place little priority on energy costs which were typically considered as part of their home energy consumption.

> *"Your typical business spends 1-2% of its turnover on gas and electric. Compared with salaries, leasing or renting buildings, energy is insignificant."* (Business02, ICE vehicle, England, sole business)

In the sample, one business produced its own energy by means of a wind turbine and two businesses used a 'green' tariff.

> *"I'm currently with [supplier] and they allow me to use their rapid chargers on the motorway and they're vegan, and they're green and actually, it was a tiny bit more expensive than a not green tariff but not that I would notice, I'm already saving money on fuel, so I figured let's try and be a little bit altruistic and have a green tariff."* (Business05, EVs, England, microbusiness)

Importance of access to a household vehicle for emergencies

In the registration survey, we asked workshop participants to what extent they would rely on their household vehicle in an emergency situation. A greater reliance on the vehicle in emergencies may be associated with a reduced willingness to be flexible in their charging, since they may perceive a need for the vehicle to be charged whenever possible. Overall, most participants indicated they would rely on their vehicle 'very much' or 'quite a lot', as shown in Figure 10.

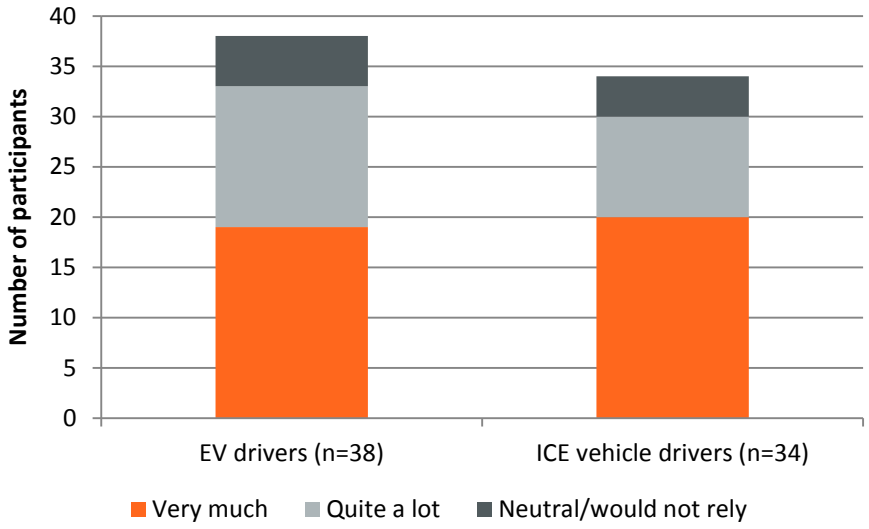


Figure 10: Participants' perceived reliance on household vehicles for emergencies

We asked participants to briefly explain *why* they would rely on their household vehicle in an emergency situation. Responses fell under the following themes:

- Lack of public transport or other transport options, often due to living in a remote area

  "I live in a rural area and public transport is not very regular." (B12, BEV driver, England, rural)

  "People in rural areas haven't got an option of any other transport if they've only got an EV in the family." (P06, PHEV driver, Wales, rural)

- Preference for using a car over calling out an ambulance (for medical emergencies)

  "Because we've waited two hours for an ambulance in the past." (B08, BEV driver, Scotland, urban)

  "Rural location, ambulance may be busy." (B30, BEV driver, England, rural)

  "We would want to be able to get immediately to the location we needed to go to without having to wait for public transport, or organise lifts. We live quite remotely too." (C02, ICE vehicle driver, parent of young child, England, rural)

  "We don't believe in undue pressures being placed on the ambulance service." (S10, STB EV driver, partner has mobility difficulties, Wales, urban)

- Feeling that a car is the only option

  "In those rare [emergency] situations I would require a car to get from A to B." (I01, ICE vehicle driver, England, rural)

  "As an elderly lady, the convenience of a car is essential." (I35, ICE vehicle driver, Scotland, urban)

For business participants, emergency situations were not a big concern, but they were clear that vehicles can be crucial to the operation of the business, and so any situation in which they could not access the vehicle(s) would have a big effect:

> *"[Having an EV that is not charged would be a] catastrophe, as cars need to be on the road making money."* (Business09, EVs, Scotland, small business)

Inter-group differences regarding importance of access to a household vehicle for emergencies

Participants from Scotland and Wales were more likely to state that they would rely on their vehicle 'very much' compared to participants from England. Some participants living in rural areas also indicated that they heavily rely on their vehicle due to a lack of available public transport. Additionally, those participants living with vulnerable individuals expressed concerns about not being able to reach a hospital quickly without access to a private vehicle.

3.2 Attitudes towards smart charging options

This section discusses the participants' views of the six options for smart charging. During the workshops, we presented participants with a summary of each option and completed two immersive exercises in order to facilitate their understanding of the options.

Prior to their interviews, we provided business participants with slides detailing the different smart charging options. During the interviews, we asked participants to share what they considered were the advantages or disadvantages and practicalities of each for their organisations. Very few of the business participants were aware of the different options prior to the interviews.

The following sections summarise the key findings in relation to each of the smart charging options and are supplemented with relevant insights from participants.

3.2.1 Static time-of-use energy tariffs

Static time-of-use tariffs comprise of several price bands for electricity throughout the day, which are dependent on the time of day, day of the week, or season. Higher rates are applied when demand for electricity is greater. In some cases, installation of a smart electricity meter is required to use a static time-of-use tariff. These types of tariff aim to encourage users to use electricity at times when more electricity is available cheaply.

Summary of attitudes towards static time-of-use energy tariffs

For household participants, this was the most simple and acceptable option. Many participants said that they would find it easy to shift their electricity use and EV charging to fit in with off-peak tariff bands.

Business participants generally rejected this option, as their organisation's operational requirements would often require them to use electricity and charge EVs during peak times, which may mean higher expenditure on electricity.

What are the perceived advantages or benefits of static time-of-use energy tariffs?

General concept

In general, many participants indicated that they would be happy to use this type of tariff. Common themes that emerged were that the concept of this type of tariff was sensible and that the multiple price band

structure was simple and clear, which therefore made this type of tariff easy to understand. Participants were also of the opinion that this type of tariff would become necessary in helping to balance electricity supply and demand as the popularity of EVs increases.

Additionally, several participants pointed out that using this type of tariff would not require much technical knowledge, making it accessible for the majority of people.

Benefits for the electricity network and environment

Participants felt that this type of tariff would be effective at incentivising consumers to use electricity (including charging their EVs) at times when electricity demand is low. They also felt that this would help National Grid to balance electricity supply and demand, and allow them to take better advantage of renewable energy.

> *"I'd probably go with static time-of-use if I changed the tariff at all…I do avoid charging at the peak times if I can…for the good of the grid and the planet as a whole."* (B41, BEV driver, Wales, urban)

Ease of use

Participants liked that this type of tariff comprises of a set number of fixed tariff bands, as this makes it is easy for consumers to remember the tariff bands and the cheapest times at which to use electricity. Similarly, participants indicated that they thought it would not require much thought, time or effort to plan and shift their electricity use, and specifically their EV charging, to fit in with off-peak tariff bands. Participants also felt this was relevant to certain appliances that do not need to be used at certain times of day, such as washing machines.

> *"It's simple to use, easy to set up with a charging timer and a car, and you just set it up and forget it."* (EV driver, England)
>
> *"Easy for users – they know the rates so it's their choice when to charge."* (B26, BEV driver, England, urban)

Some participants felt it would be easy to charge an EV during the off-peak periods (i.e. overnight), as they would not be likely to drive the car during that time of day (as illustrated by the timeline exercise during the workshops). Therefore, it was perceived that this type of tariff would suit most people's lifestyles.

> *"If it's overnight when it's cheaper, then it's great because that's the only time the car's really not in use."* (M02, ICE vehicle driver, mobility difficulties, parent of young children, England, rural)

Financial benefits

Many participants felt that using this type of tariff would allow them to make savings on their electricity bills by shifting electricity use to certain times of day, particularly in contrast to using other types of tariff (e.g. a fixed-price tariff, where shifting energy use would not make any difference to the cost of electricity bills). It was felt that BEV drivers would benefit in particular.

> *"Allows you to take advantage of lower costs at low demand times."* (B01, BEV driver, Scotland, rural)

A small number of the business participants suggested that this type of tariff would work well for their organisation as they worked fixed office hours, meaning that they could take advantage of lower off-peak charging without impacting their operations.

> *"Might work well for us as a business because we could charge out of [operating] hours. Doing the smart thing, using it to charge up out of hours so it would be cheaper for us to do that. It's a cost benefit to us – that's the main benefit."* Business16, EVs, England, microbusiness)

A disadvantage of a static time-of-use tariff can be higher electricity costs during peak periods, compared with a fixed-price tariff. However, several participants indicated that the penalties associated with these higher costs at peak times would be offset by the savings made when using electricity at off-peak times.

> *"Potential penalty of using energy at peak, but offset by savings."* (B01, BEV driver, Scotland, rural)

Participants also mentioned that the simple pricing structure would allow them to easily predict the cost of their electricity bills.

> *"It's probably the easiest one to understand to forecast what your costs are going to be."* (B08, BEV driver, Scotland, urban)

Consumer control over electricity use

Participants frequently mentioned that using this type of tariff would give consumers control and responsibility over when they use electricity, when they charge their EV, and the cost of their electricity bills.

What are the concerns or perceived barriers to uptake for static time-of-use energy tariffs?

General concept

Several participants indicated that they would not consider using this type of tariff for various reasons. For example, some participants thought that this type of tariff was difficult to understand, or that other members of their household would find it difficult to understand. Additionally, some participants thought that the need to shift electricity use to particular times of day was too restrictive. Most business participants felt that this type of tariff would not be suitable for their business needs, irrespective of business size or whether they currently use an EV or not. Some business participants opposed this view however, and believed that their business would benefit from this type of tariff.

Concerns for the electricity network

One concern for the electricity network that participants expressed was that if this type of tariff became popular, peaks in electricity demand would not decrease, but would simply shift to different times of day.

> *"If there is a best time to charge it, then everyone charges it, then that's creating a new peak time as well, isn't it?"* (I14, ICE vehicle driver, Wales, urban)

Another concern was that if not enough people used this type of tariff, its effects on balancing overall electricity supply and demand would be very limited.

Practical concerns

Some participants disliked the fact that using this type of tariff typically requires a smart meter, whilst others were concerned that obtaining timers for EV charging and electrical appliances would be required to take full advantage of this type of tariff.

Whilst some participants thought that this type of tariff would be simple to use, other participants felt that monitoring electricity prices, planning electricity use, and then shifting electricity use (in particular EV charging) to off-peak times would require too much user input. Participants thought that there might be

practical challenges using this type of tariff if it applied to both EV electricity use and general household electricity use because they thought it would be difficult or inconvenient to shift usage of certain electrical appliances, such as a fridge or an electrical oven. Similarly, most business participants suggested that if they needed to use an EV to meet their business' operational needs, they would ensure that it was sufficiently charged, regardless of the time of day and cost of electricity.

> *"I could be on the road at 4am…I'd get back at 6am [towards the end of the cheapest rate]…it doesn't matter, because I've got to do it. As a taxi firm…it just doesn't work. Off peak demand doesn't work – we're a 24/7 country these days with businesses working around the clock."* (Business08, ICE vehicles, Scotland, microbusiness)

Additionally, several participants thought that using this type of tariff would cause conflicts within families due to some family members wanting to use electricity at peak times.

> *"I think on static [time-of-use] tariff, I'd predict I'd be lynched inside a month, on the dynamic [time-of-use] tariff probably inside a week."* (B43, BEV driver, Wales, rural)
>
> *"This is just looking at the car, that if you were to go for a tariff that worked for the car, when your kids are leaving lights and everything on throughout the house, throughout the peak periods, then that's going to have a massive negative impact." (S01, STB EV driver, England, rural)*

Some participants also expressed concern that shifting usage of EV charging and other household electrical appliances (e.g. washing machines) to times of day when they are unlikely to be monitored (e.g. overnight) poses a fire risk.

> *"I was doing washing the other night, and we had a fire on our washing machine, and I will never now put that washing machine on overnight. Not a chance."* (EV driver, England)

Financial concerns

Several participants thought that peak prices for this type of tariff would be too high and that the incentives would be too insignificant to warrant shifting EV charging times.

Additionally, many participants (including business participants) were concerned that needing to use electricity at peak times could lead to increased electricity bill costs. Participants also voiced a concern that high charging costs could be incurred in the event of an unexpected, urgent, or emergency situation where the car is needed earlier than expected.

Furthermore, participants said that they would be worried that their EV would take more time to charge than the time covered by the off-peak tariff bands, thereby forcing them to undertake some charging in peak periods.

A common theme that emerged was that this type of tariff could financially discriminate against those who are unable to use electricity or charge their EVs at off-peak times, for example those who do not have fixed routines, such as shift or night workers and families with young children.

> *"Not everybody follows the standard pattern, so I would be very concerned about anything that discriminated against people in a serious way who are working on minimum wage, doing shift work… there have to be safeguards, don't there, for people who their energy bills are a significant proportion of their weekly expenditure."* (B05, BEV driver, Scotland, rural)

Lack of trust in electricity suppliers

Some participants lacked trust in electricity suppliers' pricing systems and cast doubts over whether static time-of-use tariffs are fair and regulated across different suppliers. Participants were also concerned that suppliers would increase the electricity prices over time, reducing the overall potential savings on offer.

> *"In reality, my real concern is that most of us don't trust the electricity companies, and the electricity companies have taken 20 years to fail to roll out smart meters. So, if they can't roll out a basic meter that'll help us when it comes to trying to control how our cars are charged."* (EV driver, England)

What provisions should be implemented to increase acceptability of static time-of-use energy tariffs?

Incentives from electricity suppliers

Some participants mentioned that off-peak prices need to be significantly cheaper than peak prices to encourage consumers to shift their electricity use to off-peak times. Similarly, other participants mentioned that peak prices should not be too high, as this would discourage consumers from opting for this type of tariff, and that off-peak prices should be very low. Several participants mentioned that they would be more likely to consider this type of tariff if electricity suppliers guaranteed that electricity prices would not increase significantly, or often, and that the timing of off-peak and peak price bands would not shift often.

> *"Before you decide to enter, you want to know that you're not going to get ripped off and they're just going to start charging you whatever they feel and might be setting you ridiculously high tariffs and then, all of a sudden, you're finding that, long-term, that you're actually worse off than what you actually planned to be."* (EV driver, Scotland)

There was general consensus for static time-of-use tariffs to have no more than five price bands, to avoid overcomplicated pricing structures.

Several participants also said that a lack of standing charge, or a low standing charge, would make them more likely to opt for this type of tariff. It was suggested that a lack of standing charge would also make it easier to compare offers from suppliers offering the same type of tariff.

Additionally, participants mentioned that if this type of tariff was offered by several suppliers (perhaps with slight differences between each tariff offered) then the increased choice may help consumers to find a static time-of-use tariff to suit their needs. It was felt that competition between suppliers should also cause a decrease in electricity prices. Participants mentioned the importance of tariffs being fair and regulated amongst suppliers.

> *"Choice is important. Consumers should be able to choose a tariff that suits their needs or lifestyle."* (B05, BEV driver, Scotland, rural)

Participants would be more likely to opt for this type of tariff if electricity suppliers offered short contract terms.

Smart charging technologies

Many participants mentioned that smart charging technologies (e.g. timers or scheduling functions built into EVs, or remote control of charge points via a smartphone app) could help consumers to engage with static time-of-use tariffs and maximise their potential savings. However, several participants mentioned the

importance of being able to override scheduled charges in case they needed to charge their EV immediately for an unexpected or emergency car journey.

> *"My car is set to charge at midnight, and I had an emergency with my cat and I had to take her to the vet, and my local vet was closed. Thankfully I had just enough charge, but the car didn't start charging because I set it at midnight. I could have been stranded."* (EV driver, England)

Other smart technologies

Participants thought that electrical appliances should come equipped with delay start timers, which would allow consumers to schedule electricity use. Additionally, participants mentioned that smart technologies could automatically schedule electricity use to take place during off-peak times for various appliances on behalf of the consumer.

Other smart technologies could also allow consumers to monitor electricity prices and their electricity expenditure.

Household energy systems

Some participants mentioned that having a home battery storage system or an additional energy supply system (e.g. solar panels) at their home would encourage them to use a static time-of-use tariff, as they could save money on their electricity bills by reducing their reliance on the grid to provide them with electricity at peak times. For example, having a home battery storage system would encourage consumers to store energy in the battery during off-peak periods so that it was available for use during peak times. Having solar panels at home would encourage participants to use solar energy during peak times, where possible.

Some participants indicated they would like the option of having one electricity tariff for charging their EV, and another tariff for their other household energy use.

Vehicle specifications

Several participants thought that this type of tariff would be more desirable as EV charging rates increase, since shorter charge times might enable drivers to undertake a full charge (0-100% state-of-charge) within a single off-peak period.

3.2.2 Dynamic time-of-use energy tariffs

Dynamic time-of-use energy tariffs comprise of real-time or predictive prices for electricity throughout the day. Similar to static time-of-use tariffs, prices for electricity depend on the time of day, day of the week, or season and higher rates are applied when demand for electricity is greater. However, electricity prices on dynamic time-of-use tariffs may change as often as half-hourly and these types of tariff cannot be used in conjunction with prepayment meters. The aim of these types of tariff is to encourage users to use electricity at times when more electricity is available cheaply.

Summary of attitudes towards dynamic time-of-use energy tariffs

Household participants felt that using this smart charging option could save them money on their electricity bills, particularly compared with other types of tariff.

However, most participants said that they would avoid this option because they felt it was too complicated and that they would find it difficult to shift their electricity use and EV charging to fit in with off-peak times. Business participants thought using this type of tariff would be an extra administrative burden.

What are the perceived advantages or benefits of dynamic time-of-use energy tariffs?

General concept

A few participants said that this type of tariff was easy to understand. Some participants also liked the fact that this type of tariff is based on real-time pricing signals, and so more accurately reflects the variations in electricity prices than a static time-of-use tariff.

Benefits for the electricity network and environment

Several participants felt that this type of tariff could incentivise consumers to use electricity and charge their EVs at times of low electricity demand, and would therefore help National Grid to balance electricity supply and demand and take better advantage of renewable energy.

Ease of use

Participants liked the idea of being provided with upcoming electricity prices in advance, and felt this would help with efficient planning of electricity use.

A few participants also suggested they would find it easy to shift electricity use for certain appliances (e.g. a washing machine or EV) to fit in line with cheaper pricing signals on this type of tariff, as they would expect general trends for electricity prices to remain the same between days (e.g. cheaper electricity overnight). Additionally, some participants felt that it would be easy to charge an EV during times when electricity is likely to be cheapest (i.e. overnight), as they would not be likely to drive the car during that time of day (as illustrated by the timeline exercise during the workshops).

> *"I think the general rule of thumb; every day would be the same. Even though it changes half-hourly, you know that between 10pm and 5am, it's going to be at its cheapest, generally, so it is just as easy as static time-of-use."* (B01, BEV driver, Scotland, rural)

Some participants thought that this type of tariff offers more flexibility than a static time-of-use tariff, so could provide a better fit with people's lifestyles, although the reasons for this were unclear.

Whilst business participants were generally critical of dynamic time-of-use tariffs, some participants felt that they may suit businesses more than households.

> *"I think that [type of tariff] suits businesses better than home users, because the businesses are able to set up processes for managing their demand…"* (EV driver, England)
>
> *"If you're the energy manager for a large company of a huge office complex or a large shopping centre, then I could see dynamic time-of-use tariffs as being a business tool."* (B05, BEV driver, Scotland, rural)

Financial benefits

Several participants mentioned that they think using this type of tariff would have the potential to make notable savings on electricity bills (including businesses' electricity bills), particularly in contrast to the static time-of-use tariff.

> *"I suppose an advantage is it should be cheaper overall."* (EV driver, England)
>
> *"My understanding is that the potential savings go beyond even static time-of-use tariffs, so again, if... you just look at a bigger picture, the potential overall savings are more than static time-of-use."* (B01, BEV driver, Scotland, rural)

One participant thought that off-peak electricity prices on a dynamic time-of-use tariff had the potential to be significantly cheaper than the off-peak rate on static time-of-use tariffs, so felt that there would be more opportunities per day to save money.

In addition, a few participants felt that any penalties for using electricity at peak times would be offset by savings made when using electricity at off-peak times.

Consumer control over electricity use

Participants thought that notifications about upcoming electricity prices would inform participants about the cheapest and most environmentally friendly times to use electricity; this was seen as a positive attribute as it gives consumers control and responsibility in relation to planning their electricity use.

What are the concerns or perceived barriers to uptake for dynamic time-of-use energy tariffs?

General concept

Many participants, including business participants, indicated that they would not consider using this type of tariff for various reasons. For example, a lot of participants thought that this type of tariff was too complicated, difficult to understand, and would be unpredictable, due to the fact that pricing signals could change often throughout the day, between days, and between seasons. The overarching theme from the business participants was that this type of tariff would not be suitable for their business needs, irrespective of business size or whether they currently use an EV or not.

> *"It would be like playing the lottery every day when you came home."* (EV driver, England)
>
> *"Too over-complicated, too precise. How much clock-watching do we need?"* (I14, ICE vehicle driver, Wales, urban)

Additionally, some participants also thought that receiving notifications of upcoming electricity prices in advance would be confusing and irritating.

