EQUAL EV PHASE 2: TECHNOLOGY VIABILITY AND FUTURE SERVICES FOR VULNERABLE CUSTOMERS

DR STEPHEN SKIPPON, EV CONSUMER SPECIALIST

EDMUND HUNT, SERVICE DESIGN LEAD CONSULTANT

WILLIAM BAKER, FAIR FUTURE LEAD CONSULTANT

TANYA BERI, UX CONSULTANT

THURSDAY 3 MARCH 2022

DOCUMENT CONTROL

ESC programme name	**SSEN Equal EV Phase 2**
ESC project number	ESC00553
Version*	1.0
Status	Approved: Contains reviewed and approved content
Restrictions*	
Release date	4/03/2022
External release ID	(if project release process requires it)

* Refer to the Information Classification Policy

Review and approval

	Name	**Position**
Author	Stephen Skippon	EV Consumer Specialist, ESC
Reviewer(s)	William Baker	Fair Future Programme Lead, ESC
	Richard Hartshorn	EV Readiness Manager, SSEN
	Georgios Simopoulos	Innovation Project Manager, SSEN
Approver	Edmund Hunt	Service Design Lead Consultant, ESC

Revision history

Date	**Version**	**Comments**
3.03.2022	1.0	Final Version

CONTENTS

1. EXECUTIVE SUMMARY 3
1.1. Energy Systems Catapult 3
1.2. PROJECT BACKGROUND 3
1.3. WORK PACKAGE 1: TECHNOLOGY LANDSCAPE 3
1.4. WORK PACKAGE 2: CUSTOMER JOURNEY ROADMAPS, PAIN POINTS, AND POSSIBLE SOLUTIONS 3
1.5. WORK PACKAGE 3: THE ROLE OF THE DNO 4
1.6. WORK PACKAGE 4: RESEARCH DESIGNS FOR SELECTED CONCEPTS 4
1.7. WORK PACKAGE 5: BUSINESS CASES FOR SELECTED CONCEPTS 4
1.8. CONCLUSIONS 4
2. ACKNOWLEDGMENTS 6
3. INTRODUCTION 7
3.1. TECHNOLOGY LANDSCAPE 8
3.2. CUSTOMER JOURNEY ROADMAPS, PAIN POINTS, AND POSSIBLE SOLUTIONS 8
3.3. THE ROLE OF THE DISTRIBUTION NETWORK OPERATOR (DNO) 9
3.4. RESEARCH DESIGNS FOR SELECTED CONCEPTS 9
3.5. BUSINESS CASES FOR SELECTED CONCEPTS 9
4. WORK PACKAGE 1: TECHNOLOGY LANDSCAPE 10
4.1. ELECTRIC VEHICLES 10
4.2. ELECTRIC VEHICLE CHARGING TECHNOLOGY 14
4.3. SMART CHARGING 20
4.4. VEHICLE TO GRID (V2G) AND VEHICLE TO HOME (V2H) 21
4.5. JOURNEY PLANNING 21
4.6. MOBILITY AS A SERVICE (MaaS): ALTERNATIVES TO HAVING A CAR 22
4.7. CONNECTED AND AUTONOMOUS VEHICLES (CAVS) 22
5. WORK PACKAGE 2: CUSTOMER JOURNEY ROADMAPS, PAIN POINTS, AND POSSIBLE SOLUTIONS 23
5.1. CUSTOMER JOURNEY MAPS 23
5.2. PAIN POINTS 33
5.3. POTENTIAL SOLUTIONS 37
6. Work PaCKAGE 3: ROLE OF THE DISTRIBUTION NETWORK OPERATOR (DNO) 47

6.1. Present DNO role in supporting vulnerable electricity users: The Priority Services Register 47
6.2. The PSR and customers with mobility impairments and/or high levels of anxiety 48
6.3. Beyond the PSR 48
6.4. Possible extensions to the DNO's role 48

7. WORK PACKAGES 4 AND 5: Development of three selected concepts 67
7.1. Selection of concepts for further development 67
7.2. Community of First Responders 67
7.3. V2H resilience service 74
7.4. Temporary EV charging service when PSR members have a power cut 78

8. Conclusions 82

1. EXECUTIVE SUMMARY

1.1. ENERGY SYSTEMS CATAPULT

Energy Systems Catapult was set up to accelerate the transformation of the UK's energy system and ensure UK businesses and consumers capture the opportunities of clean growth.

We are an independent, not-for-profit centre of excellence that bridges the gap between industry, government, academia and research.

We take a whole system view of the energy sector, helping us to identify and address innovation priorities and market barriers to decarbonise the energy system at least cost.

1.2. PROJECT BACKGROUND

Scottish and Southern Electricity Networks (SSEN) is carrying out a Network Innovation Allowance (NIA) funded project, Equal Electric Vehicles (Equal EV) in which it is exploring the enablers and barriers to people with disabilities and/or other vulnerabilities adopting and using electric vehicles (EVs). Stage 1 of the project, carried out by Impact Research, identified four key barriers for members of these groups that could limit their ability to engage with EVs: up front EV costs, charge-point access, range anxiety, access to charge-point information.

SSEN subsequently commissioned the Energy Systems Catapult to carry out Equal EV Stage 2. This study aimed to explore the viability of technologies to remove these barriers, understand the customer journeys that EV users experience, explore pain points on these journeys that are experienced by vulnerable users, generate ideas for mitigating these, understand the potential role(s) for DNOs in this mitigation and their associated costs and benefits, and select promising ideas for further development.

The project was positioned at Step 1 of the four-step Innovation Funnel: The Ideation and Conceptualisation stage. Its principal outputs included plans for developing three promising ideas to Step 2, the Feasibility Demonstration Stage.

The project consisted of five Work Packages (WPs).

1.3. WORK PACKAGE 1: TECHNOLOGY LANDSCAPE

A rapid review of emerging EV products and services, including relevant mobility solutions, Vehicle to Grid (V2H), 2G, Vehicle to Home (V2H), wireless charging, Mobility as a Service and autonomous vehicles.

1.4. WORK PACKAGE 2: CUSTOMER JOURNEY ROADMAPS, PAIN POINTS, AND POSSIBLE SOLUTIONS

Aimed at exploring the customer experience of using an EV from the perspective of two vulnerable groups:

- People with mobility impairments
- People with high levels of anxiety

The first vulnerable group were the focus of Equal EV Stage 1; the second group were included to enable the project to consider the needs of people with mental health difficulties, as the impacts of

mental health difficulties on peoples' normal functioning can be severe, yet the needs of people with these difficulties are often neglected in comparison with those of people with physical health issues.

1.5. WORK PACKAGE 3: THE ROLE OF THE DNO

Explored the potential role of a Distribution Network Operator (such as SSEN) in alleviating some of the potential pain points that the two vulnerable groups might experience in engaging with EVs.

1.6. WORK PACKAGE 4: RESEARCH DESIGNS FOR SELECTED CONCEPTS

Selected three proposed ideas for further research to test their feasibility, from among those generated in WP 2 and WP 3. Research designs were developed to address the key uncertainties and contribute to an overall assessment of feasibility for each proposal.

1.7. WORK PACKAGE 5: BUSINESS CASES FOR SELECTED CONCEPTS

An outline business case was developed for each of the three proposed ideas, to contribute to an overall assessment of feasibility for each proposal. The business cases focussed on the scale of the opportunity, i.e. how many people might be positively affected by implementation of the proposed idea, and on approximate estimates of the costs of implementation.

1.8. CONCLUSIONS

This is a summary of the main conclusions; for the full set of conclusions please see the Conclusions section of the report.

- The market for electric vehicles appears to be taking off in the U.K. Battery Electric Vehicles (BEVs) made up 11.6% of all new car sales in 2021, with sales of new Plug in Hybrid Electric Vehicle (PHEVs) making up a further 7%.
- Around 5.9% of drivers with full U.K. driving licence holders also hold "blue badge" disabled driver parking permits. The difficulties those with mobility impairments will have in using EVs have begun to be recognised but so far little has been done to address these difficulties.
- Around 6.6% of adults have high levels of anxiety in any given week. The potential difficulties that drivers with high levels of anxiety will face in engaging with electric vehicles have not yet been widely recognised.
- People with mobility impairments identified multiple pain points in acquiring and using EVs, particularly around the prospect of charging an EV, especially at public chargers.
- People with high levels of anxiety identified pain points at all stages in acquiring and using EVs.
- Workshops with members of these vulnerable groups generated 44 ideas/concepts for mitigating these pain points.
- The main role that the DNO can play in facilitating these two vulnerable groups is via their Priority Services Registers (PSRs), specifically in ensuring that their personal mobility is not compromised by inability to charge their EV during power cuts.
- Although people with mobility impairments are able to join the PSR now, there is not a PSR category for those with high levels of anxiety, nor indeed for people with other mental health issues.
- Creating new PSR categories for those with mental health difficulties should be a priority for DNOs.
- The project generated a further 71 ideas/concepts for ways that the DNO could improve the potential for members of the two vulnerable groups to engage in using EVs. Three of these were explored in more depth:

    - **Setting up a Community of First Responders.** This has the potential to help around 870 EV drivers with mobility impairments and 1835 EV drivers with high levels of anxiety in the SEPD

area by the early 2030s. Costs are estimated to be low for both variants of this concept – where first responders outside the powercut area provide PSR members with access to their home EV chargers, and where they provide other support such as making shopping trips on behalf of EV drivers on the PSR.

- **Enabling PSR households to use Vehicle to Home (V2H) to provide back-up power for their dwelling during a power cut.** This has the potential to help around 6090 EV drivers with mobility impairments and 1835 EV drivers with high levels of anxiety in the SEPD area by the early 2030s. Cost are estimated to be low in the early years, rising to medium by the early 2030s as EV uptake increases.

- **Providing a temporary EV charging service during power cuts**. This has the potential to help around 870 EV drivers with mobility impairments and 1835 EV drivers with high levels of anxiety in the SEPD area by the early 2030s. Cost are estimated to be fairly low for this concept.

- There is considerable potential to improve charge point design to make charging more accessible to users with mobility impairments, but innovations remain largely at the trial/pilot stage so far
- Inductive (wireless) charging would considerably reduce the difficulties experienced by members of both vulnerable groups when charging, both at home and at public charging locations. Unfortunately, this technology is not yet deployed on a wide scale
- There are several nascent services that offer to assist with charging
- Some forms of Mobility as a Service, especially ride hailing, could considerably reduce the difficulties experienced by members of both vulnerable groups. However, the subjective impressions of research participants were that few of their vehicles are adapted for wheelchair users at present.
- Fully autonomous cars could considerably reduce the difficulties experienced by members of both vulnerable groups in engaging with electric vehicles, but these remain a rather distant prospect.
- People with other mental health difficulties, and members of other vulnerable groups such as those with learning difficulties and acquired brain injuries may also experience substantial difficulties. Their needs have not been widely recognised and to date not researched.

2. ACKNOWLEDGMENTS

We would like to thank Hala Osman, Sarah Warbis, Alice Broomhall, and Ruth Clarke of our project partners Impact Research for running Workshop 2, participating in Workshop 1, and for providing valuable feedback during this project. We would also like to thank Catherine Marris and Le Ho-Everiste of Motability, Graham Footer of Disabled Motoring UK, Stephen O'Neill of Ofgem, Nick Reed of Reed Mobility, Caitlin Tullet of Transport Scotland, Jose Paris of Zumo, and our colleagues Thalia Skoufa, Transport Practice Manager, and Dr. Rose Chard, Fair Future Programme Lead, at Energy Systems Catapult for participating in expert interviews and/or providing relevant insights and feedback.

3. INTRODUCTION

SSEN is carrying out a Network Innovation Allowance (NIA) funded project, Equal Electric Vehicles (Equal EV) in which it is exploring the enablers and barriers to people with disabilities and/or other vulnerabilities adopting and using electric vehicles (EVs). Stage 1 of the project, carried out by Impact Research, identified four key barriers for members of these groups that could limit their ability to engage with EVs: up front EV costs, charge-point access, range anxiety, access to charge-point information.

SSEN subsequently commissioned the Energy Systems Catapult to carry out Equal EV Stage 2. This study aimed to explore the viability of technologies to remove these barriers, understand the customer journeys that EV users experience, explore pain points on these journeys that are experienced by vulnerable users, generate ideas for mitigating these, understand the potential role(s) for DNOs in this mitigation and their associated costs, benefits and select promising ideas for further development.

The project was positioned at Step 1 of the four-step Innovation Funnel[1] shown in Figure 1: The Ideation and Conceptualisation stage. Its principal outputs included plans for developing three promising ideas to Step 2, the Feasibility Demonstration Stage.

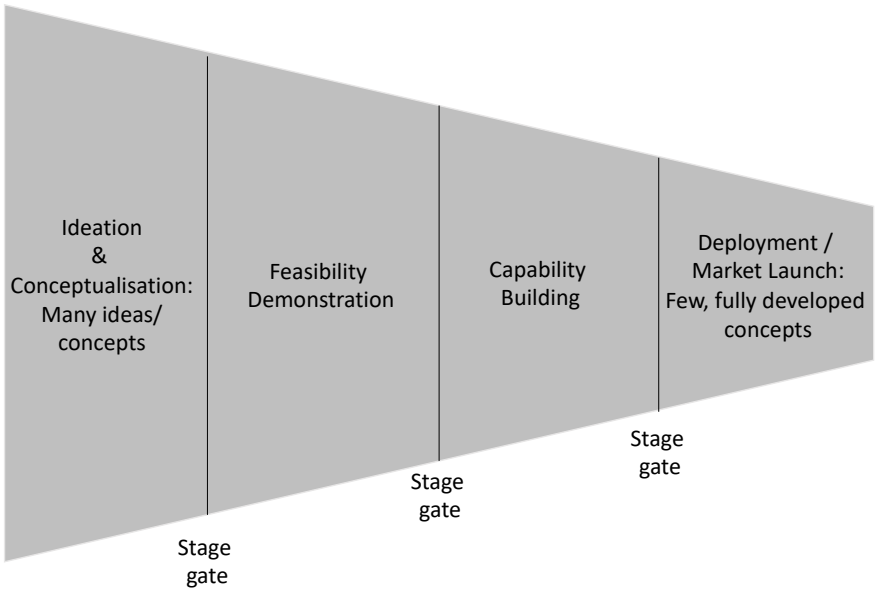


Figure 1. The four-step Innovation Funnel for progressing ideas to market deployment/launch. As ideas/concepts progress from left to right, some are removed at each stage gate while the remainder gain more commitment and budget

[1] See, for example, https://www.myriadassociates.com/news/2020/what-is-an-innovation-funnel/

The project consisted of five Work Packages (WPs):

3.1. TECHNOLOGY LANDSCAPE

This Package consisted of a rapid review of emerging EV products and services, including relevant mobility solutions, Vehicle to Grid (V2H), 2G, Vehicle to Home (V2H), wireless charging, Mobility as a Service and autonomous vehicles. It was carried out using desktop research and interviews with leading experts on EVs and associated technologies.

3.2. CUSTOMER JOURNEY ROADMAPS, PAIN POINTS, AND POSSIBLE SOLUTIONS

Work Package 2 of the Equal EV project was aimed at exploring the customer experience of using an EV from the perspective of two vulnerable groups:

- People with mobility impairments
- People with high levels of anxiety

The first vulnerable group were the focus of Equal EV Stage 1.

The second group were included to enable the project to consider the needs of people with mental health difficulties, as the impacts of mental health difficulties on peoples' normal functioning can be severe, yet the needs of people with these difficulties are often neglected in comparison with those of people with physical health issues. Depression and anxiety are among the most frequently experienced mental health difficulties. Since depression reduces motivation to be active it is likely to reduce engagement with car travel. For this reason, the project focussed on people with high levels of anxiety. According to the most recent Adult Psychiatric Morbidity Survey, carried out in England in 2014, the one-week prevalence of anxiety in the adult population of England was 6.6%.

The work package consisted of two main steps:

1. Development of a set of customer journeys, covering all aspects of user engagement with them, including both acquisition and use. This work was carried out by the ESC Consumer Insights team, based on the findings of Equal EV Stage 1 research and knowledge of the evidence base concerning user experience in the published research literature.
2. A series of three workshops:

   Workshop 1, run by ESC, involved expert participants from ESC, Impact Research (contributing their knowledge gained from Equal EV Stage 1 research), SSEN, and Motability

   Workshop 2, run by Impact Research, involved six participants with mobility impairments, recruited from among participants in the Equal EV Stage 1 research

   Workshop 3, run by ESC, involved six participants who self-reported high levels of anxiety, and scored in the medium anxiety range on the PHQ-9 questionnaire, a widely used clinical screening questionnaire for anxiety. They were recruited from ESC's *Home Truths* consumer panel.

Each of the workshops addressed three topics:

- Review and adaptation of the Customer Journeys from the perspective of the two vulnerable groups
- Identification of "pain points": difficulties that might be encountered by members of the two vulnerable groups at points along the customer journeys. The exercise to elicit these involved individual ideation and group discussion.
- Ideas generation: An exercise to elicit ideas for solutions to mitigate the pain points. This exercise also involved individual ideation and group discussion.

Findings from the three workshops were then consolidated.

3.3. THE ROLE OF THE DISTRIBUTION NETWORK OPERATOR (DNO)

This work package explored the potential role of a Distribution Network Operator (such as SSEN) in alleviating some of the potential pain points that the two vulnerable groups might experience in engaging with EVs. It was conducted through a series of interviews with SSEN staff, and a workshop involving ESC staff and SSEN staff from the customer experience team, strategy and PSR operations. Participants were briefed on the customer journeys and pain points discussed in the preceding sections, and then took part in an ideas generation exercise designed to elicit potential solutions for the pain points, with an emphasis on solutions that could be implemented in whole or part by a DNO.

3.4. RESEARCH DESIGNS FOR SELECTED CONCEPTS

In this work package three proposed ideas were selected for further research to test their feasibility, from among those generated in Work Packages 2 and 3.

Research designs were developed to address the key uncertainties and contribute to an overall assessment of feasibility for each proposal.

3.5. BUSINESS CASES FOR SELECTED CONCEPTS

In this work package an outline business case was developed for each of the three proposed ideas, to contribute to an overall assessment of feasibility for each proposal. The business cases focussed on how many people might be positively affected by implementation of the proposed idea, and on approximate estimates of the costs of implementation.

