



## Final report

Understanding the costs and impacts of potential approaches to providing electric vehicle charging for households without private off-street parking

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Report for the Climate Change Committee  
JJ2/1121

**Customer:****Climate Change Committee****Customer reference:**

JJ2/1121

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**Contact:**

Harry Scammell  
Ricardo Energy & Environment  
Gemini Building, Harwell, Didcot, OX11 0QR,  
United Kingdom

**t:** +44 (0) 1235 75 3227**e:** Harry.scammell@ricardo.com

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and OHSAS18001

**Author:**

Harry Scammell, James Roscoe, Micaela  
Zabalo, Ferdinand Turrall

**Approved By:**

Nikolas Hill

**Date:**

13 May 2022

**Ricardo Energy & Environment reference:**

Ref: ED16003- Issue Number 1

## Executive summary

As the UK's road vehicle fleet transitions to electric vehicles, there will be a corresponding necessity to increase the provision of supporting infrastructure for these vehicles. For households with access to private off-street parking, the cheapest and most convenient method of charging will be installing a home charger and charging on their driveway. For households without access to private off-street parking, there will be a reliance on the public charging network to provide energy for their electric vehicles. There is currently a lack of public electric vehicle chargers for households without off-street parking in the UK. These public chargepoints are typically more expensive to invest in than off-street home slow chargers, and this therefore deters investment and hence their availability. Ricardo Energy & Environment ('Ricardo') has therefore been commissioned to provide the Climate Change Committee (CCC) "Understanding the costs and impacts of potential approaches to providing electric vehicle charging for households without private off-street parking". Specifically, the main questions to be answered by this study are:

1. Understanding the charging wants and needs of electric vehicle (EV) users without access to private off-street parking.
2. Understanding of the cost and wider impacts of charging for households without access to private off-street parking under different business models for different charger types.
3. Understand how charging behaviour might be impacted by particular types of business models for different charger types and locations.
4. Provide recommendations for the different actors involved in the deployment of EV charging infrastructure for optimal roll-out of public infrastructure.

This document provides details on attractive charging options and charging behaviour for EV users without access to private off-street parking, and viable business models for public chargepoints. The cost data and methodology for calculating the cost of charging for different locations under different business models is also provided. Part of the research involved a targeted stakeholder consultation exercise to provide a deeper understanding into the public charging state-of-play. These stakeholders included Local Authorities (LAs), Charge Point Operators (CPOs) and Distribution Network Operators (DNOs).

The outputs from the project identified a set of parameters which EV users find attractive when seeking a public charge point, which include faster charging, greater reliability, and easier payment methods. The research has also indicated that there is unlikely to be a single charging location preference for EV users without access to private off-street parking, with on-street residential, workplace, destination and en-route charging all representing large proportions of total charge events for these users.

### Summary of key findings for the review of attractive charging options

- The most attractive charging options are faster chargers that can work immediately, have a high level of reliability, and are readily available for use with short connection times<sup>1</sup>.
- Business models need to incorporate a rapid and effective maintenance programme to increase the reliability of chargepoints.
- Faster charging speeds and higher utilisation rates of chargers can be expected to provide increasing opportunities for improved business cases for charging providers.
- Free charging presents a significant advantage in the public charging experience, either offered through manufacturer incentives or as a result of a chargepoint operator's business model.

Current business models for public chargepoints are largely concession contracts, where the LA facilitates the land/existing infrastructure for the chargepoint, and the CPO operates and maintains the chargepoint. The LA can fix the cost to the end user for the chargepoint as part of the concession

<sup>1</sup> Note: survey responses do not account for cost of charging or whether EV users would be willing to pay more for these services.

contract, and can also take a share of the revenue from the chargepoint in some cases. In almost all cases the 75% CAPEX funding grant from OZEV has been utilised which indicates the LAs reliance on this funding. CPOs often pay the remaining 25% of the capital costs for chargers.

There are other business models which may be viable in the future, with rapid charging hubs and en-route rapid charging offering a better commercial case, and so can likely attract private investment if the contracts are long enough to recover the cost of investment (around 15-20 years). The business model will depend heavily on the utilisation rate (total kWh delivered per charger per day) of the chargepoint, with higher utilisation rates potentially resulting in lower costs to end users. This could improve the business case for public charger points in future, as the uptake of EVs increases and charger utilisation improves.

Typically, deploying chargepoints in rural areas is challenging. A lower uptake of EVs in these locations result in a lower utilisation of the chargepoints. This makes the locations less attractive for CPOs to install chargepoints in rural areas. However, there are some interesting business models for rural areas. One LA declared a climate emergency and has received fully funded chargepoints as a result. These chargepoints have been placed in community centres around the county and are used to increase tourism within the local area. The chargepoints have dual payment methods (contactless payment or RFID cards), and the local residents can get cheaper charging through using the RFID cards and tourists pay a higher fee using contactless payments. These chargepoints have been well utilised, and could increase the uptake of EVs in these areas as a result.

For the purposes of this project, seven (BM1 to BM7) business models have been selected at different locations and charger types to take forward for the cost calculations -see Table ES1. These business models will have different types and lengths of contracts, with the most common being concession contracts for on-street residential. Long contracts will be applicable for the higher-powered chargers.

**Table ES1: Summary of the selected business models**

Business model	Charger location	Description
BM1	On-street residential	Lamp post chargers (3 to 5.5 kW AC power rating)
BM2	On-street residential	Fast charging on-street (7 to 22 kW AC)
BM3	Destination charging	Destination cost recovery model (22 kW AC to 150 kW DC)
BM4	Destination charging	Destination fully funded model (22 kW AC to 150 kW DC)
BM5	Destination charging	Destination profit making model (22 kW AC to 150 kW DC)
BM6	Rapid charging	En-route rapid charging (50 to 150 kW DC)
BM7	Rapid charging	Forecourt rapid charging (50 to 150 kW DC)

A baseline set of parameters for each business model and charger technology were developed, including CAPEX/OPEX, charger utilisation, contract lengths, grant levels and grid upgrades. The cost to the end user has been calculated under these assumptions, and a summary of the key findings is shown in the Box below.

**Conclusions from baseline calculations and main sensitivities:**

- Costs to consumers arising from baseline case calculations are in line with consumers willingness to pay (based on survey responses), indicating they are feasible business models.
- Lamppost charging offers the cheapest costs to consumers without access to off-street charging, followed by on-street residential.
- There is a business case for higher power on-street residential charging, as these result in lower costs to consumers.
- Rapid charging is the most expensive modelled option for consumers, with higher costs for higher power chargers. However, higher costs for higher power rates are relatively small

(en-route rapid chargers: 50kW at 0.35ppkWh, 150kW at 0.40ppkWh), despite seeing that consumers are willing to pay more for higher power (i.e. due to the utility benefits).

- Rapid charging costs are very sensitive to grid upgrade costs, making locations with sufficient grid capacity more attractive.
- Costs to consumers across all business models are very sensitive to utilisation rates, with higher rates reducing end costs. Rapid charging shows the highest volatility to utilisation rates, resulting in higher prices than consumers are willing to pay for cases of low utilisation. This suggests chargers in busy urban areas are more attractive, as higher rates and lower costs can be expected. However, a large operator operating across multiple different localities could standardise costs, as the lower utilisation area revenue could be offset by areas with higher utilisation across their charging network.
- As utilisation is expected to increase in the future, EV charging is expected to transition from a regulator-driven market to a self-regulated market, which could result in grants being phased out and contracts lengths being reduced. The effect of these parameters on overall costs to consumers would be limited for cases where utilisation is high.

The results from the cost calculations have been used in conjunction with the research into Task 1 on attractive charging options for EV users without access to private off-street parking, and therefore consider the impacts different business models may have on overall charging behaviour. Five impact categories have been considered in the analysis, covering the seven business models selected above:

1. **Impacts on the grid** to what extent are grid connections, upgrades and reinforcements required for the charger type and business model? Can smart charging be implemented to facilitate the stabilisation of the grid?
2. **Impacts on traffic/congestion** does the business model create additional traffic demand at the charger locations? Will dedicated EV bays cause issues with local residents?
3. **Impacts on EV uptake** are the combinations of business model and charger type attractive for end-users in terms of charging speed, reliability and cost to make switching to an EV more attractive?
4. **Urban and rural considerations** how do the business models vary between rural and urban areas? Are they all feasible in both urban and rural applications?
5. **Impacts on CPOs and LAs** how attractive are the business models to the CPOs and LAs in terms of profitability and planning issues?

There are multiple actors involved in the deployment of EV charging infrastructure, including central government, LAs, CPOs, and DNOs. Each actor has a different role to play in implementing public chargepoints, with the specific aim to support households without off-street parking – summarised in Table ES2 below. These cover aspects such as providing sufficient detail and resources to LAs such that they can take ownership of their chargepoint delivery strategies and ensuring that customer experience is optimised to increase the utilisation of the chargepoints which will in turn reduce the cost to the end-user.



**Table ES2: Summary of the recommendations to facilitate deployment of charging infrastructure for EV users without private off-street parking**

<b>Central government</b>	<ul style="list-style-type: none"> <li>• Provide detailed guidance to LAs to inform the most appropriate chargepoints types, location, proximities, and required resourcing to help them achieve this.</li> <li>• Enhance collaboration between key players in the EV charging infrastructure rollout, potentially through a dedicated governing body.</li> <li>• Ensure that systems are in place to ensure accountability and frequent reporting from the recipients of government economic support.</li> <li>• Explore the potential uses in terms of interoperability of the open set data on chargepoints that will be available from 2023.</li> <li>• Remove any potential planning, ownership, and access barriers for the implementation of new chargepoint locations.</li> <li>• Provide areas with low EV uptake (e.g. rural areas) with greater support to ensure that 'no one is left behind', with a particular focus on the rural business model case.</li> </ul>
<b>Local authorities</b>	<ul style="list-style-type: none"> <li>• As lamp post chargers can offer the cheapest charging solution in urban residential areas, where it is applicable and easy to install lamp post chargers should be implemented as they are a low-cost, low-risk option.</li> <li>• Currently some LAs take a share of the cost per kWh for charging the end user (e.g. 1p per kWh of electricity drawn). This should be reviewed as it could represent an additional tax to the end-user, for users without private chargers.</li> <li>• Reduce the possibility for local monopolies of CPOs to develop by having open, competitive tenders for charging locations of different types and establish procurement routes for chargers and facilitate the land for potential charger sites.</li> <li>• Proactively seek charging locations rather than relying on public requests to ensure infrastructure is available to make EVs a natural choice for all drivers.</li> </ul>
<b>Chargepoint operators</b>	<ul style="list-style-type: none"> <li>• Ensure a good standard of customer experience when charging, which could include effective maintenance to ensure reliability and standardising payment methods (e.g. contactless payments).</li> <li>• Allow any potential savings from reduced VAT rates from electricity for public charging to be passed onto the consumer, and not taken as additional profit.</li> <li>• Maximise the utilisation potential for the chargepoints, by including technologies such as booking systems and idling fees for vehicles parked but not charging.</li> <li>• Work with the DNOs to facilitate the use of smart charging in on-street residential charging areas.</li> </ul>
<b>Distribution network operators</b>	<ul style="list-style-type: none"> <li>• Ensure quick connection times of public chargepoints to the grid.</li> <li>• Facilitate knowledge sharing with CPOs and LAs on sites with spare grid capacity or areas which would not be expensive to upgrade the grid.</li> <li>• Ensure that smart charging is an option for residential on-street chargers, to offer users without private chargers the same benefits that smart charging brings.</li> </ul>

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# 1 Introduction

Ricardo has been commissioned to provide the Committee on Climate Change (CCC) “Understanding the costs and impacts of potential approaches to providing electric vehicle charging for households without private off-street parking”.

## 1.1 Background

There is currently a lack of public electric vehicle chargers for households without off-street parking in the UK. These public chargepoints are typically more expensive to invest in than off-street home slow chargers, and this therefore deters investment and hence their availability. Households without access to private off-street parking are underrepresented in the rollout of EVs, with only 7% of current EV owners not having access to private off-street parking compared with over 30% of households in the UK not having access to private off-street parking. Previous research in this area has identified that 28.3% of drivers are put-off from switching to an EV as they have nowhere to install their own chargepoint (SMMT, 2021), which indicates that the current provision of public EV charging is not satisfactory for households without access to private off-street parking.

Previous research (Table 1-1) has indicated that, even when available, the use of public chargepoints can be significantly more expensive than the use of a residential home charger.

**Table 1-1: Costs of EV charging (\$) based on 10-year present value cost (Botsford, 2018)**

Costs of EV charging (\$)	Residential	Workplace	DC Fast Charging	Public Charging
Charger cost	500	1,500	30,000	2500
Installation cost	750	5,000	25,000	7500
O&M	3,209	5,811	227,250	14,529
Cost total	4,459	12,311	282,250	24,529
kWh	29,714	29,714	364,000	22,286
Cost/kWh	0.15	0.40	0.78	1.10

Typically, properties with access to off-street parking are more valuable (Leaders, 2019), and therefore will attract persons with a higher household income. This results in lower-income households less likely to have access to off-street parking. It is also well established that current EV owners are more likely to have a higher household income (Circular., 2019), and therefore it is imperative that households without access to private off-street parking firstly have access to public chargers in the vicinity of their home, and are also not significantly impacted by increased costs of public charging as this will only deter lower-income households further from switching to an EV.

There are many different business models currently existing (or planned in future) for public chargepoints, including concession contracts for local authorities (LAs) and chargepoint operators (CPOs), smart charging, and various destination charging business models with varying levels of cost recouperation. There is a need to consolidate the effectiveness of these, which will help to establish the most cost-optimal deployment of infrastructure which will be most attractive to customers. The purpose of this study is to therefore gain an understanding of the cost of charging for households without access to private off-street parking under different business models for different charger types. The study also assesses the charging behaviour of these specific EV users, and understands how charging behaviour might be impacted by particular types of business models for different charger types and locations. This identifies the charging preferences of EV users and the types of business model which can help to increase the utilisation of the chargepoints.

## 1.2 Project scope

The main questions to be answered by this study are:

1. Understanding the charging wants and needs of electric vehicle (EV) users without access to private off-street parking.
2. Understanding of the cost and wider impacts of charging for households without access to private off-street parking under different business models for different charger types.
3. Understand how charging behaviour might be impacted by particular types of business models for different charger types and locations.
4. Provide recommendations for the different actors involved in the deployment of EV charging infrastructure for optimal roll-out of public infrastructure.

A comprehensive literature study has been conducted covering research areas of EV user charging behaviour, current and potential future business models, and innovative charging options. A systematic evidence assessment of the available literature was conducted to pull out key insights under each research area, consisting of:

- Review of attractive charging options for EV users
- Review of charging behaviour
- Research into innovative, practical charging options
- Research into viable commercial business cases
- Review of current charging policy

This research has formed the basis for understanding the charging needs and wants of EV users with access to private off-street parking, and used to create links between what the customers want out of the charging experience and viable business models.

A short, targeted stakeholder engagement exercise was undertaken (covering CPOs, LAs and distribution network operators (DNOs)) to gain a deeper understanding of the current and viable business models being deployed for public chargepoints, and other aspects of the charging wants and needs of EV users. The list of interview questions asked to each different stakeholder group are shown in A1.2 (LAs), A1.3 (DNOs), and A1.4 (CPOs).

A review of innovative charging options has been undertaken to identify potential future charging options which may be attractive to users without access to private charging by offering improved levels of service or reduced costs.

A number of business models currently exist for public chargepoints, with the most common being public-private partnerships for on-street chargers in residential areas. Various business models at different levels of maturity have been explored in this study, which cover: on-street residential chargers, destination chargers, en-route rapid charging and forecourt rapid charging. This study focusses on public chargepoints only, and therefore workplace charging is not considered in detail in this analysis. The types of chargers considered in this study is shown in Table 1-2 below.

**Table 1-2: Type of public chargepoint considered in this study**

Charging type	Typical charger powers	Description
On-street residential	Lamp post chargers (3 to 5.5 kW AC power rating) Fast charging on-street (7 to 22 kW AC)	Users typically charge at these locations for a long period of time, typically overnight. Chargers are located near to users home.
Destination charging	22 kW AC to 150 kW DC	Chargepoints are provided at shopping centres, supermarkets, and car parks. Users charge up at these locations out of convenience as they are travelling to the destination anyway.
En-route rapid charging	50 to 150kW+ DC	Rapid chargers placed along major trunk roads to enable longer journeys. Users mostly charge out of necessity.
Forecourt rapid charging	50 to 150kW+ DC	'Refuelling station' model, whereby multiple rapid chargers are placed in one location to provide quick charge times for users.

The study outputs include calculating the costs of selected business models to the end-user. Seven business models are considered, covering on-street charging, destination charging and rapid charging (Table 1-2).

**Table 1-3: Selected business models for cost calculations**

Business model	Charger location	Description
BM1	On-street residential	Lamp post chargers (3 to 5.5 kW AC power rating)
BM2	On-street residential	Fast charging on-street (7 to 22 kW AC)
BM3	Destination charging	Destination cost recovery model (22 kW AC to 150 kW DC)
BM4	Destination charging	Destination fully funded model (22 kW AC to 150 kW DC)
BM5	Destination charging	Destination profit making model (22 kW AC to 150 kW DC)
BM6	Rapid charging	En-route rapid charging (50 to 150 kW DC)
BM7	Rapid charging	Forecourt rapid charging (50 to 150 kW DC)

The sensitivity to utilisation rates (total kWh per day delivered by the charger) is also explored to understand how the costs to the end user may vary in areas with low-utilisation or low EV uptake.

Wider impacts of each business model have also been explored in detail. This covers the following categories:

1. **Impacts on the grid** to what extent are grid connections, upgrades and reinforcements required for the charger type and business model? Can smart charging be implemented to facilitate the stabilisation of the grid?
2. **Impacts on traffic/congestion** does the business model create additional traffic demand at the charger locations? Will dedicated EV bays cause issues with local residents?
3. **Impacts on EV uptake** are the combinations of business model and charger type attractive for end-users in terms of charging speed, reliability, and cost to make switching to an EV more attractive?
4. **Urban and rural considerations** how do the business models vary between rural and urban areas? Are they all feasible in both urban and rural applications?

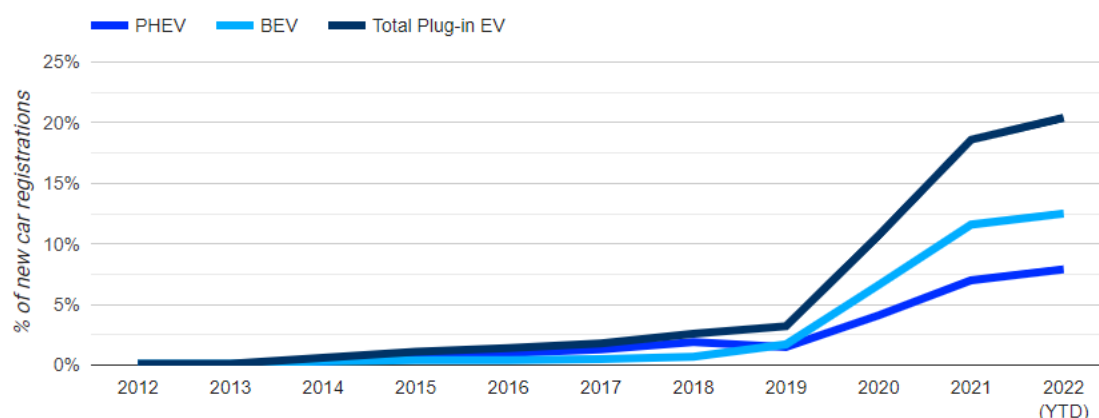
- 
5. **Impacts on CPOs and LAs** how attractive are the business models to the CPOs and LAs in terms of profitability and planning issues?

This document provides recommendations to the different actors involved in the deployment of charging infrastructure to support households without access to private charging based on the research undertaken in this study and the cost calculations provided for each business model. This includes central government, LAs, CPOs and DNOs.

## 2 Desk research and literature review

The UK has set a goal of 50%–70% of the new car market being ultra-low emission by 2030 to achieve climate, air quality, and energy security ambitions (ICCT, 2020). To reach this goal, the UK government has announced that all new petrol and diesel cars and vans will be phased out by 2030 (HM Government, 2021). As a result, the number of plug-in electric vehicles (EV) in the UK have recorded the largest annual increase, with more than 305,000 EVs registered in 2021, registering a growth of 74% on 2020. Figure 2.1 highlights the increasing trend of consumers switching to electric vehicles, where the annual market share of new car registrations has recently passed 20% (Zap Map, 2022). Consumers are increasingly attracted towards switching to EVs, due to longer range and greater model choice available. At least 1 in 3 households rely on on-street parking as they have no driveway or garage and still more have no designated off-street parking (SMMT, 2021). Currently, EVs are more expensive at the moment, people who don't have off-street parking typically have lower household income, and so having expensive on-street charging will only further deter people for getting an EV. Therefore, it is imperative that households without access to private off-street parking firstly have access to public chargers in the vicinity of their home and are also not significantly impacted by increased costs of public charging as this will only deter lower-income households further from switching to an EV.

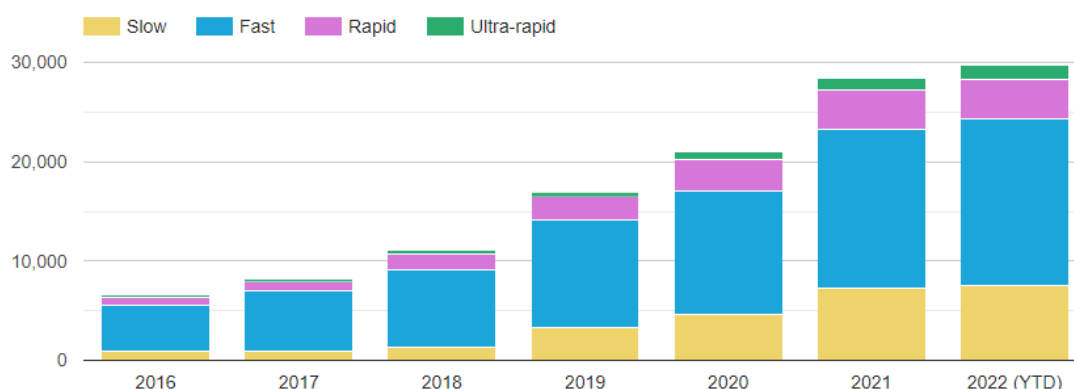
**Figure 2-1: Registrations of plug-in vehicles as a share of total new car registrations in the UK (2012 to date) (Zap Map, 2022)**



Source: SMMT, OLEV, DfT Statistics. Updated: January 2022



In response to the increasing numbers of electric vehicles, the UK's charging point infrastructure is continually changing and adapting to consumer demands. There are 8 million households (On-Street households) outside of London that have no off-street parking and therefore rely on public charging (Field Dynamics, 2021). Figure 2.2 presents a breakdown of chargepoint devices by slow (3-5kW), fast (7-22kW), rapid (25-99kW) and ultra-rapid (100kW+) power rating for the past five years and 2021 to date. There has been a sharp increase in the number of public EV chargepoints in the UK, with a 335% increase between 2016 to 2021. The significant increase in growth of slow chargers is evident, as LAs are implementing on-street charging options to enable EV purchases for residents without off-street parking (Zap Map, 2022).