Concerns for the electricity network

One concern that participants expressed (as with static time-of-use tariffs) was that if this type of tariff became popular, peaks in electricity demand would not decrease, but would simply shift to different times of day. Further, it was felt that notifying customers of particularly expensive upcoming electricity prices could cause a surge in electricity use when the notification is received, as consumers may attempt to use electricity at a cheaper rate before the prices increase.

Practical concerns

Some participants pointed out that some consumers would not be able to use this type of tariff, as it cannot be used in conjunction with a prepayment meter. Additionally, several participants disliked the fact that using this type of tariff requires a smart meter. Another concern was that obtaining timers for electrical appliances would be required to save a significant amount of money on electricity bills when using this type of tariff.

Participants mentioned that those who live in areas of poor broadband or mobile network connectivity, or those who do not own a smartphone, may encounter challenges using this type of tariff.

A very common subject raised by participants (including business participants) was that monitoring electricity prices, planning electricity use, and shifting electricity use and EV charging to times when electricity is cheaper on a daily basis would be too onerous for consumers, therefore causing stress and frustration. Similar to the

static time-of-use tariff, participants thought that using a dynamic time-of-use tariff may not suit both EV electricity use and general household electricity use because it would be difficult or inconvenient to shift usage of certain electrical appliances that are likely to be required at the same time each day, such as an electrical oven.

> *"That is a complete waste of time; I've got enough to worry about as it is. If I need to charge, I need to charge."* (Business04, EVs, England, microbusiness)
>
> *"Not sure I have the time or inclination to consider prices at 2pm every day."* (B22, BEV driver, parent of young child, England, rural)
>
> *"It's just something to worry about when you have enough, lots to deal with anyway, with a disability."* (M02, ICE vehicle driver, mobility difficulties, parent of young children, England, rural)
>
> *"If you have young families, generally you tend to be time poor because you're spending so much time looking after your children, and so it [monitoring electricity prices] is an inconvenience, and where does your priority lie? Is it on your energy and getting the cheapest deals, or on looking after and caring for family?"* (C02, ICE vehicle driver, parent of young child, England, rural)

Some participants were also concerned about increased risk of fire caused by shifting usage of certain electrical appliances to times of day when they are unlikely to be monitored, such as using a washing machine overnight.

Due to the frequent changes in electricity prices on this type of tariff, several participants thought it would be difficult to remember which times of day are cheaper than others.

Additionally, several participants thought that using this type of tariff would cause conflicts within families due to some family members using electricity at more expensive times.

> *"Issues with family use during times of peaks being penalised. Planning is easier for single persons than families."* (B10, BEV driver, parent of young child, Scotland, urban)

Financial concerns

Several participants thought that using this type of tariff would be more expensive than other types of tariff (e.g. static time-of-use tariffs) and others said that the incentives for using this type of tariff would be too insignificant to warrant shifting energy use.

> *"Even though the dynamic [time-of-use tariff] could save you money, I don't necessarily see whether or not that would make a big difference."* (M02, ICE vehicle driver, mobility difficulties, parent of young children, England, rural)
>
> *"I don't think we'll change behaviours because I don't think there'd be sufficient incentives to change behaviours."* (B05, BEV driver, Scotland, rural)

Quite a few participants were concerned that needing to use electricity at times when electricity is more expensive could lead to increased costs of electricity bills. Due to the frequent changes in electricity prices on this type of tariff, several participants thought it would be easy to accidentally use electricity or charge an EV at more expensive times of day. Similarly, business participants were concerned that if they used this type of tariff, they could be penalised for using energy at times when electricity is more expensive in order to fulfil their operational requirements.

> *"The power curve is fairly well known… because we're a nine-to-five business, we are kind of held to ransom, so we are kind of held to those working patterns. There's an element of loss of control."* (Business10, EVs, Scotland, small business)

Many participants voiced a concern that it would be very difficult to predict the running costs of an EV or the cost of electricity bills on this type of tariff, due to electricity prices changing so often. Uncertainty regarding cost of electricity bills was also highlighted as a disadvantage of this type of tariff by business participants, as they mentioned the importance of predicting future expenditure on energy.

> *"It's unpredictable – predictability is important. I need to know what my costs are going to be so that I can price my products accordingly."* (Business11, ICE vehicle, Wales, sole business)

> *"The fluctuating cost makes it impossible for planning."* (Business09, EVs, Scotland, small business)

Similar to the static time-of-use tariff, a common theme that emerged was that this type of tariff could financially discriminate against those who are unable to use electricity or charge their EVs at times when electricity is cheaper. For example, those who do not have fixed routines, such as shift workers and families with young children.

One participant also expressed a concern that the complicated pricing structure of dynamic time-of-use tariffs makes it difficult to compare offers from suppliers offering the same type of tariff.

Lack of trust in electricity suppliers

Several participants lacked trust in electricity suppliers' pricing systems and were concerned that suppliers could make more profit from this type of tariff than was deemed fair. Some participants were concerned that electricity suppliers would increase electricity prices over time.

> *"Can we trust energy companies to reduce pricing as this is not obvious when energy costs go down at present?"* (I02, ICE vehicle driver, parent of young child, England, rural)

Additionally, participants thought that if consumers were saving considerable amounts of money through using this type of tariff, suppliers may increase the standing charge due to loss of profit.

What provisions should be implemented to increase acceptability of dynamic time-of-use energy tariffs?

Incentives from electricity suppliers

Some participants mentioned that electricity prices in off-peak periods should be significantly lower than the peak prices; otherwise this type of tariff may fail to encourage consumers to shift their electricity use.

Participants also mentioned that their electricity bills, or the peak prices, should be capped, or that the supplier should guarantee that electricity prices will not increase by a particular percentage; this was viewed as important to give participants security and predictability over their bill.

> *"For the dynamic [time-of-use tariff], yes [, cap the prices]. Yes, you'd want an upper limit."* (I05, ICE vehicle driver, parent of young child, England, urban)

Participants suggested that suppliers should provide evidence to convince customers they will save money when using this type of tariff compared with other types of tariff. Other participants suggested that suppliers

could provide customers with comparisons between monthly energy expenditure so that customers could monitor how much money they are saving or spending over time.

> *"I'd want some kind of real feedback, so at the end of the month, just a brief statement saying 'this month, if you used static time[-of-use tariff]… it would have cost you £250, but because you've used dynamic [time-of-use tariff], it's actually only cost you £180. You've just saved £70."* (B05, BEV driver, Scotland, rural)

Several participants also said that a lack of standing charge or low standing charge would make them more likely to opt for this type of tariff. An offer of a free smart meter would encourage some participants to adopt this type of tariff. Participants also said they would be more likely to opt for this type of tariff if there was no fixed-term contract with the electricity supplier.

> *"There is that fear, in this country particularly, you'll be locked in [to a contract], you're going to get screwed over at some point, and you see it happen all the time."* (I05, ICE vehicle driver, parent of young child, England, urban)

In relation to receiving notifications about upcoming electricity prices, several participants said that they would like to be able to receive notifications without being reliant on owning a smartphone or having Internet access. Some participants also said that they would like to receive notifications at least 24 hours in advance of the upcoming prices, and would like to receive the notifications at the same time each day, to help with planning their EV charging.

> *"You would have to be informed by the electric company when the peak times were, because obviously it can be varied day to day, can't it?"* (M01, mobility difficulties, England, urban)

Smart charging technologies

Similar to static time-of-use tariffs, participants frequently mentioned that smart charging technologies could help EV drivers to maximise the benefits of a dynamic time-of-use tariff by scheduling EV charges for times when electricity is cheapest.

Additionally, participants suggested that they would like it if smart charging technologies could be used to automatically schedule charges to take place when energy prices are cheapest, removing the need for them to manually monitor the price changes on a daily basis. Similarly, participants mentioned that they would like to be able to set preferences so that charging occurs only when electricity costs are below a specific price per kWh.

Other smart technologies

It was also felt that other smart technologies could help consumers to control the electricity use of household appliances remotely and therefore save money on their electricity bills. Several participants suggested that smart charging technologies could automatically schedule electricity use to take place when energy prices are cheapest for various appliances in addition to their EV (e.g. white goods).

Participants also suggested that such smart technologies or online services could also allow consumers to monitor upcoming electricity prices and their electricity expenditure.

Household energy systems

A few participants indicated that they would be more likely to adopt a dynamic time-of-use tariff if they had a home battery storage system or an additional energy supply system (e.g. solar panels) at their home, as they

could rely on these systems to supply electricity at peak times (when electricity is more expensive) and save money on their electricity bills. For example, consumers could store energy supplied by the grid in their home battery during at off-peak times and use this stored energy when general demand for energy is greater. Similarly, those consumers with solar panels could use solar energy during times when energy is in high demand.

3.2.3 Third-party charge management schemes

Third-party charge management schemes allow a third party to directly control the timing and speed of EV charging. These types of scheme generally require the user to have a smart charge point installed. The aim of these schemes is to give the third-party (e.g. an energy supplier) the ability to control charging to avoid times when demand for electricity is high.

Summary of attitudes towards third-party charge management schemes

Many participants saw the potential of this smart charging option to save money on electricity when combined with a time-of-use tariff. Additionally, business participants thought using this option would reduce the time and effort they would need to spend managing their electricity consumption.

However, household participants were generally opposed to this concept, predominantly because they did not like the idea of relinquishing control to a third party and were concerned about financial costs associated with using these schemes.

What are the perceived advantages or benefits of third-party charge management schemes?

General concept

Some participants thought that third-party charge management schemes were generally a good idea. A few participants also said that this type of scheme is easy to understand.

Benefits for the electricity network and environment

Many participants recognised the ability of this type of scheme to help avoid charging EVs at times when electricity is in high demand, which means it would help National Grid to balance electricity supply and demand, allow them to better take advantage of renewable energies, and reduce the likelihood of blackouts or brownouts.

Ease of use

Participants thought that third-party charge management schemes could save EV drivers time and effort when managing charging, as they would not be required to schedule their own charges. Similarly, business interviewees' main perceived advantage of this type of scheme was that it took away an extra part of business administration, therefore saving them time and energy to focus on other aspects of the business.

> *"[Third-party charge management schemes are a] clever idea and certainly of interest. Anything that doesn't involve interaction from our end would be popular. We're a small organisation, so less admin for me is appealing… it would be nice not to have energy management to deal with."* (Business10, EVs, Scotland, small business)

Financial benefits

Many participants said that this type of scheme could save EV drivers a significant amount of money on their electricity bills when combined with a time-of-use energy tariff, as the scheme could work to avoid charging EVs at times when electricity is more expensive (i.e. when electricity is in high demand).

One participant also felt that because this type of scheme could reduce peaks in energy demand, it could help distribution networks and energy suppliers to avoid spending money on additional resources to manage electricity supply (e.g. reinforcing or building network cables to transport additional energy). Ultimately, it was felt that this may mean the reduced costs could be passed onto consumers in the form of lower electricity prices.

What are the concerns or perceived barriers to uptake for third-party charge management schemes?

General concept

Several participants thought that this type of scheme is too complicated. For example, some participants thought that using this type of scheme would require technical knowledge and skills, so would not suit all EV drivers.

Participants also thought that the involvement of a third party in managing EV charging is unnecessary, especially because EV drivers are typically able to schedule charges themselves using charge scheduling functions built into EVs. In addition, participants thought that using this type of scheme could lead EV drivers to rely heavily on the third party which may reduce their ability to make informed choices regarding their electricity use.

> *"Can owners not do this themselves, without need for third party?"* (P01, PHEV driver, Scotland, urban)

Practical concerns

Some participants disliked the fact that using this type of scheme requires a smart meter and a smart charge point, particularly because smart charge points tend to be more expensive than standard charge points (i.e. charge points without GPS or Internet connectivity).

Additionally, some participants thought that EV drivers would be required to spend a lot of time and effort planning charges and setting charging preferences or requirements for the third party to manage. Participants mentioned that those without fixed routines may find it more difficult to plan charges than those with fixed routines.

> *"My time is worth more than that."* (S09, STB EV driver, Wales, rural)
>
> *"You have to be quite planned for all of this… so it wouldn't suit everyone's lifestyle."* (C02, ICE vehicle driver, parent of young child, England, rural)

Participants also mentioned that those who live in areas of poor mobile or network signal may experience difficulties with this type of scheme if they are unable to reliably communicate with third parties to set charging preferences or requirements.

Participants were concerned that using this type of scheme would require EVs to be connected to a power source for long periods of time so that third parties could schedule charges efficiently; some felt this could lead to an increased risk of tripping over the charging cable.

Many participants voiced a concern that using this type of scheme would likely result in EV charging being delayed (i.e. charge may not be delivered as soon as an EV is connected to a power source). Participants were concerned that this delay in charging may result in the EV not being sufficiently charged for an unanticipated car journey (such as in an emergency). This concern was particularly prominent for those who do not have fixed routines because their journey patterns are less predictable.

> *"They [the third party] are not, obviously, going to know if you need to take your car out for an emergency."* (M01, ICE vehicle driver, mobility difficulties, England, urban)
>
> *"You're more likely to be stuck in an emergency situation."* (B01, BEV driver, Scotland, rural)

A few participants also thought that family conflicts could arise if individual members of the household set different charging preferences or requirements.

Financial concerns

In general, some participants thought that the incentives for using this type of scheme would be too insignificant to warrant using it, particularly when they can manage the charging themselves for no additional cost. When compared with EV drivers scheduling charges themselves, a few participants thought that this type of scheme would result in more expensive electricity bills.

> *"I just can't see how having a third party managing your electricity for you could be cheaper than doing it yourself, you've got to pay a middle man to do it for you, so why would it be cheaper?"* (EV driver, Scotland)
>
> *"The difference is going to be so microscopic that you're just talking about pennies and fractions of pennies. There's no benefit really."* (B05, BEV driver, Scotland, rural)

Several participants expressed concern that using this type of scheme would make predicting the cost of EV charging very difficult, as the third party would manage when charging happens; participants felt that this uncertainty would make it difficult to compare offers from different third parties.

A few participants expressed a concern that there may be financial penalty for those who are unable to specify charging preferences or requirements which enable their EV to be charged during off-peak times (e.g. those without fixed routines, such as shift workers and families with young children).

Lack of trust in third parties and their systems

Participants generally expressed concerns that the third party would make mistakes when managing EV charging or would not adhere to EV drivers' set preferences or requirements for charging, which could result in the EV not being sufficiently charged for subsequent car journeys.

> *"Trust is the thing. You need to be able to trust that it will do what you need, and if it undermines that, then you can only stop using it."* (EV driver, England)

Furthermore, some participants recognised that this type of scheme would require a technical system to allow the third party to control and interact with their charge point. Participants expressed a lack of trust that this system would function without issue.

Participants also expressed concerns about third parties using this type of scheme to collect data about EV drivers and monitor their location or behaviours.

Lack of EV drivers' control over charging

The majority of participants disliked that using this type of scheme would reduce EV drivers' control over their electricity use in relation to EV charging, as the third party would assume responsibility for scheduling charges.

> *"I don't like surrendering control of my life."* (I06, ICE vehicle driver, England, urban)
>
> *"You'd lose visibility and control."* (EV driver, Scotland)

What provisions should be implemented to increase acceptability of third-party charge management schemes?

Third party organisation

Due to some participants' concern that involvement of a third party would mean having to deal with multiple organisations for charging their EV, a few participants suggested that the third party should be the government, National Grid, or the EV driver's energy supplier.

EV drivers' ability to influence and monitor charging

The majority of participants said that the ability to set charging preferences or requirements for third parties to adhere to was an important feature. For example, many participants liked the idea of requesting a certain amount of charge by a particular time. Other participants suggested allowing customers to set preferences or requirements based on the cheapest times of day (in conjunction with a time-of-use tariff). Some participants also stated that they would like to be able to set a minimum and maximum amount of charge for their EV, which they felt would help to maintain battery health. Additionally, several participants said that they would like to set default preferences or requirements so that they would not be required to set preferences or requirements for each charge on a daily basis.

> *"There needs to be a guarantee to overcome these concerns because nobody, whether they're commuting, taking the kids to school, whatever it is, wants to be in a situation that the car hasn't got enough to do what you need it to do. So, when you plug it in, you need to know 100% that that will be delivered."* (EV driver, England)

A few participants suggested that setting preferences should be as easy as possible. Some participants mentioned that they would like to use a smartphone app, whereas others mentioned that they would like to be able to set the preferences without having to use an app or even a smartphone; instead having the ability to set preferences using an EV's in-built system was preferred.

Moreover, participants frequently mentioned the importance of being able to override charges scheduled by the third party in case they need to charge their EV immediately for an unexpected or emergency car journey; crucially, it was indicated that this feature should be provided without EV drivers being penalised by the third party.

> *"If I need to do a rare evening airport run, I need a full battery. As a consumer, I need 100% control – or at the very least, an override function… I would still want a big, red button, just bang, I need that car at twelve o'clock at night, that's it, get lost."* (B05, BEV driver, Scotland, rural)

Several participants also mentioned that they would like to be able to remotely monitor their EV's charging status.

Incentives from third parties

Many participants said that they would be more likely to opt for this type of scheme if it was offered to them for free or at a low cost, with one participant suggesting that the cost for the service could be integrated with an EV purchase. Additionally, some participants suggested that the equipment required to use this type of scheme (e.g. smart charge points) should be offered to EV drivers for free, or at a low cost.

Furthermore, participants mentioned that before EV drivers opted for this type of scheme, they would like third parties to guarantee that EV drivers would be likely to save money on their electricity bills.

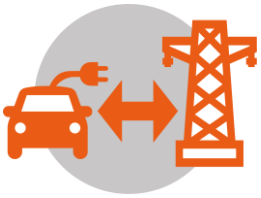
> *"You'd probably have to have a guaranteed sort of saving."* (B08, BEV driver, Scotland, urban)

Participants indicated they would like third parties to guarantee that they would adhere to EV drivers' charging preferences or requirements (e.g. so EV drivers would be guaranteed to receive the amount of charge they have requested by a time that they have specified). In addition, some participants mentioned that third parties should send customers confirmation of any charging preferences or requirements that they have set, to increase users' confidence in the system.

Furthermore, a few participants said they would be more likely to opt for this type of scheme if there was no fixed-term contract between themselves and the third party, or if the contract term was short.

One participant suggested that the third party should be easily contactable in the event of a charging issue. Another participant suggested third parties should offer a guarantee that this type of scheme would not affect battery health.

3.2.4 Vehicle-to-grid (V2G) services



With V2G services, users can return energy stored in their EV batteries to the grid when electricity is in high demand. Users can be compensated for making their EV battery power available to the grid. These services require the user to have a V2G-enabled vehicle and charge point. The aim of these services is to encourage users to provide energy to the grid so that overall demand for electricity can be met.

Summary of attitudes towards V2G services

Participants were generally positive about V2G services, viewing them as an efficient and sustainable means of balancing the grid. Participants also liked the idea of being compensated for allowing the grid to access energy stored in their EV battery.

However, participants were concerned that using V2G services could leave their EV without enough charge for upcoming journeys. Household participants were also concerned about financial costs associated with using these services and potential adverse effects on their EV battery health.

What are the perceived advantages or benefits of V2G services?

General concept

In general, many participants indicated that this type of service is a sensible, logical idea and one that they would be happy to use. Several participants stated that they would be happy to allow the grid to access energy stored in their EV battery.

Benefits for the electricity network and environment

Most participants (including business participants) mentioned that this type of service would incentivise EV users to provide electricity to the grid when demand is high, and would therefore help National Grid to balance electricity supply and demand and rely less on 'dirty' fuels (e.g. oil and coal).

> *"That's a fantastic idea – you're recycling the surplus back to the grid – compensating for waste of energy."* (Business06, ICE vehicle, England, small business)
>
> *"There's not much that I don't like about it, it makes a lot of sense… it could work well for meeting peak demands."* (Business02, ICE vehicle, England, sole business)
>
> *"Well, I just think you're giving back what you're not using. Anything that's contributing is helpful."* (S07, STB EV driver, England, urban)

Ease of use

A few participants felt that EV drivers would not be required to spend very much time or effort managing this type of system; they would be willing to leave their EV connected to a power source at times when they would not be using the vehicle anyway.

> *"If the car is sat there doing nothing, and you don't plan on going out, and you do have means to get to somewhere in an emergency, yes, sell it [energy] back and make a bit of money off it."* (M02, ICE vehicle driver, mobility difficulties, parent of young children, England, rural)

Financial benefits

The majority of participants mentioned that allowing the grid to access energy stored in their EV battery would allow them to make savings on their electricity bills, or even to make more money than they spend on electricity.

> *"It could potentially pay for your charging, zero cost, charging cost."* (EV driver, England)
>
> *"If you can make some money by selling it back, then why not… it should result in the person feeling like they're being paid back fairly."* (Business18, EVs, England, microbusiness)

One participant also mentioned that because this type of system encourages EV drivers to return energy to the grid when it is in high demand, it could help network distributors avoid spending additional money on managing electricity supply (e.g. network reinforcement) to meet demands. Ultimately, it was recognised these types of costs could be relayed to consumers (i.e. through higher electricity prices).

EV drivers' control over electricity use

Some participants mentioned that using this type of service would give EV drivers control and responsibility in relation to charging and the cost of their electricity bills.

EV battery health

One participant pointed out that using this type of system could mean that an EV battery may continue to be charged and discharged when the vehicle is not used for long periods of time (e.g. when on holiday), which would be better for battery health than not using the battery at all for those periods of time.

What are the concerns or perceived barriers to uptake for V2G services?

General concept

Several participants thought that this type of service is too complicated and unrealistic. One participant also mentioned that they were uncomfortable with the idea of allowing the grid to retrieve energy stored in their EV battery.