4. WORK PACKAGE 1: TECHNOLOGY LANDSCAPE

4.1. ELECTRIC VEHICLES

There are around 140 makes & models of electric cars on the U.K. market at present. The majority are fully electric with no internal combustion engine, often referred to as Battery Electric Vehicles (BEVs). Manufacturers' quoted electric ranges are typically between 200 and 300 miles, and battery sizes range from around 50kWh to around 90kWh. There has been a considerable advance in ranges of BEVs in the past 5 years, achieved by incremental improvements in Lithium battery technology and battery management. This trend is likely to continue with incremental improvements in energy storage density, battery life, recharge times, and cost reductions, but there are no major step changes in battery technology on the immediate horizon. Price parity with internal combustion engine vehicles (ICEVs) is expected within around 5 years. However there remains a gap between the ranges manufacturers quote and the ranges users experience in real-life driving. The ranges people experience in the real world can still be substantially lower than manufacturers' stated ranges, particularly if the vehicle is driven at inter-urban cruising speeds (60+ mph), when loaded with passengers and/or luggage, or in winter conditions.

Plug-in Hybrid Electric Vehicles (PHEVs) have smaller batteries than BEVs and typically have electric ranges of around 30 miles. They also have an internal combustion engine and run using this when the battery has been discharged. Sales of new PHEVs will be banned in the U.K. in 2035, five years after the ban on sales of ICEVs. Earlier types known as Extended-Range EVs (EREVs) or Range-Extended EVs (REEVs) are disappearing as BEV ranges have increased.

4.1.1. HOW IS THE RANGE OF AN ELECTRIC VEHICLE MEASURED?

EV ranges are measured using the Worldwide Harmonised Light Vehicle Testing Procedure (WLTP) which is more representative of typical driving than previous tests – but electric ranges are affected by type of driving, vehicle and load (passengers & freight) mass, weather conditions, etc. and are frequently lower than the WLTP figure. Also, manufacturers are able to optimise the vehicles that are used in the testing, which again leads to their quoted ranges being higher than ranges that are typically experienced in practice.

As they use their electric car, users gradually build *implicit* knowledge of its range and how that varies with driving conditions, load, etc. "Implicit" knowledge is stored non-consciously, so people access it automatically but are unable to articulate it.

4.1.2. HOW THE RANGE OF ELECTRIC VEHICLES AFFECTS CONSUMERS' WILLINGNESS TO CONSIDER THEM

In the Consumers, Vehicles and Energy Integration (CVEI) Project commissioned by the Energy Technologies Institute a stratified sample of 200 U.K. mainstream consumers were provided with a BEV, PHEV, and unfamiliar ICEV for 4 days to familiarise themselves with each type of vehicle, then asked about their willingness to consider a BEV or PHEV (Beard, Durrell, Kent, Skippon, Kinnear, Al-

Katib, et. Al, 2019[2]). Their willingness to consider a BEV increased markedly with the range of the vehicle, as shown in Figure 2.

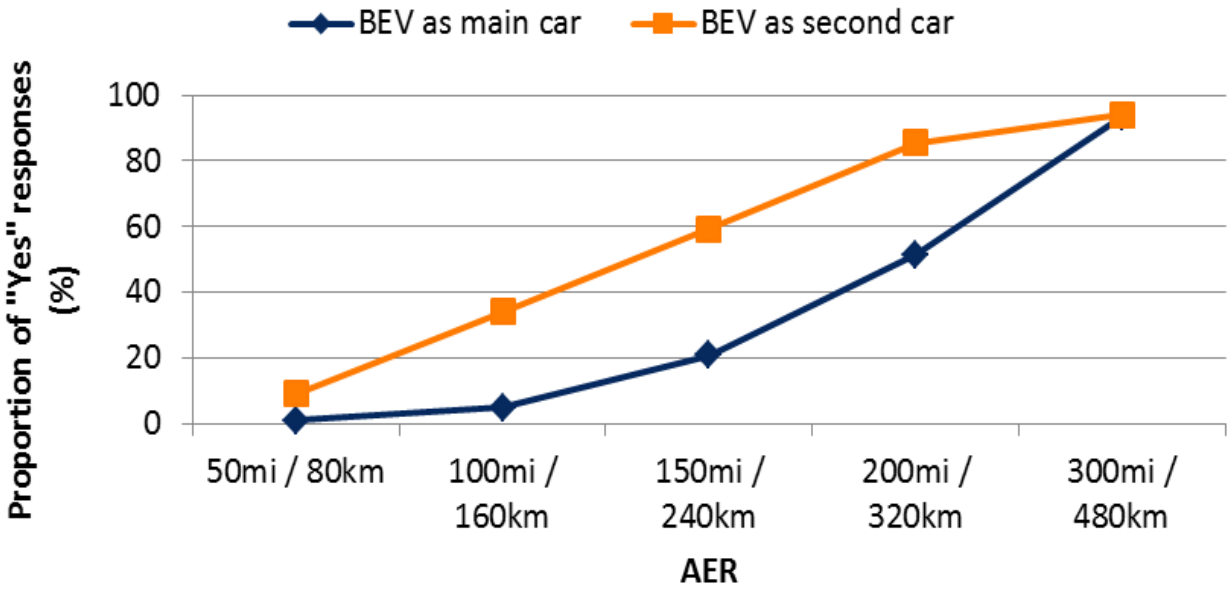


Figure 2. How willingness to consider a BEV is affected by its All-Electric Range (AER). Data from the U.K. – based CVEI Consumer Uptake Trial, which had 200 mainstream consumer participants.

Figure 2 shows that around 20% of mainstream consumers would be willing to consider a BEV as the main car in a household, and 60% as a second car, if its range was 240km (150 miles). Many BEVs in the market have ranges at or above this level, but while prospective buyers are increasingly willing to consider BEVs, barriers to actually choosing a BEV remain, particularly high purchase cost, long recharge times, and perceptions of inadequate public charging infrastructure.

Nevertheless, BEVs made up 11.6% of U.K. new car sales in 2021, and 25.5% of new car sales in December 2021, so the trend towards BEVs having an increasing share of the market is continuing.

Figure 3 shows the equivalent CVEI data for PHEVs. 50% of mainstream consumers would be willing to consider a PHEV as a main car in their household if its All-Electric Range (AER) was 80km (50 miles), while 60% would be willing to consider a PHEV with this range as a second car. PHEVs on the market at present (early 2022) tend to have smaller AERs than this, though this is a matter of design choice rather than technical limitation. The CVEI research indicated that 10% of mainstream consumers would be willing to consider a PHEV as a main car in their household if its All-Electric Range (AER) was 40km (25 miles), while over 20% would be willing to consider a PHEV with this range as a second car. In 2021, PHEV sales made up 7% of all new car sales in the U.K. Again, barriers to PHEV adoption remain, particularly high purchase cost, and perceptions of inadequate charging infrastructure.

[2] Beard, G., Durrell, L., Kent, Skippon, S.M., Kinnear,N., Al-Katib, H., et. Al (2019). Deliverable D5.3 - Consumer Charging Trials Report: Consumers, Vehicles, and Energy Integration Project PPR917: Mainstream consumers' attitudes and behaviours under Managed Charging Schemes for BEVs and PHEVs. Available from ESC.

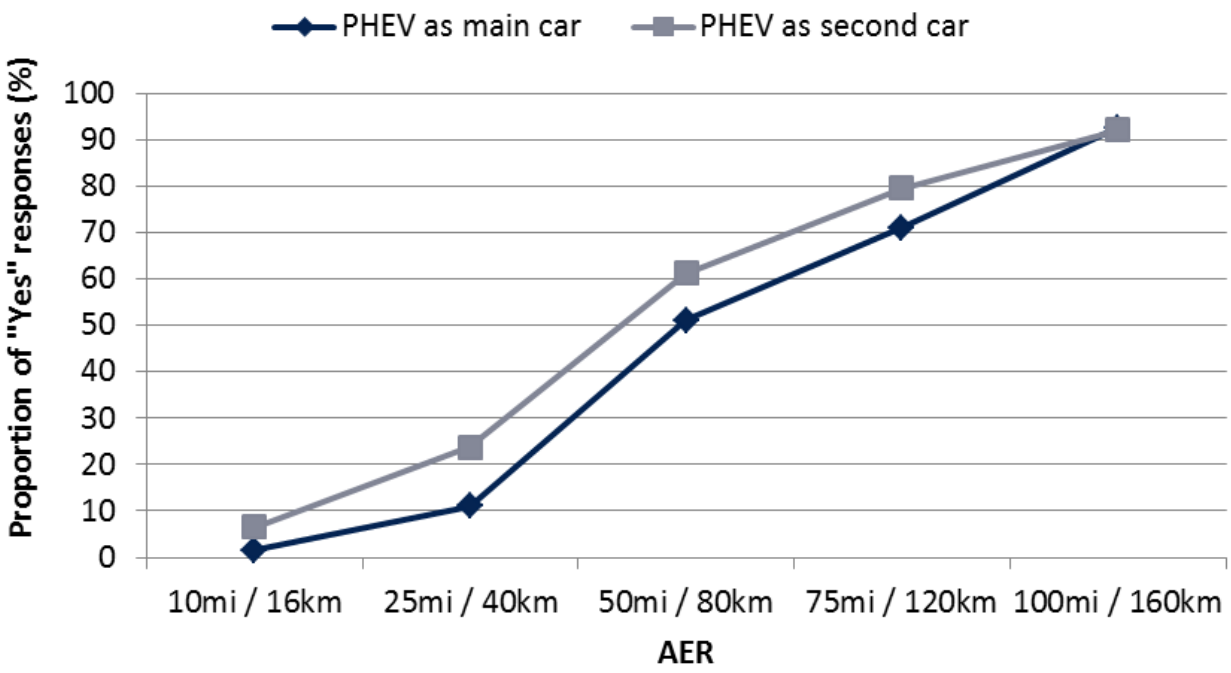


Figure 3. How willingness to consider a PHEV is affected by its All-Electric Range (AER). Data from the U.K. – based CVEI Consumer Uptake Trial, which had 200 mainstream consumer participants.

In conclusion, the range of BEVs on the market has increased substantially in the past 5 years and is now sufficient for a large percentage of mainstream consumers to be willing to consider them as both second and main cars in their households. New BEV sales have not yet caught up with this percentage but are expected to do so as vehicle prices decrease, and perceptions of public charging infrastructure improve.

The AER of PHEVs currently on the market is generally too low to attract similar levels of interest, and their uptake is consequently lower than that of BEVs. Some market commentators suggest that the market opportunity for PHEVs is already in decline due to the rapid improvement in the AER of BEVs.

4.1.3. HOW MIGHT EV UPTAKE DEVELOP OVER THE COMING DECADES?

Figure 4 shows the predicted numbers of each of four major classes of vehicles (including BEVs and PHEVs) in the U.K. over the period to 2050 modelled using the CVEI Analytical Framework under six different Narratives (sets of assumptions). The Narratives are summarised in Figure 5 (see Skippon, Kinnear, Beard, Al-Katib, Greenleaf, Bird, and Dodson, 2019[3] for an overall summary of the CVEI project including the whole-system analysis).

BEV numbers increase in all Narratives, but with very large differences in how far: to 34.1m in the ULEV Enabled Narrative, but to only 13.4m in the Hydrogen Push Narrative (where instead the FCVs dominate). In the Transport on Demand Narrative BEV numbers peak at 22.4 million in 2040 but then fall, as increasing dominance of the Mobility as a Service (MaaS) model requires fewer vehicles on the road.

[3] Skippon, S.M., Kinnear, N., Beard, G., Al-Katib, H., Greenleaf, J., Bird, N., and Dodson, T. (2019). Consumers, Vehicles, and Energy Integration Project: Deliverable 8.1 Final Project Summary Report. Available from ESC.

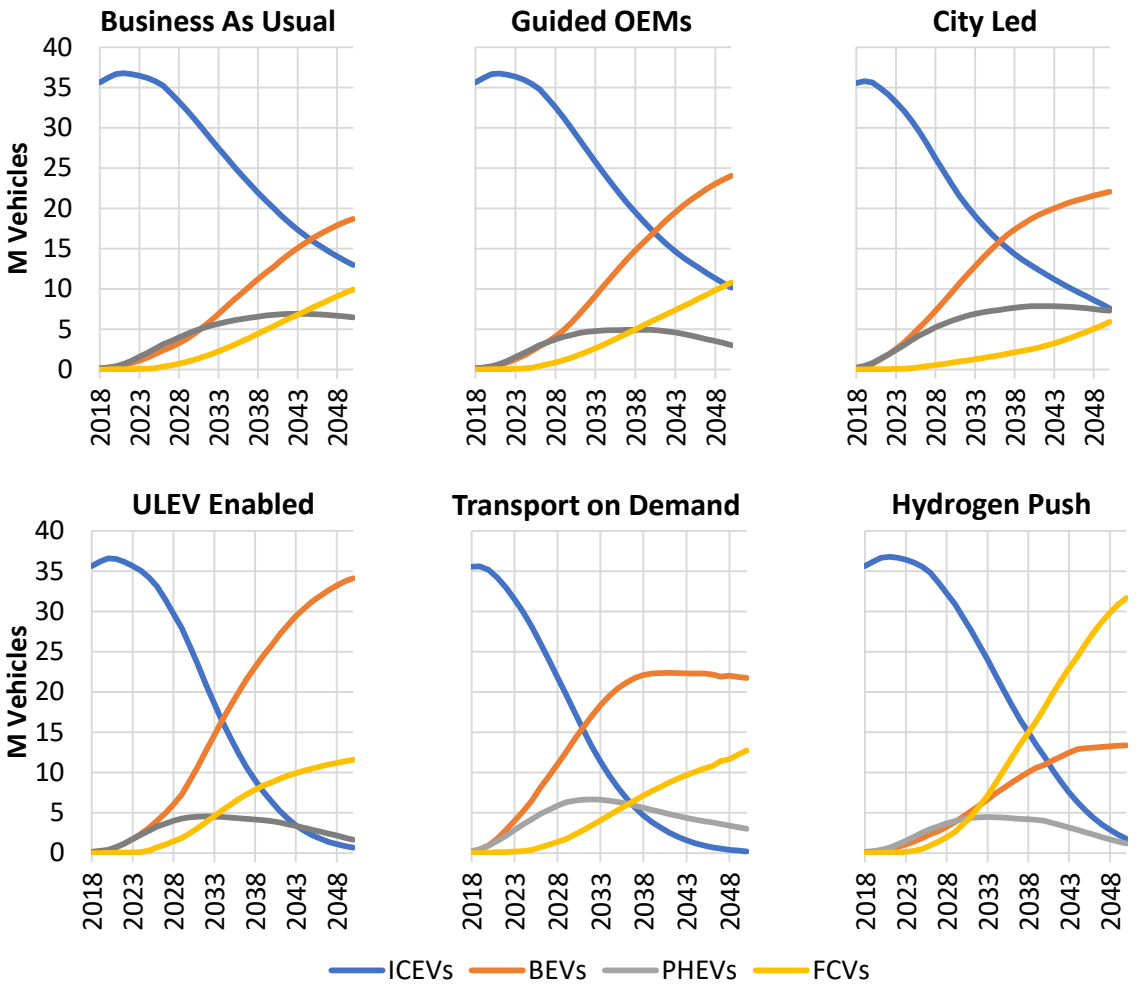


Figure 4: Numbers of major powertrain types in the UK light duty vehicle parc over the interval to 2050 under each Narrative (M Vehicles = Million vehicles; ICEV = Internal Combustion Engine Vehicle; BEV = Battery Electric Vehicle; PHEV = Plug-in Hybrid Electric Vehicle; FCV = Fuel Cell Vehicle)

In all Narratives PHEVs play a transitional role, providing some fuel flexibility and system resilience in the short to medium-term. PHEV numbers initially increase in all Narratives as their costs reduce and their AER improves. After 2040 their numbers level off or decrease, depending on the Narrative concerned. They become less attractive than BEVs or FCVs, both of which are expected to improve substantially by this date.

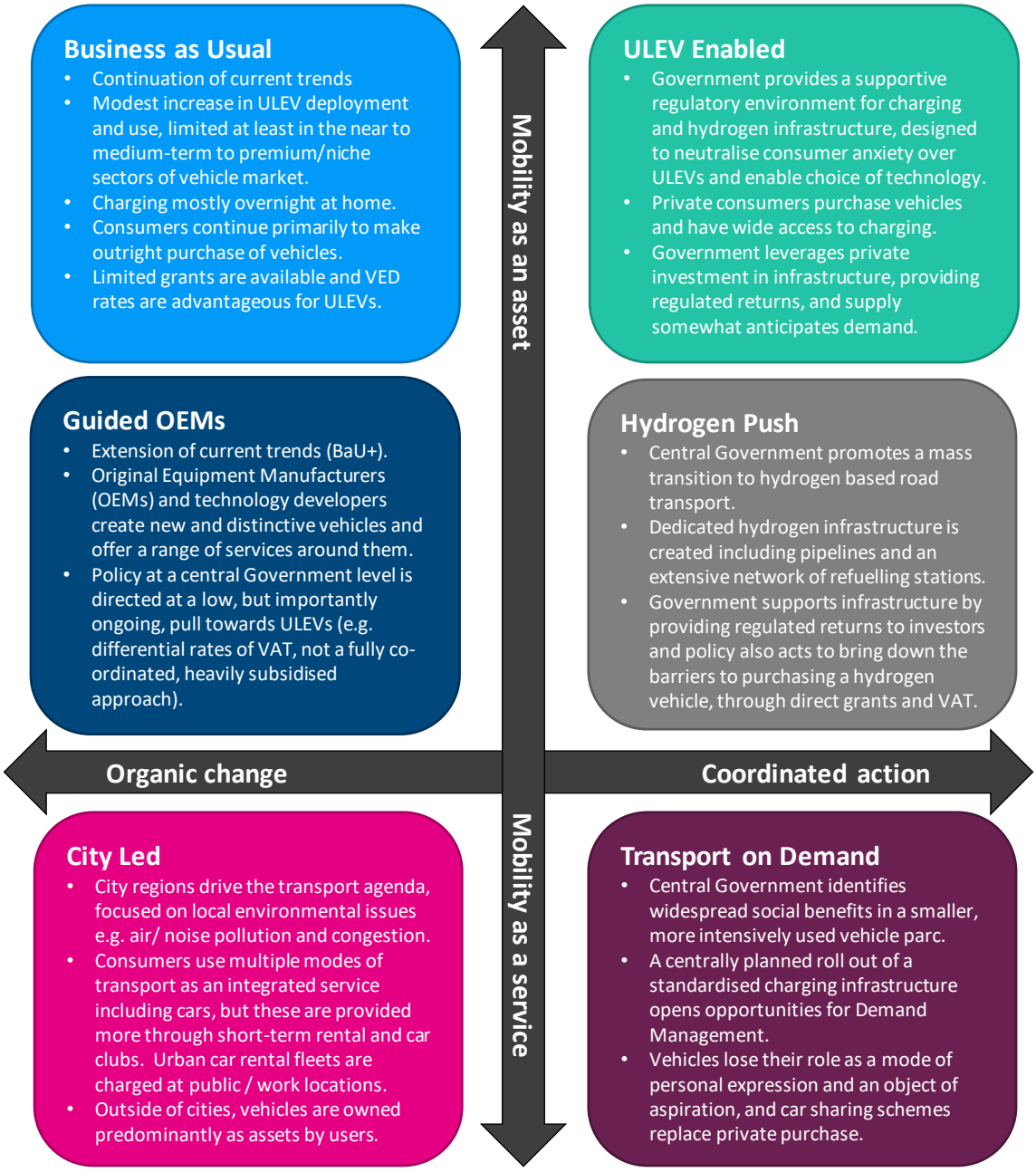


Figure 5: Summaries of the six Narratives in the CVEI whole-system analysis

4.2. ELECTRIC VEHICLE CHARGING TECHNOLOGY

4.2.1. HOME CHARGING

Around 70% of households have off-street parking so can potentially charge an EV at home. 7kW home charging points have largely replaced the older 3.7kW type, though these are still considered suitable for Plug-in Hybrid Electric Vehicles (PHEVs) with their smaller batteries. Home charging points require a dedicated circuit and in older properties with fuses rated to less than 100A may also require an upgrade to the domestic supply. Modern home charging points are designed to work with

smart meters and are capable of smart charging[4], but there remains a legacy population of older home charging points that are not suitable for smart charging. Charging cables are often tethered to the charging points and only require connection to the vehicle, but some home charging points use a free cable that must be plugged in by the user to both the vehicle and the charging point.