**Figure 2-2: Number of public charging points by speed (2016 to date) (Zap Map, 2022)**

Total devices: 29687, Updated: 24 February 2022



### AC vs DC charging

EV chargers can either be alternating current (AC) or direct current (DC). Power from the electricity grid is always AC, however batteries can only store power as DC. Therefore, using an external AC charger point requires an onboard charger (also known as an on-board converter) in the vehicle to convert the AC power from the grid to DC for storage in the battery. DC chargers have the potential for higher charging speed as a result of converters not being required onboard the vehicle. Typically, AC chargers are 7kW, 22kW and in some cases 43kW. DC chargers can reach higher power ratings of 50kW, 150kW and even higher.

Different EV models have different on-board chargers, and therefore can accept varying levels of charging power. For example, a Nissan Leaf can charge at 6.6kW maximum from an AC charger, whereas a Renault Zoe can accept up to 22kW AC charging (Andersen, 2022). Vehicles can still charge at any AC charger, however the power delivered to the vehicle is limited by the on-board converter. This means that AC public chargepoints rated at 22kW may not be delivering 22kW to every vehicle, and this maximum charging rate will depend on the vehicle make and model.

Currently relatively few car models can charge on AC above 7kW, with mainly premium models able to charge at 11kW or higher (which requires a 3-phase electricity supply), however more models are becoming available with this option (though usually for an additional premium for more affordable vehicle segments).

## 2.1 Review of attractive charging options

### Summary of key findings

- The most attractive charging options are faster chargers that can work immediately, have a high level of reliability, and are readily available for use with short connection times<sup>2</sup>.
- Business models need to incorporate a rapid and effective maintenance programme to increase the reliability of chargepoints.
- Faster charging speeds and higher utilisation rates of chargers can be expected to provide increasing opportunities for improved business cases for charging providers.

<sup>2</sup> Note: survey responses do not account for cost of charging or whether EV users would be willing to pay more for these services.



- Free charging presents a significant advantage in the public charging experience, either offered through manufacturer incentives or as a result of a chargepoint operator's business model.

In the UK, the majority of current EV drivers have access to private off-street parking (86%), however there is a growing consensus that public on-street charging is required to facilitate the transition to electric vehicles (Zap Map, 2020). The International Council on Clean Transportation (ICCT) states that by 2030, the proportion of electric vehicle charging energy provided by home and work charging declines to 80%. More electric vehicles are deployed where there is less home charging availability, causing an increase in the need for public charging (ICCT, 2020).

Currently there is a poor perception of the UK charging network and this section investigates the potentially most attractive charging options for consumers, which are necessary to improve the public perception of EV charging infrastructure and therefore increase EV uptake for users without private parking.

The summary of the findings of our review are presented below in 4 key themes:

1. Availability, reliability, and faster charging
2. Cost and payment methods
3. Smart charging functionalities
4. Interoperability functionality

### Availability, reliability, and faster charging

Consumer preferences and views of ideal charging stations are for fast charging stations that can work immediately, with short connection and waiting times. According to research, they also appear willing to pay more for these types of solutions (eCharge4Drivers, 2021).

A survey (New Motion, 2021) asked 10,000 EV drivers what three changes would most improve their charging experience. Table 2-1 highlights that better availability of public chargepoints and faster charging are the key areas for development for the UK charging network. Offering EV drivers the guarantee that they can travel anywhere with their EV will require building EV infrastructure to cope with every eventuality, and reduce drivers concerns for long-distance travel.

**Table 2-1: EV driver preferences for future charging experiences (New Motion, 2021)**

Country	Faster charging	Increased availability	Single charge card	Improved charge route planning	Charging without a cable	Smart off-peak charging	Charging without a charge card
UK	41%	43%	28%	26%	26%	25%	24%

In the survey, 68% of drivers had access to home charging, 38% have access to workplace charging, and 15% have neither.

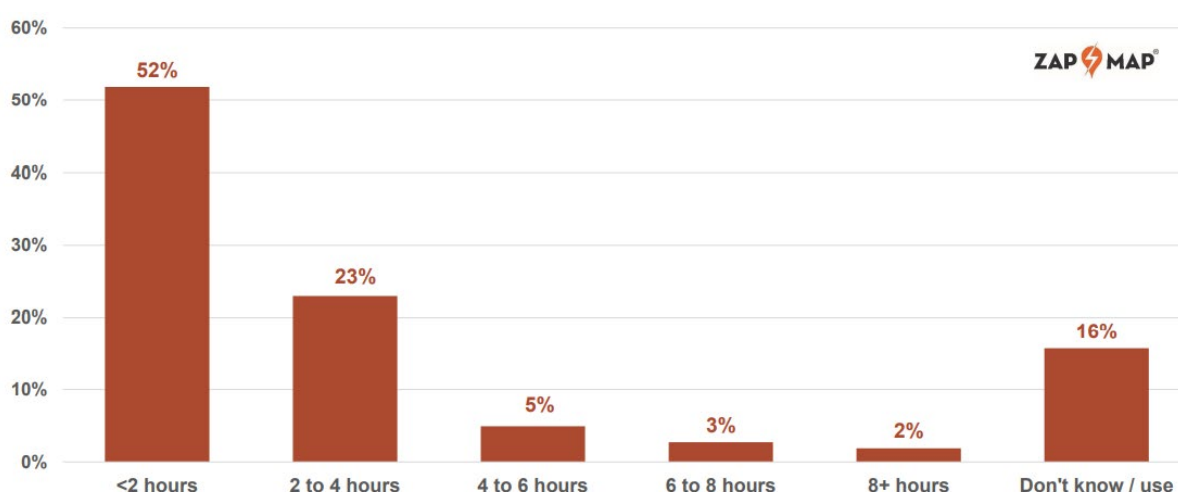
Key findings from surveys based on UK public on-street charging infrastructure found that availability, reliability, and ease of use are currently inadequate. A survey (Innovate UK, 2021) found that only 22.75% of respondents said that public rapid chargers always worked. The SMMT Blueprint for the Electric Vehicle Revolution states that chargepoints need to become as reliable and easy to use as a fuel pump. Reliability of chargepoints is an important factor for consumers, where potential downtimes due to system malfunctions can be exacerbated by slow maintenance response times. The average reliability rate for a charger in the UK is just 91.7%, compared to 99% in the Netherlands (SMMT, 2021). The Netherlands has a higher EV uptake and is one of the leading countries for the rollout of EVs (ICCT, 2021), the degree to which higher charger reliability has influenced this is difficult to ascertain. In addition, two of the most-often-cited problems BEV and PHEV owners have when visiting a charging station and being unable to power up are the charger was out of service (58%) and no charger available or too long to wait 14% (JD Power, 2020). Business models could incorporate a rapid and effective maintenance programme for chargepoints to ensure minimal downtime and improve customer satisfaction. In addition, the long wait times could be addressed through efficient booking systems to deal with the increasing pressures on EV charging infrastructure.

Another key point from survey analysis is the key issue with EV drivers concerns over the availability of chargepoints, and whether they are adequate to meet rising demands. A survey (Innovate UK, 2021) found that over 42% of EV drivers said that they occasionally or often had to queue or to give up or could rarely find an available charger. Scenario analysis found a low number of BEVs per fast charger suggests that in early years it is necessary to obtain geographic coverage, but once sufficient coverage is achieved, fewer chargers per BEV are needed to address capacity (ICCT, 2020). This is the result of the move to more longer-range electric vehicles, faster charging speeds, and higher utilisation rates of chargers. As a result, more vehicles will be supported per publicly accessible charger in future years (ICCT, 2020). These trends can be expected to provide increasing opportunities for improved business cases for charging providers.

From the stakeholder consultations, one LA with a higher-than-average EV on-street charging network stated that damages and breakages to chargepoints were not uncommon, and as a result impacts customer satisfaction. A key insight to their high utilisation rates of on-street public charging was the rapid response times of CPOs. In addition, one CPO indicated that when 3<sup>rd</sup> parties are involved it becomes more difficult to provide effective and rapid maintenance repairs to chargepoints. As a recommendation to ensure effective maintenance, CPOs suggested that the most effective business models have contracts that last the lifetime of the chargepoint. Due to the familiarity with the technology in place and the real-life data, involving these stakeholders is considered crucial to increasing the customer support and the reliability of chargepoints. Evidence from the literature supported this, highlighting a current limitation of the EV charging system is that there is no open dataset of live chargepoint information, meaning information is restricted to specific CPOs (Transport and Environment, 2021).

Another key focus area is the charging behaviour of EV drivers and perspective drivers, which may be a factor for concerns on the availability of chargepoints. From the stakeholder consultations, it was noted from one CPO that often vehicles are left on charge longer than required, which as a result reduces the availability and effective utilisation of chargers. In addition, there was an agreement from stakeholders (LAs, CPOs, and DNOs) that many consumers believe they need to charge their vehicles more than is required. This behaviour pattern mirrors the conventional refuelling of internal combustion engines with diesel and petrol, and could somewhat be alleviated through improved availability and reliability of chargers. However, a report from Transport and Environment states that “less than 1 in 20 cars need, on average, need to be fully charged twice a week or more” based on the daily mileage of UK drivers (Transport and Environment, 2021). In addition, Figure 2.3 highlights that there is a clear consumer preference for fast charging, as 53% charge for less than 2 hours, on slow/fast (7-22kW) chargers.

**Figure 2-3: Survey on EV drivers typical charging duration on public slow/fast (7-22kW) chargepoints (ZapMap, 2020)**



LAs also expressed that central governments play an important role for increasing the availability of chargepoints. From the stakeholder consultations, LAs highlighted a current lack of guidance on the types, proximity, and numbers of chargers that should be deployed in an area. Stakeholders agreed that an overarching framework with this information would enable a more effective deployment of on-

street charging to meet the current chargepoint availability concerns. Evidence from the literature supports the stakeholder consensus by stating that the government should collaborate with all stakeholders in the development of a strategic plan to ensure the network can support the EV expansion and place the right chargers in the optimal locations to suit consumers (SMMT, 2021). Other relevant literature adds to this by stating the government should also specifically instruct CPOs to ensure that (Transport and Environment, 2021):

- Every EV charging point is accessible to all vehicles
- Streamline the process by which EV drivers access the charging network
- Require all publicly available chargepoints to be registered on a dynamic, publicly available national chargepoint registry
- Mandate minimum levels of maintenance and repair and customer support
- Requirement of transparent pricing
- Allow renewable electricity supplied to EVs to count towards the Renewable Transport Fuels Obligation (RTFO) thereby providing an additional revenue stream for CPOs.

### **Costs and Payment Methods**

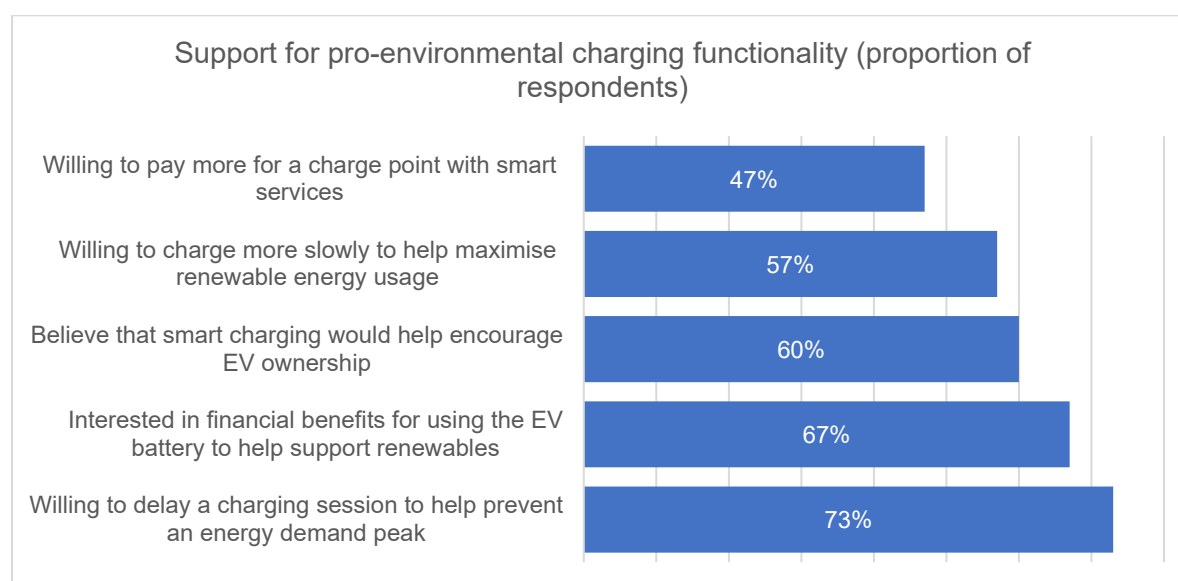
Currently, on-street charging is considerably more expensive than off-street charging, which is reflected by the majority of EV drivers opting to charge at home where possible. This was echoed by stakeholders, with one chargepoint operator highlighting that the tax rate for on-street charging is 20%, compared to 5% for private off-street parking. Evidence from the literature recognises this tax levy as one of the key barriers for the utilisation and development of on-street charging (Transport and Environment, 2021). However, if this tax rate was reduced for public charging then it must be ensured that the cost reduction is passed to the end-user, rather than the CPO taking an increased profit level. The cost premium for charging at public sites could be reduced by levying a 5% VAT rate to costs of using a public chargepoint to match that for domestic customers. Free charging presents a significant advantage in the public charging experience, either offered through manufacturer incentives or as a result of a chargepoint operator's business model (JD Power, 2020). A key insight from the literature is that for a successful charging eco-system, there should be a regulatory body that will enforce a minimum reliability standard, ease of payment, pricing transparency and real-time data sharing from public chargepoints (SMMT, 2021).

Payment methods are a key area of consumer preferences, a survey (Innovate UK, 2021) found that 85% of people want to pay for public charging by contactless debit or credit card payment, or automatic payment on plug in. In contrast, only 10% want to pay by smartphone app; and less than 5% want to pay by RFID card or tag. Customer feedback from one of the most popular public charging networks according to a survey (Zap Map, 2020) 'InstaVolt' commented that the network is "modern, super reliable, generally come in pairs and contactless payment is a huge plus". In addition, the literature supports this approach to payment methods stating that every public chargepoints should offer ad-hoc access and payment to all users through card payments or network roaming, rather than forcing users onto subscription services or requiring apps to be downloaded (SMMT, 2021).

### **Smart Charging Functionalities**

As transport energy requirements are moved to the grid the overall electricity production needs to significantly increase to fulfil the demand. Charging at off-peak times can help to free up capacity and ease pressure on grid capacity, and there is now the potential for smart charging to facilitate this by adjusting the charge speed in real time according to grid supply (New Motion, 2021). Figure 2.4 shows that overall, the sentiment is supportive of pro-environmental charging functionality, where most EV users are willing to adopt new charging patterns to support renewable energy development. A key finding to highlight is that charging more slowly is a less attractive option for consumers, and so financial incentives are an important incentive for EV drivers to adopt new charging patterns.

**Figure 2-4: EV owners across Europe were asked a variety of questions related to behaviour changes towards pro-environmental charging (New Motion, 2021)**



### Interoperability Functionality

Currently, in the UK only 60% of EV drivers agree that their main charge card gives them access to the charging they need (New Motion, 2021). A range of different approaches to paying for charging may be popular: when asked whether they would be interested in paying a fixed monthly price for unlimited charging, 39% of respondents agreed and 38% disagreed. This split in consumer preference has been reflected in CPOs' business models. In the stakeholder consultations, it was noted from CPOs that they do offer multiple payment options. A pay-as-you go model (with a QR code) for slow chargers was the most popular among consumers. The other payment option available for consumers is through monthly payment plans and specific charge cards. However, it was noted that for on-street residential charging only one charge card/app is likely needed, as users will frequently visit chargers in the same location which will likely have the same operator, and therefore would not have issues with interoperability as it is not needed. If these users were to travel to another city/residential area they would require another chargecard.

Due to the vast number of CPOs in the UK operating different charger types and business models there is an absence of an interoperable charging platform. Interoperability business models have been established in the Netherlands, Norway and China increasing the ease of use and the efficiency of chargepoint usage (BCG, 2021). Stakeholder consultations confirmed that CPOs and DNOs are sceptical of an interoperable charging platform, due to high costs of an 'overarching app network' and the desire for each CPO to be in control of their own business models. In addition, the lack of an open dataset of live chargepoint information is a key limitation for the potential of interoperability functionality in the UK (Transport and Environment, 2021).

## 2.2 Review of charging behaviour

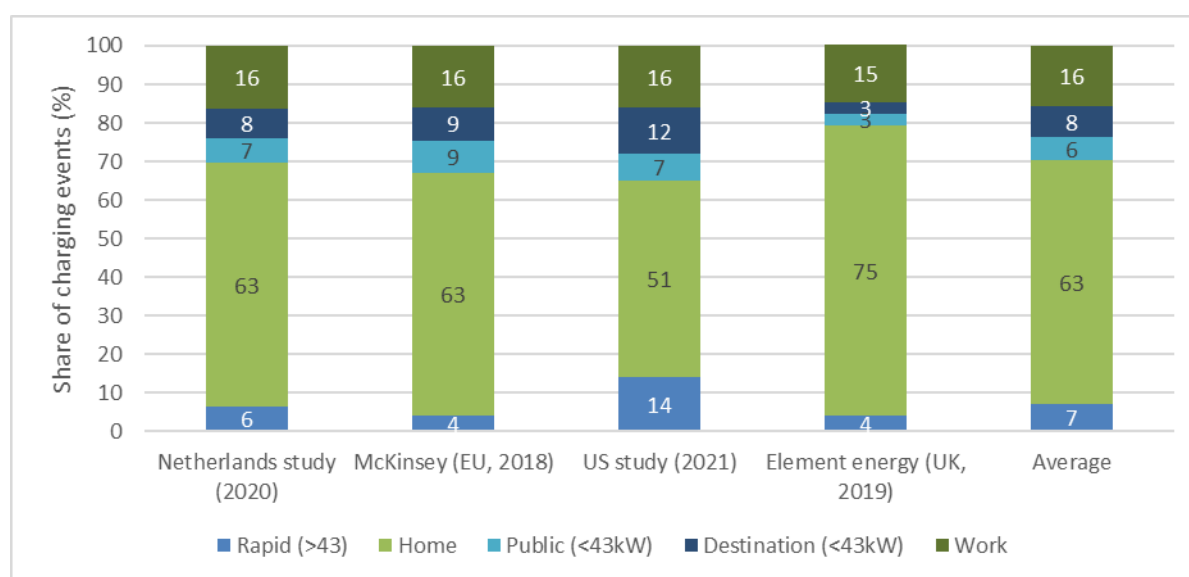
### Summary of key findings

- There is likely to be increased use of workplace, destination and rapid charging for EV users without access to private parking vs those users who do have access to a driveway
- It is unclear if the current data on charging behaviour for EV users without access to private parking is driven by the availability of the infrastructure, rather than consumer preferences.
- Current EV charging prices in the UK is above what many EV users without access to private parking are willing to pay for a quality service.

### 2.2.1 Charging behaviour by charger type

There is a clear difference in the way in which EV users without access to private off-street parking charge compared to EV users with a driveway. The majority (51%-75%) of charge events for EV users with access to private off-street parking is expected to be at home (Figure 2.5). This will be the most convenient charging method for these users, and therefore will very likely be the most common charging behaviour. Based on the analysis of identified sources, it is expected that these users will have a share of charge events on the public network of ~21%, which includes rapid chargers, destination chargers, and on-street public chargers. Workplace charging will make up around 16% of all charge events across this user group; however, it is noted that workplace charging will vary user to user due to availability of workplace chargers and the method of commuting. There is broad alignment across the literature sources, with some differences observed in the US charging behaviour which is in part due to longer distances travelled on average resulting in a higher proportion of rapid charging required.

**Figure 2-5: Proportion of charge events per location for EV users with a driveway, comparison of various sources**

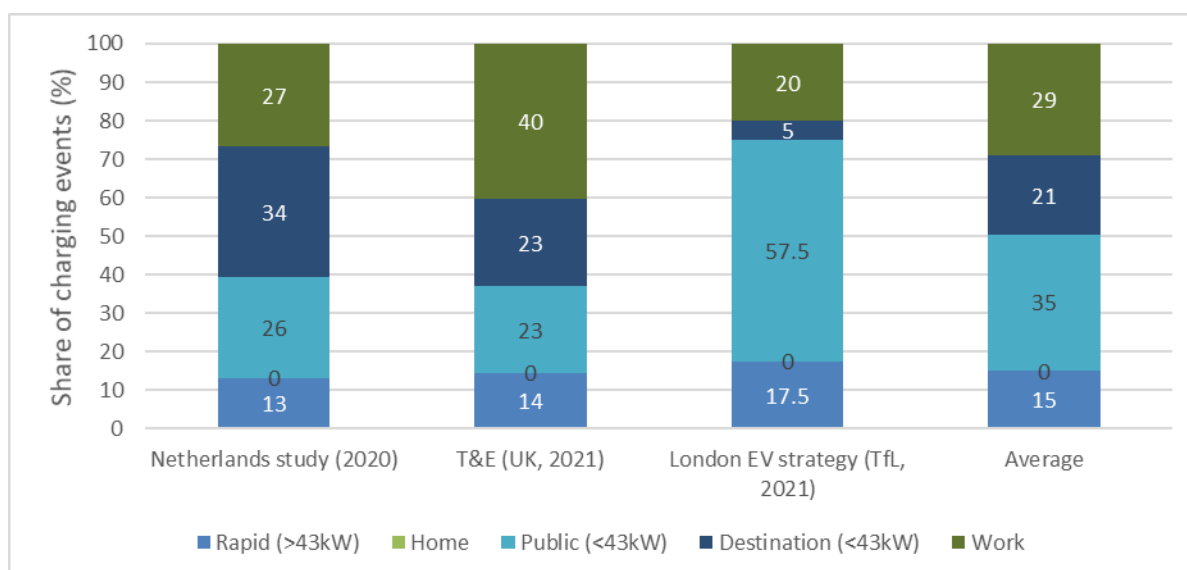


*Sources:* (R. Wolbertus and R. van den Hoed, 2020), (McKinsey & Co, 2018), (Fuels Institute, 2021), (National Grid, Element Energy, 2019)

In contrast, EV users without access to private off-street parking will of course rely heavily on the public charging network (Figure 2.6, around 71% of charge events). Based on the available sources, the expected charging behaviour of this user group is not dominated by one charging location, and instead will be split across workplace (29%), destination (21%), public on-street (35%) and rapid charging (15%). There is less consistency across the literature for EV users without access to private parking compared to the literature for EV users which do have access to private parking. This could in part be a result of lack of readily available data, as the current EV uptake is dominated by user with access to private parking. It could also be a result of EV users simply using the infrastructure which is available to them, and therefore if there were more on-street residential chargepoints available then the share of public on-street charging would increase.