Practical concerns

Some participants disliked the fact that using this type of service requires a V2G-enabled EV and V2G-enabled charge point, particularly because these items are generally less prevalent and more expensive than other EVs and charge points.

> *"Charger installed at home may not be an option."* (I07, ICE vehicle driver, England, urban)
>
> *"It can be expensive to install a different battery and charging point."* (I38, ICE vehicle driver, parent of young child, Scotland, rural)

A few participants pointed out that there is currently a limited choice of V2G-enabled EVs on the market and were not sure whether this would change in the foreseeable future. In addition, participants had some doubts that currently available technology could support this type of service.

> *"I would avoid it, just because of the risk factor at this moment with today's technology."* (EV driver, England)

In addition, participants mentioned that planning and managing charges when using this type of service would be too time-consuming. For example, one participant pointed out that EV drivers may need to plan charging around V2G services to ensure their EV has enough battery for their next journey, which may be difficult for those without predictable daily routines.

Many participants voiced a concern that allowing the grid to retrieve energy from EV batteries may leave EV drivers without sufficient charge for when they next need to use their vehicle. One participant was also concerned that EV drivers may not be physically able to unplug their EVs whilst the grid is retrieving energy.

> *"It's not suitable for business as all our vehicles need to be ready to be deployed on a job 24/7."* (Business09, EVs, Scotland, small business)
>
> *"If you're selling [energy] back, you're draining that battery on that car, if something happened, one of your children needs to go somewhere, how much charge is left in that battery?"* (C06, ICE vehicle driver, parent of young child, England, urban)

Participants were concerned that EV drivers would be required to leave their EV plugged in for long periods of time to allow the grid better access to the energy stored in their vehicle's battery; it was felt this could increase the risk of someone tripping over the charging cable.

> *"Another downside I did think of is because your car will be plugged in all the time, you have got this extra trip hazard."* (EV driver, England)

Leaving an EV connected to a power source for long periods of time may also only be suitable if the vehicle is parked off-street; some participants lacked this facility and so the compatibility of V2G services with these

types of households should be considered. Additionally, participants with multiple EVs in the household, but only one charge point would find it difficult to leave a vehicle connected for long periods of time.

A few participants also thought that individual family members could allow the grid to retrieve energy from the EV battery when other members need to use the EV, which could cause conflict.

Additionally, participants voiced a concern that if an EV driver uses the majority of their charge regularly, or if their EV battery capacity is small, they may have no or little surplus energy to offer to the grid, thereby minimising the potential benefits of this type of system.

Financial concerns

Several participants were concerned that those who cannot adjust their charging behaviour to avoid peak times would pay more for charging their EVs if they used this type of service. For example, those who do not have fixed routines and may need to drive at short notice (e.g. shift workers and families with young children) may find it difficult to leave their EV plugged in at certain times.

EV battery health

The majority of participants were concerned that using this type of service would increase the number of cycles on an EV battery, and therefore the battery would degrade faster than usual. Several participants were also concerned that this degradation would invalidate warranties on EV batteries.

> *"If your battery is discharging to the grid all the time, and then you charge it back up again, it's obviously wearing the battery a lot more, the charging and discharging all the time."* (S10, STB EV driver, partner has mobility difficulties, Wales, rural)
>
> *"[Compensation] could be negated by decreased battery life."* (B21, BEV driver, England, urban)

Lack of trust in the service and service providers

Some participants were concerned that V2G services and providers of the service are not yet established, as the service is currently not widely used. Therefore, participants had a lack of trust that V2G services would work smoothly.

Additionally, one participant thought that service providers could provide EV drivers with less compensation than promised for returning energy back to the grid.

Lack of EV drivers' control over charging

One participant disliked that using this type of service would reduce their control over electricity use in relation to EV charging, as the V2G system would assume responsibility for scheduling charges.

What provisions should be implemented to increase acceptability of V2G services?

EV drivers' ability to influence charging

The majority of participants said that they would be more likely to opt for this type of service if they could set charging preferences or requirements for service providers to adhere to. For example, many participants suggested setting preferences or requirements for their EV to charge to a certain level before allowing the grid to retrieve energy stored in the battery. Other participants (including business participants) suggested that EV users should be able to request that the grid never retrieves more than a designated percentage of the energy

stored in their EV battery, so that their EV would always have enough charge for an unanticipated car journey (e.g. 50-80 miles of electric range).

> *"In an emergency you would want, rather than take the whole battery's worth, it's good to keep some electricity back…keep some sort of percentage so you know in an emergency you've got enough range to get you somewhere, to school, to hospital, to wherever."* (S10, STB EV driver, partner has mobility difficulties, Wales, rural)

Another popular suggestion was that EV users should be able to request a certain amount of charge by a particular time, so even though energy may be returned to the grid at certain times, EV users' vehicles would still be sufficiently charged for their next journey. Furthermore, some participants proposed that users should be able to switch V2G services on and off, or set preferences to allow the grid to retrieve energy only at certain times of day.

> *"You'd have to have that minimum charge to stop them [service providers] taking it [electric range] down to 10% or something during peak time."* (M01, ICE vehicle driver, mobility difficulties, England, urban)

Moreover, participants mentioned that smart charging technologies could minimise the need for user interaction, by enabling automatic scheduling of charging or switching on/off the availability of energy for the grid. Additionally, several participants said that they would like to set default preferences or requirements, negating the need to adjust settings on a daily basis.

A few participants suggested that setting preferences for when and how much energy can be retrieved from an EV battery should be as easy as possible to encourage EV users to use the service. While some participants would have preferred to set these preferences using an app, others would have preferred to use an EV's in-built system.

Additionally, participants frequently mentioned that EV users should be provided with an option to override the retrieval of energy from their vehicle's battery, so that they could charge their vehicle immediately for an unforeseen car journey.

Incentives from service providers

Several participants said that they would be more likely to opt for this type of service if the service provider offered a discount on V2G-enabled charge points.

Many participants mentioned that the financial incentives for using this type of service would need to be significant. For this reason, several participants suggested that before EV users sign up to this type of service, service providers should guarantee that users would be likely to save a significant amount of money on their electricity bills. It was also suggested that EV users should be able to set a minimum price at which they would return energy to the grid.

> *"You can say 'I am only prepared to sell to the grid at a minimum of X'."* (EV driver, England)

The majority of participants thought it was important that users would receive as much or more money per kWh for returning energy to the grid than it would cost for them to buy that energy from the grid originally (for example, two participants specified at least 15p per kWh).

> *"If you sell electricity to the grid for lower than the going rate of buying it back, then is absolutely no benefit to you. So, it needs to be more. They need to be paying you more."* (EV driver, England)

> *"The problem with vehicle-to-grid is how much you would actually get paid for how much you're exporting. There are some schemes around at the moment for it and they pay… it's a piddling amount, basically, for the electricity that they've taken off you, so it's not really worthwhile."* (B41, BEV driver, Wales, urban)

One participant thought that the price per kWh for returning energy to the grid should be fixed, whereas another participant thought that users should be able to negotiate a price with the service provider.

One participant said that they would like service providers to send notifications to customers about how much energy was retrieved from their EV battery and how much compensation they received each time energy was retrieved. Another participant suggested that information about compensation should be provided separately to information about their overall electricity expenditure.

Additionally, participants mentioned that this type of service should be offered by several providers to create competition in the market and a wider choice of V2G services for EV users.

A few participants said that a lack of contract between themselves and the service provider, or a short contract term, would encourage them to opt for a V2G service.

Many participants suggested that service providers should offer a guarantee that using this type of service would have limited effects on the health of users' EV batteries. Moreover, a few participants suggested that service providers should offer to replace EVs' batteries if they are degraded as a result of using V2G services.

> *"If you signed up for a scheme like that you'd need a guarantee that it's not going to affect the warranty of your car, that it will run out before you actually…because you're cycling it [the battery] more."* (B43, BEV driver, Wales, rural)

Additionally, several participants said that they would like the service provider to provide a guarantee about the reliability of the service. One participant suggested that the service provider should be easily contactable in the event of an issue with the service.

Incentives from vehicle manufacturers

Several participants said that they would be more likely to opt for this type of service if they were offered a discount on a V2G-enabled EV. Participants also mentioned that replacing an EV battery in the event of damage or degradation should not be too costly for users.

> *"If it covers also the cost of the battery degradation, then obviously it might work."* (EV driver, England)

Additionally, one participant thought that this type of service would be more desirable for EV drivers when EVs have larger battery capacities; since this would provide greater opportunity to return surplus energy to the grid. Another participant thought that manufacturers should make V2G-enabled PHEVs, so that users could use petrol for unexpected journeys in the event that the grid retrieves all energy from the vehicle's battery.

Furthermore, several participants suggested that there would need to be more choice of V2G-enabled EV makes and models on the market.

Household and business energy systems

Some participants (including business participants) thought that they would be more likely to use V2G services if they had a home battery storage system or an additional energy supply system (e.g. solar panels), as they felt they could then potentially receive more money for returning energy to the grid than it would cost for

them to charge their EV. For instance, EV drivers could charge their home battery when electricity is cheaper, use this stored energy to charge their EV, and then sell that energy back to the grid at a higher price. Alternatively, EV drivers could charge their EV for free using solar energy and sell this energy back to the grid.

> *"I quite like the idea – I don't think that it's viable at the moment with technology – I am considering buying additional storage to have at home."* (Business01, EV, England, sole business)
>
> *"It could generate revenue or maximise the capture of green energy – would love to have a home battery system."* (Business10, EVs, Scotland, small business)

3.2.5 Smart charging technologies

Smart charging technologies include technologies such as smart charge points or charging timers built into EVs. These technologies can facilitate use of other smart charging options (e.g. a user could use smart charging functions in their EV to schedule a start and stop time for charging to fit with the low tariff price bands in a static time-of-use tariff). The aim of these technologies is to enable remote control and scheduling of EV charging.

Summary of attitudes towards smart charging technologies

Participants generally accepted this smart charging option, partly because the technologies are typically already established and widely used. Additionally, many participants thought these technologies were helpful for managing EV charging and could help save money on electricity when combined with a time-of-use tariff.

Household participants were concerned that energy consumers without a fixed routine or good mobile or Internet signal would not be able to make use of these technologies. There were also concerns about technical issues or breaches of data security and privacy occurring.

What are the perceived advantages or benefits of smart charging technologies?

General concept

The majority of participants thought that smart charging technologies were helpful and easy to understand. Additionally, many participants said that they trust these technologies because they are already established and widely-used. Therefore, most participants (including business participants) indicated that they would use these technologies (or already use them).

> *"I currently use a third party app to schedule my charging to coincide with my Economy 7 tariff."* (B18, BEV driver, England, urban)

Benefits for the electricity network and environment

Participants frequently mentioned that these technologies could encourage users to charge their EVs at times of lower demand (particularly if users were financially incentivised to do so with a time-of-use tariff), and would therefore help National Grid to balance electricity supply and demand and allow them to better take advantage of renewable energies.

Ease of use

In general, participants thought that using these technologies would fit in with most people's lifestyles. The majority of participants thought that these technologies would be easy to use, convenient, and would minimise the time and effort required for users to manage EV charging.

> *"Basically, it will feed into more or less all of them [the smart charging options] to optimise their use, that's … yes, it's just the technology and it will make things work better."* (B39, BEV driver, Wales, rural)

Additionally, several participants liked that EV users could use the technologies to schedule charges after they have connected the EV to a power source, which means users would not have to remember to connect their EV to a power source at a particular time.

Participants liked that these technologies could assist with several aspects of EV charging, such as planning and scheduling timings for charging, and monitoring charging status. Some participants also thought that these technologies could help users to manage aspects of V2G services, such as scheduling charging and discharging, or switching V2G services on and off.

Several participants liked that these technologies can be used in various ways, such as remote scheduling or monitoring of charging using an app or website or scheduling charges using an EV's in-built system.

Financial benefits

Many participants said that these technologies could help consumers save a significant amount of money on their electricity bills when combined with a time-of-use energy tariff, as EV drivers could use the technologies to schedule EV charges and avoid charging at times when electricity is more expensive (i.e. when electricity is in high demand).

> *"Seems most sensible option especially when combined with the static or dynamic tariffs."* (I03, ICE vehicle driver, England, urban)
>
> *"It'd be handy for that if the smart charging technology enabled you to charge at several different times during the day or night, or whatever, so you can avoid the highs [peak times]."* (I06, ICE vehicle driver, England, urban)
>
> *"You put in your requirements, and it delivers them and at the end of the month, you pay slightly less. You would be a happy customer."* (EV driver, England)

Participants also mentioned that using these technologies to plan, schedule, and monitor charging would allow them to easily predict the cost of charging their EV.

EV drivers' control over electricity use

Participants frequently mentioned that using these technologies would give EV drivers significant control and responsibility in relation to charging their EVs and the cost of their electricity bills.

> *"Like the idea of it - need to have control."* (M03, ICE vehicle driver, mobility difficulties, England, urban)
>
> *"Well, I think the smart charging [technology] is a prerequisite for almost everything else, that you can't control dynamical changing prices or anything else without some kind of smart charge, some control."* (B40, BEV driver, England, urban)

What are the concerns or perceived barriers to uptake for smart charging technologies?

General concept

A few participants thought that smart charging technologies are too complicated. For example, some participants thought that using these technologies would require technical knowledge and skills, so would not suit all EV users. Additionally, one participant thought that scheduling charges in general would not be very useful.

Practical concerns

Some participants disliked that using these technologies may require an app or smart charge point, particularly because smart charge points tend to be more expensive than standard charge points (i.e. charge points without GPS or Internet connectivity).

Additionally, several participants mentioned that scheduling charges using smart charging technologies would be too arduous, particularly for those who find it difficult to predict when they will need to charge their vehicle because they do not have a fixed routine. Participants also mentioned that those who live in areas of poor mobile or Internet signal may experience difficulties with using these technologies to schedule charges.

> *"Our broadband often doesn't work, and if we get really strong winds, we haven't got any electric either. We've actually got a generator for certain occasions."* (I21, ICE vehicle driver, Wales, rural)
>
> *"Would have concerns if mobile technology required because there are many area across the country where reception is so poor."* (I03, ICE vehicle driver, England, urban)

Several participants mentioned that they would not like to use apps to schedule charges, whereas others thought that scheduling charges using an EV's in-built system would be too difficult (particularly when attempting to schedule charges to fit in with off-peak tariff bands on a time-of-use tariff). One participant also voiced a concern that users may not be able to schedule a charge using an EV's in-built system if the EV had already run out of charge.

A few participants mentioned that individual family members could schedule charges at different times (either accidentally or knowingly), which could lead to disputes within the family.

One participant voiced a concern that using these technologies to schedule charges may result in EV charging being delayed (i.e. charge may not be delivered as soon as an EV is connected to a power source). The participant was concerned that this delay in charging may result in the EV not being sufficiently charged by the time it is required for a journey.

Moreover, participants were concerned that scheduling charges would mean that an EV may not charge immediately after it is plugged in, and so would be plugged in for longer than necessary.

> *"Plugging in a cable and leaving it or plugging all the time is a pain."* (P02, PHEV driver, England, rural)

One participant was concerned that this would increase the likelihood of someone tripping over the cable.

Financial concerns

Several participants, including business participants, mentioned that only those EV drivers who use a time-of-use tariff would be able to use these technologies in order to save money on their electricity bills.

> *"We have the capability within the [current EVs]… but our electricity tariff is a single rate tariff, we would use smart elements if energy costs varied."* (Business10, EVs, Scotland, small business)

Lack of trust in technology

A few participants expressed concerns that smart charging technologies may not function properly at all times, which could result in scheduled charges not happening and users' EVs not being sufficiently charged for their next journey. Participants were especially concerned about technical issues occurring when charging status cannot be monitored (e.g. overnight). In particular, several participants also said that they did not trust smart charging apps to function well at all times, particularly when they had experienced or heard of technical issues with existing apps.

> *"We've got a bad history with [smart charging] apps at the moment. Most of us who own [an EV model] are in, basically, a long-running, five-year dispute with [an EV manufacturer] about the fact their apps don't work."* (B05, BEV driver, Scotland, rural)

Furthermore, several participants had concerns about the security and privacy of their data when using these technologies. For example, one participant suggested that these technologies could be hacked to gain unauthorised access to users' GPS data.

> *"Security concerns of 'connected' devices."* (B03, BEV driver, Scotland, rural)

EV drivers' control over charging

Several participants mentioned that using these technologies puts too much onus on EV drivers to schedule EV charging correctly, ensuring the vehicle has enough charge for the next journey.

> *"If you'd set it wrongly, you could find yourself with a massive bill."* (I17, ICE vehicle driver, parent of young child, Wales, rural)

Conversely, one participant thought that these technologies would reduce EV drivers' control over charging.

What provisions should be implemented to increase acceptability of smart charging technologies?

Functions of smart charging technologies

Overall, participants proposed many provisions that would increase their likelihood of adopting smart charging technologies, most of which related to which functions the technologies offer to users. For example, several participants suggested that users should be able to specify a certain level of charge by a particular time of day instead of scheduling start and stop times for charging.

> *"You give it the criteria, and if you say, "I want 80% charge in the morning" and it has to do that."* (EV driver, England)

Other participants suggested that these technologies could help users to schedule charges to occur at times when electricity is less expensive on time-of-use energy tariffs. For example, based on electricity prices on a time-of-use tariff (e.g. setting a preference for charging to occur only when electricity is priced at 10p per kWh or less).

> *"Auto-charging as soon as the supply cost drops to a pre-set level."* (I31, ICE vehicle driver, Scotland, rural)

> *"You can allow the system to figure out, "Oh, it [electricity] has just gone extra cheap, I'll take it."* (EV driver, England)

Additionally, a few participants suggested that these technologies could help users to manage V2G services, such as using the technology to switch V2G services on and off.

To minimise the time and effort required for users to manage charging, several participants said that they would like to be able to programme default settings for scheduling charges. For example, setting defaults for charge to be delivered to their EV at the same time each day or setting default preferences for certain times of day that the grid would be allowed to retrieve energy from EVs' batteries when using V2G services.

Instead of programming default settings, one participant suggested that these technologies could 'learn' users' daily routines and schedule charges for when each user is least likely to use their EV (e.g. when the user would typically sleep).

Moreover, participants thought it was vital for users to be able to override scheduled charges so that they can charge their EV instantly for any unplanned journeys. One participant suggested that users should be able to override scheduled charges remotely (e.g. with an app).

> *"You have to remember to override it if you need a full charge at an unexpected time."* (P05, PHEV driver, England, urban)

Many participants suggested that these technologies could provide information or advice to users regarding the scheduling of EV charges, so that they can make informed decisions. For example, a lot of participants thought that it was important for these technologies to provide information about the cost of charging at different times of day when on a time-of-use tariff. Another suggestion was that these technologies should advise users of the most environmentally friendly times of day to charge. One participant also suggested that these technologies should provide users with the location of their nearest emergency services.

Many participants also mentioned that they would like to be able to monitor their EV's charging status using smart charging technologies. In particular, one participant mentioned that being able to monitor charging status would reassure users that the technology is functioning properly. In addition, participants suggested that these technologies could allow participants to monitor the cost of each completed charge or provide users with the predicted cost of future scheduled charges.

> *"I would like to see it 'charging' to be confident it was working. E.g. if set it up at 8pm, I would want it to work at 7am next morning. Not sure I trust electricity - perhaps over time this would become better."* (S09, STB EV driver, Wales, rural)

One participant also suggested that these technologies could allow users to monitor the environmental benefits of each completed charge.

Design of smart charging technologies

Many participants suggested that being able to schedule and monitor EV charging using smart charging technologies without spending too much time or effort would be ideal.

> *"I think it needs to be 'set and forget'. I think if [the technology is] smart enough, it can read your usage and then use them accordingly."* (EV driver, England)

Some participants mentioned that they would like to use an app or website to schedule and monitor charges, with some participants suggesting that smart charging technologies should be integrated into, or connected to, existing apps for certain EVs. Conversely, other participants mentioned that they would like to be able to schedule charges without having to use an app, a smartphone, or the Internet (e.g. using an EV's in-built system or a smart charge point). Those who live in areas of poor Internet or mobile signal were especially keen on the idea of using smart charging technologies without having to use a smartphone or the Internet.

> *"It would be good to manage the charging through an app at home."* (I38, ICE vehicle driver, parent of young child, Scotland, rural)

One participant suggested that smart charging technologies should be compatible with all EV makes and models. Another participant recommended that EVs should be designed so that users can schedule charges using an EV's in-built system even if the EV has already run out of charge.

Furthermore, one participant suggested that these technologies should be designed so that several members of the same household can schedule charges or override scheduled charges for the same EV.

Participants also mentioned that they would like to see improved reliability of such technologies and for these technologies to become more established, which would increase consumers' level of trust in them.

Incentives from technology providers

Many participants said that they would be more likely to opt for these technologies if they could use them for free or at a low cost.

Additionally, several participants said that they would be keen for technology providers to provide future customers with a guarantee that using the technology would allow them to save money on their electricity bills.

> *"I think the technological solution like that has to go hand in hand with an economic one; which is that if you buy this smart charger, which responds to signals that come from us, the electricity supplier, then your cost for keeping your vehicle charged ready for your commute in the morning will be much lower than if you don't."* (EV driver, England)

One participant suggested that technology providers could offer a loyalty points scheme for those who use the technology.

Several participants mentioned that technology providers should guarantee users that the technology would function properly at all times (e.g. that users' EVs will always receive the amount of charge requested by the user, by the time they have specified).