Home charging can be problematic for disabled users, for instance if there is insufficient room to manoeuvre a wheelchair around the car to access the chargepoint and vehicle connection point.

At the moment, many EV users are on standard tariffs that do not differentiate EV charging from other domestic loads. However, there are several tariffs specifically aimed at EV users:

- British Gas: *Electric Drivers June 2022*: reduced price from 00:00 to 05:00; free smart meter
- E.On: *E.On Charge*: fixed price for 1 year, £30 rebate after 6 months, 100% from renewable sources
- Ecotricity: *Fully charged*: cheaper overall rate, £40 discount on home charger, 50% discount on charging at Ecotricity public chargers
- Edf: *98*: half-price electricity in evenings and at weekends: requires a smart meter
- Ovo: *EF Everywhere*: Free subscription to BP Pulse public charging network, 100% from renewable sources
- Octopus Energy: *Octopus Go*: reduced rate 5p per kW/h between 00:00 and 04:30; *agileOctopus*: half-hourly pricing linked to wholesale prices – encourages users to respond to price signals and charge outside peak hours
- Scottish Power: reduced rate between 00:00 and 05:00 plus home charger packages. Only available to existing customers and requires a smart meter
- Shell Energy: *Charge and Drive 2021*: Credits account holder with £6.67 per month (claimed to be equivalent to cost of charging for 2000 miles of driving). 100% from renewable sources; free smart meter provided

Even with relatively few electric car charging tariffs, their diversity can make them difficult to compare for anybody considering them.

4.2.2. PUBLIC CHARGING POINTS

Public charging points are classified according to location and speed of charge:

1. Residential on-street: 7 kW (older ones are 3.7kW)
2. Town/city centre on-street: 7 kW (older ones are 3.7kW)
3. Destination – e.g. shopping centre, supermarket, entertainment venue, hotel: 7kW (slow) 22kW (fast), 50kW (rapid)
4. Workplace: mainly 7kW, some faster
5. Strategic road network (e.g. motorway services: some 7kW but increasingly 50kW and some faster, particularly Tesla network (mostly 150kW, some 250kW) and BP Pulse (150kW)
6. Residential rapid charging hubs: 50kW. These are proposed as a solution for households without off-street parking: likely to be 50kW and may be located at local destinations such

[4] Smart Charging refers to EV charging which is controlled to contribute to the management of load on the local network (to enable operation within network constraints), and/or to contribute to the management of overall supply-demand balancing at national level. It generally delivers a benefit to the user, such as reduced charging costs.

as shopping centres, supermarkets, entertainment venues, or at local fuels retail sites (some fuels retailers have plans to install faster chargers, e.g. 150kW, across their retail site networks)

There is an increasing tendency towards 50kW charging points at public locations where dwell times are short, such as those on the strategic road network.

Technology is developing for super-rapid charging stations (up to 350kW), although availability of vehicles that can accept such high charge rates lags behind; and the higher the charge rate, the heavier and more unwieldy the cables are likely to be.

Users continue to complain about lack of inter-operability between networks, which means that they must register with a multitude of different networks and carry multiple cards. There are also frequent complaints about poor reliability (charging stations out of action). The U.K. Government's Office for Zero-Emission Vehicles (OZEV) in a recent consultation on the user experience, has sought feedback on proposals to address the former by making it mandatory for new rapid chargers to be equipped with credit/debit card readers, and to address the latter through standards for operational availability of chargers in public locations.

4.2.3. USE OF PUBLIC CHARGING POINTS BY PEOPLE WITH IMPAIRED MOBILITY

61% of disabled people would only consider an EV if charging was made more accessible, according to research commissioned by Urban Foresight and design partners Duku, with a sample of 702 participants from RiDC's pan-disability consumer panel. There are major difficulties for these people, particularly when their mobility impairments require them to use a wheelchair. These problems have received little attention so far, and few public charge points have been designed with the needs of people with mobility impairments in mind. However, there are now initiatives in place to develop adaptations to charge points and their immediate surroundings. Adaptations that have been suggested and/or piloted include:

- Sufficient space around the vehicle
- Sufficient space around the charge point
- Dropped kerb, level surface around the charge point
- Clear ground markings to aid accurate parking
- Clear, visible markings indicating where the cable will reach to
- Clear signage for price, over-stay fees, and other fees
- Tethered cables (at the charge point end) to simplify connection
- Charge point display screen at height appropriate for use from wheelchair
- Minimisation of cable weight and/or supported cable (e.g. overhead support)
- Minimum standards for lighting around the charge point and its bay
- Measures to prevent hogging of bays by users of vehicles that are not charging
- No bollards or collision barriers preventing approach to charge point in a wheelchair
- Human assistant available – either by calling ahead, or by calling when on-site
- Free helpline with number clearly displayed
- Booking system for disabled-adapted charge points
- Up-to-date information in journey planning Apps on location of disabled-adapted charge points, whether they are in service, current occupancy status (e.g. click to get live camera view)
- Weather protection

4.2.4. INNOVATION IN PUBLIC CHARGING POINTS

4.2.4.1. LAMP-POST CHARGERS

Charging points attached to lampposts have been developed and deployed (e.g. in several London boroughs, Coventry, and Leicester) to address the issue of increasing street clutter[5] in residential on-street settings. In the example shown in Figure 6, a portable cable (brought in the vehicle) is used to limit roadside clutter when the charging station is not is use. The maximum density of these charging stations is limited by the spacing between lampposts, which is influenced by road geometry, height of posts, lighting class, speed limit, and light specification.

Figure 6: example of lamp-post public charging point, intended to reduce road-side clutter

4.2.4.2. POP-UP CHARGING POINTS

Pop-up charging points are another innovation designed to reduce street clutter. Like rising bollards, they are flush with the surface when not in use and rise out of the ground when required. They are currently being trialled in Oxford. Present models supply 7kW and are intended to be suitable for residential on-street charging stations.

4.2.4.3. INDUCTIVE (WIRELESS) CHARGING

Wireless charging is a radical alternative for transferring energy from a charging station to a vehicle's battery. Instead of using a cable to connect them, it uses a transmitting plate on the ground and a receiving plate underneath the vehicle. An alternating electric current in the transmitting plate creates a varying magnetic field in the air gap between the plates, which in turn induces an electric current in the receiving plate, which charges the battery. Transfer efficiencies of over 90% have been achieved.

There remain several technical issues: ensuring accurate alignment of a variety of different vehicles over the transmitter plate, excess heating in the air gap, and detecting the presence of unwanted metal and organic objects (e.g. human feet, cats) between the plates. As a result, wireless charging of EVs has remained in the trial stage for over five years, although some auto manufacturers appear

[5] Street clutter can be a particular problem for those in wheelchairs and those with prams and pushchairs

now to be offering it as an option on high-end EV models. It remains unclear how quickly it will be rolled out for mass-market consumer EVs.

U.K. trials include a trial involving 25 double decker buses in London (TfL) and a trial involving taxis in Nottingham.

4.2.4.4. DYNAMIC CHARGING

There are two alternative forms of delivering power for electric propulsion on roads under development, in which vehicles pick up electricity continuously rather than storing it onboard in a battery.

"Dynamic" wireless charging is similar to static wireless charging, but instead of a single fixed transmitting plate, there is a continuous transmitter installed into a road surface, so that vehicles can pick up electricity continuously as they drive. This is seen as a potential solution for decarbonizing heavy goods road transport. It is still in the early prototype stage, and application to light duty cars and vans remains a distant prospect.

An alternative to dynamic wireless charging is for vehicles to pick up electricity via overhead cables, in the same way that electric trains do. This is also seen as a potential solution for decarbonizing heavy goods road transport. It is a revival of a concept that was in use 50 years ago for urban buses. The revival of the concept for heavy goods vehicles is still in the early prototype stage and application to light duty cars and vans remains a distant prospect.

In both solutions, the HGV may also have an onboard battery to enable travel on sections of road where there are no transmitters in the road surface or overhead cables.

4.2.5. CHARGING SERVICES

Several novel services are emerging that provide an alternative to home charging for users who do not have access to off-street parking. Several of these are described briefly here.

4.2.5.1. MOBILE CHARGING VANS

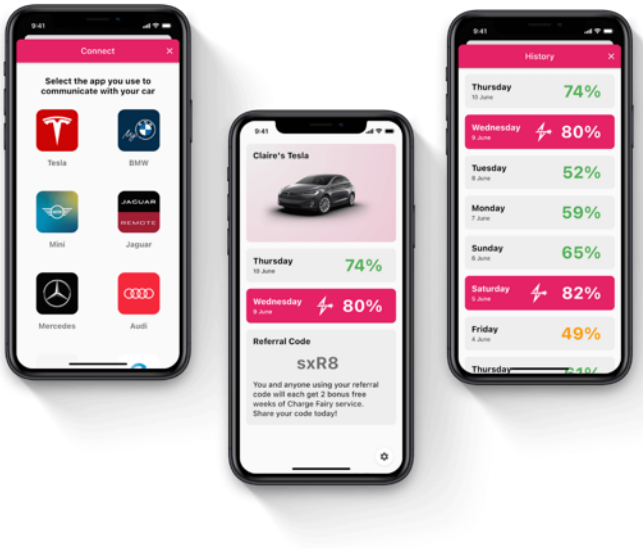


Figure 7: Charge Fairy App. Charge Fairy uses mobile charging vans to deliver charge to EV users who can't charge at home

Charge Fairy offer a subscription service with mobile charging units. Users must set up an account with their EV manufacturer and link this with the Charge Fairy app (Figure 7). This linkage enables Charge Fairy to monitor the EV's state of charge and its usage patterns. Based on this data they schedule visits to recharge the customer's EV when necessary. Their mobile charging vans are equipped with 15m cables so do not need to park right next to the customer vehicle. If double parking is necessary, they schedule visits at quiet times.

A £5.99 per week subscription buys a weekly 10kWh charge, with additional charge costing 37p per kWh. Other subscription packages are available.

4.2.5.2. VALET CHARGING

Zumo is another new charging service, presently being trialled in London, providing a service for overnight charging. Zumo collects a user's car, takes it to nearby charging station, charges it, and returns it. Users book a collection time (within the 8pm-midnight window) and a return time (within the 6am – 8am window). Keys are collected from and returned to the user's home.

Drivers arrive and depart using electric scooters. All their journeys including those in the customer's vehicle are video recorded (Figure 8). At the time of writing costs for the service are not known.

Figure 8: Zumo staff collect a user's car, drive it to a nearby public charge point, and return it

4.2.5.3. PORTABLE BATTERY PACKS

An alternative to charging services, again aimed at people without off-street parking and so unable to charge directly at home, is the portable battery pack concept. An example is provided by U.K. start-up ZipCharge Go. Its suitcase-sized portable battery pack, which has wheels and a handle much like airport carry-on luggage, has the capacity to provide an EV with "up to 20 miles of range", which the company claims is sufficient for the average U.K. commuter journey. Transferring this charge to the car is claimed to take 30 minutes. The user can then take the portable battery home and recharge it, using a conventional 3-pin plug. The cost of a unit is not yet clear but estimated to be similar to that of a Level-2 domestic charge point. They will also be available on a subscription basis for £49 per month.

4.3. SMART CHARGING

Smart charging is seen as a potential solution to the twin potential problems posed by large scale EV charging demand at national level (supply-demand balancing) and local level (operating within network constraints). Smart charging invites consumers to charge their EVs at times when there is less electricity demand from other sources, in return for a financial benefit or the knowledge that their electricity is supplied from renewable sources. Smart charging comes in two broad flavours:

User-Managed Charging (UMC): Users determine the timing of their EV charging for themselves, in response to price signals, typically in the form of banded tariffs with the lowest prices overnight (time-of-use tariffs). Several UMC tariffs are available in the U.K. market at present.

Supplier-Managed Charging (SMC): Users allow the supplier to determine the timing of their EV charging to maximise system benefits, in return for cost savings that are higher than UMC because of closer coupling to wholesale price variations. Users specify how much charge they want by a particular time and leave their vehicle plugged in to maximise flexibility. SMC is not yet available in the U.K. market.

A charging trial conducted as part of the CVEI project[6] tested the effectiveness of UMC and SMC at shifting charging demand, in a sample of 240 mainstream consumers who were provided with a BEV or PHEV for 8 weeks.

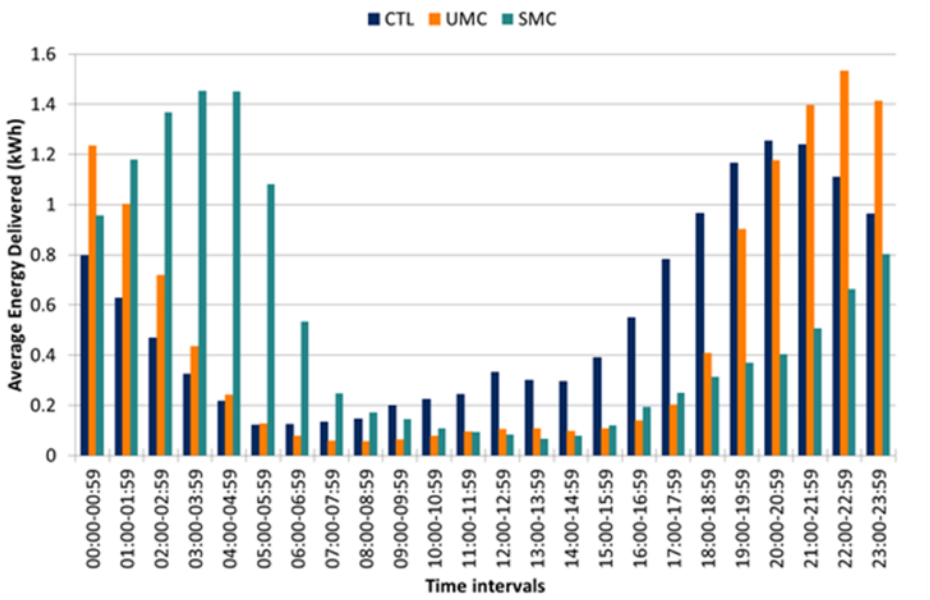


Figure 9. Smart charging works: data from the CVEI Consumer Charging Trial, showing that both UMC and SMC shift the timing of charging into the overnight period, compared to when EV users are not engaged in a smart charging scheme ("CTL" in the chart)

[6] Beard, G., Durrell, L., Ramnath, R., Wallbank, C., Kent, J., Skippon, S.M., et al. (2019). Consumers, Vehicles, and Energy Integration Project: Deliverable D5.3 – Consumer Charging Trials Report: Mainstream Consumers' Attitudes and Behaviour Under Managed Charging Schemes for BEVs and PHEVs. Available from ESC.

Figure 9 shows average hourly charging demand per user over a 24-hour period, for users in a UMC scheme, an SMC scheme, and users with no smart charging scheme (CTL). In the CTL group a substantial fraction of charging happened in the early-evening to mid-evening; in the UMC and SMC groups, charging was shifted to later times.

The CVEI Consumer Charging Trial also found that both flavours of Smart Charging had considerable appeal to its mainstream consumer participants, even to those in its control groups who did not experience using either UMC or SMC.

4.4. VEHICLE TO GRID (V2G) AND VEHICLE TO HOME (V2H)

V2G and V2H each go further than Smart Charging by enabling an EV battery to be charged when the price of electricity is low, and discharged to sell electricity back to the grid, or to provide power to the rest of the home, when electricity prices are high.

V2G-enabled chargers, like smart chargers, require a communications link to the supplier. V2G chargers are typically Direct Current (DC), enabling an EV's onboard uni-directional AC charging control electronics to be bypassed. Several hardware suppliers have developed V2G-enabled chargers, for instance Virta. At the moment these have maximum outputs of around 10kW, sufficient for domestic use.

Nissan is a pioneer among automotive manufacturers in producing V2G enabled vehicles: all its Leaf BEVs on sale today are V2G enabled. It has been trialling V2G enabled Virta chargers at its European Technical Centre in Cranfield, U.K. in conjunction with E.ON.

There are concerns that V2G could mean many more charge-discharge cycles than conventional or smart charging, thus reducing an EV battery's lifetime. Proponents of V2G argue that in practice battery discharge events would be small and infrequent; however, this might also mean that the potential value to the EV user is reduced.

4.5. JOURNEY PLANNING

There are many smart phone Apps and in-car SatNav systems available, often providing information about the location of EV chargepoints. These can be used to plan journeys in an EV with planned re-charging stops.

However, they require the user to know how far they can travel between re-charging stops and how this depends on type of driving, vehicle load, weather, etc.

EV users frequently complain that information on chargepoints is inaccurate (particularly as to whether they are in service) and doesn't tell them about present or predicted near-future occupancy.

Most Apps and in-car systems have little or no information about accessibility for people with disabilities.

Zapmap (Figure 10) is a leading U.K. source of information on chargepoint locations, available as a smartphone App or via the web. It also provides information on charging requirements for specific vehicles, what connector are needed, etc.

Figure 10. Zapmap charge point location App

4.6. MOBILITY AS A SERVICE (MAAS): ALTERNATIVES TO HAVING A CAR

Mobility as a Service provides an alternative to owning or leasing a car oneself. It is intended to make personal mobility more accessible. There are three broad types of MaaS:

1. Car clubs: Vehicles are parked at convenient locations in residential areas and at town centre locations, shopping centres, etc. Users can book a vehicle, use it, and return it. Access is typically by subscription (e.g. a monthly fee) plus pay-per-use and is typically mediated using a smartphone App. Example: Zipcar.
2. Ride hailing: Taxi services bookable via a smartphone App. Example: Uber.
3. Multimodal journey booking and ticketing platforms: online platforms/Apps enabling city dwellers to plan and book journeys within the city area that integrate travel via multiple modes (bus, tram, cycle hire, etc.) with single ticketing. Examples: Oyster (London), Moveit (Liverpool).