The most comprehensive study found in the literature was conducted in the Netherlands (R. Wolbertus and R. van den Hoed, 2020), spanning 17,191 EV drivers (including both with and without access to private parking) and over 1 million charge events. This source has charging largely split across the locations, with destination charging (34%) being the most favourable in terms of share of charge events. In contrast, the recently published London EV infrastructure strategy (Transport for London, 2021) only assumes a 5% share of charge events at destination locations for EV users without access to private off-street parking. There is likely to be a difference in charging behaviour across different geographies, and potential differences in observed charging behaviour versus the proposed infrastructure strategies.

**Figure 2-6: Proportion of charge events per location for EV users without a driveway, comparison of various sources**



Sources: (R. Wolbertus and R. van den Hoed, 2020), (Transport & Environment, 2020), (Transport for London, 2021)

## 2.2.2 Willingness to pay for charging

EV users are willing to pay more for faster charging (Figure 2.7). A recent survey of EV users in Brighton (Electric Brighton, 2020) asked EV users the price at which chargers would be so expensive they would have to consider using it (maximum price), and also what price they would be willing to pay such that the quality of service couldn't be very good (minimum price). The survey also showed that users who mainly park on-street appear willing to pay a higher maximum price for charging at each location compared to EV users with access to private parking. This is perhaps unsurprising as the cheapest charging location will be at home off-street, and therefore users with this access to home off-street charging will not be willing to pay as much for public charging.

**Figure 2-7: Analysis from an EV user survey (Electric Brighton, 2020), including users which mainly park on-street and those which mainly park off-street**



Notes: ppkWh = pence per kWh.

The survey posed the following questions relating the maximum and minimum price:

Maximum price: *What price would you consider a charger to be starting to get expensive, to the point where you would have to give some thought to using it?*



Minimum price: *What price would you consider a charger to be priced so low that you would feel the quality of service couldn't be very good?*

A review of current UK charging costs found that rapid chargers (50kW+) typically charge customers 23 to 42 ppkWh (pence per kWh), fast on-street (7-22kW) typically cost 18 to 36 ppkWh and slow lamp post chargers (3-5.5kW) cost in the range of 19 to 33 ppkWh (Table 2-2, only includes tariff on a per kWh basis). The current average prices (in pence per kWh) for each charging option are currently above the maximum willingness to pay for EV users without access to private parking. The survey results could be somewhat skewed by current EV users trying to reduce the charging prices in their area by suggesting that they would not be willing to pay above current market rates, as these users are already paying the market rates.

There are other payment methods available, with cheaper cost per kWh offered for users willing to pay a monthly subscription fee. An example of Ubitricity's two different tariff options for their 5.5kW lamp post charger include a 'pay-as-you-go' offer which has no subscription fee, a connection fee of 29p and a charge cost of 19 ppkWh, whilst the 'subscription' model has a £7.99 monthly fee, 19p connection fee and reduced charging cost of 16.2 ppkWh (FleetEurope, 2020). These subscription models appear to work for users which undertake high mileage. For the subscription model to be cheaper than the PAYG model, the EV user would have to consume around 260kWh per month across 8 charge events (£51.63 monthly cost vs £51.72 on PAYG). This equates to a monthly mileage of 680 miles (or 8,200 miles annually) based on the average car BEV efficiency (BEIS, 2021), and so can be a good option for users without private parking with a higher annual mileage.

**Table 2-2: Current UK charging prices and willingness to pay, includes only cost per kWh tariffs (i.e., no monthly subscriptions)**

Charger type	Cost of charging - ppkWh			
	mean	min	max	willingness to pay range
Lamp post (3-5.5kW)	25.5	19	33	5 to 19.5
Fast on-street (7-22kW)	28.8	18	36	7 to 22.5
Rapid (50kW+)*	35.1	23	42	9.5 to 30

\*350kW Ionity supercharger is 69ppkWh

Sources: (Whatcar, 2021), (Electric Brighton, 2020), (FleetEurope, 2020), (char.gy, 2022)

There are a number of factors which may influence the price of charging to end user:

- **Wholesale electricity price:** the recent increases in wholesale electricity price will drive up the cost of charging to the end user. Stakeholders indicated that under the concession contracts (CPOs and LAs) there may not be flexibility to change prices regularly enough to react to the wholesale electricity price. If this is the case, the end user could receive a relatively cheaper cost of charging, but the CPO is making a loss due to the increase in electricity price.
- **Charger utilisation:** current public EV chargepoints are not utilised to the maximum potential due to BEVs being a small part of the overall car fleet. As the uptake of EVs increases, CPOs could see an increase in charger utilisation (and therefore revenue) which would allow for a cheaper cost to end user for charging.
- **Changes to public funding:** Most CPOs rely on the 75% public funding from OZEV to ensure that their business models work. This is due to low utilisation rates of current chargepoints, as described above. If this funding was to decrease in future, then the cost to the end user could increase as the infrastructure has a high upfront cost to the CPO.

## 2.3 Innovative, practical charging options

The research into a practicality assessment provides an overview of the key innovative charging options and the potential business model cases.

### Summary of key findings

- Lamp post charging has been implemented by multiple LAs, which are also supported by CPO's and DNO's due to low costs, ease of grid connection, and high utilisation rates in some locations
- Smart charging is an emerging end-user practical charging option, where stakeholders are supportive elements of cheaper charging for end-users and an effective load management solution
- Ultra-fast charging is an emerging charging option, with large sums of commercial investments planned and development of rapid forecourt charging hubs across the UK
- Inductive charging is being trialled by LAs, although the emerging charging options (V2x) require manufacturers to make costly alterations to vehicles and infrastructure

### 2.3.1 Street charging options

#### Lamp Post Charging

Lamp post charging turns streetlights into chargepoints, each has 24 amps of excess supply (from the conversion to LED lighting) that can be used to charge cars, with a charger power of 3kW Installation. The costs are about £1,000 per device, with car owners charged at 33p per kilowatt-hour (kWh) on pay-as-you-go rates. Lamp post charging has a high maturity and can be funded through public-private partnerships. Stakeholder consensus was that 'concession agreements' are currently the preferred business model, with the majority of the funding required (75%) provided by central government, and the other (25%) supplied by local city councils or from alternative sources (e.g. CPOs).

From the stakeholder consultations, multiple LAs indicated that lamp post charging was popular among EV drivers and had success in deploying them. However, one LA indicated that they were unable to install any of these chargers, due to the city's narrow pavements and location of the streetlights. Of the LAs that had deployed lamp post charging, they commented that utilisation is high, however up-scaling is a key limitation. For example, one LA indicated they had 1,800 streetlights, but only 600 of them were available for charging purposes due to planning permissions. This corresponded to the views of other LAs that highlighted that there is a finite number of streetlights available, which could be a barrier for up-scaling. In addition, a LA stated that due to 3<sup>rd</sup> party arrangements regarding the ownership of the streetlights can impede implementation. The LA had to install bollards for every chargepoint, due to not having permission to implement the charger inside the streetlight. This resulted in higher installation costs, reduced profit margins and increased street clutter.

On-street residential charging is expected to make up a large share of EV charging, which could be served by lamp posts chargers. However, if there is a limitation to capacity there would need to be an alternative form of on-street charging to meet demand.

#### Pop-up and Kerbside Charging Units

Pop-up charging hubs aim to provide on-street charging without the street clutter, where the 7kW charging hubs retract into the ground when not in use, freeing up space. They are activated by an app, which also provides information to make it easy for EV drivers to locate and pay for charging. Kerbside charging units can be attached to existing street furniture such as bollards and signs, designed to have low visual impact. They are fitted with sensors to provide LAs with traffic, weather and air conditions data.

One chargepoint operator highlighted that pop-up chargers are an ambitious on-street charging option, due to the difficulties associated with 'moving objects' in the public realm. In addition, the level of maturity for this charging option is currently relatively low, supported by the fact that these charging options were not implemented by any of LAs in the stakeholder consultations.

### 2.3.2 End-user charging options

#### Innovative payment platforms

Unified payment platforms offer end-users new innovative ways to monitor, locate and pay for on-street charging, such as:

- **WeCharge:** Volkswagen customers have a choice of three individual tariffs, which gives the option for 'pay as you go' and 'charging as a service' through monthly payments and reduced costs per kWh, for a 12-month contract. App allows users to easily locate and book charging points, showing 'green power' and intelligent route guidance for long journeys (Green Car Congress, 2020).
- **EVpassport:** Distributed fleet charging ecosystem incorporating multiunit dwellings through a cloud-based, innovative use of a QR code payment method (Ford, 2021).

One distribution network operator expressed concerns that designing an app to incorporate these elements would be highly expensive and control of ownership are key issues for unified network coverages. However, the use of smart technology was noted to be effective for increasing accessibility through booking systems and chargepoint utilisation.

### Smart charging

Smart charging uses data generated by public and semi-public charging to develop smart software. Users can remotely stop or start the charge and adjust the charge rate according to the price of electricity. Charging during these off-peak times can not only reduce costs for EV drivers by using cheaper energy rates, but can also help to prevent/smooth unwanted intervals of higher demand for electricity from the grid.

One distribution network operator highlighted that smart charging for on-street chargers will be recommended as an innovative charging solution to benefit consumers, by reducing the cost of charging sessions and manages pressure on the grid capacity. A chargepoint operator was also supportive of smart charging, as it would enhance the user experience and they have the capacity to implement.

## 2.3.3 Rapid charging options

### Ultra-fast charging

Ultra-fast charging provides the ability for EV drivers to significantly reduce the time spent charging (provided their vehicle can support the higher charging speeds). Ultra-fast charging is viewed to be above 150kW, and there are chargers that can deliver 350kW (though there are currently no vehicle models available that can charge at this peak rate). This enables an increasing number of EV drivers to charge per day, and at scale fewer chargers per station are required to meet demand. In the future, the capacity of ultra-fast chargers is likely to increase. For example, 900kW chargers that can charge an EV battery from 0% to 80% in 5 minutes have recently been developed by a Chinese company (Green Car Congress, 2021), which could support potential future improvements in battery technology if the vehicles could support this power rating.

LAs highlighted that currently there is no viable business case to deploy ultra-fast charging from their perspective, due to limited funding streams. Due to the high installation and maintenance costs, these types of chargers are mainly restricted to the private sector. In addition, a chargepoint operator highlighted those high-powered chargers require higher utilisation rates for them to make commercial sense. A DNO stated that the costs of connecting these chargers to the grid and the reinforcement costs are costly, and highly dependent on locational based capacity.

### Rapid forecourt charging

Rapid forecourt charging consists of extensive ultra-fast charging networks, which are seen as essential to accelerate the adoption of electric vehicles. These chargers could be attractive for EV owners that do not have a charger at home, who can charge once or twice a week on their way to recreational activities or shopping. A recent survey (Venson, 2021) found that 68% of drivers would be more likely to make the switch to an EV if they knew they could conduct a rapid 30-minute charge at an electric forecourt rather than the inconvenience of charging their vehicle at home.

Private companies have allocated significantly large investments to install new ultra-rapid 150kW EV chargers in the UK. For example, the UK's largest independent petrol forecourt group 'Motor Fuel Group (MFG)' have committed £50 million to open 350 ultra-rapid charging stations across '60' hubs in 2022 (Autocar, 2022). A high proportion of its sites will be 'on-route' locations, and installations have already begun across the UK, with the northwest's first dedicated ultra-rapid EV site installed in Manchester, Stretford. Integrating renewable energy and storage systems also has the potential to ease the implications of the grid reinforcement costs. For example, Dundee city council have opened a rapid

forecourt charging hub with a solar canopy and energy storage system, which was the first integrated hub with PV, energy storage and rapid chargers. It delivered 24,000 charging sessions in its first year.

### 2.3.4 Emerging charging options

#### Inductive charging

Inductive charging is a wireless form of EV charging, where electricity is transferred through an air gap from one magnetic coil in the charger (hidden underneath the road surface) to a second magnetic coil fitted to the underside of a car. EV drivers, with vehicles equipped for this charging, just need to park their car in a position where the coils are aligned for charging to begin, which is being trialed in Nottingham as part of £3.4million scheme for taxis - funded by the Office for Zero Emission Vehicles (OZEV). This technology could enable EV drivers to charge more easily, while minimising street clutter by charging devices.

One LA stated that they had taken part in a pilot project for inductive charging and noted that the project had exceeded the expected timeline to implement. In addition, one chargepoint operator stated that dynamic charging requires large upfront investment costs for infrastructure development, which also means roads must be dug up, creating disruption to pedestrians and traffic.

It should be noted that there are relatively few vehicles available with inductive wireless charging, with it is being offered mainly as an option on premium vehicles currently.

#### Vehicle to grid

Vehicle to grid (V2G) offers EV drivers the opportunity to sell electricity back to the power grid from the EV battery. For example, electric car owners could charge their vehicle at off-peak rates overnight and sell energy back to the grid during the day while not in use. Bidirectional charging remains a niche technology, although it has been around for a while - a lack of standards across connectors, chargers, as well as a lack of vehicles and the issue of range anxiety remain key issues. In addition, CPOs and vehicle manufacturers would need to create the specific technology to enable vehicle to grid connections. However, from the vehicle-side the capability is increasingly being added to new models, such as those from Hyundai-Kia, and those from VW (via a future software update) (Fortune, 2021), (Electrek, 2021).

The overall sentiment from stakeholders was that vehicle to grid is currently not a viable option for on-street charging, as customers prefer to have a reliable network of public chargepoints before thinking about V2G aspects. A LA stated that they would be open to the idea of bidirectional charging, although referred to this being part of their longer-term plans.

## 2.4 Viable business models

#### Summary of key findings

- Each business model provides an alternative approach to providing electric vehicle charging for households without private off-street parking.
- Business models may be subjective to the types of actors involved, based on costs and preferences.
- User behaviour will be highly dependent on which business model is implemented, with subsidised costs being attractive to consumers.
- Emerging business models have high potential to reduce future costs, although there are key barriers to developing in the current market.

The future of the EV charging ecosystem depends on potential changes along 4 main dimensions: technology, that are split into between the EV charging and autonomous vehicles; regulatory environments; and customer expectations (Capgemini, 2019). This report outlines the different types of business models that can provide on-street EV charging for households without private off-street charging.

From the stakeholder consultations, LAs agreed that public-private partnerships, mainly through concession contracts are currently an optimal business model for installing on-street charging. Concession contracts rely on central government for the main funding source (75% OZEV) and through procurement commission CPOs to cover the other 25% investment costs and maintenance. The contract length is usually around five years, and after this period the contract can either be extended with a CPO or a procurement process to an alternative CPO that becomes responsible for the maintenance. One LA stated that this can add significant value to contracts, as CPOs uptake existing chargepoints and install additional ones. Recent work (PwC, 2018) identified four emerging business models for CPOs in the UK EV charging market (Table 2-3).

**Table 2-3: Emerging business models for CPOs (PwC, 2018)**

Business model	Description
<b>The 'Portfolio' player</b>	Acts across several charging segments (home, work, and destination charging)
<b>The 'Specialist' player</b>	Focuses on one charging segment (rapid charging operators are often a good example)
<b>The 'Network Optimiser' player</b>	Focuses on multiple charging segments and captures alternative forms of revenue in addition to EV charging, which could be helping to manage grid capacity through load shifting
<b>The 'Energy Supplier' player</b>	Typically, an electricity supplier - EV charging isn't the core business value, but they would like to build a position due to the boosted national demand for electricity. For example, they are increasingly interested in the potential for managing power demand profiles, via smart charging.

From an extensive review of the literature the following alternative business models for electric vehicle charging were uncovered, which may be viable now or in the future. Table 2-4 presents the business models uncovered, it should be noted that the classification of business models has been solely based on evidence from the literature and doesn't account for the results from the stakeholder consultations. For example, the interoperability business model is classified as 'established' although in UK there is a lack of an interoperable charging network. These are at varying levels of maturity, and focus on different aspects such as customer needs/satisfaction, profit making, and grid stabilisation (e.g. smart charging). Different business models could result in different end-user charging costs and would subsequently impact the types of infrastructure EV users without access to private off-street parking would use, and could impact the uptake of EVs for this customer group.

**Table 2-4: Business models for electric vehicle charging**

Business Model	Classification	Key words
Public private partnerships	Established	Concessions, own and operate, subsidies
Interoperability platform	Established	Unified authentication methods, network coverage
Direct billing	Established	Customer billing, established, simple platforms
Retail: Loss leader model	Established	Corporate branding, absorb costs, customer attraction, value creation financing
Retail: Cost recovery	Established	Operational cost coverage, financing
Retail: Profit making	Established	High tariffs, profit focused revenue streams, financing
Retail: Fully funded	Established	Third party investments, financing
Smart charging	Emerging	Data use, smart software, public advisory services, customer control



Business Model	Classification	Key words
Charging as a service & end to end energy	Emerging	Subscription services, ease of use, app payments, collective service
Indirect billing	Emerging	Third party billing
Rural EV charging networks	Emerging	Accessibility, local revenue streams, coordination between SMEs
Vehicle to grid (V2x)	Emerging	Bidirectional charging, storage and supply

## 2.4.1 Established business models

### 2.4.1.1 Public private partnerships

Public private partnerships constitute the development and management of public services through concessions granted by LAs with potential delegating after a given period (Capgemini, 2019). They are a cooperative agreement between two or more public or private sectors, typically constituting a long-term contract-based relationship. In terms of electric vehicle charging, LAs partner with public and private entities to finance, build, and operate charging networks. The model provides subsidies that fuels growth and enables chargepoint installation and operational costs to be covered. This is beneficial for LAs that may not have sufficient funding streams to invest in the chargepoints required in each constituency and provides a potential for revenue to be generated. The private sector also receives revenue, with the amount depending on the split of the investment streams and contract lengths. However, long length contracts can cause an issue for some LAs, who may not want to give up public land for extensive periods of time.

From the stakeholder consultations, public private partnerships were found to be the most popular business model, such as 'concession contracts' and the 'own and operate' models. CPOs develop and manage public services through concessions granted by LAs, and it has been attributed to be a reliable model to deploy on-street charging.

### 2.4.1.2 Interoperability platforms

An interoperable business model places emphasis on deploying interoperability of chargepoints to serve any customer using any service provider to maximise charger utilisation, customer experience, and optimise investments made (BCG, 2021). The key proposition of this business model is to aggregate CPOs through interoperability platforms to maximise network coverage. This should also establish technical, grid-connection, and safety standards, including standard communications protocols, to support effective chargepoint access and interoperability (BCG, 2021). It is considered as key to develop infrastructure with established players and provide consumers with a high 'ease of use'.

An example of an interoperable approach to develop an ecosystem of electric vehicle charging is through a 'roaming' centralised, simple, back-end response that provides a cloud-like system for the entire chargepoint network. Through stakeholder consultations, various platforms and payment methods were uncovered from CPOs & LAs across different cities in the UK. The lack of a centralised data network is preventing the development of an interoperable platform (Transport and Environment, 2021). CPOs outlined that they would be hesitant to develop a service that could address this issue, however competition could be fostered by removing barriers to entry and could create a simpler, standardised B2B interactions, transaction settlements and customer experience (BCG, 2021).

### 2.4.1.3 Direct billing

Direct billing is where the service provider (CPO) of public charging stations directly bill customers for their use through authentication methods and simple platforms (Capgemini, 2019). Numerous actors have adopted this business model, as it provides an established revenue stream. The benefits of this business model are that they offer a higher degree of personalisation to the CPO and enables control over profits. As a result, the CPO will have a higher control over margins and excludes the need for 3<sup>rd</sup> parties.



#### 2.4.1.4 Retail business models

Retail charging can be provided through a range of commercial business models are assessed in this section, as each one described may suit varying value propositions, revenue streams and customer preferences. These business models include:

- **Loss leader model:** EV charging provided for free, to increase branding and attract sales
- **Cost recovery:** Fees are set high enough to recoup operational and/or installation costs
- **Fully funded:** Providers will install chargepoints free of charge to a business
- **Profit making:** The fee for charging is designed to turn a profit from charging services.

The first retail EV charging business model assessed is the loss-leader model, where the company offers free charging to attract drivers. As a result, the company benefits from attracting and retaining customers, with the costs offset by the increased revenue gains (Atlas Policy, 2020). A free top up charge can be the deciding factor for a driver choosing where to offer their custom and the costs of offering, for example, 7kW charging to attract these drivers can be relatively modest (Pod Point, 2022). However, this business model is less suitable for rapid charger where the installation and operational costs are considerably higher. This business model is well suited to businesses who make more than £1 an hour of margin from customer attendance and businesses with typical 45+ minute customer dwell time (Pod Point, 2022). A key assumption of this business model being successful is that the EV charging installations are reliably available to customers, with numerous, clearly signed, and easy to use charging points.

A 'fully funded' business model can incorporate cooperation between actors, where charging infrastructure providers install chargepoints free of charge to the business. This requires long term planning and cooperation but can offer a solution for providing charging to households without private off-street charging while providing branding and financial opportunities to external actors.