> *"It [smart charging technology] has to be reliable."* (EV driver, England)

Moreover, one participant suggested that the technology provider should be easily contactable in the event of any issues.

Infrastructure

One participant said that wireless EV charging would encourage them to use smart charging technologies, as this would eliminate the risk of tripping over a charging cable when an EV is required to be connected to a power source for long periods of time.

3.2.6 Mandatory managed charging

Mandatory managed charging is the curtailment (slowing down or pausing) of EV charging by third parties, which may be required to avoid localised blackouts and brownouts if other methods of managing electricity use fail to reduce peaks in electricity demand. Mandatory managed charging would be used as a last resort, and only in extreme situations. EV drivers would not be able to override the curtailment of EV charging.

Summary of attitudes towards mandatory managed charging

Participants thought that this smart charging option may be necessary to avoid blackouts and brownouts as the popularity of EVs increases, and that its effects would likely be unnoticed because curtailment of EV charging would be temporary.

Business participants were concerned that curtailment of EV charging could negatively impact their businesses operations if their EVs did not have the expected amount of charge at the time it was needed. Household participants' main concern was that this smart charging option would impact their, or emergency services', ability to use an EV for an urgent journey.

What are the perceived advantages or benefits of mandatory managed charging?

General concept

Some participants thought that mandatory managed would be necessary to avoid blackouts and brownouts as the popularity of EVs increases.

> *"It's better than a complete power cut, yes."* (B41, BEV driver, Wales, urban)

Several participants pointed out that most people expect to have temporary power outages anyway and that EV drivers would be unlikely to notice the effects of mandatory managed charging, as any curtailment of charging would be temporary. Similarly, several participants indicated that they would find it acceptable for charging of their EV to be curtailed temporarily. One participant pointed out that EVs are usually connected to a power source for a longer period of time than it takes for the EV to reach full charge, so curtailing EV charging temporarily would be unlikely to affect how much charge an EV has for the next journey.

> *"It [curtailment of electricity supply] is probably happening to some degree anyway, we just don't notice it."* (C04, ICE vehicle driver, parent of young child, England, urban)

Another participant highlighted that curtailing charging of all EVs would be a fair system, as all EV drivers would be equally affected.

Ease of use

One participant thought that this was the most convenient of all of the smart charging options discussed, as it required no input from consumers.

> *"[Mandatory managed charging is] just something that's easy to manage…instead of the onus on me having to monitor it."* (C02, ICE vehicle driver, parent of young child, England, rural)

Ethical advantages

One participant suggested that curtailing EV charging could be a necessary intervention to ensure no loss of electricity for important services (e.g. hospitals) at peak times.

What are the concerns or perceived barriers to uptake for mandatory managed charging?

General concept

The majority of participants viewed mandatory managed charging unfavourably, and as an added complication to EV charging. Some participants said that this approach was too severe and would cause a lot of frustration for EV drivers and would increase their range anxiety.

> *"Bad, bad, bad. Everyone's circumstances are different but I would object strongly to this."* (B11, BEV driver, mobility difficulties, Scotland, rural)

Several participants held the view that it would be unacceptable and unfair for EV charging to be curtailed, particularly because EV drivers pay to have seamless running of electricity and should not be responsible for preventing blackouts and brownouts.

> *"I don't care about power outage – that should not be my problem to deal with."* (B16, BEV driver, England, urban)
>
> *"If you're taking my power off or knocking it down, I'm not getting what I'm paying for, am I?"* (M01, ICE vehicle driver, mobility difficulties, England, urban)

Concerns for the electricity network

Many participants thought that mandatory managed charging would deter ICE vehicle drivers from purchasing or leasing EVs. Similarly, one participant thought that introducing mandatory managed charging would discourage EV driving.

> *"Even the threat of this being an option will hinder EV uptake. People already have concerns over range anxiety and this would be a massive negative point."* (B07, BEV driver, parent of young child, Scotland, urban)

Additionally, several participants thought that the impact of mandatory managed charging on balancing the grid would be limited because EV drivers would find a way to avoid curtailment of their EV charging. For example, participants thought that rather than charging EVs using smart charge points (required for mandatory managed charging), some EV users would charge using standard 13amp power supplies.

> *"Almost everyone can bypass by plugging into a 13 amp socket."* (B43, BEV driver, Wales, rural)
>
> *"People will just stop using their dedicated chargers…they will go to the reliable [13 amp] socket that is not on that system."* (EV driver, England)

Practical concerns

One participant voiced a concern that mandatory managed charging would require EV drivers to have access to smart charge points, especially because they are generally more expensive than standard charge points.

Many participants, including business participants, mentioned that mandatory managed charging would be inconvenient because curtailment of EV charging may result in EVs not being sufficiently charged for essential

car journeys. Participants highlighted that this issue would be particularly pronounced for those who do not have access to other modes of transport, such as those living in rural areas.

> *"If they do force EVs on me, it [mandatory managed charging] would probably kill it [the business] off – the energy companies would be dictating freedom of movement – they'd be taking away your liberties – 1-4am is busiest time on a weekend… to be controlled by someone else isn't fair."* (Business08, ICE vehicles, Scotland, microbusiness)
>
> *"Can leave you short if vehicle is needed in emergency."* (B01, BEV driver, Scotland, rural)

Lack of trust in energy networks

Participants frequently mentioned that the introduction of mandatory managed charging would be *"an admission"* that National Grid and other energy network companies have failed to manage the electricity system, which would lead to a lack of confidence in their capabilities.

> *"Good planning should render the idea unnecessary."* (B21, BEV driver, England, urban)

Lack of EV drivers' control over charging

One of the most common concerns expressed by participants is that mandatory managed charging would reduce EV drivers' control over charging.

> *"Inflexible, lack of control by consumers."* (B03, BEV driver, Scotland, rural)

Ethical concerns

Many participants were concerned that curtailment of EV charging may result in EVs used by emergency services not being sufficiently charged, which could impact the emergency services' ability to undertake vital duties.

Some participants also mentioned that mandatory managed charging is unfair, as it would affect only those who drive EVs. One participant also thought that targeting EV drivers for environmental reasons is particularly unreasonable because driving an EV is more environmentally friendly than driving an ICE vehicle.

> *"What about non-EV users who are wasting electricity?"* (B23, BEV driver, England, urban)

What provisions should be implemented to increase acceptability of mandatory managed charging?

Planning of EV charging curtailment

In general, the majority of participants thought that mandatory managed charging should be implemented very rarely, only in extreme circumstances, and as a last resort to avoiding blackouts or brownouts. Additionally, participants thought that mandatory managed charging would be acceptable only if curtailment of EV charging was limited.

> *"Would need to be very last resort."* (I12, ICE vehicle driver, Scotland, urban)
>
> *"It depends on how long it is for, because it might be a minute or five minutes, and I don't think anyone would have a concern about that. If it is an hour or five hours; a lot of people would. If it is a very short-term issue, I think most people wouldn't even know."* (EV driver, England)

Furthermore, one participant suggested that there should be a good system for prioritising the curtailment of charging for certain EVs over others.

EV drivers' ability to influence and monitor charging

Some participants also suggested that EV users should be notified in advance that EV charging is likely to be curtailed at a particular time, which would allow EV users to shift the times at which they charge their vehicles to avoid these times. Participants also suggested that this approach could entirely negate the need to actually curtail EV charging. Several participants suggested that EV users could be notified that curtailment of charging had already occurred and the reasons for the curtailment.

> *"I would like to have a notification of when this [curtailment] is happening, whether that's on a daily or a real time basis, or maybe a monthly report or something, so we could start to see trends, then we could say, right, we know that charging is restricted between seven and 8:30, and that might encourage people to spread the charges around to reduce that [curtailment]."* (C04, ICE vehicle driver, parent of young child, England, urban)
>
> *"If there is societal give back, I could live with it, but I would need to know the reason why they did it at the time that they did it. I would be happy with that."* (EV driver, England)

Additionally, some participants thought that EV users could use smart charging technologies to request a certain level of charge by a particular time, so that even if curtailment of charging occurs, it is less likely to affect how much charge their EV has for their next journey.

The majority of participants thought that EV users should have the ability to override curtailment of EV charging (i.e. to charge at a normal rate immediately) in the event of an emergency. Many participants also thought that certain people or services (e.g. emergency services) should be made exempt from curtailment of EV charging or should be able to override the curtailment at any time.

> *"You've got to be able to override."* (I01, ICE vehicle driver, England, rural)
>
> *"I think there are certain essential users, paramedics etcetera, you need someone to be flagged."* (EV driver, England)
>
> *"You can have the whole street using energy that is completely not priority and you have a bunch of people ready to go to work, for night shift and they can't charge their cars."* (EV driver, England)

Financial incentives

One participant suggested that EV users could be financially compensated for curtailing charging of their vehicles.

Household energy systems

One participant mentioned that having a home battery storage system would increase the acceptability of mandatory managed charging, as EV drivers could charge their vehicles using energy stored in their home battery whilst electricity supply from the grid to EVs is curtailed.

Alternatives to curtailing EV charging

Participants thought that curtailment of EV charging could be avoided if energy networks better planned how to supply enough electricity to meet demands. For example, some participants suggested that energy

networks should invest in building more cables and wires to transport additional energy and meet electricity demands, which would reduce the need to curtail charging of EVs.

> *"To stop this happening more infrastructure needs to be built to guarantee enough power supply."* (I25, ICE vehicle driver, Wales, urban)
>
> *"Invest in the infrastructure instead of this."* (B20, BEV driver, England, urban)

Some participants suggested that other household electrical appliances should be curtailed in place of EVs, as this would disrupt EV users' daily routines less.

> *"[Mandatory managed charging] doesn't take into account other domestic power demands that may not be as [much of a] priority as the car (i.e. charged car for night shift work). Could have the hot tub running but no car power."* (B38, BEV driver, England, urban)

3.2.7 General views of smart charging options

At the end of the workshop, we asked household participants whether any of the smart charging options in general could fit in with their household. As shown in Figure 11, most participants said that smart charging would fit in with their household, regardless of whether they drove an EV or ICE vehicle. However, more EV drivers said smart charging could fit in with their household than ICE vehicle drivers.

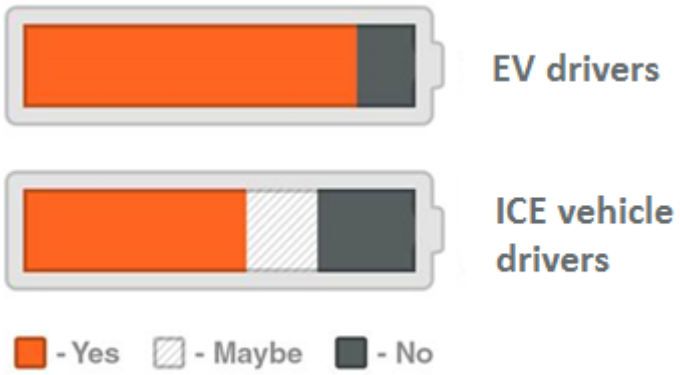


Figure 11: Participants' expectations of whether smart charging would fit in with their household

Of those participants who indicated that smart charging in general would fit in with their household, the reasons were that using smart charging options would:

- Provide an opportunity to save money
- Help to balance electricity supply and demand, and therefore prevent localised blackouts or brownouts
- Not require much alteration of existing daily routines (including EV charging times)
- Involve technology making automated decisions about energy use on behalf of household members, which would save them time and/or effort

Those participants who indicated that smart charging would not fit in with their household said so because:

- It is too difficult to predict future electricity consumption or plan EV charging, particularly for households with unpredictable daily routines, multiple EVs, or several members of the household using the same EVs at different times
- It is too difficult to shift electricity usage, particularly for those with who have a very fixed daily routine that cannot be altered

- Using smart charging options usually requires more user input (as opposed to connecting an EV to a power source and charging commencing immediately)
- Using smart charging options would increase the likelihood that EVs may not be sufficiently charged for an unexpected journey (as opposed to charging commencing immediately upon connecting an EV to a power source)

Participants stated which options they would be most likely to use, and which they would be most likely to avoid; Figure 12[10] illustrates the options that would most likely be avoided by EV and ICE vehicle participants; the static time-of-use tariff was perceived as the most acceptable amongst all participants, whilst third-party charge management schemes and dynamic time-of-use tariffs were most likely to be avoided.

> *"I would be nervous about the dynamic or third party with lack of trust and predictability."* (EV driver, England)
>
> *"The obvious one to actively avoid is the dynamic time-of-use tariff, it's just a non-runner."* (B42, BEV driver, England, rural)
>
> *"With the right hardware, the vehicle-to-grid I think is a really good long-term option for balancing the demand on the network."* (EV driver, England)

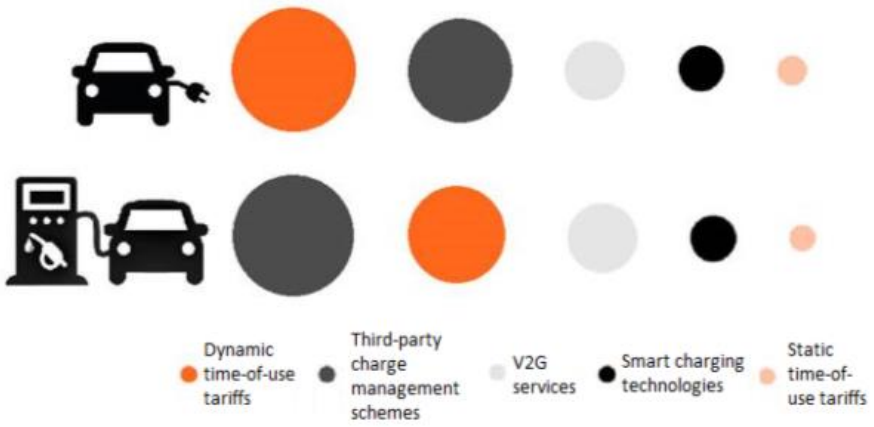


Figure 12: Smart charging options most likely to be avoided by household participants (larger bubbles indicate a higher reported likelihood they would avoid the option)

Inter-group differences regarding attitudes to all smart charging options

It was clear that some EV and STB EV drivers had previous knowledge of some of the smart charging options before participating in this research, whereas ICE vehicle drivers seemed to be less familiar with the options. Some EV drivers even had experience of using some of the options (particularly static time-of-use tariffs and smart charging technologies). Those participants with previous knowledge or experience of options tended to be more open to the idea of using them, unless they had previously experienced issues with those options. Additionally, some ICE vehicle drivers mentioned that they would not be able to use some of the options whatsoever because they did not have adequate off-street parking to accommodate charging an EV at their

[10] Note that some participants indicated they would use or avoid a combination of two or more smart charging options, so the figure is indicative of the relative number of 'votes' for each option.

home. This raises an important consideration; alternative types of smart charging solutions may be required for those without off-street parking.

Participants from Wales were more likely to say that they would use smart technologies compared to those from Scotland and England. Participants from Scotland were more likely to avoid mandatory managed charging than those from England and Wales. Participants from Scotland and Wales were more likely to avoid third-party charge management schemes than those from England. Participants from England were more likely to avoid V2G services than those from Scotland.

Participants from rural locations were more likely to say that they would avoid V2G services than those from urban locations and were also concerned that a lack of network signal where they lived meant that they would find it difficult to use some of the options. Some participants living in rural areas also expressed concerns that using some of the options could increase the likelihood that their EV would not be sufficiently charged for an unexpected journey, particularly when those participants had a lack of other available transport options.

There were no differences between households with and without vulnerable members in terms of which options they would use or avoid, although participants who had mobility difficulties or young children expressed concerns that their irregular routines would make it difficult to plan their electricity usage. Additionally, participants highlighted that those with poor fine motor skills may have difficulty using a mobile phone to interact with the options.

3.3 Provisions to increase acceptability of smart charging options

We asked participants to rank the importance of a pre-defined set of guarantees and features. Figure 13 shows the level of importance placed on various guarantees by participants, and demonstrates that the most important guarantees related to the vehicle's state of charge, with both EV and ICE vehicle drivers rating a guaranteed full charge by a certain time, and a guaranteed minimum state of charge, as most important. The least important guarantees overall were receiving money for returning energy to the grid from the vehicle's battery, and having the ability to automate charging. On average, ICE vehicle drivers rated free charge point installation and certainty about their annual energy bill as much more important than EV drivers. There were no other notable differences between the rankings provided by EV and ICE vehicle drivers.

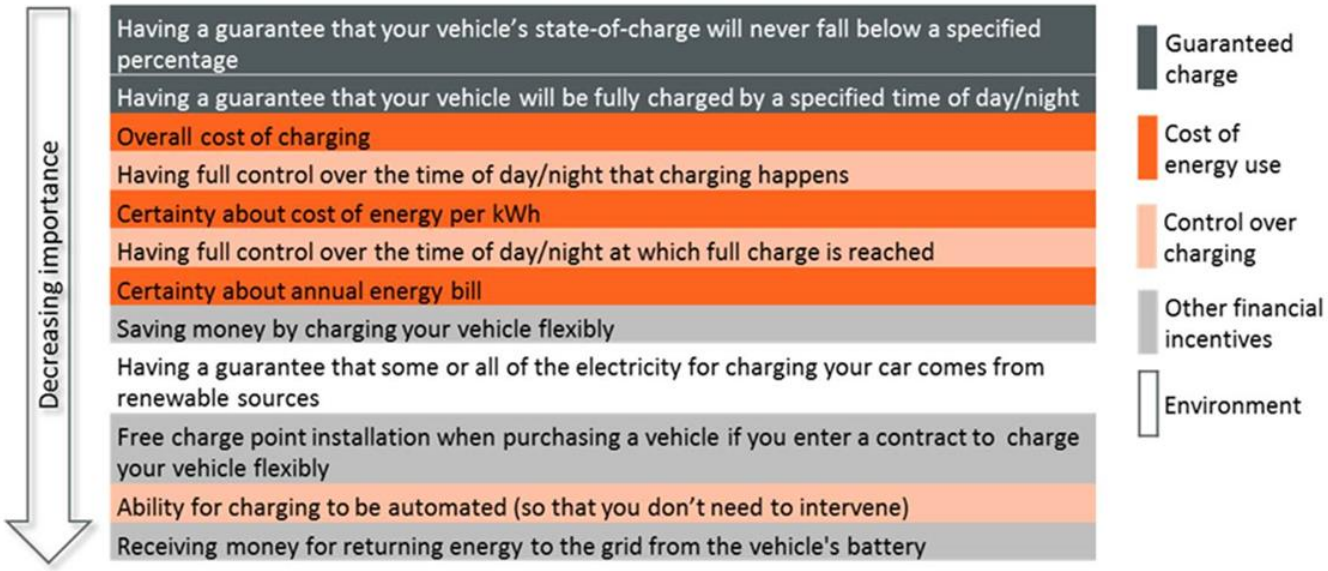


Figure 13: Level of importance placed on pre-defined guarantees by participants

Most participants were keen to offer their own suggestions for ways in which acceptability of smart charging options could be improved. Generally, the provisions suggested by participants to make smart charging more likely to fit in with their household or business fell under three categories: provision of information, adequate design of smart charging offers, and provision of guarantees.

Provision of information

Many participants said that they would like to receive **notifications** that provide information, such as:

- The upcoming prices of electricity
- How much charge has been retrieved from their EV battery
- How much money they received from allowing the grid to access energy stored in their EV battery
- Confirmation of the charging preferences or requirements that they have set (e.g. scheduling charging so that their EV has a certain level of charge by a certain time)

Additionally, participants suggested that **information** could be provided on their monthly electricity bills, such as:

- How much money they saved by using a time-of-use tariff, compared with other types of tariff
- How much money they received from allowing the grid to access energy stored in their EV battery

Participants also suggested that they could receive information about:

- The best times of day to charge (e.g. based on electricity prices or availability of renewable energy)
- The cost of each charge, dependent on the time of day at which charging occurs
- Their vehicle's current state-of-charge

Section 3.4 further details participants' information needs in relation to the smart charging options.

Adequate design of smart charging offers

A key theme that emerged between participants was that smart charging options should be designed so that they are **convenient**, meaning energy consumers could easily:

- Understand the concept behind the option or offer (e.g. simple electricity pricing structures)
- Set them up
- Interact with the smart charging option in a variety of ways (e.g. via a smartphone app or website, as well as via an EV's in-built system for those with poor Internet or mobile signal)
- Use the smart charging option regardless of the make and model of their EV
- Use the smart charging option alongside other members of their household (e.g. so that multiple household members can schedule charging)
- Contact the service or scheme provider in the event of an issue or query

Some participants also suggested that technology could make more **automated decisions** about EV charging so that managing charging is less effortful for EV drivers.

For many participants (especially household participants), control over charging and their vehicle having enough charge for upcoming journeys were important factors. Participants thought their **level of control** over charging could be increased if they had the ability to:

- Set charging preferences or requirements (e.g. setting a time by which their EV should have a certain level of charge, setting a minimum level of charge for their EV battery to have at all times, and scheduling charging to happen when electricity prices are cheapest or when renewable energy is in abundance)

- Override charges that had already been scheduled by themselves or a third party so that they could charge their EV immediately for unexpected or emergency journeys

Participants also suggested that **financial incentives** for using smart charging options should be suitable, such as:

- The service or scheme being offered to energy consumers at a low cost or free-of-charge
- Equipment required to use the option (e.g. smart charge point, V2G-enabled EV) being offered to energy consumers at a low cost or free-of-charge
- Low or no standing charges for time-of-use energy tariffs
- Off-peak prices being considerably lower than peak prices on time-of-use energy tariffs

Additionally, participants felt that services or schemes would be more acceptable if there was no contract between them and the provider of the service or scheme, or if the contract term was short.