Existing MaaS services usually require access via a smartphone App, requiring manual dexterity and unimpaired vision. Few if any can be accessed in other ways.

4.7. CONNECTED AND AUTONOMOUS VEHICLES (CAVS)

Driverless cars – cars that can drive themselves - have the potential ultimately to offer substantial benefits to members of vulnerable groups, for instance those with visual impairments.

In the next two years, CAVs are expected to become available for those who hold a valid driving licence that can drive themselves in most circumstances on certain classes of roads such as motorways, where the range of road situations that can be encountered is limited. The driver will still need to attend to the road situation so that they can take over control in circumstances the control system cannot handle. A question remains over how far users will do this in practice: there have already been crashes where users of "autopilot" systems in cars have failed to attend to the road situation and have failed to intervene when the control system has made an error. It is very likely that a system for measuring driver alertness will be required.

Fully automated vehicles that can drive themselves under all conditions on all roads without a human licence holder to take over when necessary are still a long way off: at least ten years, according to some experts in the field.

5. WORK PACKAGE 2: CUSTOMER JOURNEY ROADMAPS, PAIN POINTS, AND POSSIBLE SOLUTIONS

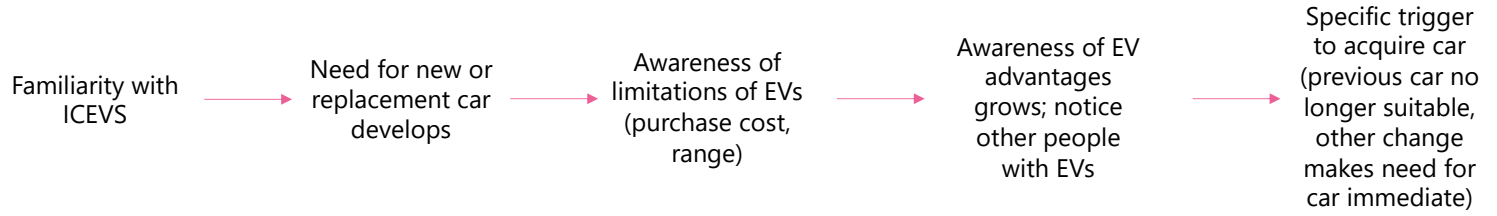
Work Package 2 of the Equal EV project was aimed at exploring the customer experience of using an EV from the perspective of two vulnerable groups: people with mobility impairments, and people with high levels of anxiety. The first step in this work package was the development of a set of customer journeys, covering all aspects of user engagement with them, including both acquisition and use. This work was initially carried out by the ESC Consumer Insights team, based on the findings of Equal EV Stage 1 research and knowledge of the evidence base concerning user experience in the published research literature. The customer journeys were then reviewed and elaborated in the three Work Package 2 workshops

5.1. CUSTOMER JOURNEY MAPS

The Customer Journey maps are shown in Figures 11 to 19. The acquisition stage is represented by three Customer Journey maps: Contemplation, Investigation, Decision. These three steps are based on a simplification of the Transtheoretical Stages of Change model (Prochaska and DiClemente, 1984[7]). The text in pink indicates elaborations added by the project team and workshop participants.

[7] Prochaska, J.O., & Di Clemente, C.C. Towards a Comprehensive Model of Change. In W.R. Miller & N. Heather (eds.) Treating Addictive Behaviours. Applied Clinical Psychology, Vol. 13. Boston, MA: Springer.

Acquisition: Contemplation stage – not actively looking for a new vehicle, but forming opinions



There's a tendency to stick with what people know, i.e. not consider an EV

Limitations / advantages could be influenced by others

The need to acquire could become immediate and decision needed more quickly

Figure 11: Customer Journey for the first stage of Acquisition: Contemplation

Acquisition: Investigation stage –
gathering information and forming vehicle preferences

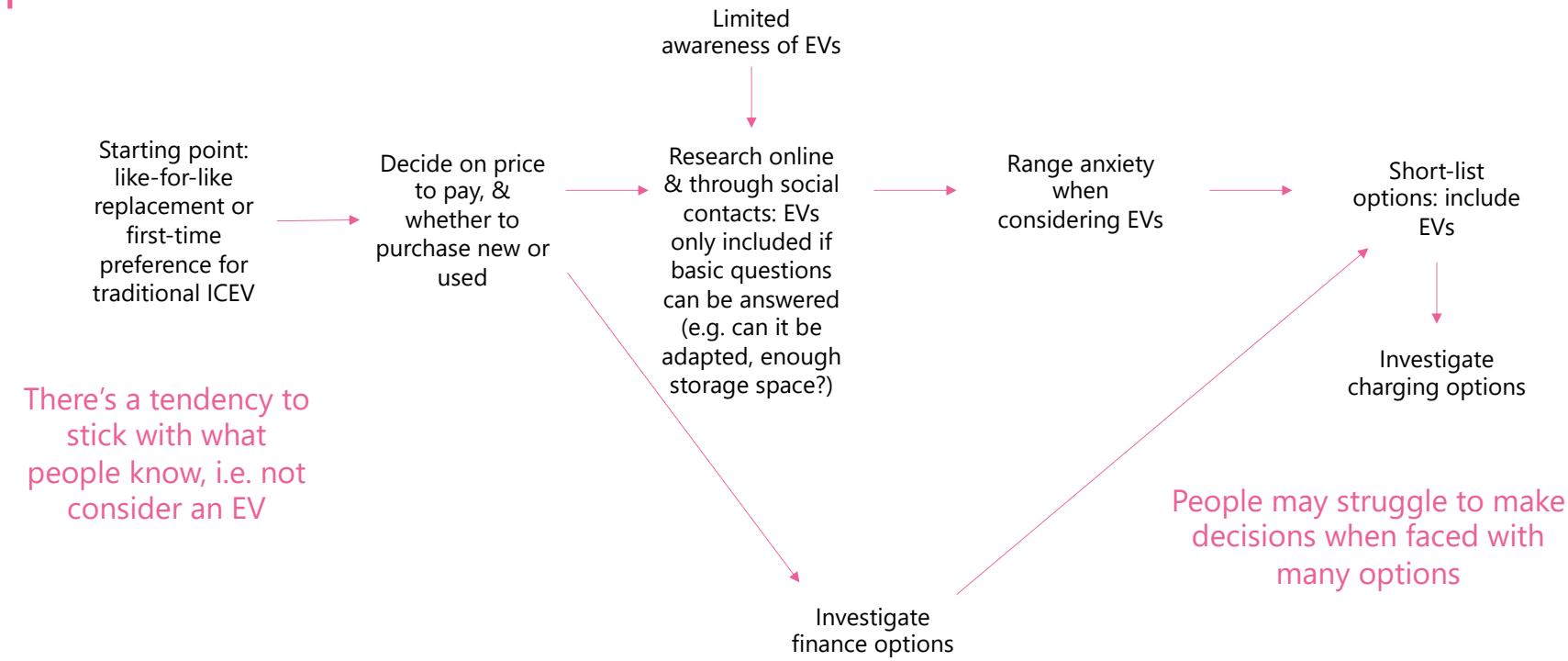


Figure 12: Customer Journey for the second stage of Acquisition: Investigation

Acquisition: Decision stage –
finalising vehicle choice

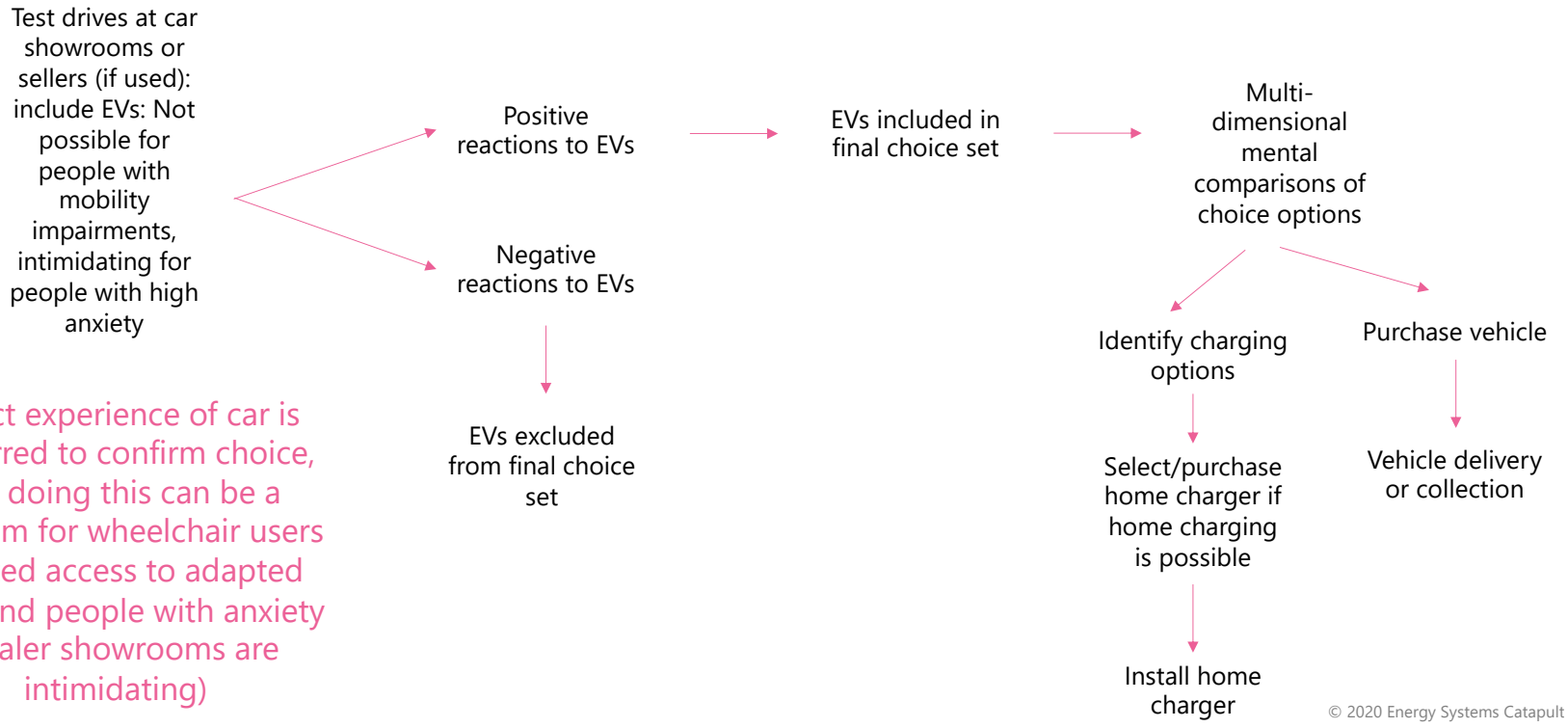
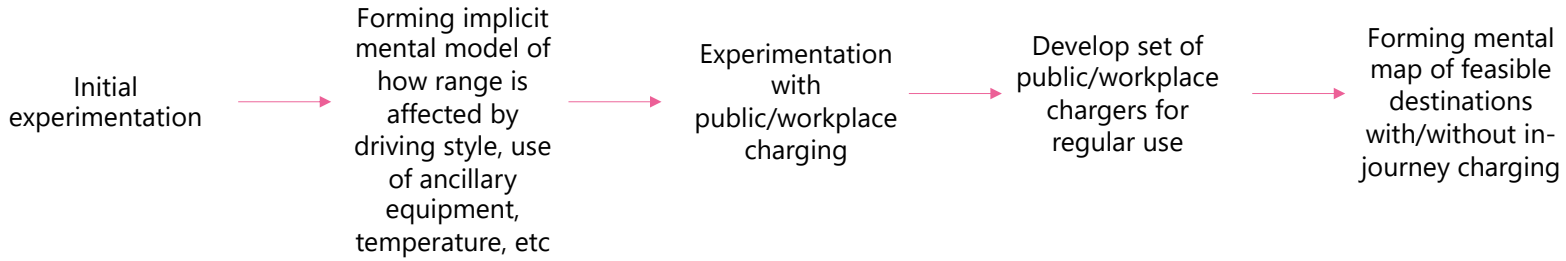


Figure 13: Customer Journey for the third and final stage of Acquisition: Decision

Use: familiarisation stage – getting to know EV & forming use habits



People may have a cautious approach to range

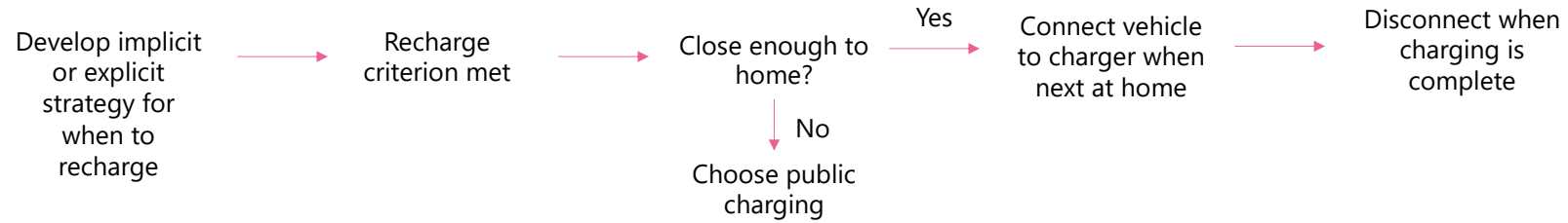
Most participants from both groups saw this as something they wanted to do in the acquisition stage before making a decision

Range anxiety only applies in unfamiliar situations

Figure 14: Customer Journey for the familiarisation stage of EV use, when the user has just acquired their EV

Use: charging at home

– for those who can



e.g. daily top-up, charge when range or SOC drops to minimum tolerable level

Figure 15: Customer Journey for charging at home – for those who have off-street parking and can install a home charging unit

Use: charging away from home

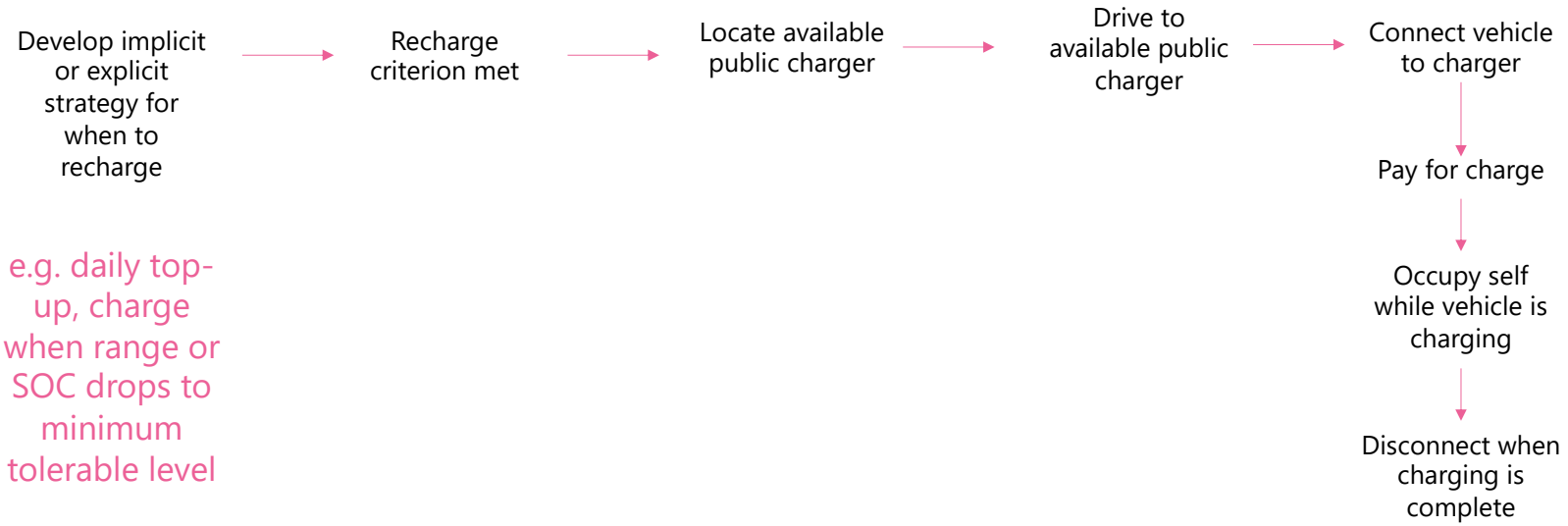


Figure 16: Customer Journey for charging away from home, at a public charging point