In contrast, commercial charging can use business models to generate cost recovery from the installation and operational costs of EV charging. For example, an operational cost or total cost recovery business model levy's a fee on drivers that use the chargepoints, which can match either an operational or total cost recovery model. A key consideration of this model is that many EV drivers will compare these prices with home electricity rates. In terms of providing a sustainable landscape of off-street parking for households without private charging price is a key consideration under any business model. The more competitive the price, the more drivers that are attracted and use these chargepoints. Another key consideration is that it is imperative that billing methods are made easy to understand, access and use.

A commercial business model also has the potential to generate additional revenues for commercial enterprises, through a profit-making model. A higher fee is levied on drivers, which enables chargepoints to pay for themselves and generate profit. This is particularly a key consideration when deploying rapid charges, where it may be unsustainable to absorb installation and operational costs of ownership.

### 2.4.2 Emerging business models

#### 2.4.2.1 Smart charging (B2B) and Vehicle-to-grid (V2G)

Smart charging as discussed in section 2.3.2 uses data generated by public and semi-public charging to develop smart software to remotely stop or start the charge and adjust the charge rate according to the price of electricity. This emerging business model can be seen to be one of the most profitable business models, with very limited costs and high potential to develop alongside vehicle to grid (V2G) and load management strategies (Capgemini, 2019). As a result, they have the potential to reduce the TCO (total cost of ownership) of charging infrastructure and costs of owning an EV, through a cheaper charging option.

Vehicle to grid leverages the potential of EV batteries, allowing bidirectional charging, to provide storage and supply of energy to public or private electricity networks (Ofgem, 2021). EV owners get paid for the energy sold back to the grid, but there are highly variable costs depending on the tariffs available and cost of electricity. In 2018, a vehicle to grid programme launched in the UK, with collaboration between OVO Energy, Kaluza, Nissan Motor Company, research consultancy Cenex, and Indra Renewable Technology, and supported by funding from the Office for Low Emission Vehicles (OLEV, now OZEV)

and the Department for Business Energy and Industrial Strategy (BEIS). The project launched 330 V2G devices, and customers in the trial have earned up to £725 a year, through just keeping their EVs plugged in when they are not in use. Additional research has shown V2G has the potential to save £3.5bn per year in grid infrastructure reinforcement, storage and generation, due to the support provided during peak hours of energy demand (Ofgem, 2021).

However, there are currently some key barriers for the development of V2G uncovered by the rollout project. Addressing these issues will help to support the success of the technology at scale (Ofgem, 2021):

- **Costs of charging hardware and installation:** V2G installation costs are around £3,700 higher than smart chargers, the cost will need to decrease to deploy at a large scale.
- **Vehicle compatibility:** The only compatible EV was a Nissan Leaf, meaning the eligible customers was relatively small. (Though as noted above, new models from Hyundai-Kia Group and VW Group also have bi-directional charging capability built in - with V2G to be updated later via software).
- **Certifications:** Delays were experienced in received certification, and further challenges around the costs/processes for connecting V2G charger to various distribution networks.
- **Market access and value:** Market access is currently limited due to high entry thresholds, early-stage development of local networks and operational processes at a national level.

#### 2.4.2.2 Charging as a service and end-to-end energy

Charging as a service and end-to-end energy are subscription based EV charging packages that offer customers minimal upfront purchasing costs. Automakers offer charging as a service and end-to-end energy subscription based EV charging package offer customers minimal upfront purchasing costs. An example of a subscription includes charging stations, management software, 24/7 driver support and ongoing maintenance and repair (Chargedevs, 2022). Customers pay a monthly fee over a fixed term, instead of any upfront costs. Automakers offer a seamless charging offer and cover all electric mobility uses in everyday life. There are high levels of competition with numerous experimentation and developments. End-to-end energy offers and develop smart services thanks to data collection, with Tesla an example of a company using these bundled energy packages (Capgemini, 2019). However, there are often high initial investment costs required to develop and successfully implement these business models.

#### 2.4.2.3 Indirect billing

Indirect billing is where public charging stations bill a third-party willing to attract customers or support the development of EV charging stations. Investors are starting to develop this business model, as it is perceived to be adaptable and durable. However, the main business model currently preferred are direct billing mechanisms, due to the limited revenue potential from 3<sup>rd</sup> party involvements in the indirect billing process (Capgemini, 2019).

#### 2.4.2.4 Rural, local and small business initiatives

Local and small business initiatives focus on providing rural destinations with EV charging networks, to make them viable for dispersed communities. This business model is especially important for towns, cities and attractions that rely on highway access, where EV infrastructure will become vital for maintaining tourism activities. It is important for coordination between small business groups and relevant actors, in order to develop a successful business model for areas that are less densely populated, which may have to satisfy local heritage regulations and planning bylaws (Ensto, 2019).

From the stakeholder consultations, Suffolk County council highlighted that they had pioneered an EV charging pilot called 'Plug-in Suffolk', across 18 sites in the county. It was highlighted that private funding is especially hard to acquire for rural EV charging, due to a limited commercial business case. This business model relies on being fully funded through public grants, and the profits generated are received by the Parish councils. The pilot project implements fast chargers (7.4kW) in community charging hubs, with the location depending on where they receive expressions of interest, and whether the site has sufficient grid capacity to install chargepoints. An innovative hybrid payment option has been added to the chargepoints to enable both RFID and contactless payments, with the aim of increasing the accessibility and utilisation rates from visitors. In addition, residents in the area are

provided with a cheaper charging price through the RFID cards/tags, which only covers the operational cost of use. The profit making arises from the contactless payments, which have a higher commercial price and a transaction fee,

## 2.5 Review of current UK charging policy

There is currently a lack of public chargers for households without off-street parking. These public chargepoints are typically more expensive to invest in than off-street home slow chargers, and this therefore deters investment and hence their availability. Households without access to private off-street parking are underrepresented in the rollout of EVs, with only 7% of current EV owners not having access to private off-street parking compared with over 30% of households in the UK not having access to private off-street parking. Previous research in this area has identified that 28.3% of drivers are put-off from switching to an EV as they have nowhere to install their own chargepoint (SMMT, 2021), which indicates that the current provision of public EV charging is not satisfactory for households without access to private off-street parking.

### 2.5.1 Current public chargepoint policy

Currently, the OZEV On-street Residential Chargepoint Scheme (ORCS) provides grant funding for LAs towards the cost of installing on-street residential chargepoints for plug-in electric vehicles of up to 75% of capital costs. Feedback from LA stakeholders indicated that the actual price of installing chargepoints was higher than initially thought, and the 75% funding often does not actually cover 75% of the CAPEX costs after installation.

Current policy is for central government to provide the funding to LAs for on-street charging provision, but it is up to the LA on where to install this infrastructure. This is often a challenge, as LAs do not typically have a dedicated EV infrastructure team, and the provision of this infrastructure is a new topic area for them. The LA stakeholders often do not know the optimal split of chargepoints by power and location to serve their area, and would appreciate clear guidance from central government on how to distribute the funding to each of slow/fast on-street residential, en-route rapid and/or rapid forecourt chargers. There is also anticipation from all stakeholder groups about what a new funding for chargepoints will look like, with many LAs and CPOs already planning for significant funds being available. In addition, there is a risk of inequity as some LAs may be left behind if they do not have sufficient funding or resourcing to implement chargepoints.

LAs in most cases respond to resident's requests to install on-street charging infrastructure, and therefore currently on-street charging infrastructure is placed in locations with the highest level of demand. This is most often in urban areas, where both population and uptake of EVs is higher than in rural areas. Stakeholders indicated that due to lower utilisation rates the business case for rural EV charging infrastructure is weak, and therefore difficult to attract CPOs to operate the infrastructure through concession contracts in rural areas. These issues could create a risk that EV users without access to private off-street parking living in rural areas do not have the satisfactory charging infrastructure, which is something that future UK charging infrastructure policy could aim to support through increased funding or other means.

### 2.5.2 Proposed policy and key commitments for public chargepoints

There have been several recent developments in UK charging infrastructure policy. The latest delivery plan for transitioning cars and vans to zero emission by 2035 includes the following relevant key commitments for providing public chargepoints (DfT, OZEV, 2021):

- Investing £1.3 billion to accelerate the rollout of charging infrastructure on motorways, on streets, in homes and workplaces
- Publication of an Electric Vehicle Infrastructure Strategy in 2021
- Ofgem has published a consultation covering distribution network connection charging with changes expected to come into force in 2023
- Fund grants for chargepoints in homes, workplaces and on-street until at least 2024/25
- Regulate to improve the consumer experience at public chargepoints in 2021

These commitments should improve the current roll-out strategy of public chargepoints, particularly with the regulation to improve the consumer charging experience which could increase public's perception

of UK charging infrastructure and as a result increase EV uptake for users reliant on the public charging network.

The results of the Ofgem consultation could have a major impact on the roll-out of high-powered chargers (50kW+). The grid upgrade costs for these types of chargers can be in the region of millions of pounds for a site of 10 chargers, and so changes to policy such as socialising the grid upgrade costs could greatly reduce the installation cost of rapid chargers, resulting in a reduced cost to the CPO and ultimately the end user. The UK Government has also set out ambitious targets for rapid chargers along motorway service stations to achieve:

- by 2023, to have at least 6 high-powered, open-access chargepoints (150-350 kW capable) at each motorway service area in England
- by 2030, to have around 2,500 high-powered, open-access chargepoints across England's motorways and major A roads
- by 2035, to have around 6,000 high-powered, open-access chargepoints across England's motorways and major A roads

As a result of these targets a rapid charging fund (RCF) of £950 million has been set up to help fund these high-powered chargers (OZEV, 2021). Rapid chargepoints will be necessary to support EV drivers in the longer-distance journeys. However, as these types are chargers are the most expensive (to install and also to the end-user), careful consideration must be taken to ensure that the number and location of these chargepoints is optimal.

The UK have also announced that from 2022 there will be minimum chargepoint requirements on new developments, specifically (Pod Point, 2021):

- All new non-residential buildings with more than 10 parking spaces must have a minimum of one chargepoint and cable routes for 20% of the total number of spaces; and
- All non-residential building undergoing a major renovation that will have more than 10 parking spaces must have a minimum of one chargepoint and cable routes for 20% of the total number of spaces.

This new policy will ensure that new non-residential developments will have destination chargers, which will go some way to satisfying the needs of users without access to private off-street parking (Figure ). One LA stakeholder has already put this into practice, with 10 destination chargers being deployed as a result of change of use planning for a shopping centre.

## 3 Cost calculations

### 3.1 Selected business models

The costs of EV charging to the end-user under different business models was calculated. The selected business models have been split into three location types: **On-street residential**, **Destination** and **Rapid** charging.

There are seven unique business models which were carried forward for the cost calculations.

#### 3.1.1 On-street residential charging

##### **BM (business model)1: Lamp post chargers (3 to 5.5 kW power rating)**

This business model is similar to typical 'home' charging, where users plug-in overnight at lamp post chargers in residential areas. These chargers are typically low power rating (3 to 5.5 kW) and therefore have longer charge times compared to other charging types. This business model was assumed in the form of a concession model, where the LA facilitates the use of the lamp post, and the CPO is under contract to provide maintenance and operation of the chargepoint, and the CPO makes a margin on charging fees.

##### **BM2: Fast charging on-street (7-22kW)**

This business model is similar to the lamp post charging, but additional cost features were considered such as civil works, grid connection costs and a higher CAPEX rate vs the lamp post business model. Again, this business model was assumed to be in the form of a concession model, where the LA facilitates the use of the lamp post, and the CPO is under contract to provide maintenance and operation of the chargepoint, and the CPO makes a margin on charging fees.

#### 3.1.2 Destination charging

##### **BM3: Destination cost recovery model**

This business model was focused on destination charging, for example at a shopping centre or car park. In this business model, the shopping centre was assumed to aim to recover the costs (either CAPEX and/or OPEX) from implementing the infrastructure through charging the end-user a fee for charging.

##### **BM4: Fully funded**

Similar to BM3, however the CPO funds the CAPEX and the OPEX of the infrastructure and takes a revenue share. The shopping centre was a facilitator of the land, much in the same way as concession contracts (BM1/2).

##### **BM5: Profit making**

The destination which has installed the infrastructure was assumed to make revenue on top of the fee the CPO is paying, using the charging infrastructure as an additional profit-making business. This resulted in high prices to the end-user but could be seen as attractive for the destination as they will make profit.

#### 3.1.3 Rapid charging

##### **BM6: En-route rapid charging (50-150kW)**

Under this business model the CPO paid for all CAPEX and OPEX and makes a profit on the sale of charging to the end-user. The higher-powered chargers were expensive due to high installation and hardware costs. This could be appealing to the end-user as faster charging is seen as being attractive. Under this business model charger powers of 50kW and 150kW were considered. Charger power rating of 350kW were not considered under this business model as this rating is not supported by passenger vehicles currently.

**BM7: Forecourt rapid charging (50-150kW)**

Similar to BM6, this business model has a number of high-powered chargers. The key difference vs the en-route chargers was that the forecourt is located in an urban environment and may not be utilised in the same way as the en-route model. The CPO again paid for CAPEX and OPEX and makes a profit. Under this business model charger powers of 50kW and 150kW were considered. Charger power rating of 350kW were not considered under this business model as this rating is not supported by passenger vehicles currently.

## 3.2 Baseline cost results

### 3.2.1 Baseline business model characterisations

The below assumptions were used to characterise the selected business models to reflect ownership/operation of the infrastructure as described in Table 4.4.

**Table 3-1: Summary of baseline business model parameters used in the cost calculation**

Business model	Grant level	Payback period	Profitability	Discount rate
<i>BM1: Lamp post chargers</i>	75%	7	0.05 £/kWh	3.5%
<i>BM2: Fast charging on-street</i>	75%	7	0.05 £/kWh	3.5%
<i>BM3: Destination cost recovery model</i>	0%	7 (22KW) 20 (50/150KW)	0 £/kWh	3.5%
<i>BM4: Destination fully funded</i>	0%	7 (22 KW) 15 (50/150KW)	0.05 £/kWh	8.5%
<i>BM5: Destination profit making</i>	0%	7 (22 KW) 15 (50/150KW)	0.08 £/kWh	8.5%
<i>BM6: En-route rapid charging</i>	0%	15	0.05 £/kWh	8.5%
<i>BM7: Forecourt rapid charging</i>	0%	15	0.05 £/kWh	8.5%

Lamppost chargers (BM1) and fast charging on street (BM2) are assumed to be run as a concession model, where the LA facilitates the use of the lamp post, and the CPO is under contract to provide maintenance and operation of the charge point, and the CPO makes a margin on charging fees. Thus, a 75% funding from OZEV (as is currently the case) is assumed and a social discount rate of 3.5% (HM Treasury, 2018). As informed by stakeholder engagement, contracts are usually 7 years long (5 years and 2 for extension). A fixed profit rate of 0.05 £/kWh was assumed, as informed from stakeholder consultation and industry values.

Rapid charging business models (BM6 and BM7) are assumed to be owned and operated by the private sector; thus, no grants are assumed. For these commercial business models, a private discount rate of 8.5% was assumed (European Union, 2016). As informed by stakeholder engagement, contract lengths for rapid charging are 15-20 years. The lower bound for these business models was assumed. A fixed profit rate of 0.05 £/kWh was assumed, as informed from stakeholder consultation and industry values.

Similar assumptions were made for destination charging for the cases where a profit is expected (BM4 and BM5), only assuming a lower contract length for those cases with a charger of 22KW to be aligned with the industry. A higher profit rate is expected for BM5 as revenues need to be shared by the shopping centre/park and the CPO. A rate of 0.08 £/kWh was assumed, informed by stakeholder consultation.

For destination cost recovery (BM3), no profit rate was assumed as the business is only run to recoup costs. In this model, a longer contract length was assumed (higher bound) as costs are not expected to be repaid immediately and in some cases all costs may not be recovered.



### 3.2.2 Baseline results and main sensitivities

Baseline costs to consumers were calculated for each of the modelled business models described in Section 4.1 and relevant power rates. The results shown in this section represent expected utilisation rates for each technology and their evolution, as presented in Appendix 2. The baseline results from the cost calculation model are summarised in Table 4-6 for each business model and power rates.

**Table 3-2 Summary of baseline cost results for each business model and power**

Business model	Cost to consumers (£/kWh)	Costs without assumed profit (£/kWh)
<b>BM0: Off-street 7KW</b>	0.23	
<b>BM1: Lamppost</b>		
Lamppost 3KW	0.27	0.22
Lamppost 5.5KW	0.26	0.21
<b>BM2: On-street</b>		
On-street 7KW	0.31	0.26
On-street 22KW	0.26	0.21
<b>BM3: Destination cost recovery</b>		
Public 22KW	0.21	
Rapid 50KW	0.27	
Rapid 150KW	0.30	
<b>BM4: Destination fully funded</b>		
Public 22KW	0.27	0.22
Rapid 50KW	0.35	0.30
Rapid 150KW	0.40	0.35
<b>BM5: Destination profit making</b>		
Public 22KW	0.30	0.22
Rapid 50KW	0.38	0.30
Rapid 150KW	0.43	0.35
<b>BM6: Rapid 50-150KW</b>		
Rapid 50KW	0.35	0.30
Rapid 150KW	0.40	0.35
<b>BM7: Forecourt 50-150KW</b>		
Forecourt 50KW	0.31	0.26
Forecourt 150KW	0.34	0.29

\* Note: Electricity cost for off-street: 0.186 £/kWh. Electricity cost for business models BM1 – BM7: 0.183 £/kWh (see section 4.3).

Baseline results from the model suggest that higher power lamppost (5.5KW) and higher power off-street business models (22KW) are the most affordable options for consumers that do not have access to off-street charging. The cost to consumers from using lamppost chargers and fast charging on-street

options decrease with higher power rates, almost converging to the wholesale electricity price. Higher energy delivered by higher power chargers allows savings for consumers, by reducing the cost per kWh. Additional infrastructure costs for higher power lamppost and fast charging on-street options are relatively small, which helps explain the observed reduction in costs to consumers. Results suggest there is a business case for higher power on-street residential charging (BM1 and BM2), as these result in lower costs to consumers. Making lamppost chargers and higher power fast on-street charging available may encourage the switch to EVs compared to access to other charging options modelled.

Costs to consumers vary in destination business models (BM3, BM4, BM5), depending on whether the shopping centre or car park expects a profit. Currently, most destination business models are run to recover costs, as the shopping centre or car park is likely to benefit from increased traffic into their businesses. In such a business model (BM3), costs to consumers are relatively small compared to rapid charging and fast charging on-street. When a profit is factored into calculations, the attractiveness of destination business models to consumers is reduced compared to en-route business models. However, the overall attractiveness of this business models will not only depend on the cost to consumers. For rapid chargers, higher power is associated to higher costs to consumers, given that the additional infrastructure and potential grid upgrade costs are significant and are not compensated by the increased energy delivered.

In terms of rapid charging (BM6, BM7), forecourt chargers offer lower costs to consumers than en-route as forecourt is located in an urban environment, and higher utilisation rates are expected. In this way, urban areas can benefit from cheaper rapid charging. En-route charging results in the highest cost to consumers compared to the other business models. Costs are higher for higher power rates, as the additional infrastructure costs for higher power chargers is significant<sup>3</sup>.

Required grid upgrade costs can vary greatly, and these can affect costs to consumers from using rapid charging. Cost to consumers can increase if expensive grid upgrades are required for the higher-powered chargers, particularly if these costs are socialised in the future. Costs to end-user can increase by 0.03 - 0.05 £/kWh if grid upgrade costs are doubled, whereas they can decrease by 0.03 - 0.05 £/kWh if no grid upgrade costs are required. This suggests it is more attractive to CPOs to adopt chargers in areas where limited grid upgrades are required.

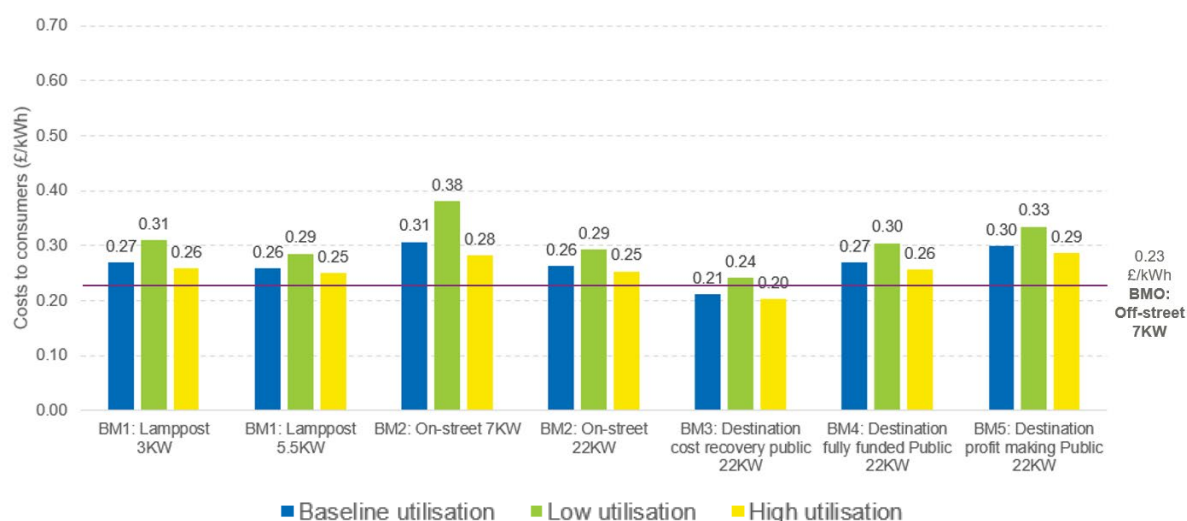
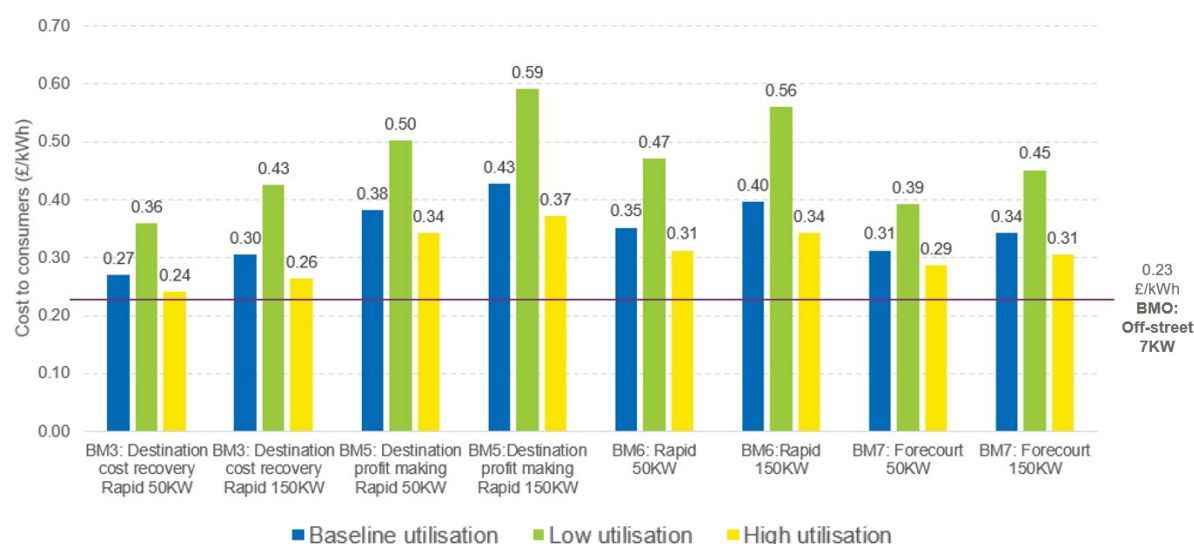
Overall, cost to consumers resulting from baseline calculations are in line to what consumers indicated they are willing to pay (see Section 2.2.2), suggesting these are attractive business models. Profitability rates assumed have a significant impact in the results obtained, except for destination cost recovery (BM3) where no profit rate was assumed (see Table 4-6). The profit rates used result in similar costs to consumers than those observed in practice, suggesting baseline parameters are aligned with the industry (see Section 2.2.2).