Furthermore, many participants indicated that smart charging options would be more appealing if supporting technology and services became more reliable and established.

Provision of guarantees

Many participants felt that **financial guarantees** could increase the likelihood of them adopting smart charging options. For example, participants suggested that energy consumers could be provided with guarantees that:

- Electricity prices would not increase significantly or very often when using time-of-use tariffs
- The price of electricity per kWh or monthly cost of electricity would be capped when using time-of-use tariffs
- They would save money
- They would receive compensation for allowing the grid to access energy stored in their EV battery or for curtailment of EV charging

The majority of participants had suggestions for the provision of guarantees specifically related to mandatory managed charging, which included suggestions that:

- Curtailment of EV charging should be time-limited, and only implemented in extreme situations, as a last resort
- Certain people or services should be exempt from curtailment of EV charging (e.g. individuals with mobility difficulties or emergency services)

Participants also thought energy suppliers should provide guarantees that the price bands on a static time-of-use tariff should not shift very often.

Furthermore, participants said that energy consumers should receive guarantees that smart charging services or schemes would not adversely affect EVs' **battery health**, or that EV batteries would be replaced, at no cost to the consumer, if there were any adverse effects.

Other provisions

Generally, participants felt that smart charging options would be more likely to fit in with their household or business if the following were accessible:

- Smart charge points and other smart appliances
- A home battery storage system or an additional energy supply system (e.g. solar panels)
- EVs with batteries that take very little time to charge or that have large capacities

Additionally, participants felt that options would be more acceptable if the service or scheme providers were established and trusted.

Inter-group differences regarding suggested provisions to increase acceptability of smart charging options

Overall, ICE vehicle drivers placed more importance on provision of guarantees than EV drivers. More specifically, EV drivers placed more importance on electricity coming from renewable sources and automated charging, whereas ICE vehicle drivers placed more importance on the certainty of costs of electricity bills and the provision of a free charge point.

There were no discernible differences between participants from England, Scotland or Wales.

Being able to use smart charging options without a smartphone or Internet access was more important to participants living in rural areas, due to having poor Internet or mobile signal.

Participants who had mobility difficulties or young children expressed a need for greater flexibility and override options to charge EVs at short notice for unexpected journeys, as their daily routines tended to be unpredictable.

3.4 Information needs of households and businesses

We asked household and business participants what information they would like to have before deciding whether or not to opt for each of the smart charging options. We also asked participants how they would like to receive this information or who they would like to provide the information.

Being able to visualise how a smart charging option would work, and what savings it would provide an individual, was felt to be very important by participants:

> *"You can't visualise some things. Oh, yes, it's this between this and this, that and the other. But, what does that actually mean? Kilowatts an hour, how many kilowatts am I using per hour? I think that there are a lot of households where they don't understand the tariffs."* (M02, ICE vehicle driver, mobility difficulties, parent of young children, England, rural)

To explore household participants' information needs further, we showed them a series of posters which displayed mock adverts for four of the smart charging options (see Appendix H). We asked participants to record what they liked and disliked about the information contained in each poster, and any additional information that they would need in order to make an informed choice about that option. Table 4 summarises participants' responses and includes the type of language used by the participants (for example when questions are asked, these use the participants' wording).

For all posters, participants stated that they liked the examples of the app interfaces, and examples of costs. They were keen on the idea of receiving additional information on contract length, terms and conditions, and penalties. They also stated that footnotes and small print should be avoided, with this information being included in the main text.

Table 4: Summary of participants' poster feedback

	All household participants	ICE vehicle drivers	EV drivers
Static time-of-use energy tariff example ('Power to the People' poster)			
	Clear electricity prices. Shows there is an option to schedule using an app, and to override scheduled charges if needed. Standing charge stated.		Demonstrates that users could plan charging around times when electricity is more likely to be from a renewable source.
	What is the cost of charge point installation? Would the peak/off-peak times change if this tariff became popular? Would there be a guarantee that peak/off-peak times would not change often?	What does one kWh equate to (e.g. how many kWh does it take to boil a kettle)? How much would it cost to fully charge an EV at certain times of day? Would this make much of a difference to electricity bills if an EV was only charged once or twice a week? What evidence is there to support claims about environmental benefits? When is sustainable energy used and how?	What would the long-term costs of EV charging be, depending on miles typically driven? What would the overall costs of electricity use be? How do electricity prices on this tariff compare with those on other tariffs? What are the potential CO_2 savings? Is the tariff fixed for a period of time? Would the app only be available to those with home charge points and smartphones? Is the app compatible with all charge points? How fair and regulated is the tariff? What is the contract length? Are there any cancellation fees? How easy would it be to switch providers?
Dynamic time-of-use tariff example ('Ec-static' poster)			
	Clear electricity prices. Information on personal electricity expenditure and comparison with previous month. Information about when the next day's electricity prices would be received. No estimated bills. Free smart meter. No requirement to submit meter readings. No fixed-term contract. No cancellation fees. Information about		Visibility of energy costs 24 hours in advance. Link between availability of renewable energy and electricity prices.

	All household participants	ICE vehicle drivers	EV drivers
	environmental benefits.		
	How would environmental benefits be achieved? How would I switch from a prepayment meter to a smart meter? Is there a way to control how often I receive notifications?	How much money could be saved on monthly or annual electricity bills compared with other tariffs? Is access to a smartphone essential? Why is the price set from 4pm onwards?	How much money could the average household save on electricity bills compared with other tariffs? How is renewable energy used at times when there is a lack of solar/wind energy? Which type of smart meter is required?
Third-party charge management scheme example ('Electrifide' poster)			
	App looks simple to use. Information about environmental benefits.	App is available across different platforms.	App is free to download. Information on how to use the scheme in conjunction with a time-of-use tariff to minimise electricity costs.
	What are the incentives for using this scheme? What costs are involved with using this scheme or the app? How does the system prioritise delivering customers' charging requirements?	Who is the 'third party'? How trustworthy is the third party and their systems? Is the app compatible with different makes of charge point?	How would customers make savings on electricity bills? How much money would customers be likely to save? When would EV charging occur? Would the EV need to be constantly plugged in? Can more than one member of a household use the app simultaneously? What happens if the third party cannot meet a customer's requirements? Who takes responsibility if the EV is not charged as required? Would customers be able to override charges scheduled by the third party?
V2G service example ('Interenergise' poster)			
	Information about potential compensation amounts. Free charge point installation. Information about the service's purpose. Information about environmental benefits. Mentions customers' ability to switch 'energy sharing' off. Emphasises that the EV driver has control, rather than a third party.		

	All household participants	ICE vehicle drivers	EV drivers
	How much would I be paid for returning energy to the grid per kWh? How much would I be paid for returning energy to the grid, compared with the costs of charging the EV? How much do V2G-enabled charge points cost? Which manufacturers produce V2G-enabled EVs? What are the advantages of V2G services over vehicle-to-home services? If the customer sold their V2G-enabled EV, how would this affect the contract?	How often would compensation be given? How much do V2G-enabled charge points cost, compared with other types of charge point? Is there a way to ensure a minimum SOC is always maintained? Would the EV need to be constantly plugged in?	What are average compensation figures based on? How would using this service affect an EV's battery health?

Overall, participants liked information to be clear in terms of how a smart charging option would operate, the costs, and an easy-to-understand app interface.

Many participants suggested that a comparison of costs with other tariffs would be useful. Participants tended not to like a daily standing charge, but appreciated that the information was given up front. They were also keen to know other associated costs – for example whether there would be a cost for installing the required charge point or downloading an app.

There was an aversion to footnotes and small print on the posters – it was felt that these were trying to hide key information which may make the proposition less attractive, particularly in relation to third-party charge management schemes (which the below quotes relate to):

> *"There would have to be some sort of guarantee, wouldn't there?"*
>
> *"Yes, but the small print says there is no guarantee."*
>
> *"Well, that is no good then. I didn't spot that."* (Conversation between EV drivers, England)
>
> *"Second footnote terrifying - too much info only in small print."* (Poster annotation – ICE vehicle/STB EV driver, England)

Contractual information was felt to be key, including any penalties for early termination.

> *"Presumably you have to sign into a contract for any of these things and what are the cancellation fees, how does it work, what are the penalties? You need know all this before."* (EV driver, England)
>
> *"The contract things now, have become very big to me, of being in contracts and having to buy yourself out. And I think that you really have to look at the small print now, on things, and I tend to do that a lot more than I ever used to."* (S08, STB EV driver, Wales, rural)
>
> *"There shouldn't be any contract. You should be free to come and go as you like."* (I36, ICE vehicle driver, Scotland, urban)

Some participants were sceptical over claims made in the posters about environmental benefits; there was a desire for evidence to support the claims.

> *"I think the comment about bringing benefits to the environment is very woolly…needs more data."* (S04, STB EV driver, parent of young child, England, rural)

Smart charging technologies and mandatory managed charging

Smart charging technologies and mandatory managed charging were not included in the poster exercise. However additional information needs were identified through the questions asked about these propositions. EV drivers did not identify any additional information needs in relation to smart charging technologies as most indicated that *"most EVs already have this"* and that they are *"already doing this"*. Amongst ICE vehicle drivers, there were some concerns about technology failure, and whether the EV would need to be plugged in at all times. Some also asked whether this technology could be used away from the home, at workplaces and public charge points.

The key additional information need from both EV and ICE vehicle drivers relating to mandatory managed charging related to what would happen in an emergency situation. There was a concern that mandatory managed charging may result in EVs not being charged when needed, and a feeling that EV drivers would be targeted. Some participants wanted to know more about this:

> *"You don't stop me using my home washing machine, cooker etc. Why penalise EV users?"* (B15, BEV driver, England, urban)

Additional information sources

When asked about what sources of additional information participants would use, responses were the same regardless of the tariff: participants primarily stated that they would use the Internet as a source of further information (the supplier's website or a search engine), or the associated app. A minority said that they would prefer to call the supplier and speak to a representative. Some EV drivers also suggested that they would use alternative online sources such as forums, Facebook groups, special interest groups, or the Go Ultra Low website. This topic was explored further during the group discussions:

> *"I'd prefer to talk face to face...existing customers and friends...you've got an electric car, can I talk to you…what do you think is the best tariff to use? You'd probably get a more honest opinion."* (S10, STB EV driver, partner has mobility difficulties, Wales, rural)
>
> *"Shouldn't there be, on all these posters, shouldn't there be some sort of Government information thing, some sort of independent thing that you can refer to?"* (I14, ICE vehicle driver, Wales, Urban)

Inter-group differences regarding household and business information needs

Overarching themes associated with the four smart charging options represented by the posters fell into the distinct categories of electricity costs or savings, environmental issues, and perceived complexity.

Participants from Wales were a little more likely to mention costs, prices or savings than those from Scotland or England. There were no differences between households with or without vulnerable members, or participants from urban/rural locations in the likelihood of mentioning costs, prices or savings.

Participants from England were more likely to mention environmental issues than those from Scotland or Wales. Again, there were no differences between households with or without vulnerable members, or participants from urban/rural locations in terms of mentioning environmental issues.

Participants from Scotland were more likely than those from England or Wales to have concerns around the complexity of the tariffs described by the four posters. Participants from urban areas were more likely than those from rural areas to have concerns around the complexity of the tariffs described by the four posters. There were no differences between households with or without vulnerable members.

3.5 Drivers' level of knowledge before and after the workshops

Due to the deliberative nature of the workshops, we endeavoured to immerse participants in information which may have changed their pre-workshop views and opinions throughout the workshop. In addition, certain participants in the workshops had very strong opinions which may have also influenced and changed participants' opinions (dominance bias). As the workshops progressed, individual participants' views evolved and changed which may have contributed to some of the directly opposing themes for each smart charging option.

At the start and end of the workshop, we asked participants to rate their level of knowledge on cost of energy use, different ways to manage energy use, how energy supply and demand is managed, and how much energy is used to charge an EV. As shown in Figure 14, average self-rated levels of knowledge in all four areas increased amongst all household participants (with the exception of knowledge of the cost of energy use amongst EV drivers, for which average scores were the same). Overall, nearly two thirds of EV drivers stated that their knowledge improved in at least one area, compared to almost all ICE vehicle drivers. This demonstrates that the workshops successfully delivered information to the participants, particularly those that do not currently drive an EV, thereby improving their knowledge of the topics under consideration.

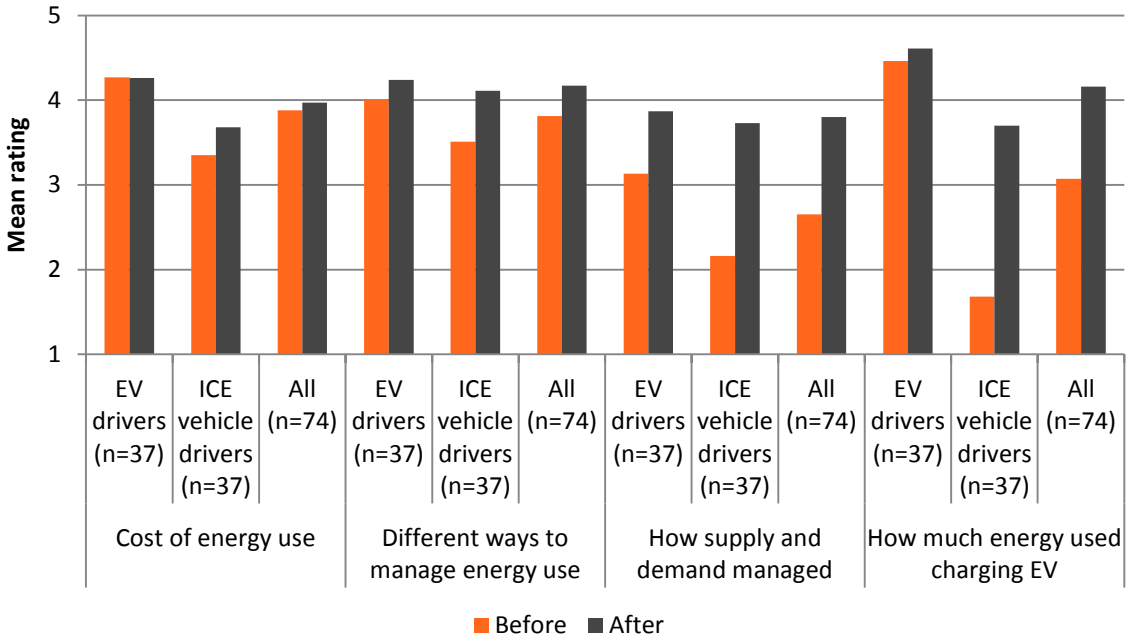


Figure 14: Participants' average self-reported levels of knowledge about several aspects of energy use before and after the workshop, from 1 ('I know nothing about this') to 5 ('I know a great deal about this')

4 Summary of key findings

The research addressed five research questions using workshops with 75 household participants and interviews with representatives of 18 small businesses. Although a large number of households took part in the research, as with all qualitative research, the findings cannot be extrapolated to the general population. Views on each smart charging option were mixed, with some participants accepting them and others rejecting them. However, all household participants felt that at least one of the options could fit in with their household. Table 5 provides a summarised response to each of the research questions, based on analysis of data captured during the workshops and interviews.

Table 5: Summary of key findings for each research question

	 Households	 Businesses
1. To what extent do households and businesses understand the need for them to become 'flexible' in their energy use, and how acceptable do they find this?		
Most participants understood and accepted the need for them to become more flexible in their energy use to accommodate increased demands on the energy network. However, some participants did not accept that EV drivers should have any responsibility for helping to balance the grid. Rather, they felt that this responsibility should lie with energy networks, suppliers, and the government.		
2. To what extent do households and businesses find various smart charging options acceptable?		
 Static time-of-use tariffs	Considered easy to understand with a clear benefit to balancing energy supply and demand, and a clear means of making cost savings. Overall, this was the favoured way of delivering flexibility.	A minority of business participants felt these types of tariff could save their organisation money on electricity bills.
 Dynamic time-of-use tariffs	Some participants saw the potential of these tariffs to save money on electricity bills, particularly when compared to other types of tariff.	Business participants did not find any aspect of this tariff acceptable.
 Third-party charge management schemes	Has the potential to save money on electricity bills when combined with a time-of-use tariff.	Has the potential to reduce administrative workload and save businesses money when combined with a time-of-use tariff.
 V2G services	Generally well-supported. Participants liked the idea of being compensated for allowing the grid to access energy stored in their EVs' batteries.	Generally well-supported. Participants liked the idea of their organisation being compensated for allowing the grid to access energy stored in their EVs' batteries.
 Smart charging technologies	Considered easy to understand and helpful for managing EV charging. Has the potential to save money on electricity bills when combined with a time-of-use tariff. Participants generally trusted these technologies because they are widely used.	Generally seen as a positive mechanism to support smart charging and engagement with the other options, in particular time-of-use tariffs.

 Mandatory managed charging	Necessary to avoid blackouts and brownouts as the popularity of EVs increases. Effects of curtailment of EV charging would likely be unnoticeable, as it would be temporary.	Business participants did not find any aspect of mandatory managed charging acceptable.
3. What are household and businesses' concerns or perceived barriers to uptake regarding smart charging options?		
 Static time-of-use tariffs	Could financially discriminate against those who are unable to use electricity at off-peak times (e.g. shift workers or parents of young children).	Synchronising energy use with off-peak tariff bands whilst ensuring sufficient charge for operational requirements would be difficult, and result in being financially 'penalised' for using electricity at peak times.
 Dynamic time-of-use tariffs	Too complex and time-consuming to plan electricity use around pricing signals. Could financially discriminate against those who are unable to use electricity at off-peak times (e.g. shift workers or parents of young children).	Too complex and time-consuming to synchronise electricity use with off-peak times whilst ensuring EVs are sufficiently charged for operational requirements. Concerns that organisations may be financially 'penalised' for needing to use electricity at peak times.
 Third-party charge management schemes	Little perceived benefit to handing over control of EV charging to a third party, particularly if the third party is not established or well-known. Concerns around potential financial costs for using these schemes.	Concerns around potential financial costs associated with using these schemes.
 V2G services	Could leave customers without enough charge for unexpected or urgent journeys. Potential adverse effects on an EV's battery health. Concerns around financial set-up costs, such as purchasing a V2G-enabled EV and charge point.	Could leave organisations without enough charge for journeys required for business operations.
 Smart charging technologies	Likely to require a fixed routine and good Internet and mobile signal, so not suitable for everyone. Concerns around faults that could occur with these technologies and data privacy or security breaches.	Business participants did not have any concerns about smart charging technologies.
 Mandatory managed charging	Discriminatory against EV drivers. Could impact EV drivers' ability to undertake urgent journeys if their EV does not have enough charge when needed.	Concerns about the negative impact on business operations if their EV does not have enough charge when needed and the potential for lost revenue, particularly if it became a common occurrence.
4. What are household and businesses' information needs before signing up to smart charging options and who would they prefer to provide that information to them?		
All smart charging options	Participants required information about contractual details and costs associated with each smart charging option, including examples of how costs savings could be made. The service provider's website was the preferred source of information.	Participants required information about how value for money would be assured, and how the required minimum state-of-charge would be assured. Energy suppliers should provide information about the most appropriate smart charging options for their business needs. The service provider's website was the preferred source of information.

5. What provisions would households and businesses like to be put in place to increase acceptability of smart charging options?		
Participants consistently mentioned that a key provision for all options was a guarantee that their vehicle would be sufficiently charged by a specified time, and that they could set a minimum state-of-charge for their EVs (with a guarantee that it would never fall below this percentage).		
 Static time-of-use tariffs	A significant and proven cost saving would be required and long-term contracts would be avoided.	A guarantee that they would not be financially 'penalised' for being on this tariff and charging when needed.
 Dynamic time-of-use tariffs	A significant and proven cost saving would be required and long-term contracts would be avoided. Suppliers of dynamic tariffs should cap peak electricity prices or the cost of monthly electricity bills.	A guarantee that they would not be financially 'penalised' for being on this tariff and charging when needed.
 Third-party charge management schemes	Ability to set EV charging preferences which third parties would be required to adhere to and an ability to override charges scheduled by the third party. Guaranteed cost savings would be essential.	Assurance that there would be a net financial benefit for allowing a third party to control EV charging.
 V2G services	Ability to set charging preferences so that their EV has sufficient charge for their next journey. Guarantees about financial benefits and discounts on V2G-enabled charge points and EVs. Guarantees about the effects of these services on EV battery health would also be essential.	Ability to specify how much power the grid would be able to retrieve from an EV battery to ensure there is sufficient charge for necessary business journeys.
 Smart charging technologies	Functions which allow the user to schedule charging and override scheduled charges so users can start a charge immediately for an unexpected journey.	Guarantee that using the technology would not increase effort for users and would enable the business to run 'as usual'.
 Mandatory managed charging	Should be time-limited and users should be given advanced warning of charging curtailment. Certain people and services should be exempt (e.g. those with mobility difficulties or emergency services).	Advance warning of curtailment of EV charging would be desirable so that businesses could plan alternative charging approaches (e.g. generators on business premises or use of public charge points) to minimise impact on business operations.

5 Conclusion

TRL used immersive workshops and interviews to explore the attitudes and concerns towards smart EV charging options amongst EV drivers, ICE vehicle drivers, and representatives of small businesses.

Generally, participants accepted and understood the need to be flexible in their energy use as the increased uptake of EVs places increasing demands on the electricity network. Participants held mixed views about who should bear responsibility for balancing electricity supply and demand, in terms of whether EV drivers should accept some responsibility, or whether it should lie entirely with National Grid, energy suppliers, or the government.