Use: smart charging/V2G/V2H

– for those who can

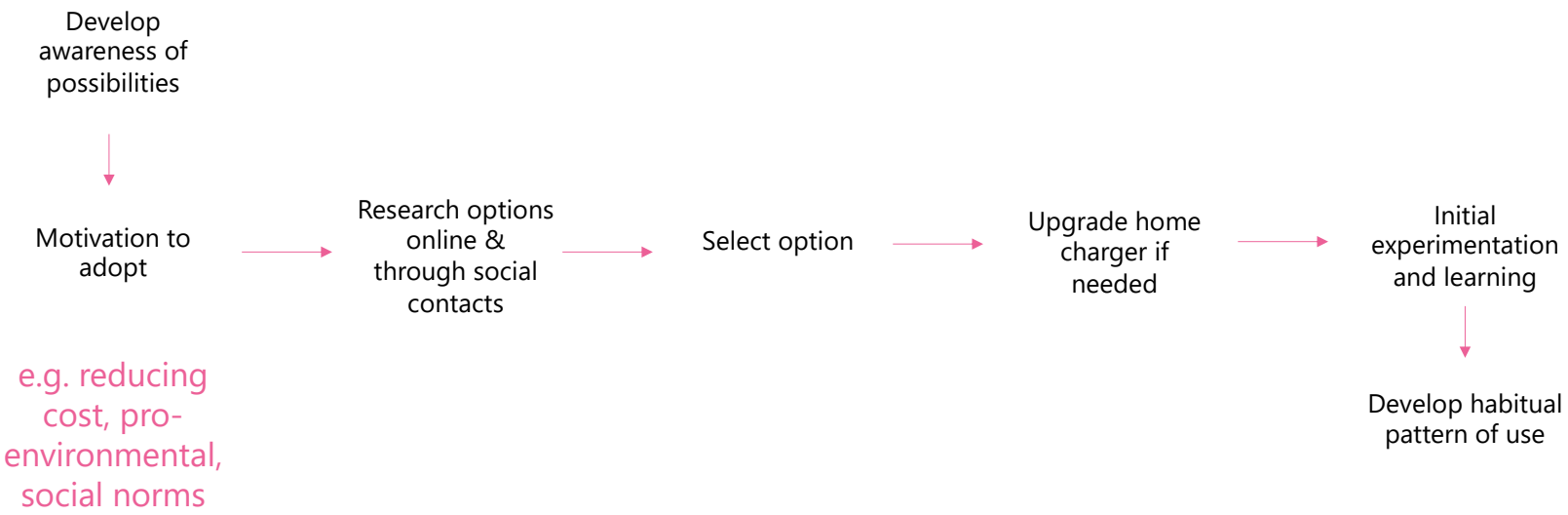


Figure 17: Outline Customer Journey for smart charging, V2G, V2H

Use: long journeys

- too long to achieve with single charge

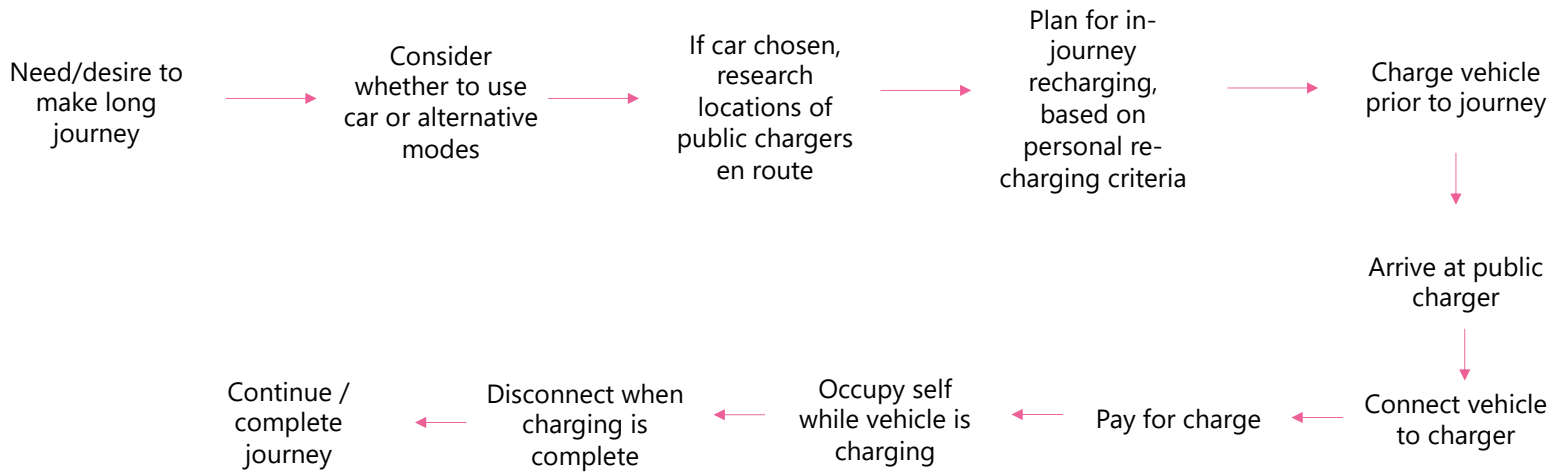


Figure 18: Customer Journey for making long journeys

Use: maintenance

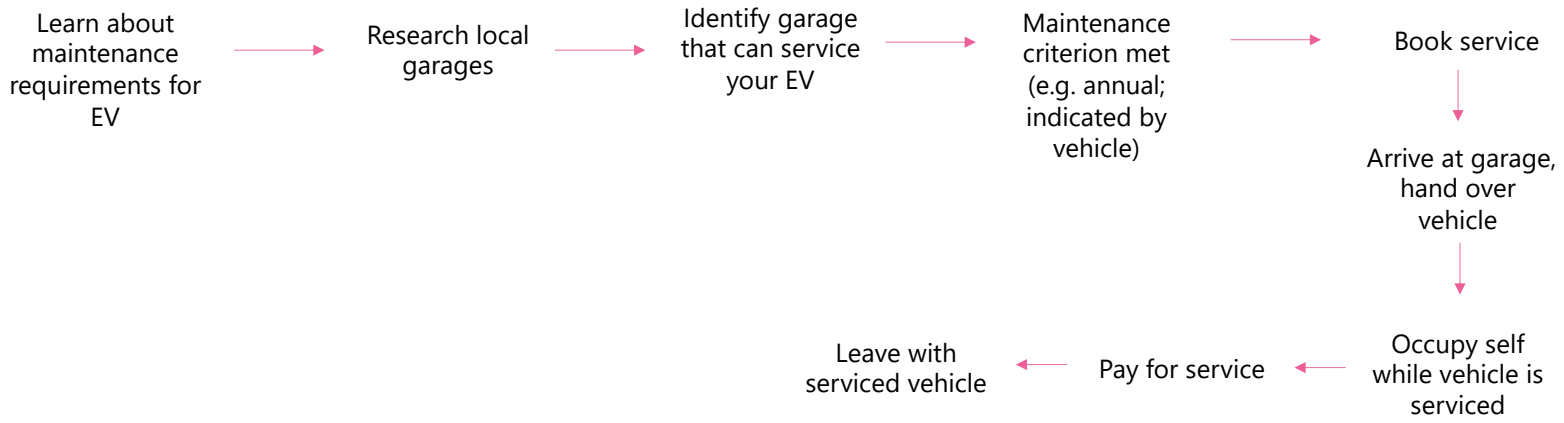


Figure 19: Customer Journey for EV maintenance

5.2. PAIN POINTS

"Pain points" are defined here as difficulties that might be encountered by members of the two vulnerable groups at points along the customer journeys. All three workshops (with SSEN, mobility impaired consumers and consumers with anxiety) carried out an exercise to elicit these, involving individual ideation and group discussion. Table 1 is a list of all pain points identified, listed by the customer journey stage to which they relate. Similar ideas generated in more than one workshop have been consolidated into a single pain point in the table.

"MI" means the pain point is expected to mainly apply to those with mobility impairments; "Anx" means the pain point is expected to mainly apply to those with high levels of anxiety; "Both" means the pain point applies to members of both vulnerable groups.

Stage	Pain Point
Contemplation	Uncertainty about where to look for basic info about EVs (Anx)
	Lack of info around EVs in relation to users who are anxious and/or have disabilities (Both)
	As a new concept, lack of prior knowledge & assumptions available from friends & family (e.g. "always buy a German car") (Both)
Investigation	Finding out about how far MI modifications (e.g. hoist) and/or wheelchair weight will impact on battery depletion and range (MI)
	Too much new information to take in when I start looking into it (Both)
	Finding out which EVs can be mobility adapted? (MI)
	Finding out how much space is left in a mobility adapted EV after adaptation (MI)
	Finding out where I could take an EV (Anx) or mobility adapted EV (MI) for service or routine repair
	Can't get a test drive in a mobility adapted version of EV I'm interested in (MI)
	If leasing I would worry I might be paying too much (Anx)

Table 1. Pain Points by customer journey stages

Stage	Pain point
Decision	Going to dealer/getting a test drive/dealing with salesperson is intimidating (Anx)
	Even longer delay between ordering and delivery for a mobility adapted EV (MI)
	Delays or other problems getting a charger installed at home (e.g. older house may need uprated consumer unit/fuse) (Both)
	Having to base my life around my car (frequent charging needed) (Both)
Familiarisation	Risk of having an accident while getting used to an EV's automatic transmission while used to manual (Anx)
	If EVs are quiet, pedestrians might not hear me coming (Anx)
Home charging	Not enough charge to use the car if there's a power cut (Both)
	Confusing tariffs (Both)
	I don't have off-street parking so can't have a home charger (Both)
	Insufficient space around car to manoeuvre in a wheelchair when connecting cable (MI)
	Mobile charging service options such as Charge Fairy/Zumo might be too expensive for me (Both)
	Cable is a trip hazard (MI)
Smart charging	If there's an emergency overnight my EV might not have enough charge for the emergency journey I need to make (Anx)
	Confusing, difficult to understand tariffs (Both)

Table 1. Pain Points by customer journey stages (cont.)

Stage	Pain points
Charging away from home, at public chargers	Can't find a Charge Point at a Disabled Space (MI)
	Not a member of the Charge Point's network so can't use (Both)
	Charge Point not working (Both; Anx - worry about this before visit)
	All Charge Points occupied (Both; Anx - worry about this before visit)
	Difficult social interaction with other users, e.g. if they're waiting to use Charge Point and I take a long time to use it (Both)
	Physically unable to get close to Charge Point (impact barrier) (MI)
	Charge Point/cable physically difficult to use (MI)
	Charge Point screen too high to see from wheelchair (MI)
	Unable to manoeuvre wheelchair around car because space is limited (MI)
	Can't see my car if I leave it charging (Anx)
	Uncertainty about future changes (e.g. charging at Tesco is free now, but for how long? What further innovations/changes might happen in next 10 years? (Anx)
	Every charge you need to do is a chance for something to go wrong (Anx)
	Discomfort or feeling unsafe waiting at Charge Point, e.g. bad weather, dark) (Both)
	Nearest local charger is a long distance away (Both)
	Using on-street chargers means I cannot park close to my home all the time, sometimes I have to walk/use wheelchair further which can be problematic in bad weather, late at night, with shopping, with children, etc. (Both)
	Charging cable can cause an obstruction that is a hazard for someone with physical disabilities (MI)
	Uncomfortable using Smartphone to interact with charger (Anx; older MI)

Table 1. Pain Points by customer journey stages (cont.)

Stage	Pain points
On the journey	Lack of confidence in range (Both)
	Diversion lengthens my journey so higher risk of running out of charge (Both)
	Being cold because range anxiety leads to not using heater (Anx)
	Having to plan every charge on longer journeys (Anx)
	Long journeys take longer (Both)
	Too anxious to make journey at all (Anx)
	Where to take my mobility-adapted EV if I break down? (MI)
	How to continue my journey if my mobility-adapted EV breaks down? (MI)
Maintenance	Getting a mobility-adapted courtesy car (MI)
	Very expensive if you need a new battery (Anx)
	Finding out where I could take an EV (Anx) or mobility adapted EV (MI) for service or routine repair (also mentioned at Investigation stage)

Table 1. Pain Points by customer journey stages (cont.)

The importance of Table 1 is that it reflects the views of members of the two vulnerable groups themselves on where they see potential difficulties in engaging with EVs. To date their perspectives have received little consideration within the EV professional community and the table shows that much needs to be done to ensure members of these groups are not excluded from full participation in the transition to EVs.

5.3. POTENTIAL SOLUTIONS

Following the identification of pain points, participants in all three workshops carried out an exercise to elicit ideas for solutions to mitigate them. This exercise also involved individual ideation and group discussion. Table 2 lists all the ideas generated and indicates which customer journey stages each idea is relevant to. As in Table 1, where similar ideas were generated in more than one workshop, they have been consolidated into a single idea here.

Possible solution	Acquisition Contemplation	Acquisition Investigation	Acquisition Decision	Familiarisation	Charging at home	Charging away from home	Smart charging, V2G, V2H	Long journeys	Maintenance
A comparison from different providers/dealers of how well EVs meet their needs		✓	✓						
Regional centres with a variety of EVs adapted with mobility equipment so people can try them out		✓	✓						
EV rental scheme with EVs that have mobility equipment already included so people can try them out to check they are fit for purpose / don't run out of charge too quickly		✓	✓						

Table 2. Possible solutions generated by workshop participants

Possible solution	Acquisition Contemplation	Acquisition Investigation	Acquisition Decision	Familiarisation	Charging at home	Charging away from home	Smart charging, V2G, V2H	Long journeys	Maintenance
Blogs / vlogs of disabled people using EVs to give people confidence they are OK	✓	✓	✓						
Having some better metrics / assurance of range with mobility equipment installed, e.g. dealership or Motability certification or assurance of the range with equipment in		✓	✓						
Ability to offer test drives for a longer period of time – e.g. over a weekend.			✓						
Motability to provide summary of key information about each accessible EV model		✓	✓						
Manufacturers to provide summary of key information about each accessible EV model		✓	✓						

Table 2. Possible solutions generated by workshop participants (cont.)

Possible solution	Acquisition Contemplation	Acquisition Investigation	Acquisition Decision	Familiarisation	Charging at home	Charging away from home	Smart charging, V2G, V2H	Long journeys	Maintenance
Pods with EV simulators so you can test drive them without having the intimidating experience of going to a dealership and dealing with salespeople		✓	✓						
Simulator pods with someone available to answer questions (maybe via video screen)		✓	✓						
EV events at community centres etc run by local people you know, so you can find out about them in a comfortable environment	✓	✓							
EVs (or simulator Pods) at places like supermarkets, shopping centres, so you could get a feel for them in a normal place rather than a dealership	✓	✓	✓						

Table 2. Possible solutions generated by workshop participants (cont.)

Possible solution	Acquisition Contemplation	Acquisition Investigation	Acquisition Decision	Familiarisation	Charging at home	Charging away from home	Smart charging, V2G, V2H	Long journeys	Maintenance
Reassurance that you can use an EV without having to have a teenager with you to explain all the apps etc	✓	✓							
Source of all the key information you need to know, out there so you can't miss it		✓	✓						
Grant from government/other to top up the Motability allowance		✓	✓						
Motability to lower advance payments, so it's a similar price to ICEV alternatives		✓	✓						
Wider range of disabled-accessible vehicles on the market		✓	✓						

Table 2. Possible solutions generated by workshop participants (cont.)

Possible solution	Acquisition Contemplation	Acquisition Investigation	Acquisition Decision	Familiarisation	Charging at home	Charging away from home	Smart charging, V2G, V2H	Long journeys	Maintenance
Disabled-accessible PHEVs to solve range anxiety	✓	✓	✓						
Reassurance that battery won't overheat if charged very fast		✓	✓						
Separate batteries for hoists in accessible Evs so hoists can be used even if main EV battery runs out		✓	✓						
Visibility of charging points in the local area		✓	✓						
The ability to add the cost of charging your EV to your personal electricity bill					✓	✓			
Home chargers are key for many people but need to be much cheaper (subsidised)					✓				

Table 2. Possible solutions generated by workshop participants (cont.)

Possible solution	Acquisition Contemplation	Acquisition Investigation	Acquisition Decision	Familiarisation	Charging at home	Charging away from home	Smart charging, V2G, V2H	Long journeys	Maintenance
Having a charging insurance package that means they will always have their car charged to a minimum level (i.e. link with Charge Fairy or similar service)					✓				
Clear communication paths between homeowners and who is responsible					✓				
Accurate real-time information about charging points – status of charger (working or not), are they in use, do they have access for someone with a mobility issue						✓			
Able to reserve a charging point ahead of arriving						✓			

Table 2. Possible solutions generated by workshop participants (cont.)

Possible solution	Acquisition Contemplation	Acquisition Investigation	Acquisition Decision	Familiarisation	Charging at home	Charging away from home	Smart charging, V2G, V2H	Long journeys	Maintenance
Indicator board at car parks etc that show how many CPs are available there									
Live info on apps about CP availability									
Adding EV chargers to all blue badge spaces									
Wider parking spaces at charging points									
Better signage at charge points to indicate clearly how to use it step by step									

Table 2. Possible solutions generated by workshop participants (cont.)

Possible solution	Acquisition Contemplation	Acquisition Investigation	Acquisition Decision	Familiarisation	Charging at home	Charging away from home	Smart charging, V2G, V2H	Long journeys	Maintenance
Collaborative effort between local authorities, parking space owners/operators and charging point operators to make public charging points more accessible including making EV charging spaces the same size as Blue Badge spaces						✓			
Single type of charging connector						✓			
Superfast chargers more widely available with charging time reduced to 5 mins						✓		✓	
Inductive charging in disabled parking spaces						✓			

Table 2. Possible solutions generated by workshop participants (cont.)

Possible solution	Acquisition Contemplation	Acquisition Investigation	Acquisition Decision	Familiarisation	Charging at home	Charging away from home	Smart charging, V2G, V2H	Long journeys	Maintenance
Charging cables coming from higher access points so they aren't on the floor					✓	✓			
Portable charging pole carried in car – plugs into socket in ground						✓		✓	
Mandate the need for a charging assistant who can help charge the car						✓		✓	
Charging hubs with several assistants who offer help with charging to everyone						✓		✓	
Offering FOB alerts for EV owners which are currently available for petrol station assistance						✓			

Table 2. Possible solutions generated by workshop participants (cont.)

Possible solution	Acquisition Contemplation	Acquisition Investigation	Acquisition Decision	Familiarisation	Charging at home	Charging away from home	Smart charging, V2G, V2H	Long journeys	Maintenance
Paying for charge using contactless card or phone						✓		✓	
Borrowing a petrol/hybrid car for long journeys as part of a lease deal but is suitably adapted for disabled consumers needs								✓	
Rescue services guaranteed to be able to help you if your EV breaks down or runs out of charge								✓	

Table 2. Possible solutions generated by workshop participants (cont.)

6. WORK PACKAGE 3: ROLE OF THE DISTRIBUTION NETWORK OPERATOR (DNO)

6.1. PRESENT DNO ROLE IN SUPPORTING VULNERABLE ELECTRICITY USERS: THE PRIORITY SERVICES REGISTER

The focus of the DNO role in supporting members of vulnerable groups is the Priority Services Register (PSR). This is a register of electricity consumers who may need extra support, particularly in the event of a power cut. Power outages taking place in the middle of the night can put a big strain on PSR services, particularly if an area with a high level of PSR members is affected.

Consumers are eligible for this extra help if they meet certain criteria. There are 30 need codes for eligible categories of need that are standard across U.K. DNOs. Eligible groups include those with chronic illnesses, people on dialysis machines, people on ventilators, people with sleep apnoea who use a CPAP breathing support machine at night, people with visual or hearing impairments, people with English as a second language, people with mobility impairments (note, there is currently not a needs code for people with high levels of anxiety). There are also temporary codes for people who have just left hospital, have experienced bereavement, are experiencing major life changes, etc.

There are several categories of priorities:

- People whose lives are dependent on medical equipment
- People needing medical equipment such as stairlifts
- People who need adapted services where SSEN offers food (via food vans), hot water, batteries, generators, having essentials delivered if people can't get out, etc.

A key issue is keeping the PSR up to date. The eligible population is constantly changing (e.g. new child, mortality) or changing residence (house moves, moving from independent living to care facilities or vice-versa, etc.)

SSEN puts considerable effort into awareness campaigns through social media, leafleting, working with wardens, engagement with community organisations, etc. Some of this effort is targeted towards specific groups that SSEN has engaged with in the past, such as people leaving hospital, people on dialysis machines, or people needing oxygen.

SSEN also uses a mapping tool to identify areas where they may be PSR gaps, e.g. areas where there are high proportions of people without English as their first language and low levels of PSR registration. It can then reach out to such groups to explain the benefits of registration.