Results for on-street charging (BM1 and BM2) assume a 75% CAPEX funding from OZEV. Without grants, only higher power chargers continue to be an attractive charging option for consumers without access to off-street charging, as they continue to be the cheapest option (0.28 – 0.29 £/kWh for lamppost 5.5KW and fast on-street 22KW, respectively). No funding seems to be needed for higher power on-street charging to be attractive in the baseline scenario. However, lower power on-street charging options do not seem to be attractive to consumers without grants as costs rise to 0.30 – 0.36 £/kWh (for lamppost 3KW and fast on-street 7KW, respectively), similar to results for rapid charging. Funding for lower power on-street charging options seems to be required for these business models to be attractive, unless higher utilisation rates are expected. This is explored later in this section.

Results, however, are very sensitive to the utilisation rates assumed, with higher utilisation rates further reducing costs to end-consumers, and lower utilisation rates significantly increasing costs to consumers. Figure 9 and Figure 10 show sensitivities to low (-50%) and high (+50%) utilisation rates.

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<sup>3</sup> It is important to note that these results factored a reduction in utilisation time for higher power technologies to avoid overestimating utilisation rates (see Section 4.3).

**Figure 3-1: Utilisation rate sensitivities for costs to consumers for on-street residential charging and destination 22 WKW (£/kWh)****Figure 3-2: Utilisation rate sensitivities for costs to consumers for rapid charging (£/kWh)**

As can be seen in the figures above, lower utilisation rates significantly increase costs to consumers, hampering the attractiveness of the different business models. Rapid charging shows the largest sensitivity to lower utilisation rates, given the significant CAPEX and potential grid upgrade costs that need to be recovered. In the model, this results in costs to consumers more than double the price that they are willing to pay. This suggests chargers in busy urban areas more attractive, as higher rates can be expected.

Higher utilisation rates reduce costs to consumers, and they also reduce the costs differences between charging options. With higher utilisation rates, on-street charging options are cheaper than rapid charging options, but by a smaller amount than with baseline utilisation rates. Rapid charging becomes more attractive than with lower utilisation rates. This is the case as costs to consumers are likely to converge to electricity prices as demand for them increases.

Grants for on-street residential charging are expected to be phased out in the future, as utilisation rates increase. Assuming a high utilisation rate (+50%), costs to consumers only increase to up to 0.28 £/kWh for lamppost (3KW and 5.5KW) and higher power fast on-street (22KW). These business models will continue to be attractive for consumers, offering the lowest costs to those without access to off-street charging. However, lower power fast on-street charging (7KW) seems to continue to be dependent on grants to be attractive, even if a higher utilisation is considered. Costs increase to 0.32 £/kWh for this

option, suggesting lower power fast on-street is not as attractive as other on-street charging options in the future (i.e., higher utilisation rates expected).

As utilisation rates grow in the future, contract length for rapid charging is expected to be shortened. Costs to consumers only increase to 0.37 £/kWh for 50KW (+0.02 £/kWh) and 0.42 £/kWh for 150KW (+0.02 £/kWh) compared to baseline costs if similar contract lengths as on-street residential are assumed (7 years). Results for forecourt charging indicate costs to consumers of 0.32 £/kWh for 50KW (+0.01 £/kWh) and 0.36 £/kWh for 150KW (+0.01 £/kWh) for 7-year contracts. Results suggest that shorter contracts (7 years) are feasible for en-route charging as demand for these options increase in the future.

The cost to consumers will be impacted by increasing electricity prices. Absolute costs to consumers across the different business models is expected to increase in a similar way from increasing electricity prices. This is the case as cost to consumers in this model is based on the total costs of the infrastructure and a margin, consisting of similar profit rate per kWh of electricity consumed for all business models. However, in relative terms, the increase in costs to consumers will be lower for rapid charging business models, as these have a higher CAPEX and electricity prices only represent a smaller proportion of overall costs, compared to on-street residential charging options where this proportion is higher. For example, baseline results indicate that a 0.10 £/kWh higher electricity price (tariff of ~0.28 £/kWh as expected from the tariff cap update), represents an increase of ~30% of costs to consumers for using rapid charging compared to ~36% increase for on-street residential charging costs to consumers.

#### Conclusions from baseline calculations and main sensitivities:

- Costs to consumers arising from baseline calculations are in line with consumers' willingness to pay (based on survey responses), indicating they are feasible business models.
- Baseline costs to consumers are in line with costs seen in practice, suggesting baseline parameters are aligned with the industry.
- Higher power lamppost charging (5.5KW) and fast on-street (22KW) offer the cheapest costs to consumers without access to off-street charging. These charging options are most likely to attract consumers to switch to EVs in the near future.
- There is a business case for higher power on-street residential charging (BM1 and BM2), as these result in lower costs to consumers.
- Rapid charging is the most expensive modelled option for consumers, with higher costs for higher power chargers.
- Rapid charging costs are very sensitive to grid upgrade costs, making locations with sufficient grid capacity more attractive.
- Forecourt charging is cheaper than en-route rapid charging, as higher utilisation rates are expected. Consumers in urban areas, where forecourt charging options are located, can benefit from lower rapid charging costs. On the contrary, consumers in rural areas are likely to pay more due to potentially lower utilisation rates/lower charging options – this needs to be considered throughout the ramp up of EV charging infrastructure to ensure a just transition
- Costs to consumers across all business models are very sensitive to utilisation rates, with lower rates significantly increasing end costs. Rapid charging shows the highest volatility to lower utilisation rates, resulting in higher prices than consumers are willing to pay. This suggests chargers in busy urban areas more attractive, as higher rates can be expected.
- In the longer-term future (with higher utilisation rates), the differences in costs to consumers become smaller for the modelled charging options, making rapid charging options more attractive.
- As utilisation is expected to increase in the future, grants are expected to be phased out (for on-street charging options) and contracts lengths to be reduced (for rapid charging options). The effect of these parameters on overall costs to consumers is expected to be limited for cases where utilisation is high.

- Higher electricity prices will increase costs to consumers across all business models, with this increase representing a higher relative rise for those business models with lower CAPEX costs – i.e., on-street residential charging.

## 4 Wider impacts of charging types and business models

This section aims to combine the research into viable business models for EV charging infrastructure and cost calculations with the expected charging behaviour of EV users to understand the impacts these business models may have on charging behaviour and subsequent wider implications.

The wider impacts categories covered are as follows:

1. **Impacts on the grid** to what extent are grid connections, upgrades and reinforcements required for the charger type and business model? Can smart charging be implemented to facilitate the stabilisation of the grid?
2. **Impacts on traffic/congestion** does the business model create additional traffic demand at the charger locations? Will dedicated EV bays cause issues with local residents?
3. **Impacts on EV uptake** are the combinations of business model and charger type attractive for end-users in terms of charging speed, reliability and cost to make switching to an EV more attractive?
4. **Urban and rural considerations** how do the business models vary between rural and urban areas? Are they all feasible in both urban and rural applications?
5. **Impacts on CPOs and LAs** how attractive are the business models to the CPOs and LAs in terms of profitability and planning issues?

A summary of the wider impacts for each business model explored is shown in the Table 5.1 below, with the following sections exploring these impacts in greater detail.

It is noted that there are other innovative charging types and business models for users without access to private off-street charging which are not included in this list, but are worth considering in the future mix of charging options. Co Charger is a community charging application which enables motorists with EV chargers on a private driveway to share them with neighbours for a slightly increased fee (Co Charger, 2022). This will allow users without a private charger to use a private charger for a slightly increased rate to private charging, as the household with the private charger aims to make a slight profit.

Another innovation is dedicated pavement cable gullies which allow a cable to be run from private electricity supplies to the street underground to not obstruct the walkway. This has been piloted in Oxfordshire under the OxGul-e project funded by OZEV (Energy saving trust, 2021). Installing gullies is significantly cheaper than providing residential on-street charging, such as through a free-standing bollard. The return on investment is approximately two years. It is anticipated that the cost could be met by homeowners, in the same way that the provision of dropped kerbs is funded. This could be a solution in future for households without access to private off-street parking, as it would allow for private charging level prices and convenience.



Table 4-1: Summary of the wider impacts for each business model

Type of charging	Business model	Grid	Traffic/congestion	EV uptake	Urban/rural	CPOs/LAs
On-street	BM 1: Lamp post chargers (3-5.5kW)	<ul style="list-style-type: none"> <li>✓ No impact on the grid</li> <li>✓ No connection required</li> <li>✓ Smart charging capabilities</li> </ul>	<ul style="list-style-type: none"> <li>✓ Increase in dedicated EV parking spaces</li> <li>✓ Potential for booking systems</li> <li>✗ Long charging times</li> <li>✗ Potential localised increase in traffic</li> </ul>	<ul style="list-style-type: none"> <li>✓ Residential charging</li> <li>✓ Standardised payment potential</li> <li>✓ Ease of use</li> <li>✓ Low cost the end-user</li> </ul>	<ul style="list-style-type: none"> <li>✓ Suitable for urban areas</li> <li>✓ Use of existing street scape</li> <li>✓ Lower sensitivity to utilisation</li> <li>✗ Limit on scalability in some areas</li> <li>✗ Potential planning difficulties</li> </ul>	<ul style="list-style-type: none"> <li>✓ Easy to implement</li> <li>✓ Lower CAPEX and OPEX costs</li> <li>✓ Shorter payback periods and contract lengths</li> <li>✓ Less variation in costs</li> <li>✓ Concession contract and OZEV funding capability</li> </ul>
	BM 2: Fast charging (7 – 22kW)	<ul style="list-style-type: none"> <li>✗ Can require grid connection and reinforcement costs</li> <li>✗ Civil works cost's location dependent</li> </ul>	<ul style="list-style-type: none"> <li>✓ Dual charging technology</li> <li>✓ Booking systems</li> <li>✗ Potential for localised increase in traffic due to demand for fast charging</li> </ul>	<ul style="list-style-type: none"> <li>✓ Faster charging times</li> <li>✓ Reliability from booking systems</li> <li>✓ Suitable for rural community charging hubs</li> <li>✓ Standardised payment potential</li> </ul>	<ul style="list-style-type: none"> <li>✓ Suitable for urban/rural areas</li> <li>✗ Rural community charging hubs require more funding</li> <li>✗ Planning difficulties</li> </ul>	<ul style="list-style-type: none"> <li>✓ Concession contract and OZEV funding capability</li> <li>✗ Higher CAPEX and OPEX (vs lamp post)</li> <li>✗ High variation in utilisation and costs</li> </ul>
Destination charging	BM 3: Cost recovery	✗ Potential grid connection and reinforcement costs depending on charger power	✓ Limited impacts on traffic/congestions	✓ Reduced costs of charging	✓ High utilisation at popular 'destinations'	✓ Driven by the market
	BM 4: Fully funded			➤ Variable costs depending on CPO	✓ Suitable for urban and rural areas	✓ CPOs develop effective partnerships with

Type of charging	Business model	Grid	Traffic/congestion	EV uptake	Urban/rural	CPOs/LAs
	BM 5: Profit making			✗ High costs not attractive		private companies ✓ LAs don't need to be involved
Rapid charging	BM 6: En-route rapid charging (50 to 150kW)	<ul style="list-style-type: none"> <li>✗ High grid connection and reinforcement costs</li> <li>✗ High civil work costs</li> </ul>	<ul style="list-style-type: none"> <li>✓ Quick charging turnover times</li> <li>✓ Drivers charge through normal journey patterns</li> </ul>	<ul style="list-style-type: none"> <li>✓ Rapid charging times</li> <li>✓ Payment options</li> <li>✓ Reduces range anxiety of drivers</li> <li>✗ High cost</li> </ul>	<ul style="list-style-type: none"> <li>➤ Installation focused on areas with high utilisation</li> <li>✗ Less economic incentive in rural areas</li> </ul>	<ul style="list-style-type: none"> <li>✗ High installation and hardware costs</li> <li>✓ Reduced impact on LAs</li> <li>✓ Commercial business model</li> <li>✓ Rapid charger fund available</li> </ul>
	BM 7: Forecourt rapid charging (50 to 150 kW)	<ul style="list-style-type: none"> <li>✓ Renewable innovations reduce impact</li> <li>✗ Similar impacts as en-route charging</li> </ul>	<ul style="list-style-type: none"> <li>✗ Queues for 'more desirable' fast charging</li> </ul>	<ul style="list-style-type: none"> <li>✓ Availability</li> <li>✓ Similar model to petrol/diesel</li> </ul>	<ul style="list-style-type: none"> <li>✗ Installation focused on areas with high utilisation</li> <li>✗ Less economic incentive in rural areas</li> </ul>	<ul style="list-style-type: none"> <li>✓ LA will have more input through public-private partnerships</li> <li>✓ Rapid charger fund available</li> </ul>

## 4.1 On-street residential charging

Under on-street residential charging two types of model are explored:

- Lamp post charging (3 to 5.5 kW)
- On-street fast charging (7 to 22 kW)

### 4.1.1 BM 1: Lamp post chargers (3 to 5.5 kW power rating)

#### Impacts for the grid

Lamp posts are already connected to electricity grids, so therefore there are no connection or upgrade fees needed. In addition, lamp posts have switched to LED lightbulbs resulting in spare capacity for electric vehicle charging (in kW). There is also the potential for incorporating smart charging into this type of on-street residential charging. This would reduce the costs of charging sessions for EV drivers, and ease pressure during peak hours on the distribution network operator. Lamp post chargers work in a similar way to residential home chargers, in which the operational pattern can be predicted more easily compared to other types of chargers. As a result, there is a very low impact on the grid.

#### Impacts for traffic and congestion

Lamp post charging may result in possible conflicts for EV parking spaces. Due to the limited number of lamp post chargers, there could be accessibility issues for multiple EVs wanting to charge at the same time. In addition, non-EV drivers may be against having these 'EV only' parking bays, as it reduces the number of residential parking spaces. As a result, this could create legal and planning issues in certain areas where lamp post chargers are implemented. Another potential area to consider is if EV drivers travel longer distances to find these chargers and reduce the utilisation for EV users in that area. This could be a particular issue if there are clusters of charging locations, and they are not distributed equally across residential areas. The potential consequence of this would be an increase in congestion and traffic from the greater numbers of EVs in the local area. In response to this, booking systems could be implemented as a potential solution to reduce the risk of traffic and congestion, or alternatively implement a local charge card system whereby local residents can be charged a lower fee.

#### Impacts on EV uptake

Lamp post chargers could be effective at increasing EV uptake, by providing households without private off-street parking access to a network of chargepoints close to where they would be parking overnight in many cases. This will especially be evident in residential areas with a quality network of lamp post chargers, where EV owners will be able to leave their vehicles to charge close to their houses.

The cost of lamp post charging is the lowest of the charging options (Section 4.4). As cost is one of the key drivers for attractiveness of EV charging infrastructure, an effective wide-spread network of lamp post chargers in residential areas without off-street parking could influence households to switch to electric vehicles. The cost to the end-user is slightly affected by the utilisation rates, however as it could be seen as an attractive charging option for EV users without private charging it could be expected that lamp post would be well utilised, driving the price to the end user down and increasing the attractiveness of this charging option. Due to low charger power rating lamp post chargers are only suitable for overnight or long-stay charging, and so would not be attractive for users which have a private charger. This would reduce the competition for these charger types and leave them available for use by households without access to private chargers only.

#### Impacts on urban/rural considerations

Lamp post chargers in urban areas are valid given their utilisation rates being the highest for such areas. In contrast, all the LAs interviewed stated that this was not the case for rural areas, due to both low utilisation rates and a lack of existing lamp posts. As a result, it can be determined that these charger types are more relevant for urban areas where there are more available lamp posts. There may also be challenges in specific areas, where the lampposts may be on the opposite side of the pavement (i.e. on the near-side rather than near the kerb) or the lamppost may be made from concrete. In these cases, a satellite bollard charger is required to utilise the existing lamp post connection. This could be an issue if the demand for lamp post chargers increases greatly as it is seen as an attractive option for end-users, as there are limited number of lamp posts in suitable areas.

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## Impacts on CPOs, LAs

From the stakeholder consultations, both CPOs and LAs were highly supportive of lamp post chargers. The impacts would be shorter cost recovery periods and contract lengths compared with more expensive and higher voltage charge points. However, it is highly dependent on the local planning context, as some LAs were unable to install any of these types of charging infrastructure due to the type of lamp post installed (concrete/wooden).

There are no civil works required for 'easy install' lamp post chargers (i.e. no satellite bollard required). This is extremely beneficial for the LA, as there are no road closures required and limited impacts on the pedestrian walkway. They are also the lowest cost charger to install and maintain, and so funding requirements are also minimised.

### 4.1.2 BM 2: Fast charging on-street (7-22kW)

#### Impacts for the grid

Fast charging on-street require grid connections and reinforcement costs, the costs and extent of the impact is highly dependent on the location of the chargepoint. For example, in areas which already have existing grid capacity, stakeholder have indicated that connection costs can range between £2,000 – £5,000. However, if fast chargers are installed in areas without the existing grid capacity costs can increase considerably (up to £315 per kW additional capacity required, Section 4.3). This was highlighted in the stakeholder consultations with LAs, which stated they currently avoid higher costs by identifying sites with the existing grid capacity to install fast charging infrastructure. However, this was noted as a key concern for the future upscaling of on-street charging infrastructure. LAs stated that some on-street areas are unviable for EV charging infrastructure due to financial barriers that arise from the high grid connection, upgrade and reinforcement costs.

#### Impacts for traffic and congestion

Fast charging on-street can provide benefits for traffic and congestion if managed effectively. The development of new innovative technology such as dual charging bays are being used by multiple LAs, confirmed through the stakeholder consultations. As a result, fast charging infrastructure can support higher utilisation rates and reduce traffic/congestion from drivers queuing to charge. In addition, a newly developed 'NetX project', supported by Innovate UK and funded by the Office for Zero Emission Vehicles is trialling a new charging innovation, which allows three times as many EVs to be charged at an existing charging site (Drive Electric, 2021). NetX is a three-socket charger that can extend an existing single charge point, increasing the capacity of a standard 7kW fast charger to three vehicles. One LA who was part of the OZEV funded trial was interviewed and supported this development, highlighting that new technology could support high utilisation rates.

However, there is the possibility that the increase in demand for chargepoints could increase localised traffic and congestion in areas. An effective management strategy identified from the stakeholder consultations was the emergence of booking systems for fast on-street chargers. An LA stated that a Charge Point Operator had developed an app-based booking system to enable EV drivers to securely book charging sessions. As a result, this supports the findings from Task 1.1 where the reliability and availability concerns for chargepoints are addressed. Drivers can ensure they can confirm exact times and locations for charging sessions. This could also reduce range anxiety and support EV uptake.

#### Impacts on EV uptake

The cost to the end-user of 7kW on-street chargers is higher than that of the 22 kW chargers. This is a result of a greater throughput of electricity in the 22 kW per day, resulting in a higher revenue for the CPO which outweighs the increase in CAPEX costs for the 22 kW chargers. The 7kW chargers are more expensive than the lamp post chargers, and therefore in a residential area where overnight charging is preferred lamp post chargers would be deemed a more attractive option to users compared to the 7 kW chargers. Therefore, a network of 7 kW on-street chargers is unlikely to increase EV uptake for households without private off-street parking more than the availability of lamp post chargers.

On-street chargers rated 22 kW (AC) cost to the end-user is in line with the lamp post chargers, based on the baseline utilisation rates, but can offer a faster charge to users – but only where this is possible for the vehicle. This was identified in Task 1.1 as one of the key preferences for the future charging ecosystem from EV drivers, and therefore could potentially be more attractive to end-users compared to lamp post chargers. Booking systems for 22 kW chargers would be essential to ensure EV drivers could book a slot for charging their vehicle, with potential idling fees implemented to deter users from

parking for long periods of time at these chargers without charging. There is a risk that 22 kW chargers placed in on-street residential areas would not see the required utilisation rates to make them commercially viable. This is because vehicles are likely parked overnight in on-street residential areas, and so a 22 kW charger would effectively be wasting the higher power rating, unless users would be willing to move their vehicle after it has been fully charged. In addition, as noted in Section 2, most current EV models are not able to charge above 7kW AC, though more models are becoming available with 11kW AC charging capability (at least as an option).

### **Impacts on urban/rural considerations**

From the stakeholder consultations, effective business models were identified in both urban and rural areas. However, the main contrast in the operation and development of this charging infrastructure was the level of support through grants that was required. Due to a high contrast in utilisation rates in urban and rural areas, the rural areas that had successfully developed charging infrastructure relied on 100% grant funding from central government (compared with maximum 75% in urban areas). The LAs stated that there was no business case for CPOs to invest in rural areas, as there was no guarantee that investments would be recovered. However, a key point observed from one pioneering 'fast on-street' model was that there was high variation of utilisation in rural areas, and it is difficult to understand which locations will be the most utilised.