When considering smart charging options, factors relating to convenience, saving money and being environmentally friendly were key to all participants; yet EV drivers placed greater emphasis on being environmentallyfriendly than saving money. Participants from rural locations were concerned that a lack of mobile or Internet signal would mean they would find it difficult to use some of the options, such as smart charging technologies. Moreover, participants with mobility difficulties or young children expressed concerns that their irregular routines would make it difficult to plan their electricity use. Nonetheless, all participants felt that at least one of the options could fit in with their household.

Static time-of-use tariffs were the most popular option among household participants, whereas third-party charge management schemes, dynamic time-of-use tariffs, and mandatory managed charging were least favoured. V2G services were also well received, although participants required more evidence that V2G service providers and other third parties involved in these services would be trustworthy, and that this option would not adversely affect EV battery health. Participants recognised the role smart charging technologies could play in supporting implementation and engagement with other smart charging options.

Business participants felt time-of-use tariffs would generally not be suitable for their business because operational needs would outweigh any perceived benefits of shifting EV charging to off-peak times. Due to the existing cost savings associated with running vehicles on electric power rather than fossil fuels, additional savings associated with smart charging were seen as relatively insignificant to business participants.

Participants suggested various ways in which acceptability of smart charging options could be improved. Suggestions around adequate design of smart charging offers included being able to easily set up and use the options, having control over EV charging, and being financially incentivised to use the options. Due to poor Internet or mobile signal, participants living in rural areas placed importance on being able to use smart charging options without a smartphone or Internet access. Participants who had mobility difficulties or young children expressed a need for greater flexibility and override options to charge EVs at short notice for unexpected journeys, as their daily routines tended to be unpredictable. Suggestions around the provision of guarantees included guarantees about the cost of electricity bills and the effects of using a service or scheme on the health of EV batteries.

In relation to information needs, many participants said that they would like to receive notifications about costs of electricity and EV charging, compensation for services (e.g. for allowing the grid access to energy stored in their EV battery), and their vehicle's current SOC. Participants also valued information that is clear in terms of how an option would operate and the finer details of the contract and associated fees. Additionally, participants required evidence to substantiate any claims made about an option (e.g. environmental benefits). The vast majority of participants said that they would use the supplier's website, a search engine, or the app associated with the smart charging offer for further sources of information about it.

The general acceptance of smart EV charging illustrated by this research is a promising finding, given smart charging options will help energy networks to balance demand on the energy system and avoid undertaking costly network reinforcements which would ultimately be funded by all electricity bill payers. Smart charging will also deliver additional benefits to EV drivers by saving them money on their electricity bills and saving time required to manage charging. Because participants' attitudes towards individual smart charging options were mixed, providers of such options may need to consider tailoring their marketing to different groups of customers, and offering more than one product.

As with all qualitative research, it should be noted that the current sample does not represent the wider general population, so caution is required in extrapolation of the findings to all vehicle drivers. Rather, this research provides a detailed insight into the views and attitudes of the current sample, which can be used to guide future research and policy making in relation to smart EV charging solutions.

Future research to identify the impact of smart charging on the UK's energy system should continue to explore energy consumers' attitudes towards and use of various smart charging options, with particular focus on consumers without off-street parking. This research could include further qualitative studies, quantitative surveys or stated preference techniques to explore consumer choice in greater depth; specifically how consumers trade-off between various attributes of smart charging options when choosing their preferred option. Robust real-world evaluations should also be conducted (preferably using Randomised Controlled Trial designs) to collect quantitative data on consumer engagement with smart charging options. This would provide a more detailed understanding of the potential (positive and negative) impacts of smart charging options on the energy system, and the steps which can be taken to maximise their effectiveness for balancing EV charging demand.

6 Case studies

This section provides case studies, detailing several participants' circumstances and their views in relation to smart charging options.

Case study 1: BEV driver

Participant B41 is aged 56-65 and lives in an urban area in Wales. There are two adults in the household, and B41 classed themselves as 'non-working (retired, in education etc.)'. The current household vehicles are a BEV and a diesel car; both are privately owned and used purely for personal/leisure purposes. The household produces its own energy via solar PV, and uses a 'feed in' tariff to sell energy back to their supplier.

In terms of responsibility, B41 felt that National Grid should be responsible for managing any future peak demand issues. Education and technology to manage charging via time-of-use tariffs were seen as the best way to manage increases in demand.

B41 felt that the household already uses smart charging. B41 sets a timer (built-in to his EV) to charge the vehicle overnight: *"Well, I only charge at night anyway for the benefit of the grid, that's one thing I do for the environment, even though I'm not on a variable rate I still set my car to charge overnight*."

The favoured smart charging option was "*smart charging [technologies] – I would snap up in an instant. Vehicle-to-grid, I might depending on implementation details, the rest [of the options discussed] leave me completely cold."*

B41 stated that they would avoid a dynamic time-of-use tariff, having already looked into this and concluded that it is *"not worthwhile, too much of a gamble".* They would not be keen on V2G services (preferring vehicle-to-home *"so that I have complete control"*). In order to consider V2G services, B41 stated that they would need to be compensated at least 15p/kWh because *"there are some [V2G] schemes around at the moment for it and they pay…it's a piddling amount, basically, for the electricity that they've taken off you, so it's not really worthwhile."*

The most important guarantees for B41 were a kWh cost certainty, saving money by charging flexibly, and having full control over charging time.

Case study 2: ICE vehicle driver

Participant I34 is aged 26-35 and lives in an urban area in Scotland. They live alone, and classed themselves as 'supervisory or clerical and junior managerial, administrative or professional'. They have one privately owned petrol vehicle which is used for commuting and personal/leisure purposes. The household is on a standard variable tariff.

I34 felt that EV drivers should be responsible for helping to manage future peak demand issues *"to some extent – charge only if required and not for the sake of it. Be responsible!"* They also felt that the government should take responsibility *"since they are pushing for BEVs".* They felt that additional renewable energy sources should be made available to help manage increases in demand.

I34 felt that smart charging would fit in with their household, and their favoured smart charging option was the static time-of-use tariff because *"it's clear cut, you know the times and prices".* However, they were concerned that individuals working night shifts (as I34 sometimes does) *"are not going to benefit"*. In order to address this, I34 suggested a tailored cheaper period of four or five hours for each household. They would also consider dynamic time-of-use tariffs and V2G services, although they initially felt that V2G services *"sound too good to be true! Would compensation be worthy cost of charging vehicle twice?"* and later expressed concerns

that V2G services are money-making mechanisms: *"If they're charging you 28p a kilowatt they'll make money out of that 28p so why should they not give you that 28p back …it's extortion…to make their bonuses, to line their pockets."*

They would avoid third-party charge management schemes due to concerns around cost and battery charge in emergency situations, although they did like the feature of setting a minimum charge *"so you could say I don't care how you charge it, when you charge it but make sure I have the minimum percent".* They were also against mandatory managed charging (again due to concerns around emergency situations).

The most important guarantees for I34 were the overall cost of charging, receiving money for returning energy to the grid from the vehicle's battery, and having a guarantee that the vehicle will be fully charged by a specified time.

Case study 3: STB EV driver

Participant S09 is aged 36-45 and lives in a rural area in Wales. They live in a household with one other adult and two children aged 5-18. They classed themselves as 'intermediate managerial, administrative or professional'. There are two privately owned vehicles in the household (one petrol and one diesel) which are both used for commuting and personal/leisure purposes, and S09 said they were 'quite likely' to buy a BEV in the next 3 months. The household is currently on a standard variable tariff.

S09 felt that EV drivers should be responsible for managing future peak demand issues *"to the extent they respond to recommendations from the government and they plug in at lower energy time".* They felt that other parties with responsibility were the Welsh government *("provide advice and guidance on when people should charge"),* energy suppliers (*"setting different tariffs for different times of the day to change use")* and also employers (*"free/low cost charging available during the day").*

They felt that smart charging would fit with their household, particularly the time-of-use tariffs. They were keen on using smart charging technologies as enablers alongside these, as *"you're in charge and take responsibility for the electricity you're using".*

They would avoid third-party charge management schemes, expressing that they were *"concerned that you don't have control over [your] own usage and the company can charge the price when they want".*

The overall cost of charging, saving money by charging flexibly, free charge point installation and a guarantee that electricity comes from renewable sources were all very important to S09.

Case study 4: ICE vehicle driver and parent of young child

Participant C04 is aged 26-35 and lives in an urban area in England. They live in a household with one other adult and one child aged under 5. They are currently on leave to look after their small child, but otherwise classed themselves as "higher managerial, administrative or professional". There is one privately owned diesel vehicle in the household which is used for commuting and personal/leisure purposes. The household is currently on an Economy 7 tariff.

As a parent, C04 felt that convenience is *"really important - cars are there to be used so they would need to be fully charged ready for whenever you would require. My priority would likely be having a fully charged car over cheaper usage."* They were not keen on any smart charging options which required any time commitment, commenting in relation to the dynamic time-of-use tariff, *"Where is your time best spent? Monitoring cheapest tariffs and constantly changing behaviour accordingly or on other more pressing demands of family life? Would the time invested in monitoring rates produce that much money saved?"*

There were also concerns around the availability of the car for emergency situations, with C04 stating that they would like a *"minimum reserve in the battery. If you could have a battery that, you set that level of reserve according to your needs, so you could say, I want to maintain at least a quarter charge because that will be sufficient for my emergency needs"*. When considering V2G services, they remarked that *"I would have concerns around the car being unusable if the grid was using all the power. I would want some sort of hybrid (fuel backup) or minimum mileage to cater for emergencies. In theory, this would be fine as long as the car had a usable mileage left in it for emergencies."*

C04 felt that smart charging would fit with their household *"as long as it was low maintenance and easy to manage".* Their preferred option was the static time-of-use tariff because *"the times don't change so you don't need to track it, it would be an initial piece of work to set up and then fairly self-sustainable".* They would use smart charging technologies alongside this as they are *"convenient and flexible"* and *"you don't have to plug in the vehicle at particular times, the smart technology would recognise when the cheapest time to charge would be."*

They would avoid the dynamic time-of-use tariff, which they considered to be *"too much faff to manage".*

Having full control over the time at which charging happens and at which a full charge is reached, having a guaranteed minimum state of charge, and the ability for charging to be automated were the most important guarantees for C04.

Case study 5: Individual with mobility difficulties and parent of young children

Participant M02 is aged 36-45 and lives in a rural area in England, in a household with one other adult, and four children (two aged under 5). They classed themselves as 'non-working (retired, in education etc.)'. M02 suffers from chronic pain syndrome, but is able to drive.

M02 did not feel that smart charging would fit in with their lifestyle, as they use the car for many short trips, and have a different routine each day; *"for a larger family I don't think [smart charging] is particularly good because of the fact that I have to have routine…for smaller families it could work."* Emergency journeys were a key concern for M02; *"whether or not you have the distance to the nearest hospital on the charge in your car always there. That would be an aspect."* They were also concerned about the exclusion of households on prepayment meters from using some of the smart charging options *"with regards to not working with the prepaid meters, the fact that the people who are mainly on a prepaid meter may not be, and I'm stereotyping my own situation here, but they would be maybe not working and therefore, they would be at home to be able to take advantage of it."*

M02 felt that technologies which remove the need to think about charging routines may be beneficial, such as using the static time-of-use tariff alongside smart technologies: *"I believe that would work, where you would just plug it in and smart it up and forget about it. I think that's what a lot of technology is doing now, is helping you forget about to-do things."* They would consider using V2G services as long as there was a guaranteed minimum charge: *"If the car is sat there doing nothing, and you don't plan on going out, and you do have means to get to somewhere in an emergency, yes, sell it back and make a bit of money off it."*

The dynamic time-of-use tariff was not attractive from the perspective of an individual with a disability. *"Okay, my electricity's going to be 40p a thingy here and 10p here…it's just something to worry about when you have enough, lots to deal with anyway, with a disability. It's like, you don't want it; you just want to pay your bill and get on with it…you want to know what you're paying. I mean, I'm solely on benefits, so I need to know the money going out, money coming in."* M02 questioned whether individuals in a *"household where you are*

registered disabled [i.e. those on the Priority Services Register] may not be entwined with the rest [of domestic energy users]" in the application of mandatory managed charging.

Overall, M02 felt that smart charging may result in third parties having too much control: *"you don't want your life to be controlled about what the electricity company are going to do".*

Overall cost of charging, annual energy bill certainty, free charge point installation, and control over the time at which the EV is charged were all very important to M02.

Case study 6: Representative of a small business that uses an ICE vehicle

Participant Business12 represented a small business based in North Wales which uses two ICE vehicles. The vehicle is typically used for travelling around Wales for business assignments (these journeys tend to vary from 10 to 180 miles each way) as well as the daily commute (approx. 10 miles each way).

The participant said that it was 'very unlikely' that their organisation would adopt plug-in vehicles in the next five years. The main reason for this was a lack of charging points in Wales, *"[We're in] North wales, a small town, rural, squashed between the mountain and the seas…lovely but we haven't got charging points*". In order for an EV to be an acceptable option, a significant increase in range would be needed; the participant was under the impression that the range of EVs would not be sufficient: *"[We've got] no options - you'd be looking at having a 200 mile range to accommodate the kinds of journeys needed…not practical use for work. Not practical for commutes."*

The participant reported that the organisation is conscious of environmental issues and seeks ways of reducing its environmental impact. The organisation has a fixed price energy tariff for its energy supply and the participant felt that this is acceptable for their operational requirements, suggesting that their current energy arrangements are satisfactory and none of the smart charging options presented would be attractive to them, even if they had EVs in their fleet.

Case study 7: Representative of a small business that uses an EV

Participant Business10 represented a small business based in Scotland. They have one EV in their fleet and are hoping to add ten more EVs to the fleet in order to build a local community car club. The participant sees the organisation as *"embracing electric vehicles"*.

A number of factors influenced the decision to invest in EVs, with the main factors being the environmental impact and making organisational changes towards a more sustainable business. The organisation is keen to *"walk the walk a bit more in terms of being green."* The participant described saving money as a being a *"mild economic reason"* for investment in EVs.

The organisation's EV could undertake all of the necessary journeys required to achieve the operational requirements; there had never been any problems or challenges with the vehicle's range.

In terms of reducing their energy costs, the organisation had invested in efficiencies including procurement of a wind turbine. The revenue generated from the excess energy is split with 50% profit going to the organisation and 50% being shared amongst the local community.

In addition to these savings, the organisation is investigating options for solar and battery systems.

The participant was familiar with the different energy supply options having completed an online qualification in EVs. The participant felt that V2G services were the most attractive option for the organisation, saying that it "*Seems a no brainer!*" in terms of balancing the grid at times of peak demand. The participant liked the idea

of third-party charge management schemes, as they felt that this type of scheme would remove some of the additional admin associated with managing energy demand. In terms of static time-of-use, the participant had some concerns about this and would need more information about the precise costs and time bands, suggesting that *"if there's a particular phase i.e. 3-5 there's a peak with staff at their desks and if the tariff for that time is highest, that could hurt the business."*

Cost of energy was important to the organisation; the interviewee said that they would *"go for the cheapest [option]"* and that in *"an ideal world, we'd pick one with sustainable power"*.

Appendix A Summary of household workshop participant demographics

	BEV/PHEV drivers			ICE vehicle/STB EV drivers[11]			All participants
	BEV drivers	PHEV drivers	All BEV/ PHEV drivers	ICE vehicle drivers	STB EV drivers	All ICE vehicle/STB EV drivers	
Total	33	5	**38**	29	8	**37**	**75**
England	21	3	**24**	13	5	**18**	**42**
Scotland	8	1	**9**	10	-	**10**	**19**
Wales	4	1	**5**	6	3	**9**	**14**
Urban	17	2	**19**	19	3	**22**	**41**
Rural	16	3	**19**	10	5	**15**	**34**
Children aged <5?	5	-	**5**	9	1	**10**	**15**
Mobility difficulties?	1	-	**1**	3	1	**4**	**5**
Under 36	4	-	**4**	8	-	**8**	**12**
36-45	4	1	**5**	5	1	**6**	**11**
46-55	13	-	**13**	8	3	**11**	**24**
56-65	11	2	**13**	4	2	**6**	**19**
66-75	1	2	**3**	3	2	**5**	**8**
Over 75	-	-	**-**	1	-	**1**	**1**
Male	30	4	**34**	17	2	**19**	**53**
Female	3	1	**4**	12	6	**18**	**22**

[11] Including mini workshop participants

Appendix B Breakdown of household workshop participant demographics

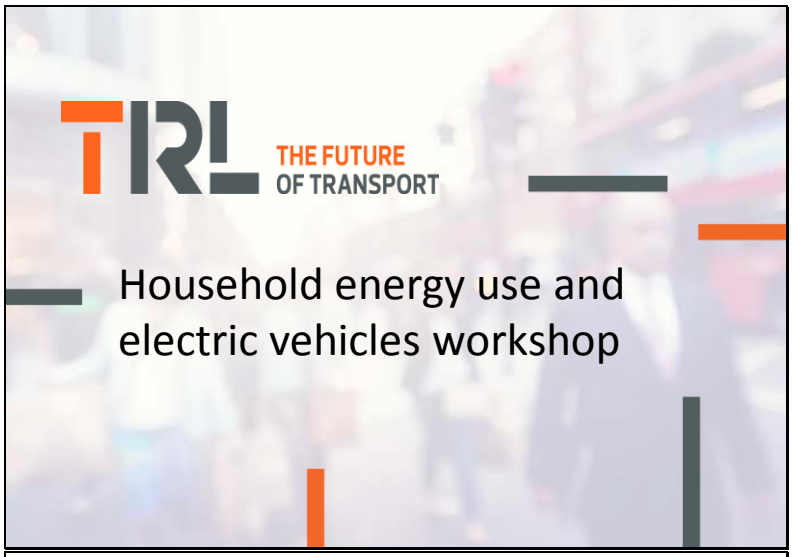
ID no.	Vehicle type driven	Country	Urban/ rural	Children aged <5?	Mobility difficulties?	Age	Sex	No. of cars in household
B01	BEV	Scotland	Rural			26-35	M	≥3
B03	BEV	Scotland	Rural			56-65	M	2
B05	BEV	Scotland	Rural			56-65	M	2
B06	BEV	Scotland	Urban			46-55	M	2
B07	BEV	Scotland	Urban	✓		36-45	M	1
B08	BEV	Scotland	Urban			46-55	M	2
B10	BEV	Scotland	Urban	✓		36-45	M	2
B11	BEV	Scotland	Rural		✓	46-55	M	2
B12	BEV	England	Rural			56-65	M	1
B13	BEV	England	Rural			36-45	M	2
B14	BEV	England	Rural			36-45	M	2
B15	BEV	England	Urban			46-55	M	2
B16	BEV	England	Urban			56-65	M	≥3
B18	BEV	England	Urban			56-65	M	2
B20	BEV	England	Urban			46-55	M	1
B21	BEV	England	Urban			56-65	M	≥3
B22	BEV	England	Rural	✓		46-55	F	2
B23	BEV	England	Urban			46-55	M	2
B24	BEV	England	Urban	✓		26-35	M	2
B26	BEV	England	Urban			56-65	M	1
B27	BEV	England	Rural	✓		26-35	M	2
B29	BEV	England	Rural			46-55	F	1
B30	BEV	England	Rural			46-55	M	2
B31	BEV	England	Urban			56-65	M	≥3
B32	BEV	England	Rural			26-35	F	2
B35	BEV	England	Urban			46-55	M	1
B38	BEV	England	Urban			46-55	M	2
B39	BEV	Wales	Rural			66-75	M	≥3
B40	BEV	England	Urban			46-55	M	≥3
B41	BEV	Wales	Urban			56-65	M	2
B42	BEV	England	Rural			56-65	M	1
B43	BEV	Wales	Rural			46-55	M	2
B44	BEV	Wales	Rural			56-65	M	2
P01	PHEV	Scotland	Urban			66-75	M	2
P02	PHEV	England	Rural			56-65	F	1
P04	PHEV	England	Rural			56-65	M	2
P05	PHEV	England	Urban			36-45	M	2
P06	PHEV	Wales	Rural			66-75	M	2
I01	ICE vehicle	England	Rural			46-55	M	≥3
I02	ICE vehicle	England	Rural	✓		56-65	F	1
I03	ICE vehicle	England	Urban			36-45	F	2
I05	ICE vehicle	England	Urban	✓		26-35	M	2
I06	ICE vehicle	England	Urban			56-65	M	2
I07	ICE vehicle	England	Urban			26-35	F	1
I09	ICE vehicle	Scotland	Rural			46-55	M	2

ID no.	Vehicle type driven	Country	Urban/ rural	Children aged <5?	Mobility difficulties?	Age	Sex	No. of cars in household
I12	ICE vehicle	Scotland	Urban			56-65	M	1
I14	ICE vehicle	Wales	Urban			66-75	M	1
I17	ICE vehicle	Wales	Rural			46-55	F	2
I18	ICE vehicle	Wales	Urban	✓		36-45	M	2
I21	ICE vehicle	Wales	Rural			56-65	F	≥3
I23	ICE vehicle	Wales	Urban			46-55	F	1
I25	ICE vehicle	Wales	Urban			66-75	M	2
I28	ICE vehicle	Scotland	Urban			66-75	F	1
I29	ICE vehicle	Scotland	Rural			46-55	M	≥3
I31	ICE vehicle	Scotland	Rural			46-55	M	2
I33	ICE vehicle	Scotland	Urban			36-45	F	1
I34	ICE vehicle	Scotland	Urban			26-35	M	1
I35	ICE vehicle	Scotland	Urban			76-85	F	1
I36	ICE vehicle	Scotland	Urban			46-55	F	1
I38	ICE vehicle	Scotland	Rural	✓		26-35	M	1
S01	ICE vehicle ('soon-to-be' EV)	England	Rural			56-65	F	2
S04	ICE vehicle ('soon-to-be' EV)	England	Rural			56-65	M	2
S05	ICE vehicle ('soon-to-be' EV)	England	Urban			46-55	F	2
S06	ICE vehicle ('soon-to-be' EV)	England	Urban			66-75	F	2
S07	ICE vehicle ('soon-to-be' EV)	England	Urban			46-55	F	1
S08	ICE vehicle ('soon-to-be' EV)	Wales	Rural			66-75	F	2
S09	ICE vehicle ('soon-to-be' EV)	Wales	Rural			36-45	F	2
S10	ICE vehicle ('soon-to-be' EV)	Wales	Rural		✓ (partner)	46-55	M	1
M01	ICE vehicle	England	Urban		✓	26-35	M	1
M02	ICE vehicle	England	Rural	✓	✓	36-45	M	1
M03	ICE vehicle	England	Urban		✓	46-55	M	1
C02	ICE vehicle	England	Rural	✓		26-35	F	≥3
C04	ICE vehicle	England	Urban	✓		26-35	F	1
C05	ICE vehicle	England	Urban	✓		36-45	M	1
C06	ICE vehicle	England	Urban	✓		26-35	M	2

Appendix C Business interviewee information

ID no.	Country	Size	No. of vehicles	Includes EV(s)?	Vehicle(s) used solely for business?	Telephone or face-to-face interview?
Business01	England	Sole	1	✓		Telephone
Business02	England	Sole	1			Telephone
Business03	England	Sole	3+	✓		Face-to-face
Business04	England	Micro	2	✓	✓	Telephone
Business05	England	Micro	2	✓		Face-to-face
Business06	England	Small	1		✓	Telephone
Business07	Scotland	Micro	3+		✓	Face-to-face
Business08	Scotland	Micro	2		✓	Telephone
Business09	Scotland	Small	3+	✓	✓	Face-to-face
Business10	Scotland	Small	3+	✓	✓	Telephone
Business11	Wales	Sole	1			Telephone
Business12	Wales	Small	2			Telephone
Business13	Wales	Micro	1	✓		Telephone
Business14	England	Sole	1			Telephone
Business15	England	Small	3+		✓	Telephone
Business16	England	Micro	2		✓	Telephone
Business17	England	Small	3+		✓	Telephone
Business18	England	Micro	3+	✓	✓	Telephone

Appendix D Presentation slides used for full-length workshops



TRL

Welcome!