Maintaining the PSR in compliance with GDPR requirements involves regular data cleansing: for instance, writing to register members to confirm details and see if they need further support. SSEN has agreed data sharing arrangements with water companies, NHS Scotland, Telecare, and oxygen providers. Other energy industry organisations such as energy suppliers also advise DNOs of customers with needs relevant to the PSR.

SSEN staff are trained to identify customers who can't heat their homes or suffer from cold. These customers can be referred to home energy advice services, or other services such as Green Doctor, Citizens Advice etc.

6.2. THE PSR AND CUSTOMERS WITH MOBILITY IMPAIRMENTS AND/OR HIGH LEVELS OF ANXIETY

The PSR is a direct tool that DNOs can use for supporting people with mobility impairments and people with high levels of anxiety to engage with EVs. For instance, it can flag that such people may become immobilised at home when there are power cuts.

Customers with mobility impairments are a relatively small fraction of all PSR households. SSEN is able to provide some specific help, for example deploying generators during outages to assist people who need electricity for wheelchairs or electrically assisted doors.

The most valuable service SSEN sees itself as able to provide at present to those with high levels of anxiety is staff time: a friendly ear, or support if they are having a panic attack (for instance during a power cut). Staff can also refer people to charities such as the Samaritans.

There might be potential for extending staff training to enable further support for customers with high levels of anxiety to engage with the transition to EVs.

6.3. BEYOND THE PSR

Beyond the PSR, DNOs have influence with other stakeholders in the value chains for EV acquisition and use, and the potential to draw their attention to needs of people in these vulnerable groups in relation to EV adoption and use.

6.4. POSSIBLE EXTENSIONS TO THE DNO'S ROLE

A workshop was run by ESC and SSEN staff to explore the potential for extending the DNO's role to provide greater support for people with mobility impairments and people with high levels of anxiety who have EVs. SSEN representatives were from teams covering customer experience, strategy and PSR operations. Participants were briefed on the customer journeys and pain points discussed in the preceding sections, and then took part in an ideas generation exercise designed to elicit potential solutions for the pain points, with an emphasis on solutions that could be implemented in whole or part by a DNO. Table 3 lists all the ideas generated and indicates the stage(s) of the customer journeys to which they are most relevant.

Possible solution	Acquisition Contemplation	Acquisition Investigation	Acquisition Decision	Familiarisation	Charging at home	Charging away from home	Smart charging, V2G, V2H	Long journeys	Maintenance
Create blog, vlog, podcast with real-life experiences of EV owners with disabilities	✓	✓							
Proactively manage voltage fluctuations on networks – some EVSE stop working if voltage changes much, so we should look at customers who are on PSR, have smart meter and an LCT and then see if smart meter voltage alerts trigger warning that it won't be charging so we can alert customer and then manage voltage on that section of network to stop happening again					✓				
Awareness when disabled customers are learning to drive / learn in modified electric cars or have a specific section of awareness.	✓	✓		✓					

Table 3. Possible solutions generated by DNO workshop participants

Possible solution	Acquisition Contemplation	Acquisition Investigation	Acquisition Decision	Familiarisation	Charging at home	Charging away from home	Smart charging, V2G, V2H	Long journeys	Maintenance
Create a knowledge hub of information and partner with EV manufacturers and Motability, Installers etc to promote general info across your EV, how to connect, FAQs and general hints and tips for those further along the journey, can promote PSR here as well	✓	✓		✓					
Challenge existing charging apps to become more accessible for language, or other requirements to unlock the barrier				✓	✓	✓			
Introduce a EV needs code that we send a prewarn text when we have weather warning so they charge their car					✓	✓		✓	

Table 3. Possible solutions generated by DNO workshop participants (cont.)

Possible solution	Acquisition Contemplation	Acquisition Investigation	Acquisition Decision	Familiarisation	Charging at home	Charging away from home	Smart charging, V2G, V2H	Long journeys	Maintenance
Offer to install small battery storage in homes of vulnerable customers – with view that it is there for them to use to help power their homes in event of outage, but they can use to participate in flex markets in meantime helping ensure everyone (fuel poor, mobility vulnerable) can join in at start, and not at end					✓		✓		
Create a community of 'first responders' who are prepared to share their EV charger with those in need in event of power cut or if others don't have a home charger – ideally they'll have battery storage at home, or V2G capability or even an EV that can charge others directly					✓	✓	✓		

Table 3. Possible solutions generated by DNO workshop participants (cont.)

Possible solution	Acquisition Contemplation	Acquisition Investigation	Acquisition Decision	Familiarisation	Charging at home	Charging away from home	Smart charging, V2G, V2H	Long journeys	Maintenance
Add a layer of information onto existing maps (e.g. Zapmap), for disabled motorists to feedback and filter to give their feedback on those which are more accessible						✓		✓	
Resilience service – have systems set up so EV does V2H and powers their home in event of powercut – can react ad-hoc and be scheduled					✓		✓		
As a DNO have an emergency EV partner during outages that could help a PSR customer in need if they need to charge their car to leave home or go elsewhere					✓				
Facilitate V2H or V2X to help keep the house on supply from the car during a power cut					✓		✓		

Table 3. Possible solutions generated by DNO workshop participants (cont.)

Possible solution	Acquisition Contemplation	Acquisition Investigation	Acquisition Decision	Familiarisation	Charging at home	Charging away from home	Smart charging, V2G, V2H	Long journeys	Maintenance
Have welfare vans adapted and equipped for mobile EV charging					✓	✓			
Emergency back-up service / support "bus" to help people if they are stranded whilst public charging						✓			
Battery storage charging points so if power cut there is a charge available					✓	✓			
Engage further with large EV forecourt consultants/installers to discuss how they can adapt their existing sites to make them more accessible						✓			
QR code inside charge flap linking to video of how to charge					✓	✓			

Table 3. Possible solutions generated by DNO workshop participants (cont.)

Possible solution	Acquisition Contemplation	Acquisition Investigation	Acquisition Decision	Familiarisation	Charging at home	Charging away from home	Smart charging, V2G, V2H	Long journeys	Maintenance
Partner with NHS to make hospitals and health centres EV hubs				✓	✓	✓			
Partner with NHS to make hospitals and health centres EV hubs						✓			
Educate NHS trusts re smart charging/flexible connections for EV hubs at hospitals to enable cars to come off charge without having to manually unplug if working or visiting hospitals						✓	✓		
Create an industry-agreed (ENA, Energy UK, automotive industry body like SMMT) pack of info for use in dealerships on key things to consider and timescales	✓	✓							

Table 3. Possible solutions generated by DNO workshop participants (cont.)

Possible solution	Acquisition Contemplation	Acquisition Investigation	Acquisition Decision	Familiarisation	Charging at home	Charging away from home	Smart charging, V2G, V2H	Long journeys	Maintenance
Case studies / profiles / video diary / podcasts of disabled and anxious people using EVs	✓	✓							
Use stats to create anxiety-easing info like "you're always closer to an EV charger than a petrol station", etc.		✓							
Work with EV Sellers to provide answers to DNO related FAQs – assist in sales, but also in education of customers	✓	✓							
Build on EV Charge Point Locator, so that customers we know have EV Charger, in a power cut we send them their nearest live charging point					✓				

Table 3. Possible solutions generated by DNO workshop participants (cont.)

Possible solution	Acquisition Contemplation	Acquisition Investigation	Acquisition Decision	Familiarisation	Charging at home	Charging away from home	Smart charging, V2G, V2H	Long journeys	Maintenance
Engage with organisations like Scope to make disabled people aware of the PSR or other local organisations					✓				
Regular contact with customers (annually?) to check a range of points that would help everyone in industry like PSR eligibility, if have BEV/PHEV, typical annual miles, if have any LCTs, etc.					✓				
People with high anxiety can be identified for PSR by having formal diagnosis					✓				
Use EVs and / or their chargers to safely provide a power source for medical equipment					✓		✓		

Table 3. Possible solutions generated by DNO workshop participants (cont.)

Possible solution	Acquisition Contemplation	Acquisition Investigation	Acquisition Decision	Familiarisation	Charging at home	Charging away from home	Smart charging, V2G, V2H	Long journeys	Maintenance
Revisit the definitions of vulnerability to consider customers for whom an inability to use transport when needed would make them vulnerable so we can give them the extra support and protections they need			✓		✓				
Setting up data sharing agreements with automotive industry (and charities like DMUK/Motability) to help increase visibility of customers with PSR eligibility and stimulate DNO support			✓		✓				
Create a sub-category in the PSR for EV owners/regular users of EV Charge points					✓				

Table 3. Possible solutions generated by DNO workshop participants (cont.)

Possible solution	Acquisition Contemplation	Acquisition Investigation	Acquisition Decision	Familiarisation	Charging at home	Charging away from home	Smart charging, V2G, V2H	Long journeys	Maintenance
Educate or create a training system about the end to end EV customer journey from getting a car, to installer, to charging etc for companies involved in that customer's journey	✓	✓	✓	✓					
Using car dealerships, council sites and SSEN sites as "first responder" EV charging access points					✓	✓			
"Mythbuster" campaign, led at governmental level - focused on busting those perceived concerns	✓								
Share outputs of this project to all parts of EV value chain to raise awareness of needs of vulnerable groups									

Table 3. Possible solutions generated by DNO workshop participants (cont.)

Possible solution	Acquisition Contemplation	Acquisition Investigation	Acquisition Decision	Familiarisation	Charging at home	Charging away from home	Smart charging, V2G, V2H	Long journeys	Maintenance
Incorporate vulnerability safeguards into any DSO/DNO services (like procuring flexibility) to ensure they are protected. This could be a set of principles for third parties to ensure they meet our expectations for supporting vulnerable customers					✓		✓		
Having a relationship with EV installers so we can let them know about planned maintenance in case it impacts a charging point so customers aren't going to points that aren't working						✓			
Help improve visibility to charge points and their availability		✓	✓			✓			

Table 3. Possible solutions generated by DNO workshop participants (cont.)

Possible solution	Acquisition Contemplation	Acquisition Investigation	Acquisition Decision	Familiarisation	Charging at home	Charging away from home	Smart charging, V2G, V2H	Long journeys	Maintenance
Help relive anxiety with realisation that there are far more charge points than petrol stations		✓			✓				
Work with installers to build charge hubs just outside CMZs						✓			
Temporary EV Charging service when PSR customers have a power cut					✓				

Table 3. Possible solutions generated by DNO workshop participants (cont.)

Possible solution	Acquisition Contemplation	Acquisition Investigation	Acquisition Decision	Familiarisation	Charging at home	Charging away from home	Smart charging, V2G, V2H	Long journeys	Maintenance
Workiᵑᵍ with 3rd parties (e.g. AI / smart platforms) to help ensure customers' EV charging isn't affected by powercuts / minor voltage changes					✓				
Long power cuts: deliver portable battery (or generator) to PSR members who have an EV					✓				
When registering on the PSR ask if they are an EV user					✓				
Concierge service for charging EVs for those who–need it - like a befriending service					✓	✓			
Open up SSEN charging points at offices and depots for PSR in outages					✓	✓			

Table 3. Possible solutions generated by DNO workshop participants (cont.)

Possible solution	Acquisition Contemplation	Acquisition Investigation	Acquisition Decision	Familiarisation	Charging at home	Charging away from home	Smart charging, V2G, V2H	Long journeys	Maintenance
Tell vulnerable customers (or all' that we'll deploy third party mobile charging services in event of outage to keep them charged					✓	✓			
Find a way of doubling up existing infrastructure e.g. streetlights					✓	✓			
Run a competition to help create new charge point designs, designed by disabled / anxious people for disabled / anxious people					✓	✓			
Creating a policy for wireless EV charging connections so industry and customers know that no issues with this and is very clear					✓	✓			
Help to facilitate contactless charging					✓	✓			

Table 3. Possible solutions generated by DNO workshop participants (cont.)

Possible solution	Acquisition Contemplation	Acquisition Investigation	Acquisition Decision	Familiarisation	Charging at home	Charging away from home	Smart charging, V2G, V2H	Long journeys	Maintenance
QR code inside glove box linking to video of what to do in break down/how to inflate tyres etc				✓	✓	✓		✓	
DNOs have charging points for PSR customers, enhancing the service to ensure if they have electric cars there is somewhere, they can charge it and will always have power even if a powercut					✓	✓			
Doing an audit / assessment of existing public chargepoints for accessibility						✓			
Solar charging capability for charging points					✓	✓			
Security, how do we keep points free from vandalism					✓	✓			

Table 3. Possible solutions generated by DNO workshop participants (cont.)

Possible solution	Acquisition Contemplation	Acquisition Investigation	Acquisition Decision	Familiarisation	Charging at home	Charging away from home	Smart charging, V2G, V2H	Long journeys	Maintenance
Very simple at home charging with just three options to charge either; eco, quickly or cheaply!					✓				
Alerts sent to charging app if power fails					✓	✓			
Endorse/lobby/ advocate wireless charging to be a mainstream feature/option for EV manufacturers so can be deployed sooner than later					✓	✓			
Work with installers to help install public charging near accommodation without driveways					✓	✓			
Have mobile charging points to have at events, or emergencies even vaccination points for instance						✓		✓	

Table 3. Possible solutions generated by DNO workshop participants (cont.)

Possible solution	Acquisition Contemplation	Acquisition Investigation	Acquisition Decision	Familiarisation	Charging at home	Charging away from home	Smart charging, V2G, V2H	Long journeys	Maintenance
Install charging points in laybys on main motorways where there is regular congestion or accidents or mobile charging points that can be located quickly to support on roads						✓		✓	
DNO having helpful videos about preparing for a power cut and bringing in something about EVs					✓				
Be able to let customers know where the nearest working charge point is during a power cut					✓	✓			
Offer valet charging at public locations						✓			
Use replacement electric battery packs that are being looked at be able to charge an EV					✓	✓			

Table 3. Possible solutions generated by DNO workshop participants (cont.)

Possible solution	Acquisition Contemplation	Acquisition Investigation	Acquisition Decision	Familiarisation	Charging at home	Charging away from home	Smart charging, V2G, V2H	Long journeys	Maintenance
Work with Charge Hubs/Carparks with high volume EV charging capability to build resilience (e.g. ensure they have back up supply)						✓			
In a storm we have resilience partners for things like a warm space/food –services - extend that to EV charge location points					✓				
Improve staff training in identifying and responding to the needs of people with high levels of anxiety	✓	✓	✓	✓	✓	✓	✓	✓	✓

Table 3. Possible solutions generated by DNO workshop participants (cont.)

7. WORK PACKAGES 4 AND 5: DEVELOPMENT OF THREE SELECTED CONCEPTS

7.1. SELECTION OF CONCEPTS FOR FURTHER DEVELOPMENT

Following the ideas generation outlined in the previous sections, staff from the research team and SSEN evaluated each idea on three criteria: chance of success, chance of an inadvertent negative outcome, and overall liking of the idea. The research team developed a shortlist of the most promising ideas for Feasibility-stage development based on these evaluations plus an assessment of whether the idea was known to be being trialled elsewhere already, fell within the remit of other stakeholders (e.g. Disabled Motoring UK, Motability), and whether a practical trial of the idea could be envisioned. SSEN reviewed the shortlist and selected three concepts that were developed further by the research team. The following sections describe the key areas of uncertainty for each concept, a proposed research design to address these uncertainties, and brief assessments of the scale of the opportunity and the scale of the likely costs for each concept.

7.2. COMMUNITY OF FIRST RESPONDERS

The aim of this concept is to develop a community of First Responders: members of the public who offer their services to support vulnerable people in the area who are on the Priority Services Register (PSR) and may need additional support during power cuts. Specifically, the concept as originally described was for people with a domestic EV charge point, who are not affected by a power cut, to offer PSR members who rely on an EV for personal mobility but who are affected by a power cut, the use of the First Responder's charge point. This concept is referred to here as CFR-EV. An elaboration of this concept is that First Responders might offer general support, for instance doing shopping for PSR members immobilised at home. This elaboration is referred to here as CFR-GEN.

7.2.1. KEY UNCERTAINTIES

To establish the feasibility of this concept there are several key uncertainties that need to be clarified.

7.2.1.1. SERVICE DESIGN

How would the Community of First Responders operate? What would be the role of the DNO? How would First Responders be recruited? What, if any, training would be needed for First Responders (e.g. Safeguarding?) How would the DNO maintain awareness of whether a First Responder, once recruited, was still actively engaged with their role? How the community might work and how people would engage with it need to be detailed further considering these and other questions.

7.2.1.2. USER RESPONSE

There are several questions relating to the how users interact with the community. How much would EV users on the PSR (in particular, those with physical disabilities and/or high levels of anxiety) consider being able to use a First Responder's charge point a useful service that they would draw on during a power cut? How would this vary with the duration of the power cut, or the travel distance to the First Responder?

Relating more to CFR-GEN, how much would those on the PSR (in particular, those with physical disabilities and/or high levels of anxiety) consider being able to use a First Responder for support such as doing their shopping a useful service that they would draw on during a power cut? How

would this vary with the duration of the power cut, or the time it would take for the First Responder to provide the support?

7.2.1.3. WILLINGNESS TO BE A FIRST RESPONDER

There are many unknowns regarding how the First Responders will operate in the community and what they need for it to be successful. What fraction of EV users (not on the PSR) would be willing to become a First Responder and provide access to their domestic charge point to a PSR member who was unable to charge at their own home due to a power cut? How far might these First Responders be willing to travel to support someone in need (if offering CFR-GEN)?

What fraction of the general population (not on the PSR) would be willing to become a First Responder and offer support such as doing shopping for PSR members immobilised at home?

How would these fractions vary if (a) First Responders were volunteers who provided their services for free; (b) First Responders were reimbursed by the DNO for their costs; (c) First Responders were paid a flat fee by the DNO for each PSR member they helped?

7.2.1.4. RELATIONSHIPS WITH STAKEHOLDERS

How should these new PSR services interact with other local service providers such as Local Authorities, NHS, and Social Services?

What are the views of other stakeholders such as DMUK, Motability, and Mind, on the proposed Community of First Responders (in either form?)

7.2.2. PROPOSED RESEARCH DESIGN

This section outlines several suggested research approaches that aim to address the key uncertainties outlined above. They can work independently of each other, but ideally would be carried out as a single programme of work.

7.2.2.1. STAGE 1: DESIGN SPRINTS

One way to address the uncertainties around service design is through a Design Sprint. This is typically an intensive, five-day exercise (although this is not always necessary) in which a team with the appropriate cross-section of expertise is committed full time, and completely focussed on a specific service or product design problem[8]. Key features of the process are user (target audience) input, rapid prototyping, and testing. It progresses through a series of stages, broadly lasting one day each. All members of the team are involved in all stages. The stages are, in outline[9]:

1. Problem definition – with user input
2. Ideas generation (each team member develops individual ideas for solving the problem)
3. Collective selection and development of one preferred concept – with user input
4. Prototyping
5. Testing

[8] http://www.peoplelab.energy/2019/04/10/design-sprint-hot-water-service/

[9] No two design sprints are the same, but most will broadly follow a sequence of stages like this (Knapp, Zeratsky, & Kowitz, 2016).