For urban areas, 75% OZEV funding and 25% CPO funding was sufficient to implement fast charging infrastructure. However, the pay-back period was noted to highly depend on the utilisation rates and the total cost of implementation varies significantly depending on the locational requirements (due to grid constraints and site-specific civil works). LAs highlighted that in some cases the development of fast-charging infrastructure had suffered from planning difficulties and unexpected costs associated to grid upgrades.

### **Impacts on CPOs, LAs:**

The implementation of fast charging infrastructure comes at a higher cost to CPOs and LAs (compared to lamp post chargers), however concession contracts have established themselves as the most effective business model. The higher CAPEX and OPEX costs result in the requirement for longer contract lengths to ensure total cost recovery. In addition, the financial impact is highly dependent on the utilisation rates of the chargepoints. As EV uptake is forecasted to continue the upward market penetration trend (Zap Map, 2022), it can be assumed that the utilisation of chargepoints will increase. Therefore, the business case for implementing fast chargers is expected to develop, as it can offer a localised solution for EV users without access to private off-street parking.

## **4.2 Destination charging**

Destination charging can be a very varied business model, and consist of variety charger powers depending on the type of destination. Destinations at which EV users typically spend a large amount of time (such as a hotel or long-stay car park) can have chargers with a lower power rating at 7kW, whereas destination where users park for a short period of time (such as a shopping centre) could require higher-powered chargers at 50 or even 150kW to be attractive to customers.

The business models (BM 3 to BM 5) for destination charging are focused on how the infrastructure is paid for and how much the end-user is charged for using the infrastructure. Therefore, there are some common impacts for destination charging which is outside of the business model which are present below.

### **Impacts for the grid**

Destination charging could have a large impact on the local grid supply. This is because a large destination type (e.g. a large supermarket) could have many parking spaces with many EV chargepoints at a high power rating (50kW+). This large potential power requirement would likely require grid upgrades at many sites, depending on the number and types of chargers installed. There is potential for higher powered chargers to serve more vehicles in the same time, and as such may require fewer chargers at the destination. Due to the short plug-in times at most destinations (with the exception of hotels and long-stay car parks) there is not potential for smart charging, and so the demand on the grid cannot be managed in a smart way in most cases.

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**Impacts for traffic and congestion**

There is unlikely to be any impacts on traffic or congestion at destination chargers. This is because EV users are already undertaking the journey to the destination, and so there are no additional trips added to the traffic network. There could be an exception to this if long-stay car parks offer very cheap charging, which could result in a shift in overnight parking locations from outside EV users' homes (for those without access to private off-street parking) to the long-stay car parks. This would in turn create additional local traffic demand at these locations.

There could be an increase in car trips in urban areas in some specific cases. If the EV users know there is an EV chargepoint at the destination they may be more inclined to drive to the destination instead of taking public transport or cycling. It is perhaps unlikely that this will have a major impact on the local traffic network as this will only happen when the EV users need to charge (only once a week in most cases), but there is a possibility that some destinations in specific areas could see an increase in traffic as a result.

**Impacts on EV uptake**

The impacts on EV uptake will largely depend on the business model used and how much the end-user is charged for using the infrastructure. However, destination charging in general is seen as positive as EV users are already parking at the destination and so do not have to undertake any additional trips to recharge their vehicles. The guarantee of charging infrastructure at popular destinations may give potential EV users without access to private off-street parking increased confidence in the charging network and hence are more likely to switch to an electric vehicle, given that charging infrastructure availability is one of the often-cited reasons for not switching to an electric vehicle in the UK.

**Impacts on urban/rural considerations**

Destination charging could be key for rural charging networks. Often in rural areas amenities are further afield compared to urban areas, and therefore users are more likely to be required to drive to the destination especially if the public transport network is poor. Therefore, installing EV charge points at destinations in rural areas could have a big impact on the available charging infrastructure for users without private off-street parking by increasing and expanding the available public charging network for these types of EV users. Making these types of chargers affordable in rural areas would be key, given that utilisation rates could be lower and therefore costs to the end users would be higher as a result. This could be achieved through cost recovery business models, where the destination is only aiming to recover the costs and not make a profit.

As mentioned above, there may be some implications in urban areas on the local traffic demand and reduced use of public transport and/or cycling in specific cases. However, destination charging could also be a good option for urban areas where users are travelling to a long-stay car park or a hotel. In addition, a LA highlighted that there is often high variation of utilisation in rural areas, noting that it can be difficult to plan and implement at these sites.

**Impacts on CPOs, LAs:**

The key benefit of destination charging is that in most cases the LA does not have to get involved with the implementation process as the chargepoint is installed on private land. This can greatly speed up the process of installing the infrastructure and the LAs do not need to spend any resources to support this. The Government is also stepping away from supporting the destination charging market, as indicated in the recent electric vehicle infrastructure strategy (DfT, 2022).

CPOs can also benefit from destination charging options. Contracts and partnerships with major retailers can result in their infrastructure being rolled-out at a larger scale compared to current concession-style contracts with LAs. A recent example of this is Pod Point's partnership with Tesco and Volkswagen to roll-out a variety of charge points across the country (Pod Point, 2022a). There is a risk that CPOs could gain a monopoly on the destination charging market as a result; however, it is perhaps unlikely for each major retailer to select the same CPO, with another major UK supermarket (Morrisons) selecting GeniePoint (nextgreencar, 2021).



### 4.2.1 BM 3: Cost recovery

As explained in Section 4.1.2, in this business model, the shopping centre will aim to recover the costs (either CAPEX and/or OPEX) from implementing the infrastructure through charging the end-user a fee for charging.

This business model could be a very attractive options for EV users, both with and without access to private off-street parking. As the destination installing the infrastructure is not aiming to make any profit, and only recover the costs of the infrastructure over the lifetime, the costs to the end-user a very low. Destination charging is already seen as an attractive charging option for users, given that they would be driving to the location anyway and would be leaving their vehicles parked for some time. By implementing a cost-recovery type business model which results in cheap charging prices for end-users this type of charging would become increasingly attractive. This attractiveness could result in a high utilisation rate of the infrastructure, which would further drive the price down close to the price for electricity.

This business model could also be seen as attractive to EV users with a private charger, if the price is close to that of home charging. If there were limited chargers at the destination it could be that users with private chargers are taking up the spaces.

### 4.2.2 BM 4: Fully funded

This is similar to BM3, however the CPO funds the CAPEX and the OPEX of the infrastructure and takes a revenue share. The shopping centre is a facilitator of the land, much in the same way as concession contracts (BM1/2).

This business model has slightly higher prices to that of the cost recovery model. This is a result of the CPO making a profit on the infrastructure with the increased costs being passed to the end-user. These prices could still be attractive for users without access to private off-street parking, given that the location is very convenient for users and there is potential for higher power chargers at certain destinations. However, a slight increase in price could deter the EV users with a private charger which could free capacity for users without private charging. This increased availability of destination charging could increase the attractiveness of EVs for users without access to private charging.

### 4.2.3 BM 5: Profit making

Under this business model the destination which has installed the infrastructure makes revenue on top of the fee the CPO is paying, using the charging infrastructure as an additional profit-making business. This will likely result in high prices to the end-user, but could be seen as attractive for the destination as they will make profit.

As this business model results in the highest cost to the end-user from the destination charging business models, it may have the least positive impact on uptake for EVs. However, as the retailers (or other destination type) can create revenue from this it may be more appealing for the retailer to install, and therefore increase the total volume of chargepoints available and accelerate the implementation. By improving the visibility of chargepoints across destination locations it could encourage EV uptake, particularly as charging availability is an often-cited reason for not switching to an electric vehicle.

## 4.3 Rapid charging

Under rapid charging, two types of model are considered:

- En-route rapid charging (50 – 150kW)
- Rapid forecourt charging (50 – 150 kW)

### 4.3.1 BM 6: En-route rapid charging (50-150kW)

#### Impacts for the grid

Rapid charging is known to result in high CAPEX and OPEX costs (Section 4.3), which are associated with the impact on the grid. The impact on the grid is significant, where there are high grid connection, reinforcement, and civil work costs. This is due to the high-power requirements (kW) of rapid chargers. As a result, there is an overall requirement to increase the capacity of the grid in areas that install rapid chargers. However, the newly announced 'rapid charger fund' by the UK government will provide £950 million to rollout at least '6,000 high powered 'en-route' chargepoints along motorways and major A-

roads by 2035' (HM Government, 2022). Depending on what the funding is used for, it could help to alleviate some of the costs in grid upgrade requirements.

### **Impacts for traffic and congestion**

The benefit of installing rapid en-route charging infrastructure is the quick charging turnovers from EV charging, which can reduce the waiting times of drivers. This is important as en-route rapid charging will be a necessity for the longer journeys which require more than the vehicle's range to complete. Rapid chargers can charge an EV from 30% to 80% state-of-charge in around 30 minutes, and currently there are an estimated 5,400 currently in operation in the UK. In addition, on average, 100 new rapid chargers were added to the UK network every month during 2021 (HM Government, 2022). En-route charging also offers drivers with the opportunity to charge during their normal journey patterns. Therefore, there is a limited impact on traffic and congestion as drivers do not need to adjust where they drive. It can be determined that this form of charging infrastructure will continue to grow, as the government has committed to ensuring every motorway service area has at least six rapid chargers by the end of 2023 (HM Government, 2022).

### **Impacts on EV uptake**

The impact on the EV uptake is positive, as it satisfies the consumer preferences of providing faster charging and can give EV users confidence when undertaking long journeys. Along with the recent commitments made by the UK government, the availability of rapid chargers is forecasted to increase (HM Government, 2022). The increased availability of en-route rapid chargers can also reduce the 'range anxiety' experienced by drivers, leading to greater EV uptake (see earlier in Section 2.1). Oversupply of this infrastructure could reduce the range required by EVs and therefore could reduce the size requirement for the on-board battery.

En-route rapid charging comes at a high price to the end-user. However, this may not deter from EV uptake given that en-route charging will be out of necessity, and so users are more likely to be willing to pay higher fees for this type of charging. Although only 98% of all car trips are under 50 miles, (EV energy taskforce, 2022), giving users confidence that there will be charging infrastructure available during longer journeys will create a positive impact on EV uptake. This charging type is extremely sensitive to utilisation rates, given that the CAPEX of the infrastructure (hardware, installation, and potential grid upgrade) is so high. This means that the number of chargepoints at each site must be carefully considered such that there are not chargers which are underutilised as this can lead to a very high cost to the end-user.

### **Impacts on urban/rural considerations**

Whilst en-route charging will be primarily deployed on motorways and major trunk roads in the UK, there are still urban and rural considerations to be made in terms of utilisation. Due to the high cost of the infrastructure, the cost to the end user is sensitive to the overall utilisation rate. From the stakeholder consultations, LAs highlighted that rural areas often have lower rates of utilisation. Therefore, there is less financial incentive for investments of rapid chargers in rural areas and will require significantly more government support to be attractive for CPOs to implement. Rapid chargers that are installed through certain business models (see earlier Section 5.2) may be able to mitigate the impact of lower utilisation rates in some areas. For example, the large-scale deployment of en-route rapid charging infrastructure has the potential for cost-recovery, where highly utilised chargepoints offset the costs from other areas with lower utilised chargepoints.

### **Impacts on CPOs, LAs:**

In terms of LAs, the impacts are fairly minimal for en-route rapid charging. This is a result of the infrastructure being placed largely at motorway service areas (MSAs) and hence often do not require the LAs to get involved with the planning and implementation.

The commercial case for en-route rapid charging is often better than for other types of charging. This is because EV drivers are using the infrastructure out of necessity and prefer faster charging. Therefore, the consumer is willing to pay more for en-route rapid charging. This results in an improved commercial case from the CPOs side, and are therefore more likely to install this type of infrastructure. This will only improve as per the recent government announcement of the £950m rapid charger fund able to offer support for this type of charging.

### 4.3.2 BM 7: Forecourt rapid charging (50-150kW)

#### Impacts for the grid

The impact on the grid is similar to 'en-route' rapid charging infrastructure (BM 5). There are high grid connection, reinforcement and civil work costs. However, there has been key examples of forecourt charging installing on-site renewable energy, such as solar canopies. For example, Dundee city council opened a rapid forecourt charging hub in 2018, with 20 fast-charging bays on top of a city centre multi storey car park (Drive Dundee Electric, 2022). The forecourt is largely powered by solar panels and has an energy storage system to reduce the impact on the grid. Another LA in the stakeholder consultations indicated that a similar rapid forecourt has been implemented to ease pressure on the grid.

These innovations would be necessary to facilitate the interactions of forecourt charging with the grid, given the potentially high utilisation rates and high charger power ratings. Sites could also be selected specifically in areas with spare grid capacity, although due to the high-power rating it is unlikely these chargers could be installed without significant grid reinforcements.

#### Impacts for traffic and congestion

Traffic and congestion are expected to have a greater impact on forecourt rapid charging than en route rapid charging. Due to rapid charging hubs being attractive to EV drivers, queues could become prevalent at forecourt charging stations during peak charging times. Drivers would divert from their original driving patterns, which could lead to increase pressures on traffic and congestion. This could be a bigger issue if EV users all want to charge their vehicles at the same time (e.g. after work) as is currently seen in EV drivers plugging in their vehicles at home after the working day is over. An effective management system would be essential for this to be a success, with accurate real-time information a necessity to provide users with regular updates on availability of the chargepoints.

#### Impacts on EV uptake

Overall, rapid forecourt charging could lead to an increased uptake of EVs due to these rapid chargers offering considerably faster charging sessions to meet consumer preferences. Potential EV users have also indicated that they would be more willing to switch to an EV if forecourt-style charging was available (Task 1.1).

Due to the attractiveness of this charging option (especially for users without an EV) it is expected that the utilisation rates could be higher than that seen in en-route charging (EV energy taskforce, 2022). This drives the cost down for this type of charging under the baseline utilisation assumptions. However, as EV uptake increases the utilisation for these types of chargers could increase further given that there could be a low initial cost to the end-user, as well as good availability of chargers and fast charging speeds. This would reduce the cost to the end-user further. A well utilised forecourt chargepoint could have a similar cost to the end-user as a lamp post charger, whilst offering vastly increased charging speed. This could result in some users without access to private off-street charging relying solely on this type of charging.

#### Impacts on urban/rural considerations

As discussed in BM5 (en route rapid charging), rapid forecourt chargers will more than likely be based in urban areas with high utilisation rates. The financial incentive for the high upfront costs and maintenance makes the implementation of this type of charging strategy challenging for many rural areas.

#### Impacts on CPOs, LAs

LAs could have a greater input for rapid forecourt chargers than the en route rapid chargers, through public private partnerships, although there is a greater commercial case for forecourt charging due to high utilisation rates and therefore the LAs may not need to be involved greatly. This is due to the location of installations, with land often belonging to the LA. In future there may be an opportunity to reuse existing petrol/diesel refuelling stations for these forecourt-style chargers. As new ICE vehicles are phased out there will no longer be the same demand for petrol/diesel, and so these locations could potentially be converted into forecourt-style chargers.

CPOs could see forecourt style chargers as a good investment, given the potential for high utilisation at certain sites. This will make it attractive for CPOs to be involved with forecourt chargers, which could facilitate an increase roll-out of these charger types.

## 5 Recommendations

There are multiple actors involved in the deployment of public charging infrastructure, including central government, LAs, CPOs and DNOs. Each actor has a different role to play in facilitating the deployment of public charging infrastructure, and ensuring that users without access to private parking have a reliable and affordable method for charging their vehicles. Considerations must also be taken to ensure that households in rural areas are not left behind in the roll-out of charging infrastructure, as these areas may be lagging in terms of EV uptake currently.

### 5.1 Central government

#### Summary of central government recommendations

- Provide detailed guidance for LAs to inform on the most appropriate chargepoints types, location, and proximities.
- Enhance collaboration between key players in the EV charging infrastructure, potentially through a dedicated governing body.
- Ensure that systems are in place to ensure accountability and frequent reporting from the recipients of government economic support.
- Explore the potential uses in terms of interoperability of the open set data on chargepoints that will be available from 2023.
- Facilitate where possible any potential planning, ownership, and access barriers for the implementation of new chargepoint locations.
- Provide areas with low EV uptake (e.g. rural areas) with greater support to ensure that 'no one is left behind', with a particular focus on the rural business model case.

Various feedback from the consultation exercise highlighted that LAs may not have sufficient information, guidance and resourcing for the rollout of charging infrastructure. There are potential risks of LAs implementing charging infrastructure without context specific guidance and support. For example, a rollout that does not account for learning of best practises and potentially leaves areas behind, which have limited expertise and access to vital resources. Central government could facilitate the effective and efficient implementation of infrastructure by developing an implementation roadmap, with specifications for target numbers of chargepoints (types, areas, and proximity from each other). Due to the context specific requirements of each locality, it would be beneficial to have a recognised governing body (with actors from municipalities, energy, transport, technology, environment) to orchestrate and coordinate with LAs, CPOs, DNOs, and OEMs to meet context-specific planning requirements. This could be facilitated through analysing the current coverage of chargepoints, and the needs of each LA (based on traffic, behaviour, and geographical statistics) ensuring that all investment is properly spent and accounted for. A similar approach has been successful in countries with a more advanced EV market, such as Norway, the Netherlands and China (BCG, 2021). Central government should also ensure that adequate resourcing is available for LAs implementing chargepoints, as LAs have previously indicated that they do not have sufficient resourcing.

In addition, the government could ensure that value for money is ensured through any future grants and subsidies by working closely with the private sector. All government provided economic incentives can be protected through linking subsidies to progress on implementations to provide assurance and accountability to any private entity involved. For example, in Norway 'Enova SF' (owned by the Ministry of Climate and Environment) invests in innovation and technology development (includes EV infrastructure) and takes this approach to ensure the effective/efficient utilisation of funds (Enova, 2022). Central government could also monitor the price of charging to end-users for public chargepoints to prevent CPOs from inflating the price to generate more profits. This would be beneficial for identifying any regional disparities, highlighting LAs that require additional support and acquiring knowledge of best practises. Central government could ensure that potential cost savings (e.g. from a reduction in VAT for commercial electricity or from a grant for grid upgrades) is passed onto the end-user, and not taken as additional profit by the CPO.

The recent DfT charging strategy outlines the government's commitment to make charging data available to all parties by 2023 (HM Government, 2022). This provides a major opportunity to boost the interoperability of the UK's charging infrastructure. As a result, the availability of open set data could provide CPOs, LAs, and end users with live information on availability of chargers, which could facilitate the development of effective booking systems. In addition, this information could help to increase the reliability of chargepoints through efficient reporting of breakages to the relevant parties, that require a quick maintenance response. Another potential use of this data would be to reduce the current requirement for EV drivers to carry multiple chargecards and offer a better customer experience (outlined in Section 2.1). This could be achieved through developing a 'roaming' offering – i.e. through a centralised cloud-like payment system that gives customers access to the entire chargepoint network via a credit or debit card.

Key planning and logistical barriers were identified during the consultation period of the project. For example, 3<sup>rd</sup> parties owning lamp posts not allowing LAs to install charge points, which resulted in the requirement for additional bollards to connect to the existing lamp post power supply. Consequently, high costs were attributed to these areas, and it was echoed that planning issues were a main barrier for installing charging infrastructure. Central government could facilitate and increase the number of available chargepoints by looking at legal reforms to overcome these issues. For example, Germany had a similar issue where neighbours could oppose the implementation of chargepoints for homeowners looking to act as a facilitator of land for public chargepoints. The German government recently passed a law to bypass neighbours' approval and accelerate the EV charging infrastructure rollout (BCG, 2021).

Rural charging infrastructure typically have lower utilisation rates than urban areas, due to population densities and EV uptake. The consensus from stakeholders was that this results in an unviable business case for rural areas, which leaves the risk of leaving certain areas of the UK without access to chargers. The recent DfT charging strategy aims for a market-led rollout for the majority of chargepoints (HM Government, 2022), however from our analysis this approach may be difficult for areas with low levels of utilisation and could leave areas behind. Rural areas currently have lower utilisation than urban areas, and incentives (e.g. subsidies and funding) may be needed to attract CPOs to install and maintain chargepoints. In the absence of grant funding, there is a considerable risk of areas (e.g. rural) being left behind in the EV charging infrastructure rollout. Central government could help to address this issue through providing financial support and steering development until EV ownership increases to a higher level and the private sector can take over.

## 5.2 Local authorities

### Summary of LA recommendations

- Develop comprehensive charging plans to cover a variety of charging options to suit all drivers needs, utilising clear guidance and resourcing from central government
- As lamp post chargers can offer the cheapest charging solution in urban residential areas, where it is applicable and easy to install lamp post chargers should be implemented as they are a lower-cost, lower-risk option.
- Currently some LAs take a share of the profits for charging. This should be reviewed as it could represent an additional tax to the end-user, for users without private chargers.
- Reduce the possibility for local monopolies of CPOs to develop by having open, competitive tenders for charging locations of different types and establish procurement routes for chargers and facilitate the land for potential charger sites.
- Proactively seek charging locations rather than relying on public requests to ensure infrastructure is available to make EVs a natural choice for all drivers.

The recently published UK EV charging strategy outlines the need for LAs to develop comprehensive charging strategies. This will be important in the roll-out of infrastructure as LAs own much of the public land (including lamp posts) where charging infrastructure could be deployed. Feedback from LAs has suggested that they do not have the resourcing or expertise in many cases to develop these infrastructure deployment plans, and so central government could provide this guidance and resourcing to aid LAs. LAs should utilise this resourcing and guidance from central government where possible to



ensure that the optimal mix of infrastructure is deployed to suit all needs for their specific geography. This could consider that relevant business models for the charging types. For example, a rural LA may wish to encourage the deployment of a rural community centre charging model, as this can offer a lower cost to the end-user compared to typical on-street business models. LAs should keep in mind the overall cost to the end-user of charging in their area, as there may be a risk that CPOs begin to charge high fees which could deter potential EV users.