Q1-5

- Help yourself to tea and coffee
- We will start the workshop at [time]
- Please complete questions 1 to 5 in your workbook before we start

the future of transport.

TRL

Introduction

- Housekeeping
  - Toilets, fire drill, fire escapes
- Purpose of workshop
- The workshop will last around 4 hours
  - There will be 2 breaks

the future of transport.

Workshop ground rules

- We encourage everyone to participate
- Please ask questions
- Use your workbook for notes
- Phones on silent please
- Voice recording – please speak one at a time
  - Introductions

Using household appliances: Energy costs

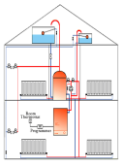
- Rank appliances by annual energy cost (Lowest→ Lowest)


Fridge freezer


40" LCD TV


Fully electric car (30 kWh; range of 115 miles; annual mileage of 8,000 miles)


Electric oven

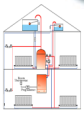

Gas central heating


£29


£30


£61


£280


£550

Managing household electricity use

- **Monitoring**
  - Smart meters
  - Apps
  - Smart plugs
  - Home monitoring systems
- **Reducing**
  - Energy-efficient appliances
  - Unplug/ switch off appliances when not in use
  - Improve insulation
- **Choosing a suitable tariff**
  - Variable rate
  - Fixed price
  - Dual fuel
  - Prepayment
  - Economy 7/ Economy 10
  - Capped energy
  - Green tariffs

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	Plug-in Hybrid Electric Vehicle (PHEV)	Battery Electric Vehicle (BEV)
Engine/ motor	Petrol/diesel engine and electric motor	Electric motor only
Fuels	Petrol/diesel and electricity	Electricity only
Charging method	Connects to an electricity supply (can also charge whilst driving)	Connects to an electricity supply
Typical electric range	10-40 miles	80-350 miles

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Electric vehicles can be charged…

At home

- Standard 13amp power supply
  - Around 18 hours for a full charge
- Dedicated EV charger
  - Around 10 hours for a full charge
  - Costs around £1,000 (but grants/deals available)

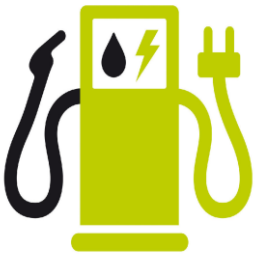
In public

- Standard EV charger
  - Around 10 hours for a full charge
- Rapid charger
  - Less than 1 hour for a full charge
- There is usually a fee

the future of transport.

Why do you drive an electric vehicle?

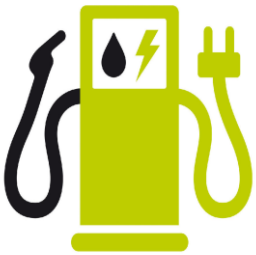
EV workshops only



the future of transport.

Would you consider an electric vehicle?

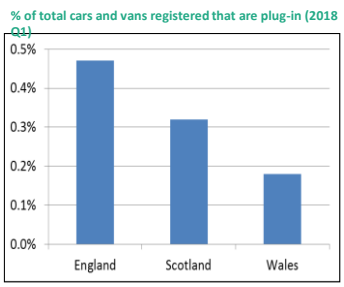
ICEV/STB workshops only

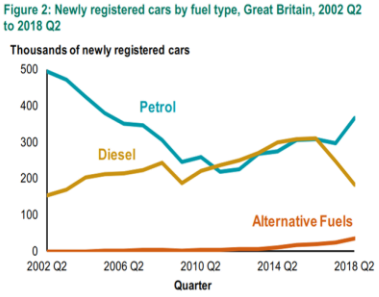


the future of transport.

UK plug-in electric vehicle uptake

- 0.5% of all registered cars/vans
- 2% of all new cars/vans sold





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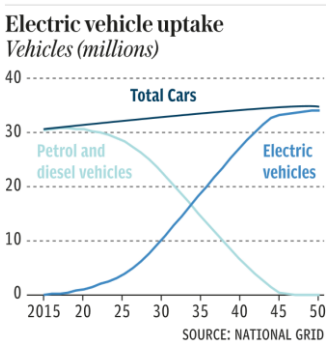
Future vehicle uptake

- Government plans to end sales of conventional petrol and diesel cars by **2040 (2032 for Scotland)**
- National Grid estimates for Britain:
  - **2030**: 11 million electric vehicles on the roads
  - **2040**: 36 million electric vehicles on the roads



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Your daily routine

EV workshops only

- Think about a typical day…
- Please place the symbols on the timeline to indicate the times at which you typically:


Leave home


Start charging your electric vehicle


Arrive home

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Your daily routine

ICEV/STB workshops only

- Think about a typical day…
- Please place the symbols on the timeline to indicate the times at which you typically:


Leave home


Arrive home

- Now imagine you have an electric vehicle as your main car… When do you think you would you charge it?


Start charging your electric vehicle

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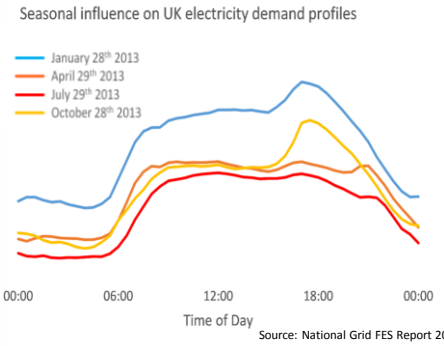
Supplying electricity

- Network operators transmit, distribute, and connect electricity to and from homes and other buildings
- National Grid is responsible for 'balancing the grid' – ensuring that electricity supply and demand is balanced at all times, on a second-by-second basis



Source: National Grid FES Report 2018

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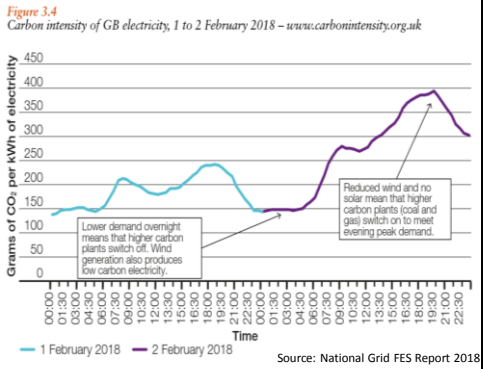
Peak demand: Balancing the grid

- Balancing the grid is more challenging during times of 'peak demand'
- Peak demand typically occurs around 17:30 on a winter weekday evening



Source: National Grid FES Report 2018

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Electric vehicles: Balancing the grid

- Much of the 'fuel' for electric vehicles will come from the grid
- National Grid predicts that electric vehicles will increase the peak electricity demand by **10-20%** by 2050

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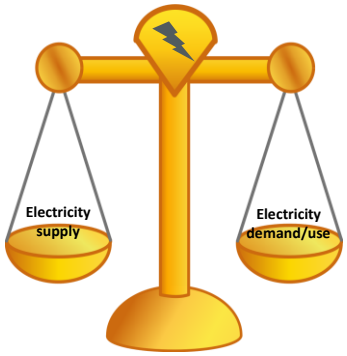
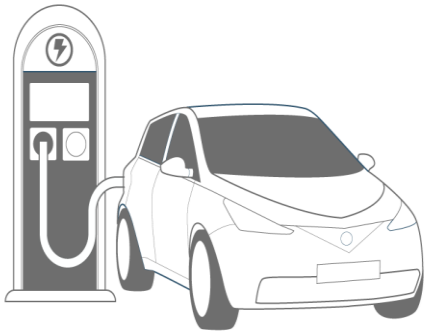
Electric vehicles: Who should be responsible for balancing the grid?



Q6

Break

- Even ID numbers - please come and have a look at the electric vehicle and charge point outside



Recap

- Household energy use
- Impact of electric vehicles on electricity use
- Peak demand and balancing the grid

- Ways to manage electricity use in relation to charging electric vehicles

Ways to manage electricity use

- We will present six methods for managing electricity use
- Use question 7 of your workbook to record your initial thoughts and concerns after each option is presented
- Workstations
- We will then discuss your thoughts and comments

Q7

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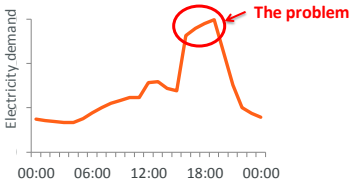

Behaviour change solutions → **Incentivise consumers to modify their behaviour**

- Cheaper charging at particular times of day
- Selling energy back to the grid
- Third-party managing their charging

Hardware intervention solution → **Curtail electricity supply to reduce peak demand**

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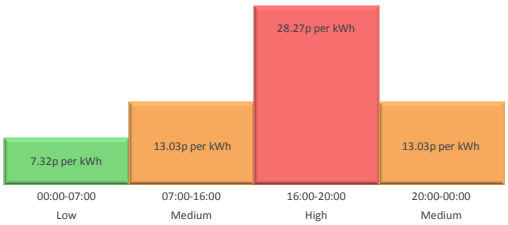
Static time-of-use tariffs

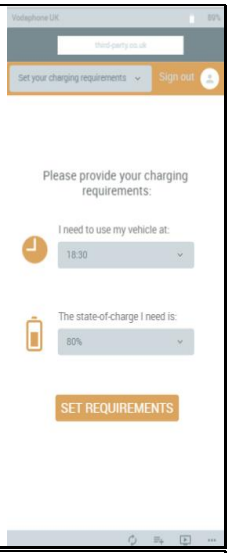
- Different **price bands** for electricity throughout the day
  - Dependent on the time of day, day of the week, or season
  - Higher rates are applied when demand for electricity is greater (i.e. when less electricity is available)
- In some cases, installation of a smart electricity meter is required
- Aim: To encourage you to use electricity at times when more electricity is available cheaply

For example…



Third-party charge management schemes

- Allows a third party to directly control charging of your electric vehicle (e.g. when and how quickly charging happens)
- Generally requires a smart-enabled charge point
- Aim: To give a third party responsibility for meeting your charging requirements whilst avoiding delivering charge when demand for electricity is high



For example…

You might use a smartphone app to specify:

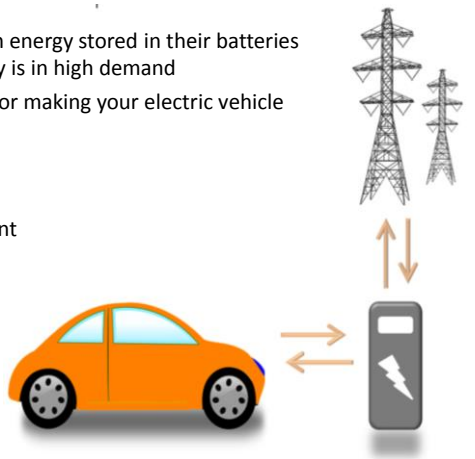
- The time at which you next need to use your vehicle
- The amount of charge you require by that time

The third party would then control charging of your electric vehicle, endeavouring to:

- Meet your requirements
- Avoid delivering charge when demand for electricity is high

Vehicle-to-Grid (V2G) services

- Electric vehicles can return energy stored in their batteries to the grid when electricity is in high demand
- You can be compensated for making your electric vehicle battery power available
- Requires:
  - A V2G-enabled vehicle
  - A 'two-way' charge point
- Aim: To encourage you to provide energy to the grid so that overall demand for electricity can be met



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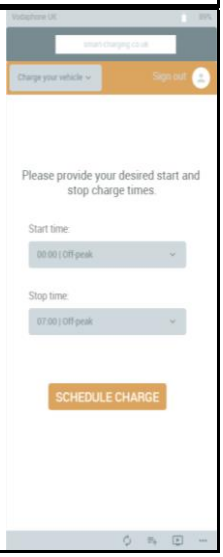
Smart charging technologies

- Includes technologies such as smart-enabled charge points or charging functions built into electric vehicles
- Could be used with time-of-use tariffs
- Needed for other charging management schemes
- Aim: To enable remote control and scheduling of charging



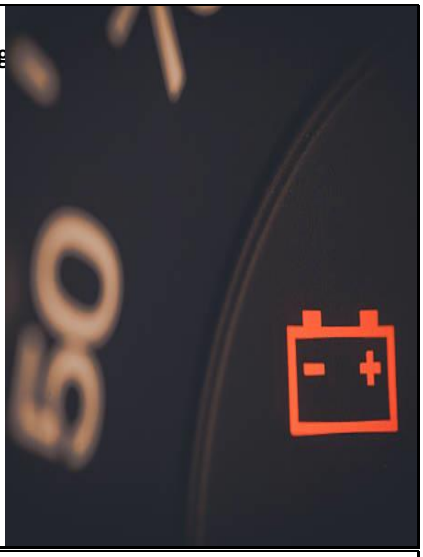
For example…

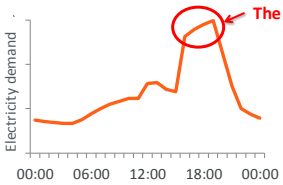
You could use the smart charging functions in your vehicle to schedule a start and stop time for charging to fit with the low tariff price bands in a static time-of-use tariff.

This means you would not have to plug in the vehicle at a specific time.

Mandatory managed charging

- Third parties may need to intervene if other methods of managing electricity use fail to reduce peaks in energy demands
  - They may slow down or pause charging of electric vehicles
- Would be used as a last resort, and only in extreme situations
- No option to override
- Aim: To avoid localised blackouts or brownouts





Behaviour change solutions → **Incentivise consumers to modify their behaviour**

Cheaper charging at particular times of day

Selling energy back to the grid

Third-party managing their charging

Static time-of-use

Dynamic time-of-use

V2G

Third-party charge management

Smart charging technologies as enablers

Hardware intervention solution → **Curtail electricity supply to reduce peak demand**

Mandatory managed charging

Workstations

Q8

Posters

- Examples of how methods could be applied in real-life settings
- Please read carefully
- **Answer question 8a of your workbook**

Smartphone app

- Please have a look at the example app
- **Answer question 8b of your workbook**

Calculator tools

- Please have a go at using the tools
- **Answer question 8c of your workbook**

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Group discussion: Methods of managing electricity use

Static time-of-use tariffs
- Set price bands
- Cheaper when electricity is less in-demand

Vehicle-to-grid (V2G) services
- Vehicles return energy to grid
- Compensation for consumers

Q9

Dynamic time-of-use tariffs
- Varying prices throughout the day
- Cheaper when electricity is less in-demand

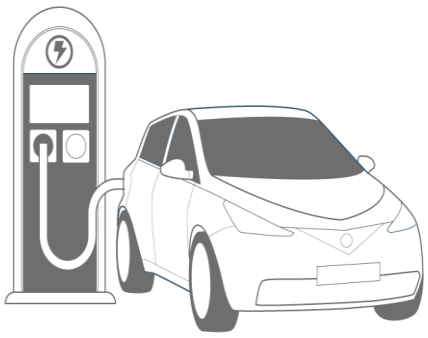
Smart charging enabling technologies
- Remote control / scheduling
- Smart-enabled charge point / vehicle

Third-party charge management schemes
- A third party directly controls charging (e.g. when / how quickly)

Mandatory managed charging
- Third parties curtail charging
- No option to override

Break

- Odd ID numbers - please come and have a look at the electric vehicle and charge point outside



Ways to manage your electricity use; features

- Please complete question 10 of your workbook

Q10

Group activity; posters

- Read the poster and imagine you are considering the option for your household:
  - Annotate the posters
    - Information you like / Useful information
    - Information you dislike / Missing information

Closing exercise

- What would be your ideal way of charging an electric vehicle?
- Has today's workshop changed any of your views on…
  - Electric vehicles?
  - Managing your electricity use?

Appendix E Workbooks used for full-length workshops

ID:	Date:

1. Please think about your last week…

a. How many miles did you drive? (If you are not sure, please provide an estimate)

_____

b. How many times did you fuel / charge your vehicle?

_____

2. How important or unimportant are the following to you?

	Not at all important	Not very important	Neutral	Quite important	Very important
Saving money on energy	☐	☐	☐	☐	☐
Being environmentally friendly	☐	☐	☐	☐	☐

3. How much do you know about…

	I know nothing about this	I don't know much about this	I know a little about this	I know quite a bit about this	I know a great deal about this
How much energy your household uses?	☐	☐	☐	☐	☐
The cost of energy use?	☐	☐	☐	☐	☐
Different ways that you can manage your household energy use?	☐	☐	☐	☐	☐
How network operators and National Grid manage electricity supply and demand?	☐	☐	☐	☐	☐
How much electricity is used when charging an electric vehicle?	☐	☐	☐	☐	☐

4. What percentage of registered vehicles in the UK is currently made up of plug-in electric vehicles?

My guess: _____ %

5. By what year does the government aim to stop sales of new conventional petrol and diesel cars and vans?

My guess: _____

6. Notes on discussion in pairs: Who should be responsible for balancing the grid?

Should electric vehicle drivers be responsible? To what extent?

Should anyone else be responsible? To what extent?

Imagine you work for an electricity network and are responsible for balancing electricity supply and demand across the network. Electric vehicles increase the demand for electricity…how would you manage this increase?

7. Initial thoughts/concerns on each of these options in relation to charging an electric vehicle in your household:

Static time-of-use tariffs (set price bands for electricity throughout the day, cheaper at times of low demand)

Dynamic time-of-use tariffs (varying prices for electricity throughout the day (as often as half-hourly), cheaper at times of low demand)

Third-party charge management schemes (third party controls when and how quickly an electric vehicle charges, third party endeavours to meet drivers' charging requirements)

Vehicle-to-grid (V2G) services (electric vehicles return energy stored in their battery to the grid, drivers are compensated)

Smart charging technologies (remote control/scheduling of charging, may be used in conjunction with time-of-use tariffs or third-party charge management schemes)

Mandatory managed charging (third party intervention to reduce peak electricity demand, slowing down/pausing of electric vehicle charging)

8. Workstation tools

a) Posters

Power to the People (static time-of-use energy tariff)

What information on the poster do you like or find useful?

What information on the poster do you dislike / not find useful?

Is there any information missing that you would like to have in order to feel fully informed?

If you wanted to find extra information after seeing this poster, where would you look and who would you ask?

Ec-Static Energy (dynamic time-of-use energy tariff)

What information on the poster do you like or find useful?

What information on the poster do you dislike / not find useful?

Is there any information missing that you would like to have in order to feel fully informed?

If you wanted to find extra information after seeing this poster, where would you look and who would you ask?

Electrifide (third-party charge management scheme)

What information on the poster do you like or find useful?

What information on the poster do you dislike / not find useful?

Is there any information missing that you would like to have in order to feel fully informed?

If you wanted to find extra information after seeing this poster, where would you look and who would you ask?

Interenergise (vehicle-to-grid service)

What information on the poster do you like or find useful?

What information on the poster do you dislike / not find useful?

Is there any information missing that you would like to have in order to feel fully informed?

If you wanted to find extra information after seeing this poster, where would you look and who would you ask?

b) Smartphone app

Is this something you might use? Why/why not?