At the end of a design sprint (CFR-EV and CFR-GEN could each require their own sprints) the team come away with better confidence on the concept, how it could work and what further needs to be tested to prove the concept.

7.2.2.2. STAGE 2: QUALITATIVE RESEARCH WITH PSR MEMBERS

Addressing the uncertainties around user response requires an in-depth understanding of how vulnerable users who are on the PSR experience power cuts and the difficulties these experiences pose for them. The appropriate methodology is therefore qualitative research, which enables participants to voice their own perspectives. Group discussion is preferred over individual interviews in this case, as hearing the experiences of others is likely to stimulate participants' thinking and recall of their own experiences.

The proposed research design is:

Groups 1 and 2: discussion groups consisting of car users with mobility impairments (wheelchair users), ideally existing EV users.

Groups 3 and 4: discussion groups consisting of car users with high levels of anxiety. Again, ideally these will be existing EV users.

Groups 5 and 6: discussion groups with members of vulnerable groups who are registered on the PSR. These don't need to be EV users as this group will be testing CFR-GEN only.

Groups 1-4 will participate in 90-minute discussions covering the following topics:

1. Explanation of the topic by the researchers
2. Discussion of their experiences of power cuts, particularly what they have found difficult
3. Introductions to the CFR-EV and CFR-GEN concepts
4. Discussion of concepts: positives, negatives, ideas for improvement, overall assessment

Groups 5-6 will participate in shorter discussions as only 1 concept will be discussed, covering the following topics:

1. Explanation of the topic by the researchers
2. Discussion of their experiences of power cuts, particularly what they have found difficult
3. Introduction to the CFR-EV concept
4. Discussion of CFR-EV: positives, negatives, ideas for improvement, overall assessment
5. Introduction to the CFR-GEN concept
6. Discussion of CFR-GEN: positives, negatives, ideas for improvement, overall assessment

7.2.2.3. STAGE 3: EXPERT INTERVIEWS WITH STAKEHOLDER ORGANISATIONS

To address the uncertainties around relationships with stakeholders, six to ten 60-minute expert interviews will be held with staff from a range of local service providers (Local Authorities, NHS, Social Services) and wider organisations (DMUK, Motability, Transport Scotland, Mind). These will explore these stakeholders' views and feedback on the CFR-EV and CFR-GEN concepts, and, in the case of local service providers, their views on how the new CFR services should interact with theirs.

7.2.2.4. STAGE 4: QUANTITATIVE SURVEYS OF MEMBERS OF THE PUBLIC

To address the uncertainties around people's willingness to be a first responder in either CFR-EV or CFR-GEN, two quantitative surveys could be carried out[10]:

Survey 1: A survey with 400 participants who are EV users with a home charging point. This survey will aim to test willingness to become a First Responder for CFR-EV (providing access to their home charger to a PSR member who is unable to charge their own EV due to a power cut) based on several potential First Responder "propositions" e.g. if (a) First Responders provided their services for free; (b) First Responders were reimbursed by the DNO for their costs; (c) First Responders were paid a flat fee by the DNO for each PSR member they helped.

Survey 2: A survey with 400 participants who are members of the general public. This survey will aim to test willingness to become a First Responder for CFR-GEN (providing support such making a shopping trip for a PSR member if their own mobility is restricted) based on several potential First Responder "propositions", e.g. (a) First Responders provided their services for free; (b) First Responders were reimbursed by the DNO for their costs; (c) First Responders were paid a flat fee by the DNO for each PSR member they helped.

7.2.2.5. STAGE 5: SMALL SCALE TRIAL

A small-scale trial could be run to assess how the CFR-EV and CFR-GEN services would operate in practice[11] and what level of user and First Responder satisfaction is generated.

7.2.2.5.1. RECRUITMENT

Sixteen participants will be recruited, six of whom will be PSR members, ten as potential First Responders. At least two of the PSR group will be people with mobility impairments who are EV users. The remaining four PSR users will be people with high levels of anxiety, who are regular car users.

7.2.2.5.2. VEHICLES AND HOME CHARGE POINTS FOR PSR MEMBER PARTICIPANTS

The two PSR members with mobility impairments will have their own EVs. The four PSR members with high levels of anxiety will be provided with a Battery Electric Vehicle (BEV) and a domestic charge point for the duration of the trial. The BEVs will be leased and insured by the research team.

7.2.2.5.3. SIMULATED POWER CUTS

The trial duration will be one month. Simulated power cuts will occur during the month of the trial. Participants will receive no advanced warning of when these will be.

7.2.2.5.4. BACK OFFICE

A back office will be established to administer contact between PSR members and First Responders. The back office will coordinate and pair requests for support with offers of support.

[10] http://www.peoplelab.energy/2019/01/30/home-truths/
[11] http://www.peoplelab.energy/2019/07/16/do-people-enjoy-using-smart-controls/

7.2.2.5.5. BRIEFINGS

PSR participants will be briefed on the nature of the First Responder service available to them, the duration of the trial and that they should expect one or power cuts during the trial.

Participants who are provided with a BEV will also be given a detailed briefing on the vehicle and charge point, including how to use both.

7.2.2.5.6. INTERVIEWS

Participants will be interviewed after their briefings and before the trial begins. This interview will record their initial views on the difficulties people with mobility impairments or high levels of anxiety might face during a power cut and how these might be affected if they relied on a BEV for their personal mobility.

During the two weeks after the completion of the trial participants will be given a second interview that will record their experiences during the trial, and their post-trial views on the Community of First Responders concept.

7.2.2.5.7. VIDEO LOGS

Participants will be asked to make video logs of their experiences during the simulated power cuts.

7.2.3. OPPORTUNITIES AND COSTS

In this section we outline (1) the scale of the potential opportunities for the Community of First Responders concept, and (2) its approximate costs.

7.2.3.1. SCALE OF OPPORTUNITIES

Based on SSEN statistics for powercuts in the Southern DNO Region (SEPD), on first sight there appears to be a strong case that EV drivers with mobility impairments or high levels of anxiety would benefit from the Community of First Responders concept, since the average low voltage powercut duration is around three hours[12]. Powercuts of this length could limit the charging of an EV battery, since the typical home charging duration is eight to ten hours. Longer duration powercuts would clearly result in an even greater risk for these drivers, and a stronger need for first responder assistance, for CFR-EV in particular. The opportunity for CR-GEN could be even greater, whereby vulnerable consumers could be in greater need for assistance if they are stranded in a powercut – for example without any access to the internet, if food becomes spoilt or if appointments need to be kept.

The success of this proposition may depend on the geographic spread of powercuts. If a large area is affected, a larger number of first responders will also be affected and thus unable to help disabled EV drivers in the case of CFR-EV. This may be less of an issue for CFR-GEN since this doesn't necessarily rely on first responders having power.

[12] Powercut data provided by SSEN

Information on geographic spread isn't readily available. However, the number of customers affected by powercuts provides some guidance. Across the SEPD region, around 10% (302,200) of consumers were affected by powercuts in 2020/21[13]. There are 617,800 consumers on the SEPD region's PSR, of whom 96,700 have a physical disability[14]. Consumers with high levels of anxiety are not currently offered PSR services. In 2014, 6.6% of the English population were recorded as having high levels of anxiety[15]. Assuming the same proportion of SSEN consumers are affected, this would suggest there are around 204,000 consumers with this difficulty.

7.2.3.1.1. CALCULATING POTENTIAL INTEREST IN THE CFR SERVICE

The following assumptions were made to calculate the maximum potential level of interest for the CFR service:

1. There is no overlap between mobility impaired consumers and those with high levels of anxiety (in reality, there will be some overlap but there are no readily available statistics to calculate this).
2. All of those with high levels of anxiety will register for PSR services (again unlikely).
3. The proportion of PSR, mobility impaired and high anxiety consumers affected by powercuts each year is the same as that for all consumers, i.e. 10%.
4. The number of consumers affected by powercuts and average length of powercuts in future years is the same as that for 2020/21.

We therefore estimate approximately 61,780 PSR consumers, 9,670 mobility impaired consumers and 20,390 consumers with high levels of anxiety are affected by powercuts each year in the SEPD area.

Furthermore, 60% of disabled[16] people in England hold a driving licence (the comparative figure for people without a disability is 78%)[17]. Assuming the same proportion applies to people with high levels of anxiety (which may be an underestimate), this suggests there are 58,020 mobility impaired and 122,300 anxious drivers in the SEPD region. We therefore estimate 5,800 mobility impaired drivers and 12,230 drivers with high levels of anxiety are affected by powercuts each year in the SEPD area.

EV take-up in the region is higher than the national average and is predicted to grow substantially in the next 10 years (to around 15% of all drivers)[18]. Assuming that take up of EVs by mobility impaired people and people with high levels of anxiety follows a similar trend, the opportunity presented by both CFR-EV and CFR-GEN for helping mobility impaired/anxious drivers is likely to grow significantly over the next 10 years.

[13] Powercuts data provided by SSEN
[14] Statistics provided by SSEN
[15] McManus, S., Bebbington, P.E., Jenkins, R., & Brugha, T. (2014). Mental Health and Wellbeing in England: the Adult Psychiatric Morbidity Survey 2014. Leeds, England: NHS Digital.
[16] This report generally uses the term "mobility impaired" rather than "disabled"; exceptions are made, as here, where the term "disabled" is used in the source of the data
[17] Department of Transport (add full details)
[18] CVEI market design and system integration report (add full details)

The maximum potential number of mobility impaired and anxious EV drivers in 10 years who may wish to use the service is estimated at 870 and 1,835 respectively. This assumes 15% of drivers in each vulnerable group have EVs by then[19], with 10% experiencing a powercut each year.

However, this is an estimated upper limit, as many may not need to use the service because their cars are already sufficiently charged before the powercut, they do not need to drive anywhere during the powercut or they decide to delay using the car until the powercut has ended and they can recharge their car again.

7.2.3.2. FACTORS DETERMINING COSTS

The following factors will be important in determining the costs of the Community of First Responders

- Set up costs of establishing first responder database
- Recruitment of first responders – the number is likely to be much larger for CFR-GEN than CFR-EV
- Training of first responders
- Promotion of service to potential beneficiaries
- Ongoing costs of maintaining database and ensuring first responders are actively engaged
- Operation of service as and when required (many drivers may not require the service for the reasons set out above)
- Recompense to first responders, if not provided free: either flat rate/PSR consumer helped or as schedule of fees according to level of service provided

The above costs may vary according to whether SSEN provides the service in-house or employs a third party to run the service. If the latter, SSEN will still incur costs with respect to project managing, monitoring, and evaluating the third-party provider.

We assess the costs associated with CFR-EV as **low** in the early stages of the initiative since it does not require the installation of any physical assets and the establishment and maintenance of a database should be relatively modest. However, these costs will grow as EV ownership by both first responders and mobility impaired/high levels of anxiety EV drivers increases, particularly if the scheme involves some form of financial recompense to first responders.

We assess the costs associated with CFR-GEN similarly as **low** in the early stages. However, they are likely to be higher than CFR-EV given that the potential pool of first responders is much larger since it doesn't require them to own an EV. Again, the costs will grow as EV ownership among mobility impaired/high levels of anxiety drivers increases. There may also be additional costs associated with ensuring that neither PSR members or first responders are taken advantage of in the provision of food and supplies for PSR members. Exploring issues and risks such as this in the feasibility stage research would be very useful.

[19] This is the average percentage of all cars that are BEVs predicted in the CVEI whole system model. See Figure 3.

7.3. V2H RESILIENCE SERVICE

7.3.1. INTRODUCTION

The aim of this concept is to provide a service that facilitates households with EVs to adopt Vehicle to Home (V2H) for their EV charging. As described in Section 2, V2H is a two-way capability: it enables an EV's battery to be charged from the mains, and to be discharged to provide a supplementary electricity supply to the house. If on a suitable tariff, the household can in principle charge the EV's battery when the price of electricity is low and supply the household demand when the price of electricity is high, thus reducing overall household electricity costs. This benefit is limited by the capacity of the EV's battery, but with many BEV batteries now exceeding 40kWh it has some potential – though of course the need to retain some charge in the EV for mobility needs means that the limit may be smaller in practice.

Apart from the cost saving, a household equipped with an EV and a V2H system can potentially use charge stored in its EV's battery to provide a backup source of electricity for domestic loads during a power cut – subject to the limits mentioned above. This may be enough to power both essential medical equipment at home, and other domestic equipment.

While EVs remain in the minority at the moment (around 3% of all cars or vans on the road) it is anticipated that their uptake will increase rapidly over the next decade. As an indication of this around 10% of new cars and vans sold in 2021 were electric.

A DNO-operated service could provide support for V2H adoption by any EV-using household within its operating areas, as this would increase overall resilience to power cuts. It could, in addition, provide extra support for V2H adoption to households on the PSR, such as a grant or other subsidy to facilitate V2H adoption for these households given their additional vulnerability in power cuts.

7.3.2. KEY UNCERTAINTIES

7.3.2.1. PRESENT COMMERCIAL AVAILABILITY OF V2H EQUIPMENT

The market for suitable V2H control, EV charging, and metering equipment for domestic use is constantly changing. A detailed survey of the market including formal quotes from suppliers, with deployment lead times, for substantial numbers of installations is needed to test the feasibility of introducing this concept in practice.

7.3.2.2. REVIEW OF PRESENT REGULATORY AND MARKET FRAMEWORKS IN THE U.K.

Likewise, it will be necessary to review the present state of regulatory and market frameworks, and any impending changes to these, to ensure that any deployment of this concept is fully compliant.

7.3.2.3. WHAT FORM SHOULD THE CONCEPT TAKE?

The concept at present only exists in outline form. At the feasibility stage there will be a need to develop one or more detailed concept designs, using a co-development process involving potential users, that map out an appealing Customer Value Proposition (CVP) and Customer Experience Model (CEM); following which there will also be a need to map out a practical operating model for delivering the CVP and CEM.

7.3.2.4. HOW APPEALING WOULD THIS CONCEPT BE TO DOMESTIC ELECTRICITY USERS WITH EVS?

Once the concept is better defined its appeal needs to be tested among domestic electricity users with EVs, and among those likely to adopt an EV in the near future.

7.3.2.5. HOW EFFECTIVE WOULD V2H BE IN PROVIDING A BACK-UP ELECTRICITY SUPPLY DURING A POWER CUT?

Finally, without much experience of V2H in the consumer market so far, there is uncertainty around how effective V2H would be as a means of providing a back-up electricity supply during a power cut.

7.3.3. RESEARCH DESIGN

7.3.3.1. STAGE 1: DESK RESEARCH

The first step needs to be a programme of desk research to address the uncertainties around commercial availability of suitable domestic equipment, and market and regulatory frameworks.

7.3.3.2. STAGE 2: DESIGN SPRINT WITH EXPANDED USER CO-DESIGN

To address the uncertainties around concept design we propose that a Design Sprint method is used in the first instance. This would take a similar form as outlined in the previous section. Key features of the process are user (target audience) input, rapid prototyping, and testing. It progresses through a series of stages, broadly lasting one day each. All members of the team are involved in all stages. The stages are, in outline:

1. Problem definition – with user input
2. Ideas generation (each team member develops individual ideas for solving the problem)
3. Collective selection and development of one preferred concept – with user input
4. Prototyping
5. Testing

In this case we propose an expanded Step 3 involving user co-development workshops. These will take place after the design sprint team has shortlisted two or three preferred concepts. Participants will include existing EV users, and members of the PSR who are either EV users or who indicate a likelihood to acquire an EV within the near future. Following the workshops, the design sprint team will select one concept to protype, incorporating user input from the workshops into the prototype design.

7.3.3.3. STAGE 3: QUANTITATIVE SURVEY OF MEMBERS OF THE PUBLIC

To address the uncertainties around how appealing this concept would be to members of the public, a quantitative survey will be carried out. The survey will be conducted with 200 participants who are EV users with a home charging point, and 200 participants who are members of the PSR and have expressed willingness to adopt an EV in the near future.

7.3.3.4. STAGE 4: PRACTICAL TRIAL OF THE EFFECTIVENESS OF V2H IN A POWER CUT

To address the uncertainties around how effective V2H would be at providing a back-up electricity supply in the event of a power cut, we propose a small-scale trial involving six households. This trial could be conducted within The ESC's Living Lab.

7.3.3.4.1. RECRUITMENT

Participating households would be recruited from among members of the Living Lab with their own EVs. In principle participating households might be expected to make some cost savings as a consequence of having a V2H system installed so an additional incentive for participation may not be needed.

7.3.3.4.2. V2H PROVISION

Participating households would be provided with a V2H-enabled system by the research team. The specific form this might take would become clear after Stage 1 has identified commercially available equipment and tariffs.

7.3.3.4.3. SIMULATED POWER CUTS

The trial duration will be one month. Simulated power cuts will occur during the month of the trial. Participants will receive no advanced warning of when these will be.

7.3.3.4.4. BRIEFINGS

Participants will be briefed on the operation of the V2H system and tariff that they are provided with. They will be told to expect one or more simulated power cuts during the trial period.

7.3.3.4.5. INTERVIEWS

Participants will be given an initial interview after their briefings and before the trial begins. This interview will record their initial views on the benefits of V2H and how they might make use of it during a power cut.

During the two weeks after the completion of the trial participants will be given a further interview. This will record their experiences of V2H and how they used it generally over the trial period, their experiences of V2H and how they used it specifically during the simulated power cuts, and their post-trial views on V2H generally.

7.3.3.4.6. VIDEO LOGS

Participants will be asked to make video logs of their experiences of using V2H during the trial period and during simulated power cuts.

7.3.4. OPPORTUNITIES AND COSTS

In this section we outline (1) the scale of the potential opportunities for the V2H Resilience Service concept, and (2) its approximate costs.

7.3.4.1. SCALE OF OPPORTUNITIES

This proposal has two key benefits:

- The potential for the EV owner to make cost savings by taking advantage of lower electricity prices at certain times, storing energy in their EV's battery for use at other times when prices are higher
- The provision of electricity to power domestic equipment during powercuts. In the case of mobility impaired drivers this may include mobility aids, medical equipment, and other domestic needs.

Unlike the CFR service, this initiative does not rely on willing third parties to support mobility impaired drivers or drivers with high levels of anxiety. However, unlike CFR, such drivers will not have access to alternative charging facilities for their EVs in the event of powercuts. Nevertheless, providing their EVs have sufficient charge, this service will provide them with instant access to electricity rather than rely on generators, which may take time to arrange.