From the cost calculations and stakeholder consultations, lamp post chargers offer the cheapest and easiest to implement on-street charging solution in urban residential areas. Therefore, where applicable it is recommended that LAs should implement these chargepoints as a lower-cost and lower-risk option. However, fast and ultra-fast chargers require more careful planning and monitoring, which will be more effectively placed at pivotal locations. In addition, grid upgrade costs should be outlined at the initial planning stage in cooperation with DNOs to prevent unexpected cost increases during installation phases. LAs could begin by choosing locations where the grid is less constrained to begin with. Thereafter, the announcement of the new Rapid Charger Fund (RCF), which will provide £950m to future proof electrical capacity at motorways and major A-road services is expected to contribute to the efficient rollout (HM Government, 2022), however effective location planning needs to be considered by all relevant parties involved (LAs, CPOs, DNOs).

Collaboration and cooperation are key requisites for an emerging EV charging ecosystem, and LAs can contribute by supplying key information about barriers to deployment, data on chargepoint utilisation, CAPEX and OPEX costs, and feedback on the best practises to relevant parties (eg. OZEV). In this sense, LAs can act as 'living laboratories' for the rollout of EV charging infrastructure and should promote experimentation of new innovative charging options. A prime example is the NetX Innovate UK study (Innovate UK, 2021), which was highlighted to be successful by multiple LAs during the consultation period and has contributed to the adoption of new technology standards. The supply of this information to central government would also be essential for informing key policy target areas and identify any gaps or areas that may be behind the overall EV infrastructure rollout.

LAs also play a pivotal role in ensuring that multiple CPOs can bid for sites to install charging infrastructure. It should be the case that competition is fostered to ensure that market prices for charging are kept competitive and as low as possible for end-users. In the tender process, they need to open a fair and competitive bidding process for all CPOs to apply towards. A recommendation could be that there are different tenders for maintenance of CPOs, and for the installation of chargepoints. As a result, contracts for maintenance can renew yearly to increase competitiveness, while the installation tender covers the pay-back period depending on the charger type. In addition, the consultations with LAs confirmed that several are taking a revenue fee from the cost of charging for end-users. LAs should consider if profit-taking is necessary, as this could be viewed as a tax to the consumer and deter private investors.

Dedicated bays for EV parking have been shown to increase utilisation of charger types and can encourage drivers to switch to EVs, validated in the stakeholder consultations. LAs should explore measures to implement dedicated bays where appropriate. However, it should be noted that this is a potentially sensitive issue for local residents which do not own EVs.

## 5.3 Chargepoint operators

### Summary of CPO recommendations:

- Ensure a good standard of customer experience when charging (see Section 2.1), which could include effective maintenance to ensure reliability and standardising payment methods (e.g. contactless payments).
- Optimise the attractiveness of public charging to improve utilisation and therefore increase revenues. This could be achieved by passing any potential savings from reduced VAT rates from electricity for public charging to the end-user, and not taking as additional profit.
- Maximise the utilisation potential for the chargepoints, by including technologies such as booking systems and idling fees for vehicles parked but not charging.
- Work with the DNOs to facilitate the use of smart charging in on-street residential charging areas.



Customer experience is key to improve the image of public chargepoints and reduce the perception that chargepoints are unavailable or out of use. Effective and rapid maintenance could be put in place to ensure that the time chargepoints are out of service is minimised as much as possible, which will also increase the utilisation of the charger. CPOs could also ensure standardised payment methods are used for public chargepoints, as EV users have indicated that often multiple chargecards are needed to use the public charging network. This could be in the form of contactless payment methods.

Maximising the utilisation rates at chargepoints is a natural aim for CPOs, as a higher throughput of users and electricity results in a higher return per charger. Implementing technologies such as booking systems and idling fees for vehicles parked but not charging are ways to improve the utilisation at chargers, and therefore should be explored further. CPOs are also in a prime position to keep updating innovative charging technologies, to increase the effectiveness and efficiency of charging infrastructure. Various trials for new charging solutions are currently underway, and CPOs should be taking every opportunity to learn from the results of these studies.

There are potential methods to reduce the cost to the end-user under the different business models explored, such as socialising the grid upgrade costs to reduce the CAPEX or reducing the VAT rate from 20% to 5% (in line with private electricity) on electricity delivered by public chargers. If these cost reduction methods are implemented, then CPOs should ensure that the cost savings are passed to the end-users, and not taken as additional profit. Users without access to private off-street parking naturally have to pay a higher rate for charging compared to charging at home off-street, and therefore could be deterred from switching to EVs if the price of charging is too high. The implementation of smart charging for on-street residential chargers could also reduce the cost to the end-user, and therefore CPOs should ensure that their chargers can support this technology and liaise with the DNOs to facilitate smart charging.

## 5.4 Distribution network operators

### Summary of DNO recommendations

- Ensure quick connection times of public chargepoints to the grid.
- Facilitate knowledge sharing with CPOs and LAs on sites with spare grid capacity or areas which would not be expensive to upgrade the grid.
- Ensure that smart charging is an option for residential on-street chargers, to offer users without private chargers the same benefits that smart charging brings.

Various feedback from the consultation exercise pointed to slow and expensive grid connections in the deployment on public chargepoints as something which has hindered the implementation of chargers. This is particularly the case for higher-powered chargers which can experience very high CAPEX costs if grid upgrades are required, which can deter the CPO from installing chargepoints. LAs have also found in some cases that on-street chargers (7-22kW) are sometimes not financially viable due to connection costs and grid upgrades required in certain areas. DNOs could proactively share knowledge with LAs and CPOs on where there might be spare capacity in the grid for charging infrastructure, which would reduce the CAPEX cost and also speed up the installation process as grid upgrades would not be required. Specific sites could be suggested for rapid forecourt chargers in urban areas, as these chargers can offer a comparatively low cost of charging to the end-user for the charging speeds if utilisation rates are high. DNOs should also be prepared for grid upgrades as a result of on-street charging in certain areas. In the event lamp post chargers cannot be used, and 7/22kW chargers would create grid constraints, there will be no choice but to upgrade the grid capacity to ensure that users have residential charging near their homes.

Smart charging can offer a lower cost to the end-user for on-street residential charging (either at a lamp post or bollard-style chargers) by utilising cheaper electricity prices at off-peak rates. This can result in longer charging times, but an overall cheaper cost of charging to the end-user. DNOs should facilitate the use of smart charging for on-street residential chargers to give users without access to private charging the same benefits smart charging brings to users with a private charger.

## 5.5 Recommendations to secure private investment

### Summary of key findings

- Utilisation of the chargers is absolutely key in driving the cost the end user down as well as securing private investment, and so effective measures should be put in place to optimise the utilisation of sites.
- Having a quick turnaround of infrastructure in terms of interaction and planning with the LA at the sites, as well as DNOs providing quick connection times is also key.
- Long contract lengths can provide greater security for private investors into the charging infrastructure, however considerations must be taken to ensure that there is a fallback option if the CPO ceases trading such that the LA is not left with the asset unmaintained/operated.
- Forecourt-style chargers could be facilitated as these types of chargers can be profitable to the private investor and attractive to the end-user if utilisation rates are high.
- Explore innovative models to obtain private investment and secure a greater number of chargepoints.

A key factor in the deployment of public EV charging infrastructure will be securing private investment to help fund the capital costs of the infrastructure. This could be in the form of the CPO funding the CAPEX, or shopping centres fronting the CAPEX costs to attract customers to their business. There are other innovative forms of private investment, such as the recent Innovate UK funded 'Charge my Street' project (ChargemyStreet, 2022), in which the public can invest into chargepoints and receive 2%-5% anticipated return on their investment.

The most likely way to increase the attractiveness of private investors into the public charging network is to increase the utilisation at the sites. This will create a greater throughput of electricity delivered and therefore come with a higher profit for the private investor. This has been confirmed by stakeholders which found some underutilised areas didn't receive any bids from suppliers, whereas other sites received 100% CAPEX funding from the CPO as the site was anticipated to have high utilisation. In the near term, where utilisation is low there may be a need for greater support from central government. Technologies such as chargepoint booking systems and bay sensors with idling fees for vehicles parked but not charging can increase the utilisation of the chargepoint, and so should be considered for future deployment. These technologies are perhaps more suitable for higher powered chargers above 7kW, as on-street residential chargers will likely have users parked overnight and idling fees may be less relevant. Potential policy options could include subsidising some of these lower-utilisation areas in the near term to make it profitable for the CPO whilst EV uptake remains low. This can reduce as EV uptake and utilisation increases over time.

Dedicated EV parking bays can also significantly increase the utilisation of chargepoints, and so LAs should explore dedicated EV bays when deploying chargepoints. However, this is a sensitive issue for local residents which do not own EVs. There has been pushback from residents which have had parking spaces turned into EV bays near to their home, when they themselves do not have an EV and so have to park further away. This could indirectly encourage households to transition to EVs, if they begin to see the number of dedicated EV bays increasing and the options for other vehicle parking decreasing.

Faster chargers also have a better commercial case, however interactions with the grid are currently challenging in terms of cost and speed of connection. DNOs could share knowledge with LAs and CPOs on where suitable locations may be for rapid forecourt chargers, as these can offer a comparatively low cost of charging for the charging speeds offered if utilisation rates are high. Grid upgrade costs could be socialised in order to reduce the CAPEX required for grid-constrained sites, which would reduce the cost for the private investors and hence become more attractive.

Longer contract lengths (e.g. 15 or 20 years) are more likely to attract private investment due to increased security over the payback period. However, this can create concerns with the LA not wanting to have a private company leasing public land for that long of a period, and concerns if the CPO was to dissolve then they would be left with assets which they could not operate and maintain. A solution could be to keep long-term contracts but set up a public body (or another supplier) who could step in in the event of CPOs going bust to operate the infrastructure for a period of time before a new CPO is found.

Increased utilisation of the sites would decrease the need for the long-term contracts with the CPO, and so this may be a near-term issue only. A solution could be to subsidise rapid chargers in the near term to allow for the shorter (e.g. 7 year) contracts to be profitable for the CPO. This would encourage private investment into the chargepoints in the near term, and when utilisation naturally increases the shorter contracts would be more viable in future.

Forecourt charging has been shown to be attractive to the end-user (due to fast charging speeds) and also the CPO (due to high profitability). At high utilisation rates this type of charging can also offer comparatively low costs to the end user (compared to en route charging). Facilitating these types of chargers could result in an increase in private investment into charging infrastructure from CPOs. However, as the cost to the end user for these types of chargers are utilisation driven there must be careful consideration of number of chargepoints required and optimal site locations for forecourt chargers to be successful. The success of these charger types will also depend on multiple factors, such as interactions with the grid and queueing at particularly desirable sites if everyone decides to charge at a similar time. Grid upgrade costs could be socialised in order to reduce the CAPEX required for grid-constrained sites, which would reduce the cost for the private investors and hence become more attractive.

CPOs are concerned over the rising electricity price and how this may impact their profits, which could ultimately deter private investment into the infrastructure. Currently under concession contracts with LAs, the CPOs are locked into a fixed price for a period of time, which can be up to 2 years. Reducing the time period for these fixed prices could resolve this issue. However, consideration must be taken to ensure the CPOs are not raising the prices exceptionally and just taking additional profit. The CPOs could potentially be locked into a fixed profitability rate (e.g. 5p per every kWh energy delivered), rather than a fixed charge for the end user. This would allow the cost to the end user to flex depending on the electricity price, but the CPO still maintains the same level of profit. The profit could even increase over time if utilisation rates were to increase, meaning that CPOs could potentially reduce the profit rates but receive the same overall profit per charger.

Innovative business models could attract private investment. An example mentioned above (ChargemyStreet, 2022) obtains investment from the public to fund chargepoints in areas where utilisation rates might be low. The minimum investment is £100, and the maximum investment is £15,000. The anticipated return is 2%, but could rise to 5% if the sites perform well in terms of utilisation. The chargepoint sites are selected based on local demand, and so there is a better chance that the chargepoint will be well utilised. This could be good for areas linked to high tourism, attracting customers to particular premises and giving returns to the local community. This could be combined with the stakeholder feedback on rural charging at community centres, using public investments.

## 6 Conclusions

The focus of this study is on facilitating the uptake of EVs for users without access to private off-street parking by identifying attractive charging options, exploring viable business models and calculating the cost to the end user under the different business models. The research has found that current chargepoints in the UK are not adequate to support EV drivers without private off-street parking in terms of availability, reliability, and ease of use.

There is unlikely to be a single charging solution to suit all EV drivers needs and preferences, and a split of residential on-street (lamp post charging, on-street bollard style chargers), workplace, destination (at shopping centres, supermarkets, and car parks), en-route rapid and rapid forecourt charging are all likely to have a substantial market share in delivering the energy required to power EVs for users without a private driveway. Therefore, effective business models and deployment strategies are required for all charging types to fully facilitate the uptake of EVs in this particular user group. As discussed in Section 5.1, a recognised governing body could work with the LAs to offer a template for the optimal mix of chargepoints. This should take into account the specific factors (e.g. geography) of the LA.

For all charger types the key to driving down the cost to consumers is high-utilisation rates of the infrastructure. Higher utilisation generates a greater throughput of electricity and therefore a higher revenue for the CPO resulting in a lower fee to the end-user for the same profit for the CPO. Measures should be put in place to optimise the utilisation rates of infrastructure, such as booking systems or bay sensors and idling fees to detect when vehicles are parked but not charging. Dedicated EV parking bays at chargepoints can also greatly increase the utilisation of the charger. The chargepoint utilisation rates are expected to increase naturally as EV uptake increases, however infrastructure may need to be deployed in excess of the needed capacity in the near term to encourage potential EV buyers to make the switch. This may require additional government support to ensure that chargepoints are profitable for the CPO to deploy but also at a low cost to the end user. This could include facilitating long-term contracts for higher powered chargers (in the near term) and introducing measures to minimise the cost impacts of grid upgrades. Oversupplying the infrastructure could have additional benefits such as reducing the perceived required EV range, which would in turn reduce the on-board battery capacities required. From the cost calculations performed in this study, all the analysed business models converged to a similar price per kWh under a high-utilisation sensitivity. This shows that utilisation could be mainly a near-term problem, and as EV uptake increases more business models will become viable for the CPO and also the end-user.

Consumers prefer faster, reliable and cheap charging, which is unlikely to be satisfied by one particular charger type. In on-street residential areas, lamp post chargers can offer the cheapest charging option for EV users without private charging. This is a result of low CAPEX and OPEX of these chargers (compared to conventional bollard-style 7kW chargers) and no grid connection costs. Lamp post chargers also utilise the existing street scape, and so do not require civil works. Where possible, lamp post chargers should be installed in residential areas to provide a cheap charging option for end-users whilst being relatively low risk to the LA due to low costs and low streetscape footprint. However, lamp post chargers are not always feasible to install. Areas which have wooden or concrete lamp posts maybe not be suitable for installation, and in rural areas the density of lamp posts may not be sufficient to make them a viable option. Therefore, where lamp post chargers are not possible bollard-style chargers will be required to provide on-street charging for users without private parking. There may be innovative solutions, including satellite bollard lamp post chargers or gully chargers utilising the households existing electricity supply, but these technologies are not as established.

Charging en-route will be a necessity for many EV users during long trips, whether they have access to a private charger or not. These are likely to be supported through the Rapid Charger Fund (RCF) recently announced by the UK government. It is important to put measures in place for rapid charging en-route to be competitive to ensure that monopolies of CPOs do not develop, which will reduce competition and likely increase the cost to the end user. As there is a greater commercial case for en-route rapid charging the market could develop naturally. However, grid upgrades can be difficult and expensive for rapid chargers and so the DNO should work with CPOs and LAs to establish quick connection to the grid where possible and the UK government should consider measures to ease the cost of the grid upgrades on the private investor which could reduce the cost to the end-user.

Rapid forecourt charging can be an attractive charging option for many users, with fast charging speeds and (comparatively vs en-route rapid) low costs to the end-user. For these reasons there is expected

to be a good utilisation for forecourt chargers and therefore a greater commercial case. The market for forecourt style chargers could naturally develop, with both EV users and private investors seeing benefit for this type of charging in an urban environment. However, as with en-route rapid charging there is a large implication on the grid due to the high power requirements which can be very expensive in certain locations. Innovations, such as a solar canopy with on-site battery storage could offer to reduce some impacts on the grid. On-site battery storage could allow for additional power supply during peak times, mitigating some of the grid capacity concerns. There could be traffic and congestion issues created, particularly if users all wish to charge at forecourt chargers at the same time. Careful planning is needed at each site to ensure that there are enough chargepoints to prevent queuing whilst also offering good utilisation of each chargepoint, as utilisation is key to driving down the cost to the end user.

The recent DfT EV charging infrastructure strategy (DfT, 2022) states that the public sector is stepping away from supporting destination charging, as this market appears to be developing naturally without public support. This does indeed appear to be the case, with PodPoint announcing a partnership with Tesco and Volkswagen to deploy chargepoints in supermarket car parks (Pod Point, 2022a) and GeniePoint partnering with Morrisons to deploy 50kW chargers (nextgreencar, 2021). There are a variety of viable business models for destination charging, and the business model selected will depend on the type of location and what they are using the chargepoints for. Profit-making models can allow the destination to generate additional profit, whilst cost-recovery models charge end-users a low fee but increase the attractiveness of the destinations business to EV users. In-app advertisements within the chargepoint app can also increase the attractiveness of the chargepoint to the destination. It is perhaps unclear as to which business model will become the most common in the long-term, with the loss-leader and cost-recovery models being more suited to the short term whilst profit making and fully-funded models being more suitable for the long-term. The fully-funded model is most similar to the public-private partnerships observed in typical on-street charging deployment, with the destination acting as the LA and facilitating the land for the CPO to operate the infrastructure and make a profit.

There is a clear distinction between viable business models and charger types in urban compared to rural areas. As utilisation is such a big factor in costs to the end user, rural areas with lower utilisation may be harder to implement profitable chargepoints at a low cost to the end-user. Feasible charging solutions in urban areas, such as lamp post chargers and rapid forecourt chargers may not be suitable in rural areas. As these are the cheapest charging type for the charger power offered, rural users may have to pay higher prices than urban EV users. There is a higher proportion of rural households with private off-street parking compared to urban households, and so the absolute scale of the problem may not be that significant. However, for households in rural areas without private off-street parking there is a real risk that they will be left behind and have a lack of charging options and/or have to pay a higher price for using the charging infrastructure. Rural areas may require further government support in the near term to facilitate the deployment of charging infrastructure as the utilisation could be low in some areas. This could improve the business case for the CPO, and could come in the form of additional CAPEX funding (100% vs current 75%) or facilitating longer contract periods which could also improve the business case for the infrastructure.

Rural LAs should explore potential innovative business models which have emerged in the market recently. One LA interviewed has deployed a rural community charging hub model, in which chargepoints are deployed at a local community centre in a rural area. The chargepoints can accept dual-payment methods, which allows the CPO to charge different fees for different users. The local residents use a chargecard and pay a lower price per kWh, whilst tourists to the area pay by contactless payment and are charged a higher fee per kWh. This has a dual benefit to the local community by offering cheaper charging fees to the local residents and also can generate revenue for the local community through higher cost of charging for tourists visiting the area. Another innovative business model ('charge my street') allows for members of the public to invest in chargepoints and allow them to be placed in areas which may not have received funding (from other private investors). This could be a solution in rural areas, and the success of this business model should be closely monitored by rural LAs.

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## A1 Appendix 1 – Stakeholder engagement

### A1.1 Stakeholders interviewed

A number of stakeholders were interviewed to gain a deeper understanding of the current public charging market, including barriers and challenges as well as opportunities for success. The stakeholders consisted of three CPOs, six LAs (covering urban and rural settings) and a UK DNO.



## A1.2 Local Authority interview questions

Have you deployed on-street chargers in your LA? If so, which types of chargers (slow/fast etc.) have you deployed and in which locations (urban/rural, destination, residential) have they been deployed?

If you have not deployed on-street chargers, is this because of financial constraints or for other issues? (i.e. have you struggled to source funding, or business case is bad for chargers)

If you have deployed chargers, which business models have you implemented for the chargers (by type and location)

Which business models have been most successful for each charger type and location? This can be in the form of charger utilisation rates, financial returns etc.

Have you managed to source private investment for chargepoints, and if so, how have you sourced this investment?

Have there been particular charger types/locations which have been difficult to source private investment for? (aiming to understand which locations may need extra funding)

What policies do you have in place to deploy chargepoints specifically for households without access to private off-street parking?

Would you be able to provide cost data for the chargers you have deployed? We will keep this anonymous and aggregate with other cost data we have found.

Is there anything else you would like to discuss on this topic?

## A1.3 Distribution Network Operator interview questions

Would you be able to provide a range in typical grid upgrade costs for different types of chargers (per kW preferably)

Are there particular locations where it is difficult to implement grid upgrades (e.g. in rural areas?)

Do you have plans to support smart charging for on-street chargepoints?

What would be the typical cost reduction in electricity for smart charging during off-peak times?

What do you, as a DNO, see as your role in supporting the deployment of on-street charging infrastructure?

Which business models have you found to be the most successful in the deployment of public chargepoints?

Are you aware of any new and emerging business models for on-street chargers (e.g. V2G, charging as a service etc.?)

Is there anything else you would like to discuss?

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## A1.4 Charger Point Operator interview questions

What types of chargers to you typically provide? (slow/fast, destination, en route, residential etc.)

Which business models do you typically use for each type of charger?

Which business models have been most successful for each charger type and location? This can be in the form of charger utilisation rates, financial returns etc.

Are there any planned innovative, but practical charging solutions?

What are the typical payment methods that users prefer? (e.g. contactless card, charge card, direct debit etc.)

Are you aware of any new and emerging business models for on-street chargers (e.g. V2G, charging as a service etc.?)

Would you be able to provide cost data for the chargers you have deployed? We will keep this anonymous and aggregate with other cost data we have found. Please provide details per component.

Would you be able to provide typical utilisation rates for different charger types and typical downtimes?

Is there anything else you would like to discuss on this topic?

## A2 Appendix 2 - Cost calculation methodology

The costs of providing the charging infrastructure under the different business models was calculated using a simplified financial model of **owning and operating the required infrastructure**. This model informed the cost to the consumer to make the infrastructure provision possible, under different business models.

The model considered the **total costs** for the specific charging infrastructure including the equipment costs, installation and all operating expenses incurred over its lifetime. The total costs were calculated for one charger. Through extensive engagement with UK DNOs on multiple research projects it is understood that grid upgrade costs (from EV charging infrastructure) are localised depending on the substation/feeder capacity. For this reason, sensitivities on different potential grid upgrade costs (e.g., low/medium/high) were used to explore the possible costs of installing the infrastructure. Case study examples used in previous Ricardo work along with additional research were used to determine a reasonable set of sensitivities. Power Systems experts within Ricardo were also consulted to ensure this data is reflective of reality. See appendix A3.1.1 for details on costs included.