Which of the following options do you think you might use it with, if any? Why/why not?

Static time-of-use tariffs? (Power to the People app)

Dynamic time-of-use tariffs? (Ec-Static Energy app)

Third-party charge management schemes? (Electrifide app)

Vehicle-to-grid (V2G) services? (Interenergise app)

c) Time-of-use calculator tool

What are your thoughts after interacting with the tool?

Is the static time-of-use tariff something you might consider? Why? Why not?

Is the dynamic time-of-use tariff something you might consider? Why? Why not?

9. a) In general, do you see 'smart charging' as something that could fit in with your household?

b) Which of the methods of managing your electricity use would you be most likely to use in your household? Why?

c) **Which of the methods of managing your electricity use would you be most likely to avoid? What risks do these options pose?**

10. Think about charging an electric vehicle...how important are the following features to you?

	Not at all important	Not very important	Neutral	Quite important	Very important	RANKING (1-3)
Overall cost of charging	☐	☐	☐	☐	☐	
Certainty about annual energy bill	☐	☐	☐	☐	☐	
Certainty about cost of energy per kWh	☐	☐	☐	☐	☐	
Saving money by charging your vehicle flexibly	☐	☐	☐	☐	☐	
Receiving money for returning energy to the grid from the vehicle's battery	☐	☐	☐	☐	☐	
Free charge point installation when purchasing a vehicle if you enter a contract to charge your vehicle flexibly	☐	☐	☐	☐	☐	
Having full control over the time of day/night that charging happens	☐	☐	☐	☐	☐	
Having full control over the time of day/night at which a full charge is reached	☐	☐	☐	☐	☐	
Having a guarantee that your vehicle will be fully charged by a specified time of day/night	☐	☐	☐	☐	☐	
Having a guarantee that your vehicle's state-of-charge will never fall below a specified percentage	☐	☐	☐	☐	☐	
Having a guarantee that some or all of the electricity for charging your car comes from renewable sources	☐	☐	☐	☐	☐	
Ability for charging to be automated (so that you don't need to intervene)	☐	☐	☐	☐	☐	

11. Now we are nearing the end of the workshop, how much do you feel you know about…

	I know nothing about this	I don't know much about this	I know a little about this	I know quite a bit about this	I know a great deal about this
The cost of energy use?	☐	☐	☐	☐	☐
Different ways you can manage your household energy use?	☐	☐	☐	☐	☐
How network operators and National Grid manage electricity supply and demand?	☐	☐	☐	☐	☐

How much electricity is used when charging an electric vehicle?	☐	☐	☐	☐	☐

12. Final questions about you

a) Which of the following best describes your current situation?

☐ Higher managerial, administrative or professional position

☐ Intermediate managerial, administrative or professional position

☐ Supervisory or clerical and junior managerial, administrative or professional position

☐ Skilled manual or service worker

☐ Semi-skilled manual or service worker

☐ Non-working (retired, in education, etc.)

b) What is the total number of people in your household?

Adults: _____

Children (aged 5 to 18): _____

Children (under 5): _____

c) Do you have any comments or feedback on today's workshop?

What did you like?

What did you not like? What could we do better?

Appendix F Pre-interview survey for business interviews

1. **What are your key business activities?**

2. **How many staff work for your organisation?**

3. **What is your role?**

4. **Of each of the following vehicle types, how many are used for work in your organisation?**

   ☐ Cars

   How many/extra info:

   ☐ Vans (<3.5T)

   How many/extra info:

   ☐ Other (please specify)

   How many/extra info:

5. **Please detail the fuel types of your vehicles**

   ☐ Petrol cars/vans

   ☐ Diesel cars/vans

   ☐ Plug-in electric cars/vans

   ☐ Alternatively-fuelled cars/vans (please specify alternative fuel sources)

6. **Please describe how the vehicles are used (e.g. how often? How long are the journeys? When do they take place?)**

7. **What energy tariff does your company currently use?**

8. **Have you switched business tariff or provider?**

9. [If yes to Q8] How often do you switch your business energy provider (or check that you are on the best tariff for your business)?

- ☐ More than once a year
- ☐ Around once a year
- ☐ Once every two or three years
- ☐ Less than once every three years
- ☐ I have never switched or looked into switching energy provider

10. How much do you know about the following energy demand management concepts?

	Never heard of it	Heard of it but couldn't describe it	Not used it but could explain it to someone	Used it and could explain it to someone
Static time-of-use energy tariffs	☐	☐	☐	☐
Variable (or dynamic) price energy tariffs	☐	☐	☐	☐
Supplier-controlled demand management systems	☐	☐	☐	☐
Vehicle-to-grid (V2G) systems	☐	☐	☐	☐

Appendix G Business interview topic guide

Introduction (to be read by facilitator)

Thanks for agreeing to take part in this interview – we appreciate you taking the time to talk to us. Today we would like to discuss your views and perceptions about the vehicles your company uses, and the ways in which your business's energy use is managed. TRL is carrying out this research on behalf of Citizens Advice.

Our discussion will last approximately 45 minutes (1hr for face-to-face) and we will work through a list of questions – if there are any that you can't, or don't want to answer, please just say and we will move on to the next question. There are no right or wrong answers: we want to learn about your own thoughts, in your own words.

Please could you confirm that you have read all of the information that was sent to you about the different options for managing EV energy demand? We will discuss these in detail during the conversation.

[If participant has not read the materials, or has any questions, briefly talk them through the slides.]

[If consent form has not been completed via email:]

I would like to talk you through a consent form.

	Yes	No
I confirm that I have read and understood the information sheet and have had the opportunity to ask questions	☐	☐
I understand that my participation is voluntary and that I am free to withdraw at any time, without giving reason	☐	☐
I agree to the interview being audio recorded	☐	☐
I agree to the use of anonymised quotes in reports	☐	☐
I agree to take part in the study as outlined above	☐	☐

[Begin recording]

I am now recording the conversation.

SECTION 1: BACKGROUND

[For current BEV/PHEV drivers only]

1. You stated in your survey that your organisation has *N* electric vehicles.

   What proportion of your fleet does this make up?

   Why did you decide to invest in EVs?

   What did you see as the benefits? Were these benefits realised in reality?

   What types of journeys do these vehicles do? Are there any journeys that they can't do? Why?

   Please describe where these vehicle(s) are charged.

   Prompts: At home / public charge points / work charge points / a combination?

2. How often are the vehicles charged?

   Prompts: Every day? When the battery is at a certain level? What time of day are they charged, why? How do you ensure vehicles have enough charge?

3. *[If >1 EV]* Do you rotate the charging of vehicles at charge points?

[For current petrol/diesel car drivers only]

4. You stated in your survey that your organisation does not have any plug-in electric vehicles currently. How likely or unlikely is it that your organisation will adopt plug-in vehicles in the next 5 years?

   Very unlikely / quite unlikely / neither (or don't know) / quite likely / very likely

[If not likely:]

4a. What is the primary reason for not considering the use of plug-in vehicles? What other reasons would play a role?

[If likely:]

4b. What fuel types/vehicles? BEVs or PHEVs? Why? Can you describe, how/ for what kind of driving you think these vehicles would be used?

What proportion of your fleet could you see being electric? Would they replace ICE vehicles, or be in addition to them?

Imagine that you did adopt plug-in electric vehicles in your business…

4c. Please describe what your options would be for charging a BEV/PHEV? At home / public charge points / work charge points / a combination?

4d. How would you decide when to charge the vehicle(s)? E.g. would you have a fixed schedule for this, or would you only charge when the battery is low? What time of day do you think you would you charge?

4e. What factors would affect your choice of when and where to charge your vehicle(s)? Prompt for availability of charging points, cost of charging, operational requirements.

SECTION 2: UNDERSTANDING OF SMART CHARGING OPTIONS FOR CHARGING

5. According to your pre-interview questions you said that you have heard of [static time-of-use / dynamic time-of-use / third-party charge management schemes / Vehicle-to-grid services]. Where did you find this information?

6. You said that your business currently uses [type of tariff] and that you have/have not switched tariff/provider. How do you decide which energy supplier/tariff type to use?

   Prompts: How important is: cost, environmental elements, certainty of costs per month, ability to reduce energy costs by being more flexible with your energy use.

SECTION 3: INITIAL OPINIONS OF EACH SMART CHARGING OPTION

7. Energy costs are said to be one of the biggest outgoings for businesses… Are there any things that your organisation is doing to reduce your energy costs? What options are available?

Prompts: If interviewee does not know, ask why – is someone else responsible for energy bills? If so, who (what is their role in the organisation)?

Does the interviewee interact with the person who is responsible for the energy bills? If so, how? What is the nature of the interactions?

For the next exercise, we will discuss each of the options for managing EV energy demand that we shared with you in the information pack to understand your thoughts on each. We will ask the same questions for each concept.

[Refer to slides that were sent prior to the interview.]

Questions/prompts	Static time-of-use energy tariffs	Dynamic time-of-use energy tariffs	Third-party charge management schemes	Vehicle-to-grid services
What is your initial response to the concept?				
What do you like about it? Prompts: Would this be an acceptable option for your organisation? Why? Why not?				
What do you dislike about it? Prompts: E.g. timing of price bands, level of user interaction required, potential for savings, state-of-charge guarantees. Are there any 'deal breakers' – what would make this option unacceptable?				
Would it fit with the operational requirements of your business? Prompts *[for EV drivers]*: How suitable would it be for your current fleet of EVs?				
[If no EVs currently] To what extent do you think that the concept would be suitable for your fleet if you were to have BEVs and/or PHEVs in the future?				
What advantages do you think this concept would offer your organisation?				
What disadvantages do you think this concept would have?				

8. Are smart charging technologies something you would consider?

[Prompts for non-EV drivers:] Hypothetically, how would/would these not fit in with your organisation?

[If yes:] How would these best work for your organisation?

Prompts: what kind of smart charging technologies would you want/need? E.g. charge point based/vehicle-based/app-based/centralised system for business. What remote scheduling functions would you want?

[If no:] Why not? Is there anything that could be done to encourage you to consider these?

Prompts: similar to above – what features would you want to see to make smart charging technologies worthwhile for your business?

9. How would mandatory managed charging affect your business' energy needs (i.e. what would the impact on your business be if the energy suppliers had total control over the energy supply?)

Prompts: more planning/operational challenges, etc.

10. What information would you need before signing up to any of the offers we just discussed?

Prompts: What information is important to you or your organisation when choosing an energy provider or tariff? Cost (set-up and on-going), compensation, level of control, amount of involvement required [e.g. interacting with app].

[EV drivers/those considering an EV only:] Guarantees (assurance of a full charge by a specific time), overriding mechanisms.

11. How do you find out about energy tariffs? Where do you look? Which sources do you trust?
12. Thinking about everything we've discussed today, how well or badly do you think time-of-use tariffs and smart charging technologies would work for your business? What are the benefits, what are the drawbacks?
13. Is there anything else that you'd like to add?

Thank you for your participation in this interview.

Appendix H Posters used for full-length workshops

H.1 Static time-of-use energy tariff example ('Power to the People Energy')

POWER TO THE PEOPLE ENERGY

We want to put you in charge of your energy!

Introducing the Wave energy tariff

The **Wave energy tariff** encourages you to shift your electricity usage to times of day when electricity demands are lower and costs are cheaper.

The price of electricity varies throughout the day; when demand for energy is high, the cost of energy increases. With Wave, there are three tariff bands throughout the day; **off-peak**, **standard**, and **peak**. Energy is cheapest during the off-peak times of day and most expensive during the peak times of day.

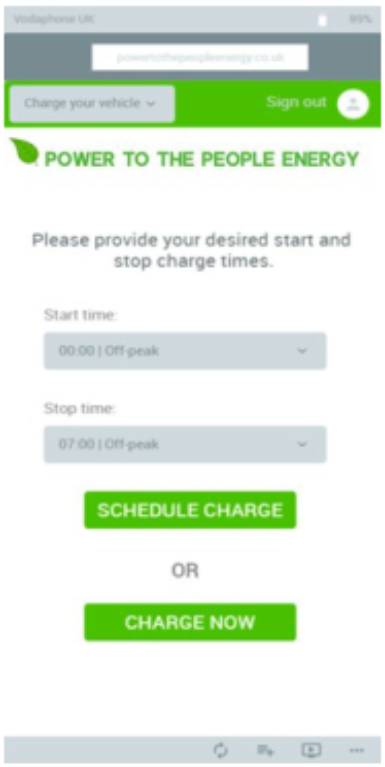
Shifting your energy use to off-peak times will save you money on your energy bill and will increase the use of wind, solar, hydro-electric and other renewable energy sources. The Wave tariff therefore brings benefits to both you and the environment!

Weekday tariff

Tariff band	Time of day	Pence per kWh*
Off-peak	00:00-07:00	7.32
Standard	07:00-16:00	13.03
Peak	16:00-20:00	28.27
Standard	20:00-00:00	13.03

Weekend tariff

Tariff band	Time of day	Pence per kWh*
Off-peak	00:00-07:00	7.32
Standard	07:00-00:00	13.03



Smart charging through the Wave app**

Wave tariff customers are given exclusive access to the Wave **smart charging app**. You can use this app to monitor and control charging of your electric vehicle, enabling you to schedule charges when energy is cheaper and save money on your bill.

If you wish, you can also specify a 'default' charging schedule in line with your day-to-day vehicle usage patterns.

For times when you just want to give your vehicle a quick boost, you can override the scheduled start and stop times by pressing the green 'CHARGE NOW' button.

*Prices are inclusive of VAT and do not include our standing charge of 25p per day (VAT inclusive). The standing charge helps cover our fixed costs, such as enabling a supply of energy to your home through distribution and metering services.

** Requires installation of a compatible smart-enabled chargepoint in your home. Contact the Wave team for advice on compatible chargepoints and home installations.

H.2 Dynamic time-of-use energy tariff example ('Ec-Static Energy')

EC-STATIC ENERGY

Save money while you save the environment!

Introducing the Nimble energy tariff

The cost of electricity varies throughout the day and decreases when demand for energy is low and more renewable energy is available (e.g. solar and wind).

Nimble encourages you to **shift your energy usage to times when renewable energy is in abundance**, rather than letting this energy go to waste.

As well as benefitting the environment, altering the times at which you use energy will **save you money on your energy bill**.

With our forward-pricing system, we are able to provide you with **accurate hourly energy prices** for the next 24-hour period*.

We will notify you of the upcoming prices at 2pm each day**.

The Nimble tariff therefore allows you to **plan your energy use to save money** and make use of renewable energy.

Additionally, Nimble can be used in conjunction with a **smart electricity meter*** to help us and you to monitor how much energy you use and when you use it, which means:

- ✓ No more guessing the cost of your energy bills
- ✓ No estimated bills, so you won't be overcharged
- ✓ No more submitting meter readings

When you sign up for Nimble, we will offer to install your smart electricity meter **free of charge**. All of our meters are industry-compliant.

There is no fixed term or exit fee with the Nimble tariff, so you are free to switch tariffs at any time.

*Each 24-hour period begins at 16:00 and ends at 15:59 the following day. Prices are inclusive of VAT and do not include our standing charge of 21p per day (VAT inclusive), which covers the cost of us providing your home with gas and electricity.

**Notifications are sent via text message or the Nimble app (accessible via a smartphone, tablet, or PC).

***The Nimble tariff cannot be used in conjunction with prepayment meters.

H.3 Vehicle-to-grid service example ('Interenergise Power')

INTERENERGISE POWER

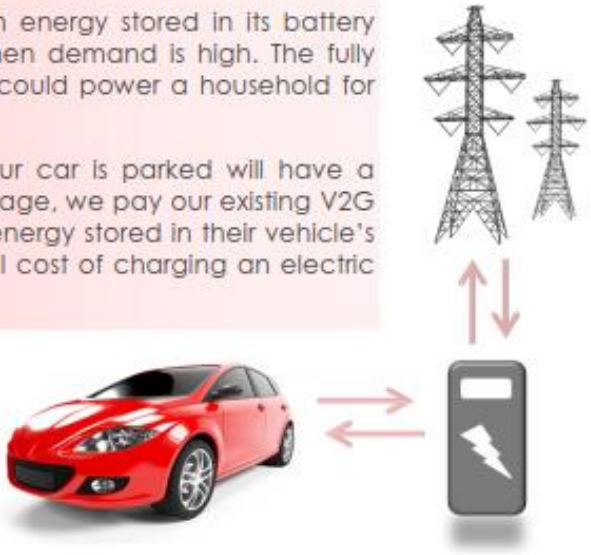
Did you know your electric vehicle can act as a portable power station?

The Interenergise Vehicle-to-Grid Service

Our new vehicle-to grid (V2G) service lets you use your electric vehicle's battery to control your energy use and make some money!

V2G technology enables your vehicle to return energy stored in its battery back to the grid to increase energy supply when demand is high. The fully charged battery of one electric vehicle alone could power a household for several days!

Selling your energy back to the grid whilst your car is parked will have a marked impact on your electricity bills*. On average, we pay our existing V2G customers **over £320** per annum to access the energy stored in their vehicle's battery, which is more than the average annual cost of charging an electric vehicle in the UK!



Am I eligible for V2G technology?

To take advantage of our V2G service, you will need to ensure that your electric vehicle is V2G-enabled.

We have teamed up with Formes, the UK's leading electric vehicle manufacturer, to offer you an exclusive discount on their range of state-of-the-art V2G-enabled vehicles**.

You will also need to have a 'two-way' electric vehicle charger at your home, which we will install for you free-of-charge**.

Can I control when my vehicle returns energy to the power grid?

Of course! With our V2G app***, you can switch 'energy sharing' on or off. Switching on energy sharing allows us to access energy stored in your vehicle's battery whenever your vehicle is connected to your charge point.

Alternatively, you can use the V2G app to indicate when you would like to make energy stored in your battery available to the grid.

We will only take energy from your battery if you have indicated that you would like us to do so.

*We will pay you 6.8p for every kWh we retrieve from your electric vehicle's battery.

**When you sign up to our Vehicle-to-Grid service on a 24-month contract.

***Our V2G app is compatible only with an Interenergise Power 'two-way' charger installed at your home. The app is accessible via a smartphone, tablet, or PC.

H.4 Third-party charge management scheme example ('Electrifide')

Electrifide

We'll take the hassle out of managing your electric vehicle charging

Due to increases in energy demand in recent years, it is important to manage energy demand to ensure that it does not exceed capacity (which could cause power outages).
At Electrifide, we want to take the hassle out of managing your electric vehicle charging, benefit the environment, and save you money along the way.

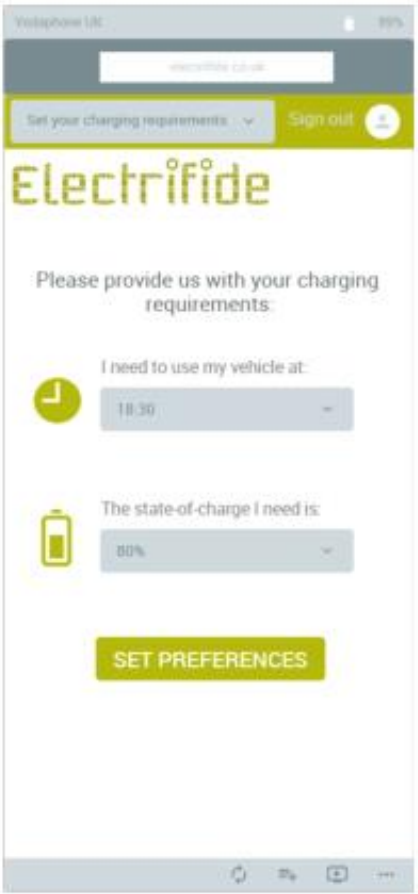
Electrifide app

The Electrifide tariff comes with our Electrifide smartphone app*.

This innovative smart charging app allows you to monitor and control charging of your electric vehicle.

You can use the app to tell us your preferences for charging; when you next need to use your vehicle and how much charge you require.

Our Electrifide smart charging system will then manage your charging on your behalf to deliver these requirements**, whilst avoiding periods of peak demand (and high energy prices) to save you money, and reduce the risk of power outages.



Benefits for you and the environment

The Electrifide smart charging system not only allows us to pass on energy cost savings to you, but increases the use of renewable energy sources, such as solar and wind.

*The Electrifide app can be used only in conjunction with compatible smart-enabled charge points. Contact the Electrifide team for advice on compatible chargepoints and home installations. The app is free to download and accessible via a smartphone, tablet, or PC.

**Our charging system will prioritise delivering your charge requirements where possible. When energy demands are particularly high, you may receive less charge than requested.

Smart electric vehicle charging: what do drivers and businesses find acceptable?

As the prevalence of electric vehicles (EVs) increases in the UK, it is important to consider how best to manage their impact on the electricity network. On behalf of Citizens Advice, TRL conducted research to gain an understanding of how acceptable drivers find the concept of being 'flexible' with their energy use, and in particular how acceptable they find various smart EV charging options: static and dynamic time-of-use energy tariffs, third-party charge management schemes, vehicle-to-grid (V2G) services, smart charging technologies, and mandatory managed charging.

In total, 75 drivers from England, Wales, and Scotland participated in a series of immersive, deliberative workshops. Participants either drove EVs or conventional internal combustion engine (ICE) vehicles. During the workshops, participants were presented with information about the smart charging options and were encouraged to interact with the options, envisaging how they might impact their households. Participants' opinions were collected via workbooks and audio recordings. In addition, semi-structured interviews were conducted with 18 representatives of small businesses that used either EVs or ICE vehicles, to discuss how the options might impact their businesses.

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