Assuming the costs of providing the V2H facility to beneficiaries is covered by SSEN, this proposition could be very attractive. The pool of potential beneficiaries will be larger than the CFR proposition because it could include all mobility impaired drivers and all drivers with high levels of anxiety who have EVs (provided they have access to off street parking), rather than only the 10% of such EV drivers affected by powercuts. It will also provide benefits in the form of continuing power supply during powercuts.

As stated above, there are currently an estimated 58,020 mobility impaired drivers and 122,300 drivers with high levels of anxiety in the SEPD area. We estimate 40,610 mobility impaired drivers and 85,630 drivers with high levels of anxiety have off-street parking, assuming the proportion of mobility impaired drivers and those with high levels of anxiety who also have off street parking is the same as that for all households (70%)[20].

The ability of the EV to provide sufficient power to homes during powercuts will depend on the electricity demand of the home and the length of the powercut (as well as the extent to which the EV is charged).

The opportunity presented by this proposition will grow as the number of mobility impaired/anxious drivers with EVs (and off-street parking) grows.

An estimated 6,090 mobility impaired and 12,840 high-anxiety drivers will have EVs (and off-street parking) in 10 years' time (this assumes 15% of such drivers will have EVs[21]).

7.3.4.2. FACTORS DETERMINING COSTS

The main costs are those of installing a V2H facility (including any internal works to electricity circuits/equipment) at each user's home. These are one-off costs; unlike the CFR proposition there are no on-going costs associated with this concept.

[20] Lipson, M. & Skippon, S.M. (2020). Electric Vehicles: What will persuade the 30% of households without off-street parking to adopt electric vehicles? Available from ESC.
[21] See Figure 3.

Some of these costs can be offset by savings made by SSEN in needing to provide fewer generators during powercuts, which are ongoing costs. SSEN may still need to provide generators for longer powercuts.

We assess the costs associated with this proposition as **low** in the early stages given the current limited number of potential beneficiaries (mobility impaired/anxious EV drivers with off street parking). However, these costs will grow as EV ownership increases.

We assess the potential costs in 10 years' time as **medium** given the likely significant cost associated with installing a V2H facility. Some of these costs may be offset, as stated above, through the reduced requirement to provide generators during powercuts.

7.4. TEMPORARY EV CHARGING SERVICE WHEN PSR MEMBERS HAVE A POWER CUT

7.4.1. INTRODUCTION

The aim of this concept is to provide an at-home EV charging service for PSR members during power cuts. As outlined in Section 1, several versions of at-home charging services are commercially available or close to market. These include:

1. Mobile charging, in which a charge delivery vehicle (with charge stored in a large capacity onboard battery) arrives at the location where an EV is parked, and transfers charge into the parked EV
2. Mobile charging staff, in which an employee of the service provider arrives on an electric scooter at the location where the EV is parked, then drives the EV off to a charging station outside the power cut area, charges it, and returns it to the location where it was parked
3. A service where a portable battery is delivered to the PSR member's home; the battery can then be used to transfer charge to the member's EV

The concept could potentially be extended to include provision of electricity for essential medical equipment in the home, and for other domestic loads. This would be straightforward for option 3 (using larger batteries or more than one battery). In the cases of options 1 and 2, it would require some form of storage at the home, perhaps by providing V2H capability for the home's EV, with the service delivering charge to the EV so that it could provide both personal mobility and also a temporary electricity supply to the home.

7.4.2. KEY UNCERTAINTIES

7.4.2.1. COMMERCIAL ARRANGEMENTS

Commercial arrangements are not specified in the present concept and are a key uncertainty. Would the services be delivered via contracts with suppliers or would they be delivered by the DNO directly, perhaps with a technology licence from the supplier?

7.4.2.2. APPEAL TO PSR MEMBERS WITH EVS

At the moment this concept (and its various options) has not been tested with PSR members so its appeal is uncertain, as are PSR member preferences between the options, and the appeal of adding electricity supply for essential medical equipment or other domestic loads.

7.4.3. RESEARCH DESIGN

7.4.3.1. STAGE 1: DESK RESEARCH

Desk research would be carried out to determine what commercial models would be most suitable for options 1, 2, and 3. In particular, for each option this research would determine whether it would be more commercially feasible from the DNO perspective if the service was contracted out to a supplier or delivered directly by the DNO.

7.4.3.2. STAGE 2: QUALITATIVE RESEARCH & CONCEPT DEVELOPMENT WITH PSR MEMBERS

Addressing the uncertainties around user response requires an in-depth understanding of how vulnerable users who are on the PSR experience power cuts and the difficulties these experiences pose for them. The appropriate methodology is therefore qualitative research, which enables participants to voice their own perspectives. Group discussion is preferred over individual interviews in this case, as hearing the experiences of others is likely to stimulate participants' thinking and recall of their own experiences.

The proposed qualitative research design is:

Groups 1 and 2: discussion groups consisting of car users with mobility impairments (wheelchair users), ideally existing EV users.

Groups 3 and 4: discussion groups consisting of car users with high levels of anxiety. Again, ideally these will be existing EV users.

Groups discussions will cover participants' experiences of power cuts, particularly what they have found difficult; introduction to each option, and discussion of positives, negatives, ideas for improvement, and overall assessment of each option.

7.4.3.3. STAGE 3: QUANTITATIVE SURVEY OF MEMBERS OF THE PUBLIC

To address the uncertainties around how appealing this concept would be to members of the public, a quantitative survey will be carried out. This survey will have 400 participants. 200 of these will be PSR members with mobility impairments who either have an EV or are car users who have expressed willing to consider having an EV as their next car. The other 200 will be PSR members who are car users and have high levels of anxiety.

The survey will explore how far the participants have experienced difficulties during power cuts, and participants' responses to options 1, 2 and 3 as developed in the Stage 2 research.

7.4.3.4. STAGE 4: MINI DESIGN SPRINT

Given that all three options are available or close to launch in the U.K. market, a full Design Sprint is not necessary, but a Mini Design Sprint (lasting 2 or 3 days, to be determined by the outcomes of Stages 1, 2, and 3). The focus of this will be the selection of a preferred concept and the incorporation of learnings from Stages 2 and 3 into the design of the preferred concept.

7.4.3.5. STAGE 5: SMALL SCALE TRIAL

To address the uncertainties around how effective this concept would be at enabling vulnerable PSR members with an EV to access personal mobility in the event of a power cut, we propose a small-scale trial involving six households. This trial could be conducted within the ESC's Living Lab. It will test two of the three options, selected based on the outcomes of stages 1-4. The trial will last for two months, and each participant will experience one option in the first month, and the other in the second month.

7.4.3.5.1. RECRUITMENT

Participating households would be recruited from among members of the Living Lab who have expressed willingness to consider acquiring a BEV. Three participants will have mobility impairments (wheelchair users) and be Blue Badge holders. Ideally, they will have their own EVs; however, if it proves difficult to recruit participants with their own EVs, these will be provided for the duration of the trial by the research team. The other three participants will have high levels of anxiety.

7.4.3.5.2. VEHICLES AND HOME CHARGE POINTS FOR PSR MEMBER PARTICIPANTS

Participants who do not have their own EVs will be provided with a Battery Electric Vehicle (BEV) and a V2H capable Type 3 domestic charge point for the duration of the trial.

7.4.3.5.3. SIMULATED POWER CUTS

The trial duration will be two months. Simulated power cuts will occur during the month of the trial. Participants will receive no advanced warning of when these will be.

7.4.3.5.4. PROVISION OF SUPPORT SERVICES

Depending on which options are chosen, the support services will be provided either by suppliers of the relevant services as sub-contractors of the principal research contractor, or by the research contractor themselves. The services will only be deployed during simulated power cuts so the logistics of this will not be a substantial burden.

7.4.3.5.5. BRIEFINGS

Participants will be briefed on the nature of the EV charging services available to them. They will be told to expect several simulated power cuts during the trial period.

Participants who are provided with a BEV will be given a detailed briefing on the vehicle and charge point, including how to use both.

7.4.3.5.6. INTERVIEWS

Participants will be given an initial interview after their briefings and before the trial begins. This interview will record their initial views on the benefits of the EV charging services and how they might make use of these during a power cut.

During the two weeks after the completion of the trial participants will be given a further interview that will record their experiences of the EV charging services and how they used them generally over the trial period, and their post-trial views on the EV charging services generally.

7.4.3.5.7. VIDEO LOGS

Participants will be asked to make video logs of their experiences of using the EV charging services during the trial period and during simulated power cuts.

7.4.4. OPPORTUNITIES AND COSTS

7.4.4.1. SCALE OF OPPORTUNITIES

The estimated number of EV drivers likely to benefit from this service will be similar to that estimated for the CFR-EV proposition since both will only provide the service during powercuts. We estimate that by 2032, a maximum of 870 mobility impaired drivers and 1,835 EV drivers with high levels of anxiety may wish to use the service per annum (based on the estimated number of EV drivers affected by powercuts per annum – see Section 7.2.3).

Many potential beneficiaries may not need to use the service because their cars were sufficiently charged before the powercut, they do not need to drive anywhere during the powercut or they decide to delay using the car until the powercut has ended and they can recharge their car again.

7.4.4.2. FACTORS AFFECTING COSTS

- Provision of at-home service as and when required (many drivers may not require the service for the reasons set out above)
- Whether the service is contracted out (e.g. Charge Fairy, Zumo, Zipcharge) or delivered directly by the DNO

We assess the costs associated with this proposition as **fairly low** in the early stages of the initiative since the number of mobility impaired/anxious drivers is very small. However, these costs will grow as EV ownership by mobility impaired/anxious EV drivers increases. The costs are likely to be higher for this proposition than the CFR service because it entails either employee costs (if delivered by the DNO) or commercial rates (if delivered by a contracted provider), as opposed to the likely lower costs associated with CFR's reliance on volunteers.

8. CONCLUSIONS

- The market for electric vehicles appears to be taking off in the U.K. The range of BEVs on the market has increased substantially in the past 5 years and is now sufficient for a large percentage of mainstream consumers to be willing to consider them as both second and main cars in their households. New BEV sales have not yet caught up with these figures but are expected to do so as vehicle prices decrease, and perceptions of public charging infrastructure improve.
- The all-electric range of PHEVs currently on the market in the U.K. is generally too low to attract similar levels of interest, and their present rate of uptake is consequently lower than that of BEVs. Some market commentators suggest that the market opportunity for PHEVs is already in decline due to the rapid improvement in the range of BEVs.
- Around 70% of U.K. households have access to off-street parking and so can charge their EVs at home. The remaining 30% will be dependent on public charging points for their everyday charging. A more extensive network of public charging points will also be needed to support people making longer journeys. There is a trend towards deploying more rapid (50kW) and higher charging rate (100+ kW) charging points at public locations, and there are innovations in charge point design, such as lamp-post chargers and pop-up chargers, that facilitate deployment in a wider range of locations.
- Around 5.9% of drivers with full U.K. driving licence holders also hold "blue badge" disabled driver parking permits. The potential difficulties that drivers with mobility impairments will face in engaging with electric vehicles have begun to be recognised, but so far very little has been done to address these difficulties. For instance, research participants told us they had seen few if any charge points in disabled parking bays in their localities.
- Around 6.6% of adults have high levels of anxiety in any given week. The potential difficulties that drivers with high levels of anxiety will face in engaging with electric vehicles have not yet been widely recognised. This research highlights that this vulnerable will experience substantial difficulties at many stages in the customer journeys associated with EV acquisition and use.
- This project mapped out customer journeys for all key parts of the experience of acquiring and using an electric vehicle: three stages of acquisition (contemplation, investigation, and decision); familiarisation; charging at home; charging away from home; smart charging; making long journeys; and maintenance.
- People with mobility impairments identified multiple pain points in the customer journeys. Many of these were focussed on the prospect of charging an EV, especially at public chargers. There were also many pain points identified around the process of acquiring an EV.
- People with high levels of anxiety identified pain points at all parts of the customer journey. The prospects of having to visit a car showroom and making a long journey were particularly daunting.
- The three workshops generated 44 ideas/concepts for mitigating these pain points.
- The main role that the DNO can play in facilitating these two vulnerable groups is via Public Services Register (PSR), specifically in ensuring that their personal mobility is not compromised by inability to charge their EV during power cuts. Another important role that the DNO can play is in using its influence among other stakeholders to effect change.
- Although people with mobility impairments are able to join the PSR now, there is not a PSR category for those with high levels of anxiety; nor indeed for people with other mental health issues. DNOs should update the PSR needs code to address this.
- The project generated a further 71 ideas/concepts for ways that the DNO could improve the potential for members of the two vulnerable groups to engage in using EVs, many of which were focussed on mitigating the problems they might encounter during power cuts.
- Three ideas/concepts were explored in more depth to establish what would be required for a feasibility study, an assessment of the likely scale of the opportunity, and an assessment of the likely scale of costs involved. These ideas were:
    - **Setting up a Community of First Responders.** This has the potential to help around 870 EV drivers with mobility impairments and 1835 EV drivers with high levels of anxiety in the SEPD

area by the early 2030s. Costs are estimated to be low for both variants of this concept – where first responders outside the powercut area provide PSR members with access to their home EV chargers, and where they provide other support such as making shopping trips on behalf of EV drivers on the PSR.

  - **Enabling PSR households to use Vehicle to Home (V2H) to provide back-up power for their dwelling during a power cut.** This has the potential to help around 6090 EV drivers with mobility impairments and 1835 EV drivers with high levels of anxiety in the SEPD area by the early 2030s. Cost are estimated to be low in the early years, rising to medium by the early 2030s as EV uptake increases.
  - **Providing a temporary EV charging service during power cuts**. This has the potential to help around 870 EV drivers with mobility impairments and 1835 EV drivers with high levels of anxiety in the SEPD area by the early 2030s. Cost are estimated to be fairly low for this concept.
- There is considerable potential to improve charge point design to make charging more accessible to users with mobility impairments, but charge point innovations intended to address the needs of mobility-impaired drivers remain largely at the trial/pilot stage so far.
- Inductive (wireless) charging would considerably reduce the difficulties experienced by members of both vulnerable groups when charging, both at home and at public charging locations. Unfortunately, this technology is not yet deployed on a wide scale.
- There are several nascent services that offer to assist with charging: for instance, mobile charging (where a user's vehicle is charged from a mobile source); valet charging (where staff take a user's EV to a nearby charge point, charge it, and return it), and mobile batteries (that can charged at home and wheeled to the EV). All of these have potential benefits to offer to members of the two vulnerable groups, at a cost.
- Some forms of Mobility as a Service, such as ride hailing, could considerably reduce the difficulties experienced by members of both vulnerable groups in engaging with electric vehicles. A ride hailing service that operates EVs would offer the potential for them to use EVs for their personal travel without the need to own/lease and operate a vehicle themselves. Ride hailing services are increasingly common, and we can expect them to move towards wider EV use in the near future. However, the subjective impressions of research participants were that few of their vehicles are adapted for wheelchair users at present.
- Fully autonomous ("driverless") cars likewise could considerably reduce the difficulties experienced by members of both vulnerable groups in engaging with electric vehicles. However fully autonomous cars remain a rather distant prospect.
- People with other mental health difficulties, and members of other vulnerable groups such as those with learning difficulties and acquired brain injuries may also experience substantial difficulties; some similar to, some different from those highlighted here. Their needs have not been widely recognised and to date not researched.

LICENCE/DISCLAIMER
Energy Systems Catapult (ESC) Limited Licence for **EQUAL EV PHASE 2: TECHNOLOGY VIABILITY AND FUTURE SERVICES FOR VULNERABLE CUSTOMERS**

ESC is making this report available under the following conditions. This is intended to make the Information contained in this report available on a similar basis as under the Open Government Licence, but it is not Crown Copyright: it is owned by ESC. Under such licence, ESC is able to make the Information available under the terms of this licence. You are encouraged to Use and re-Use the Information that is available under this ESC licence freely and flexibly, with only a few conditions.

Using information under this ESC licence
Use by You of the Information indicates your acceptance of the terms and conditions below. ESC grants You a licence to Use the Information subject to the conditions below.

You are free to:
- copy, publish, distribute and transmit the Information;
- adapt the Information;
- exploit the Information commercially and non-commercially, for example, by combining it with other information, or by including it in your own product or application.

You must, where You do any of the above:
- acknowledge the source of the Information by including the following acknowledgement:
- "Information taken from [REPORT NAME], by Energy Systems Catapult";
- provide a copy of or a link to this licence;
- state that the Information contains copyright information licensed under this ESC Licence.
- acquire and maintain all necessary licences from any third party needed to Use the Information.

These are important conditions of this licence and if You fail to comply with them the rights granted to You under this licence, or any similar licence granted by ESC, will end automatically.

Exemptions
This licence only covers the Information and does not cover:
- personal data in the Information;
- trademarks of ESC; and
- any other intellectual property rights, including patents, trademarks, and design rights.

Non-endorsement
This licence does not grant You any right to Use the Information in a way that suggests any official status or that ESC endorses You or your Use of the Information.

Non-warranty and liability
The Information is made available for Use without charge. In downloading the Information, You accept the basis on which ESC makes it available. The Information is licensed 'as is' and ESC excludes all representations, warranties, obligations and liabilities in relation to the Information to the maximum extent permitted by law.

ESC is not liable for any errors or omissions in the Information and shall not be liable for any loss, injury or damage of any kind caused by its Use. This exclusion of liability includes, but is not limited to, any direct, indirect, special, incidental, consequential, punitive, or exemplary damages in each case such as loss of revenue, data, anticipated profits, and lost business. ESC does not guarantee the continued supply of the Information.

Governing law
This licence and any dispute or claim arising out of or in connection with it (including any noncontractual claims or disputes) shall be governed by and construed in accordance with the laws of England and Wales and the parties irrevocably submit to the non-exclusive jurisdiction of the English courts.

Definitions
In this licence, the terms below have the following meanings: 'Information' means information protected by copyright or by database right (for example, literary and artistic works, content, data and source code) offered for Use under the terms of this licence. 'ESC' means Energy Systems Catapult Limited, a company incorporated and registered in England and Wales with company number 8705784 whose registered office is at Cannon House, 7th Floor, The Priory Queensway, Birmingham, B4 6BS. 'Use' means doing any act which is restricted by copyright or database

right, whether in the original medium or in any other medium, and includes without limitation distributing, copying, adapting, modifying as may be technically necessary to use it in a different mode or format. 'You' means the natural or legal person, or body of persons corporate or incorporate, acquiring rights under this licence.

OUR MISSION

TO UNLEASH INNOVATION AND OPEN NEW MARKETS TO CAPTURE THE CLEAN GROWTH OPPORTUNITY.

ENERGY SYSTEMS CATAPULT
7TH FLOOR, CANNON HOUSE,
18 PRIORY QUEENSWAY,
BIRMINGHAM, B4 6BS.

ES.CATAPULT.ORG.UK
@ENERGYSYSCAT