**Revenues** were calculated based on the expected profitability level for the infrastructure owners/providers. To calculate revenues, the Net Present Value (NPV) of the total costs of the infrastructure was calculated together with a fixed profit rate per kWh of electricity provided. Suggested profitability levels are summarised in section 3.2.1.

**Demand** for the charging infrastructure were calculated based on average electricity consumption and different utilisation rate sensitivities. Desk-research informed these assumptions, as presented in appendix A3.1.1.

The overall **cost to the consumer** for using the charging infrastructure under the different business models was calculated based on expected revenues and electricity consumed. This allowed calculation of costs to the consumer in a per kWh:

$$\text{Cost for using charging infrastructure per kWh}_t = \frac{\text{Revenues}}{\sum_{t=1}^{t=T} \text{NPV of total electricity consumed}_t}$$

The costs to consumers depend on different business models. This includes **profit rates** for the different business cases (if applicable), and **any levels of public or private subsidiary/investment** which may be included in the business model. To characterise the different business models, the following assumptions were considered:

- Discount rate
- Funding (% grants or incentives)
- Profit rates
- Payback period of infrastructure (years)

Different discount rates were used, to reflect the ownership of the infrastructure, assuming a social discount rate for publicly owned infrastructure (HM Treasury, 2018), and a higher discount rate for privately owned infrastructure (HM Treasury, 2018). Funding varies, as informed by the desk research exercise, with some business models relying on grants. The different grant levels assumed impact the final cost to consumers for using the infrastructure, offering users a subsidised cost. Baseline profitability level assumptions were used, based on stakeholder consultation and industry values. Payback period depended on the technology based on current contract lengths observed in the industry. The assumptions used to characterise each business model and the rationale for their selection are summarised in section 3.2.1.

The costs to consumers for using the charging infrastructure provided an indication on whether the business model seems feasible, compared to what **consumers are willing to pay** for each business case. The cost to consumers (including electricity fees) obtained from desk research and this projects stakeholder engagement may have not fully reflect willingness to pay (for example, desk research values may vary per region, and participants in the survey may have an incentive to suggest lower willingness to pay), however it can give an estimate on how far the model values are for the different assumptions made on demand.

The **cost of a typical private off-street charger** was also be calculated, and used for comparison purposes to **highlight the difference in charging costs for households with and without access to private off-street parking**.

For simplicity of results interpretation, all costs in this model reflected 2022 prices and it was assumed that all upfront and installations costs are incurred in year 0 (i.e., instantly at the beginning of the time period used in the analysis).

## A2.1.1 Baseline parameters

For this phase of the project, cost and utilisation data will be collected from the most recent UK and world (where applicable) sources. This desk research will complement Ricardo's previous cost work with the CCC and the European Commission.

Table 6-1 presents up-to-date baseline averages of cost data for the charger technologies. Costs are mostly contingent on power supplied and so the table layout reflects this. Included in the hardware unit costs are the power electronics, dispenser and meter. Installation includes wiring, conduit, trenching, meter, switchgear, and service panel costs; however, it may not capture all installation costs such as signage, striping, lighting, and security cameras. For OPEX, insurance costs, back-office costs, planned and unplanned maintenance costs plus data contracts are included.

For DC rapid and ultra-rapid charging, the relationship between hardware and power rating is linear, that is to say, unit hardware costs scale with the per kW rating. From engagement with equipment manufacturers, it is clear hardware costs scale in practice. The data presented suggest non-linearity in places which is likely a reflection of the difference across manufacturers as opposed to those within. Contrary to DC charging, the relationship is non-linear for public slow/fast. There are large variances in the unit hardware cost for AC charging. For example, a combined hardware and installation costs for public 7 kW chargers range from £1,000 to £10,000 (CMA, 2021). The baseline unit hardware costs reflect an average of industry ranges across a competitive market landscape. Once the baseline has been established, ranges in CAPEX costs are to be explored as sensitivities.

For installation, a positive nonlinear relationship with cost can be observed, one that is largely driven by material and labour costs (ICCT, 2019). For public lamppost chargers, installation costs are kept low as a result of standardised labour processes and standardised material requirements. For public slow/fast the labour and material requirements are significantly affected by onsite specific attributes, such as the concentration of chargers and the existing infrastructure. Installation costs are reduced by concentrating charger points in the same area, reducing the cost of wiring and trenching per charger (CMA, 2021), and CPOs often plan for future upgrades in charger power and quantity across all site types in an attempt to reduce the cost of future installations. This could create issues whereby areas with existing chargepoints are likely to have more chargers deployed, leaving certain areas unattractive to deploy chargers. Installation costs are much higher for rapid and ultra-rapid chargers as the overheating risk caused by a higher current is controlled by installing liquid-cooled cables. Costs are particularly sensitive to the number of chargers per site (to be explored as sensitivities). Economies of scale can explain this trend (reduced variable per charger cost to the site fixed costs), but other factors like learning site-specific efficiencies and installation best practices also contribute (RMI, 2019).

The network upgrade costs capture the costs associated with required grid reinforcements. Based on previous Ricardo work with the CCC (Ricardo, 2019), these costs can be approximated to scale ~linearly with power (for a given site/network situation – i.e. assuming site/network capacity is not exceeded requiring substation upgrades), with step a change between AC and DC charging types.

**Table 6-1 Summary of cost data used in the baseline cost calculations**

Charger Type	Cost	Variable	Value	Source
Residential off-street	CAPEX	Hardware Unit	£650	Stakeholder feedback
		Installation	£375	(ICCT, 2019) (CWB, 2018), stakeholder feedback
	DNO connection	Network costs per kW	£27	(Ricardo, 2019)

Charger Type	Cost	Variable	Value	Source
	OPEX	Yearly cost	£500	Stakeholder feedback
<b>Total /kW</b>			<b>CAPEX £173</b>	<b>Total</b>
Lamppost 3-5.5 kW	CAPEX	Hardware Unit	£875	(CMA, 2021), stakeholder feedback
		Installation	£500	Stakeholder feedback
	DNO connection	Network costs per kW	N/A	
	OPEX	Yearly cost	£200	Stakeholder feedback
<b>Total /kW</b>			<b>CAPEX £458 (3kW) &amp; £250 (5.5kW)</b>	
Residential on-street/destination 7kW-22kW	CAPEX	Hardware Unit	£1,288 (7kW) & £3,358 (22kW)	(RMI, 2019), (CMA, 2021), (Ricardo, 2021), stakeholder feedback
		Installation	£3,660 (7kW) & £4,680 (22kW)	(ICCT, 2019) (CWB, 2018), stakeholder feedback
	DNO connection	Network costs per kW	£27	(Ricardo, 2019)
	OPEX	Yearly cost	£500	Stakeholder feedback
<b>Total /kW</b>			<b>CAPEX £734 (7kW) &amp; £392 (22kW)</b>	
Destination/En-route rapid 50kW	CAPEX	Hardware Unit	£23,500	(RMI, 2019), (ICCT, 2019), (Ricardo, 2021) stakeholder feedback
		Installation	£13,400	(ICCT, 2019)
	DNO connection	Network costs per kW	£315 /kW	(Ricardo, 2019)
	OPEX	Yearly cost	£1000	Stakeholder feedback
<b>Total /kW</b>			<b>CAPEX £1,053</b>	
Destination/En-route rapid 150kW	CAPEX	Hardware Unit	£74,875	(RMI, 2019), (ICCT, 2019), (Ricardo, 2019)
		Installation	£16,125	(ICCT, 2019)
	DNO connection	Network costs per kW	£315	(Ricardo, 2019)
	OPEX	Yearly cost	£3,000	Stakeholder feedback
<b>Total /kW</b>			<b>CAPEX £912</b>	

Note: \* Site limit of 2.5-3.0 megawatts of power before a step change in costs. Therefore, the maximum number of chargers per site is 50 and 20 for 50-, 150-kW chargers, respectively.



A cost of 0.183 £/kWh for electricity supply was used for calculations for all the selected business models, which was calculated from average cost for domestic electricity costs (BEIS, 2022; Ofgem, 2022) adjusted for commercial charging (BEIS, 2020) and adding a 20% VAT. A cost of 0.186 £/kWh for electricity supply was used for off-street charging, considering domestic electricity costs (BEIS, 2022; Ofgem, 2022) and a 5% VAT. Effects of increasing electricity prices was considered in the cost calculations to understand its effect for the different business models. Specifically, the announced default tariff cap update from 1 April 2022 is considered, an increase of 54% since the last update. From 1 April 2022, the level of the cap will increase to £1,971 which translates to a £0.28/kWh standard electricity price.

### Grid reinforcement costs

Grid reinforcement costs are often the most uncertain and expensive aspects of EV charging infrastructure, particularly when they are compounded by unforeseen soft costs such as delays in installation and LA disputes (RMI, 2019). Table 6-2 shows how these costs vary based on the transformer type required in a grid upgrade. The total reinforcement costs are determined by the existing capacity which, in turn, is directly related to its proximity to the distribution network (CMA, 2021). Upgrades may be routine or extremely costly, like those at MSAs, which are often located away from the distribution network. The CMA understands the cost of MSA upgrades to be £7m (and as high as £27m) to meet expected electrification requirements.

**Table 6-2: Summary of grid reinforcement costs (transformers)**

Transformer Type	kVA	Connection Cost	Capacity	Connection Time
Small	Up to 70	£1,000 - £3,000	1-3 fast or 1 rapid	8 - 12 weeks
Medium	200-1,000	£4,500 - £75,000	3+ fast or 1+ rapid	8 - 12 weeks
Large	1,000+	60,000 - £2 million	multiple fast/rapid	6+ months

Source: (EnergyUK, 2020)

### Utilisation

Table 6-3 shows baseline charger utilisation in average hours spent charging per day, a +/- 50% utilisation sensitivity adjustment and the baseline energy consumption in kWh/day. Table 6-4 shows how the baseline values are likely to develop over time and are calculated from logarithmic functions of EV stock. The functions are derived from UK utilisation and EV uptake data (ICCT, 2020).

Similar to infrastructure and network upgrade costs, utilisation rates are highly sensitive to charger type and location, however, there are additional factors affecting overall utilisation both at present and over time. The sensitivity adjustments in Table 6-3 capture these factors in a discrete-time period (within year variability). For the charger type, utilisation varies due to availability, reliability, charge time, destination, the number of EVs and willingness to pay. Next, there is lower utilisation in rural areas and higher in urban ones. Investment in rural charging infrastructure is typically much lower than for urban areas resulting from a combination of concerns about returns on investment due to lower EV uptake, and generally higher upfront costs from network upgrades.

In Table 6-4, the dynamic time period effects are captured (across year variability). Utilisation rates increase as EV stock increases per charger (ICCT, 2020). Finally, the evolution of EV vehicle markets means charging behaviour also evolves over time. Specifically, as battery technology catches up with available charging speeds, there will be shorter charge times, higher charger events per charger and higher energy consumption. The baseline calculations take into account this lifetime increase in utilisation, the subsequent increase in energy consumption and its impact on user cost.

Information from several sources is used to inform the utilisation sensitivity adjustments. The aforementioned utilisation factors, alongside uncertainties around EV uptake and infrastructure role out, are considered in the +/- 50% adjustment. Its purpose is to demonstrate the effect the factors impacting within year utilisation have at extreme values. The adjustment impacts every year across the lifetime of the charger.

**Table 6-3: Summary of current UK charger utilisation (2022)**

Charger Type	Peak Power (kW)*	Utilisation baseline (hours per day)	Utilisation range (hours per day)	Average charge time (minutes)	Energy Consumption (kWh/day)
Residential off-street	7	2.5	1.25 - 3.75	210	8.8 - 26.3
Lamppost	3 - 5.5	4	2 - 6	240	6 - 18 (3kW) 11 - 33 (5.5kW)
Residential on-street	7 - 22	2.5	1.25 - 3.75	210	8.8-26.3 (7kW) 27.5 - 82.5 (22kW)
Destination/en-route	22	2.6	1.3 - 3.9	60	28.6 - 85.8
Destination/en-route	50	2	1 - 3	50	50 - 150
Destination/en-route	150	1.3	0.65 - 1.95	32	97.5 - 292.5
Forecourt	50	3	1.5 - 4.5	50	75 - 225
Forecourt	150	1.9	1.05 - 2.85	32	157.5 - 427.5

Sources: (Ubitricity, 2021), (TfL, 2021), (Pagani, 2019), (ICCT, 2020), (Gilleran, 2021), (UKPN, 2018), (ICCT, 2020), (ICCT, 2019)

Note: \* the actual average charging power seen for a particular charger/type/site will in most cases be lower than the peak range (potentially significantly for rapid chargers), as it is influenced by the max charging power/profile of particular vehicle models, the battery state-of-charge during the specific charging event, and site/network conditions at the time of charging.

**Table 6-4: Summary of future UK charger utilisation assumed**

Charger Type	Peak Power (kW)*	Utilisation 2022 (hours per day)	Utilisation 2025 (hours per day)	Utilisation 2030 (hours per day)	Utilisation 2035 (hours per day)
Residential off-street	7	2.5	2.5	2.5	2.5
Lamppost	3	4	6	8	8
Lamppost	5.5	4	4.8	6	6
Residential on-street	7 - 22	2.5	3.8	5	5
Destination/en-route	22	2.6	3.9	4.2	4.2
Destination/en-route	50	2	3	4	4
Destination/en-route	150	1.3	1.9	2.6	2.6
Forecourt	50	3	4.5	6	6
Forecourt	150	1.9	2.9	3.8	3.8

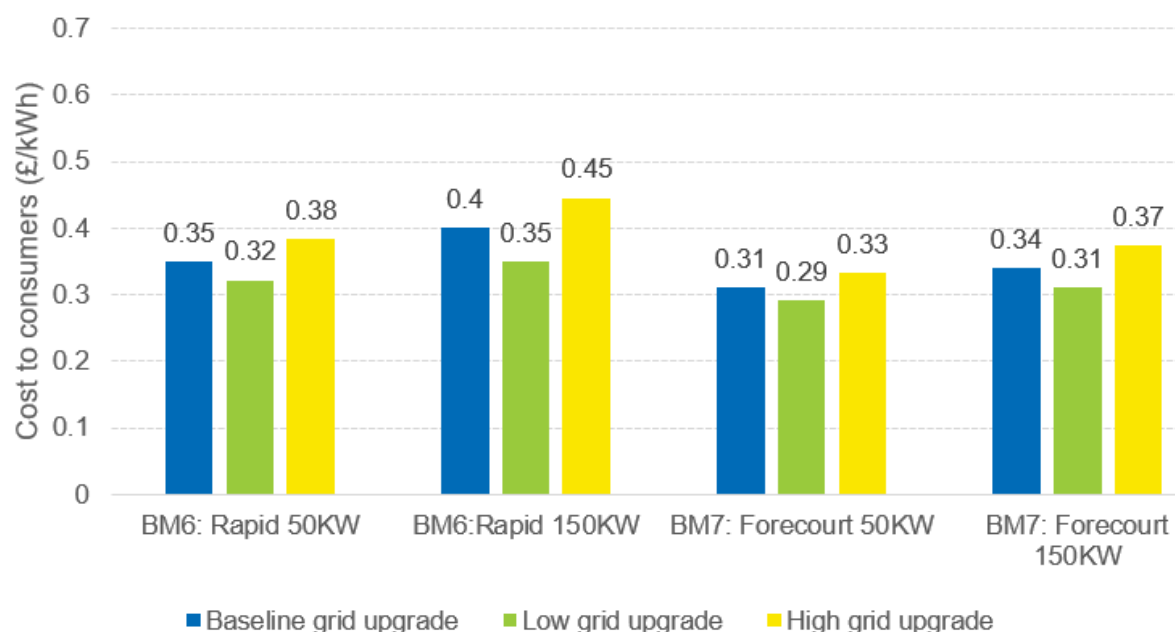
Sources: (Ubitricity, 2021), (TfL, 2021), (ICCT, 2020), (ICCT, 2020), (ICCT, 2019)

## A2.1.2 Main sensitivities

As explained in section 3.2.2, different sensitivities were calculated for the cost to consumers model besides sensitivities to utilisation rates, that are presented in detail in that section. Details on the other sensitivities explained in section 3.2.2 are presented below.

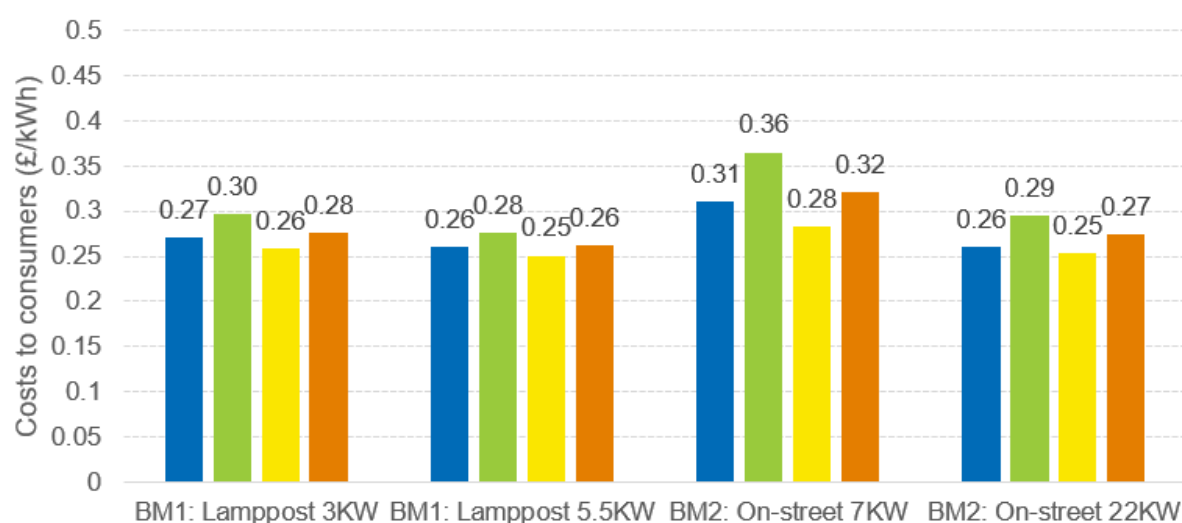
**Grid upgrade costs** can vary significantly for rapid charging. Thus, sensitivities for grid upgrades were considered for baseline calculations, assuming no grid upgrades (low) and double the grid upgrades than in the baseline (high), which was assumed at 315 £/KW (baseline). Grid upgrade costs can vary significantly for rapid charging.

Figure 6-1: Costs to consumers (£/kWh) for rapid charging options with different grid upgrades costs



Sensitivities for **grants** were calculated. In the baseline, on-street charging business models (BM1 and BM2) assumed a 75% CAPEX funding from OZEV. In the future, grants are expected to be phased out. Thus, sensitivities were calculated if grants were removed for baseline utilisation rates and for higher utilisation rates for those business models.

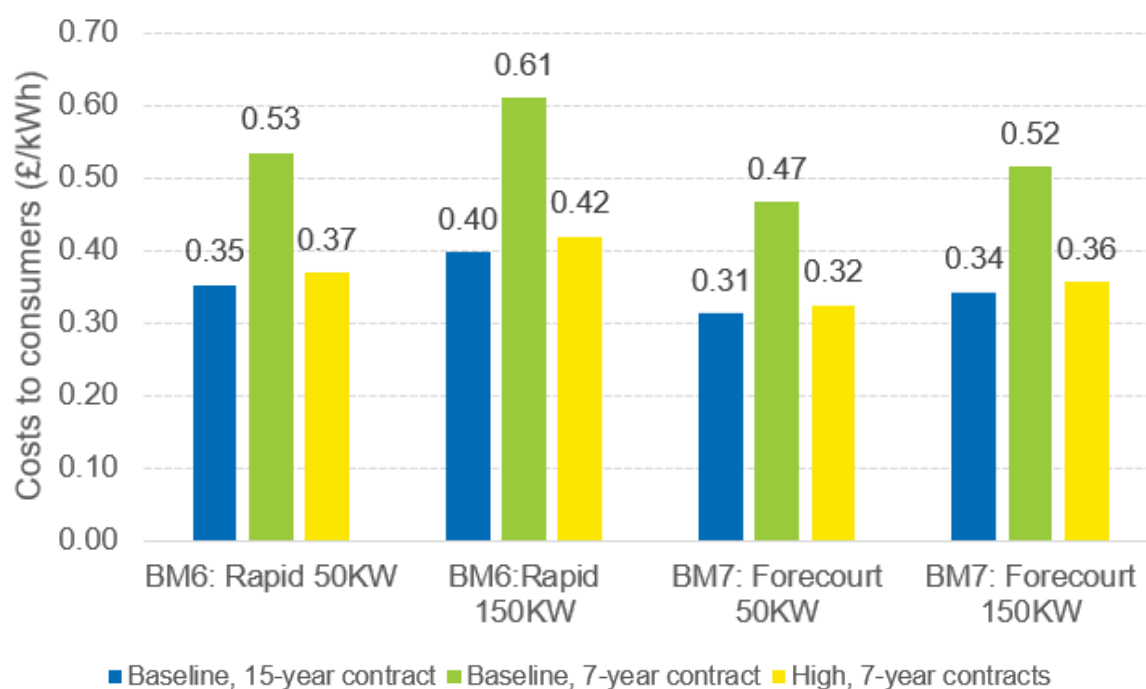
Figure 6-2: Costs to consumers (£/kWh) for baseline and high utilisation rates, without and with grants (75%)



■ Baseline ■ Baseline no grant ■ High ■ High no grant

Sensitivities for **contract lengths for rapid charging business models (BM6 and BM7)** were considered. 15-year contracts were assumed in baseline calculations, as indicated by stakeholders. Costs to consumers for shorter 7-year contracts (similar to years for on-street charging) were calculated with baseline and high utilisation rates to understand whether shorter contracts are feasible as demand for rapid charging options increase.

**Figure 6-3: Costs to consumers (£/kWh) for rapid charging with different contract lengths for baseline and high utilisation rates**



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Ricardo  
Energy & Environment

The Gemini Building  
Fermi Avenue  
Harwell  
Didcot  
Oxfordshire  
OX11 0QR  
United Kingdom

t: +44 (0)1235 753000  
e: enquiry@ricardo.com

[ee.ricardo.com](http://ee.ricardo.com)